

coding

SENSE & CONTROL

New Smart Cart Accessory: Motor Drive

The new Smart Cart Motor Drive Accessory can drive the Smart Cart forwards and backwards at constant or variable speeds – and can be programmed for sense and control using PASCO Capstone software!



Smart Cart Demo Kits

See page 104
Everything you need for
great physics demos!
Demo manual included.



Capstone 2.0 + Coding

See pages 68-71
Blockly coding in PASCO
Capstone offers limitless
lab possibilities!



Sense and Control

See page 6
Control hardware
outputs with PASCO
sensor inputs!

PHYSICS DEMOS

WITH THE AMAZING
PASCO SMART CART
DEMO KIT!!

Demos
Captive Your
Students!

See Page
104



PASCO
wireless smart cart

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Given the past year's events, we understand many educators were unable to use their PASCO equipment as frequently as they would during a normal school year.

One Year Extension!

All products with an active PASCO 5-Year Warranty during 2020 will receive an extra year of coverage.

To ensure all PASCO customers get the most out of our 5-Year Warranty, all PASCO products currently under PASCO's 5-Year Warranty will receive an extra year of coverage. We hope that this additional year of coverage will help educators feel confident in returning to their hands-on PASCO equipment when the time comes.

The Newest Smart Cart Accessory

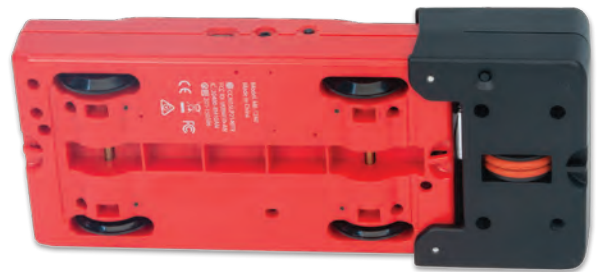
Smart Cart Motor



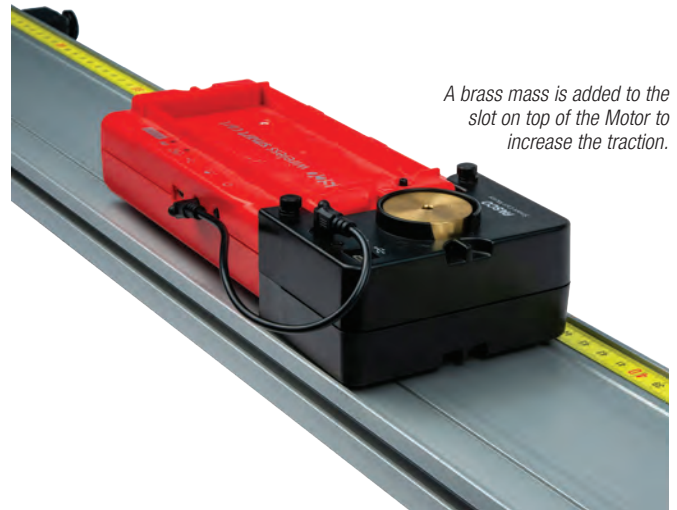
ME-1247

NEW

The Smart Cart Motor is a motor-driven wheel that attaches to the Smart Cart to make it go at a constant velocity, forwards or backwards. In PASCO Capstone or SPARKvue, you can control the motor remotely through its wired connection to the Smart Cart by setting the power on a scale of -100 to +100%.



This view of the underside of the Smart Cart with Motor shows the red motor-driven wheel. It can be used on or off a track.



A brass mass is added to the slot on top of the Motor to increase the traction.

Add power to your Smart Cart and control its motion:

- ▶ Control the Smart Cart via software
- ▶ Constant velocity
- ▶ Constant acceleration
- ▶ Programmable with Blockly in Capstone and SPARKvue

```

Code
Blockly
Logic
  set [ ] to 44 motor drive acceleration
  sleep for 20 ms
  set x to 0
  set k to 700
  set v0 to 0.15
  set a to -0.05
  set Power to 0
  set t to get time in ms
  in number output a enter
  in text output Eqn enter x = 1/2at^2
  repeat until x <= 1 -0.6
  do
    set t to get time in ms
    set x to v0 + a * t
    set P to value of Position m
    change Power by 0.5
    set SmartCartMotorAccessory to Power
  in number output Out enter x
  
```

Program with Blockly in Capstone or SPARKvue to make the Smart Cart with Motor follow an equation of motion.



Includes:

- Smart Cart Motor
- Smart Cart Connector Cable
- USB Charging Cable

Order Information

Smart Cart Motor ME-1247

Requires a Smart Cart (see pages 98-99)
 Also requires PASCO Capstone Software (see pages 68-71)
 or SPARKvue Software (see pages 72-73)

Smart Cart Demonstration Kit

ME-1272 (with red cart) ME-1273 (with blue cart)

The Smart Cart Demonstration Kit comes with either a Red Smart Cart or a Blue Smart Cart and all the accessories you need to perform amazing physics demonstrations in kinematics and dynamics.



Demonstration Manual Included!



Includes:

- Smart Cart (red or blue)
- Smart Fan Accessory
- Two 250-g Cart Masses
- Smart Cart Rod Stand Adapter
- Smart Ballistic Cart Accessory
- Smart Cart Vector Display
- Sail
- Grattells Case
- Demonstration Manual

16 Demonstrations Included:

- ▶ Differences between Velocity and Acceleration
- ▶ Independence of x- and y-Projectile Motion (Level Track)
- ▶ Independence of x- and y-Projectile Motion (Uphill)
- ▶ Independence of x- and y-Projectile Motion (Downhill)
- ▶ Newton's First Law Using Vector Display
- ▶ Newton's First Law Using Smart Fan Carts
- ▶ Newton's Second Law (Push-Pull Force Sensor)
- ▶ Newton's Second Law (Hanging Mass)
- ▶ Newton's Second Law (Fan)
- ▶ Newton's Third Law (Force Vectors)
- ▶ Newton's Third Law (Fan Cart)
- ▶ Impulse and Force
- ▶ Collisions
- ▶ Centripetal Acceleration
- ▶ Simple Harmonic Motion
- ▶ Buoyant Force



Order Information	
Red Smart Cart Demonstration Kit	ME-1272
Blue Smart Cart Demonstration Kit.....	ME-1273

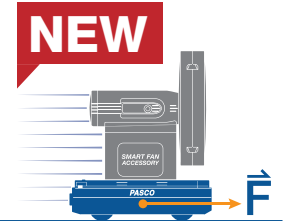
Block-based Coding



Blockly Block-based Coding

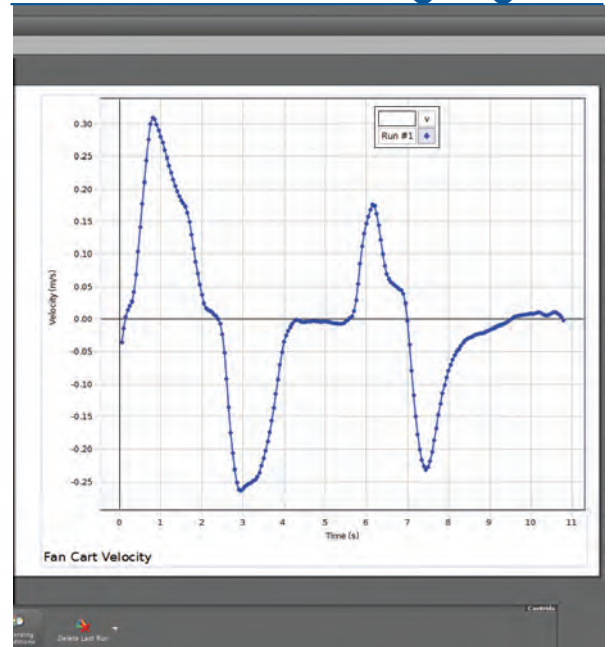
- ▶ Control all PASCO sensors and interfaces
- ▶ Create sense and control programs
- ▶ Control outputs from sensor inputs

Bring computational thinking into your science lab!



```

Write output voltage Smart Fan Accessory - 0
Sleep in ms 100
set k to -110
set b to 160
set Xo to 0.3
set N to 0
repeat 10000 times
do
change N by 1
set x to Read Measurement Position, Blue - m
set v to Read Measurement Velocity, Blue - m/s
set P to k x x - Xo - b x v
Write output voltage Smart Fan Accessory - P
Write numeric to UED power - P
Sleep in ms 20
if absolute v 0.1 > and N 100 <
do
set Xo to -1 x - Xo
set N to 0
Write output voltage Smart Fan Accessory - 0
  
```



We have added block-based coding into our Capstone and SPARKvue software!

With Blockly coding, students can control how outputs respond to sensor data. Students can use any PASCO sensor as a Blockly input.

Blockly Coding

Help Students Develop Computational Thinking Skills

Introducing students to coding and code-based outcomes is easier than ever before with Blockly coding. Blockly integrates computational thinking into the exploration of science phenomena to provide students with a new world of STEM opportunity. With Blockly, students can create custom data collection parameters, feedback loops, data displays, and so much more.

Use Blockly in SPARKvue to:

- ▶ Introduce students to computational thinking
- ▶ Investigate phenomena while learning to code
- ▶ Create data-driven feedback loops
- ▶ Program collection parameters for any PASCO sensor or interface

```

set Number of steps to 0
repeat while true
do
if absolute value of Acceleration - x - m/s² ≥ 15
do
change Number of steps by 2
in number output Steps - enter Number of steps
repeat while absolute value of Acceleration - x - m/s² ≥ 15
do
sleep for 20 ms
  
```

Learn more at [PASCO.com/coding](https://www.pasco.com/coding)

```

Code
Code execution enabled
Blockly Lua
Logic
Loops
Math
Text
Lists
Variables
Functions
Hardware
Code Output
Time
value of Sound Wave
set 550 Output to 1
set 550 Output (0.001-100000) frequency to 1 Hz
turn 550 Output on: true
zero sensor Wireless Sound Wave Sensor
  
```

PASCO devices are recognized in Blockly allowing students to write code around device inputs and outputs.

For more information on PASCO Capstone Software, see pages 68-71.

For more information on SPARKvue Software, see pages 72-73.

NEW //code.Node PS-3231 

The //code.Node is a turnkey coding solution that combines real-world sensor inquiry, Blockly coding, and live data displays to drive computational thinking in STEM learning. It includes six interactive sensors and three device outputs that measure and respond to phenomena using code created in PASCO's software.

Sensor Inputs	Device Outputs
▶ Light	▶ RGB LED
▶ Magnetic Field	▶ 5x5 Array
▶ Motion	▶ Speaker
▶ Temperature	
▶ Sound	
▶ Switches	



Order Information
 //code.Node..... PS-3231

NEW //code.Node Multi-pack (Set of 8) PS-3311



- Includes:**
- //code.Nodes (8)
 - //code.Node Holders (8)
 - USB Charging Cables (8)
 - Essential Coding to Learn
 - Teacher's Manual
 - Storage Box

Order Information
 //code.Node Multi-pack (Set of 8) PS-3311

NEW //code.Node Holder PS-3233



- Includes:**
- Holder
 - Velcro Straps (2)

Order Information
 //code.Node Holder PS-3233

NEW //code.Node Cart PS-3235

Cart Accessory for the //code.Node

Turn your //code.Node into a programmable cart for computational thinking activities.

The //code.Node Cart allows students to program the //code.Node to respond to physical phenomena. When the //code.Node is active and fitted inside the cart, velocity and position data are collected and reported wirelessly. Programmed values can trigger sounds, lights and displays.



Order Information
 //code.Node Cart..... PS-3235
 Requires:
 //code.Node..... PS-3231

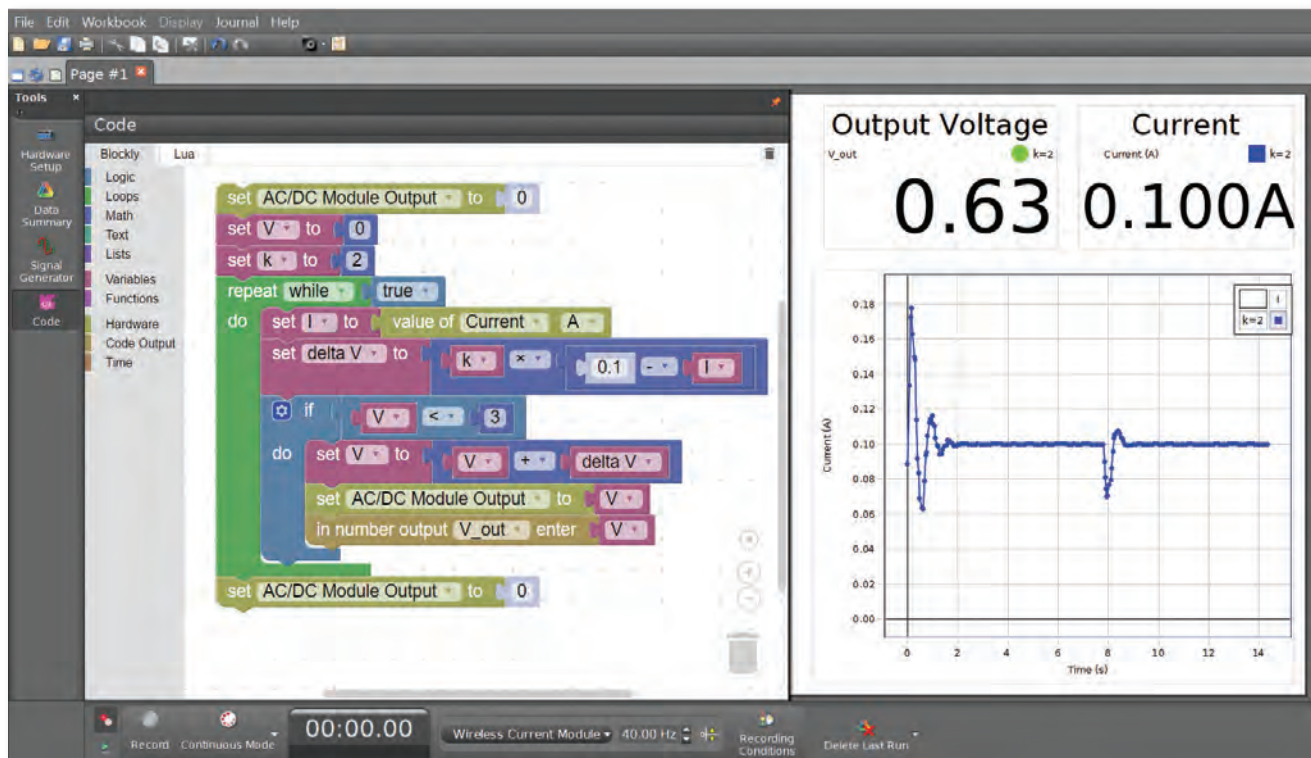
Sense-and-Control

Using PASCO Sensors, Output Devices, and Equipment

- ▶ Blockly programming is built into PASCO Capstone and SPARKvue software.
- ▶ Access all sensor readings through code.
- ▶ Use code to control outputs such as signal generators, fans, and motors.

How PASCO Makes Sense-and-Control Seamless

With the recent integration of Blockly coding into our data collection software, you can use code to read sensors and to control how devices respond to data without having to download any drivers. Plus, you can graph the output from your code in real time or display it using any of Capstone's displays.



In PASCO Capstone, the Blockly code runs adjacent to a graph of the Current Sensor measurement and Digits Displays of output from the code.

Example: Construct a Constant Current Source

- ▶ Use the Modular Circuits (EM-3536) variable resistor, Wireless Current Module (EM-3534), and AC/DC Module (EM-3533).
- ▶ The voltage is adjusted in code to react when the resistive load is changed so as to keep the current constant.
- ▶ In Capstone, record the current and voltage readings and see the current graphed in real time as the code executes.



Modular Circuits (pages 218-221)

Sense

- ▶ Because Blockly is embedded in Capstone, any PASCO sensor or interface can be accessed through code.
- ▶ PASPORT, ScienceWorkshop, and Wireless Sensors



PASPORT Sensors (pages 25-45)



ScienceWorkshop Sensors (pages 18-24)



Wireless Sensors (pages 49-65)

Control

- ▶ Output messages to Capstone Digits Displays

reaction time = 384 ms

PASCO Capstone Software (pages 68-71)

- ▶ Control the speed and direction of a Smart Fan (ME-1242) on a Smart Cart (ME-1240).



Smart Fan (page 100)

- ▶ Control the speed and direction of a Smart Cart Motor (ME-1247).



Smart Cart Motor (page 103)

- ▶ Activate motors, lights, and a coil in Modular Circuits (EM-3536) using the AC/DC Module (EM-3533).



AC/DC Modular (page 221)

- ▶ On the //code.Node (PS-3231), change the color of the LED, the intensity of the LED array, and the frequency of the speaker output.



//code.Node (page 5)

- ▶ Control the frequency and amplitude of the signal generator outputs on the 550 (UI-5001) and 850 (UI-5000) Universal Interfaces.



550 Universal Interface (page 16)



850 Universal Interface (page 14)

- ▶ Control the frequency and amplitude of the Function Generator (PI-8127).



Function Generator (page 256)

- ▶ Control when or where the ball is launched by a Smart Ballistic Cart Accessory (ME-1246).

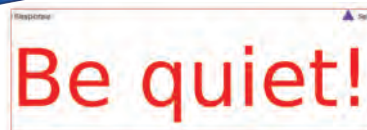


Smart Ballistic Cart Accessory (page 102)

Suggested Sense-and-Control Projects

1. Loud Noise Sensor

- Uses the Sound Level Sensor (PS-2109)
- Explore sound level data to determine what sound level is considered to be loud.
- When a person is too loud, display a message that says **“Be quiet!”**



2. Design a Red-Light Green-Light Game

- Uses Motion Sensors (PS-3219) and the //code.Node (PS-3231)
- Computer randomly changes the //code.Node LED to red or green, while motion sensors track the progress of each student toward the goal line.
- If the student is still moving after the LED turns red, they have to go back.
- Computer keeps track of how many red/green changes each student uses to cross the goal line.
- Display **“Winner”** when someone crosses the goal line.



3. Identify the Color of Objects

- Uses Wireless Light Sensor (PS-3213), Smart Fan (ME-1242), and Smart Cart (ME-1240)
- Study the Light Sensor readings when the sensor is pointed at different colored objects, and develop code that determines the color.
- Display color name on screen.
- Use color to control a Smart Fan on a Smart Cart: Make the cart go forward when the Light Sensor is pointed at a blue object, stop when it's pointed at red, and reverse when it's pointed at green.



4. Clap On Clap Off Light

- Uses Sound Level Sensor (PS-2109), 550 Universal Interface (UI-5001), and Modular Circuits (EM-3536)
- When someone claps twice, the light turns on.
- Clap twice again and the light goes out.



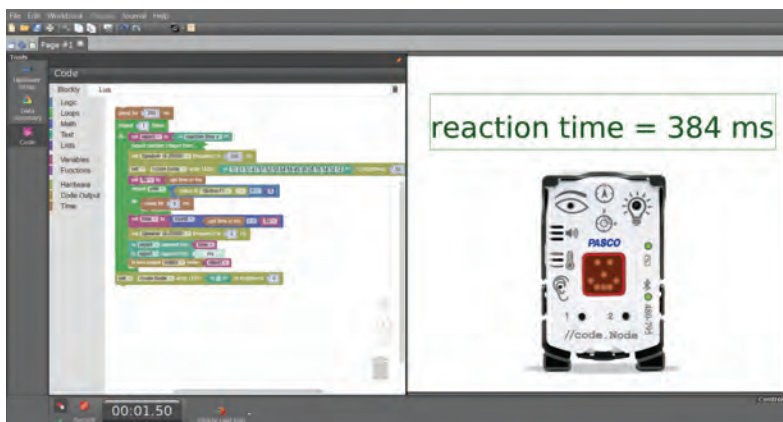
5. Biofeedback: Warm up Your Hands

- Uses Wireless Temp Link (PS-3222) with Surface Temperature Probe (PS-2131) and //code.Node (PS-3231)
- Display temperature on a graph.
- The //code.Node sounds a low frequency note. As the temperature rises, the frequency of the note increases.



6. Reaction Timer

- Uses a //code.Node (PS-3231) to record how long it takes the student to press a button in response to a signal.
- Program waits a random time and then the //code.Node beeps and lights LEDs.
- Student presses the //code.Node button as soon as they see and/or hear the signal.
- Computer measures the time between the signal activation and the pressing of the button and displays the reaction time in a Digits Display.



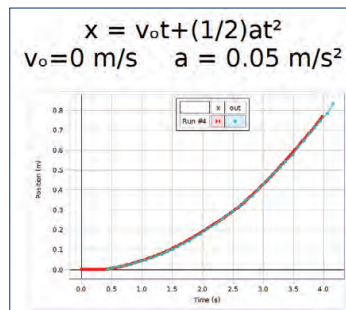
7. Control Position of Smart Fan Cart

- Uses a Smart Fan (ME-1242) and Smart Cart (ME-1240) on a track.
- Use kinematics to determine how much deceleration is required to stop a cart within a certain distance.
- Use graphs to explore how much fan thrust creates enough acceleration.
- Make the cart stop at a designated position.



8. Make the Smart Cart with Motor Follow Equations of Motion

- Uses a Smart Cart (ME-1240) with a Smart Cart Motor (ME-1247).
- Control the output of the Motor using equations of motion in the code.
- Graph the actual position on top of the theoretical equation of motion.



9. Intruder Detectors

- Detect movement with a Wireless Motion Sensor (PS-3219).
- Try to move an object without tripping an alarm using the Wireless Accelerometer (PS-3223) as a shake detector.
- Breaking the laser switch beam on the Wireless Smart Gate (PS-3225) triggers an alarm.
- Non-Contact Temperature Sensor (PS-2197) for sensing human body heat.



10. Play a Song

- Write code to play musical notes on the 550 Universal Interface (UI-5001) with the Mini Speaker (WA-9605), or use the sound output on a //code.Node (PS-3132).



Measuring with Sensors

In Physics and Engineering, we measure everything in every way we can. Sometimes sensors make it possible to perform measurements that we could not get any other way.

PASCO offers a couple of different ways to go: interface-based sensors or wireless sensors. However, you can use a wireless sensor at the same time you are using sensors connected to an interface. Which way you choose depends on your platform and your purpose.

Which platform do you use?

1. Mac® and/or Windows® Desktop Computers or Laptops

Recommendation:

- **PASCO Capstone Software** (see pages 68-71): This data collection and analysis software is the preferred choice of physics and engineering teachers.
- **550 or 850 Universal Interface:** Choose the 550 if you are teaching high school physics (unless you are one of those high school teachers who has to have the most powerful tools). Choose the 850 if you are teaching college physics or engineering.



850 Universal Interface
UI-5000 (see page 14)

or

550 Universal Interface
UI-5001 (see page 16)



Wireless Force
Acceleration Sensor
PS-3202 (see page 53)



PASPORT
High Resolution
Force Sensor
PS-2189 (see page 29)

2. Tablets (iPad® or Android™) and/or Chromebook™

Recommendation:

- **SPARKvue Software** (see page 72-73): SPARKvue is our tablet and Chromebook™ software. While PASCO Capstone is very powerful, it is only available for Mac® and Windows®.
- **Wireless Sensors and Wireless AirLink Interface:** Use wireless sensors because tablets may not have a USB port. Whenever a wireless sensor is not available, use the AirLink with a PASPORT sensor.



SPARKvue



Wireless Force
Acceleration Sensor
PS-3202 (see page 53)



AirLink®
PS-3200 (see page 48)

3. Need a Stand-alone Datalogger? **SPARK LXi** DATALOGGER

Recommendation:

- **SPARK LXi:** This all-in-one datalogging solution works for classrooms without computers or for outdoor use. The SPARK LXi can be used with wired PASPORT sensors as well as PASCO's wireless sensors. It is battery-powered, has a large color touchscreen, and is loaded with PASCO SPARKvue, MatchGraph, and Spectrometry.



SPARK LXi top view



SPARK LXi
PS-3600A (see page 46-47)

New to sensors? Have sensors already?

1. New to Sensors?

- **PASCO Capstone Software** (see pages 68-71): Unless you are using tablets or Chromebook™, we recommend Capstone for physics and engineering labs.
- **550 Universal Interface:** The 550 Interface is perfect for beginning data acquisition. It has multiple sensor ports to accommodate those experiments that require more than one sensor (as most experiments do). It also has a signal generator and powered output for electronics and speakers.
- **PASPORT Sensors:** Many of these sensors have multiple sensor elements in one sensor, such as the Absolute Pressure/Temperature Sensor (page 32).
- **Wireless Sensors** (see pages 49-67): This is a low-cost solution because no interface is required for the wireless sensors. They are connected via Bluetooth® in PASCO software (Capstone or SPARKvue).



550 Universal Interface
UI-5001 (see page 16)

Wireless Force Acceleration Sensor
PS-3202 (see page 53)



Wireless Smart Cart
ME-1240 (see page 98-99)

2. Have ScienceWorkshop Analog Sensors?

- **PASCO Capstone Software** (see pages 68-71): Unless you are using tablets or Chromebook™, we recommend Capstone for physics and engineering labs.
- **850 Universal Interface:** The 850 Interface is our most versatile and powerful instrument. It has twice as many sensor ports as the 550 for those more demanding experiments. It also has three signal generators, a high-power output (15 V at 1 A) for speakers and heating elements, and two high-frequency outputs (DC to 500 kHz) for electronics.
- **Use Your Existing ScienceWorkshop Sensors** and add any PASPORT sensors you need: You may want to use the PASPORT 2-Axis Force Platform (page 30) or the Absolute Pressure/Temperature Sensor (page 32).



850 Universal Interface
UI-5000 (see page 14)

3. Have PASPORT Sensors?

- **PASCO Capstone Software** (see pages 68-71): Unless you are using tablets or Chromebook™, we recommend Capstone for physics and engineering labs.
- **550 or 850 Universal Interface:** Choose the 550 if you are teaching high school physics (unless you are one of those high school teachers who has to have the most powerful tools). Choose the 850 if you are teaching college physics or engineering.
- **Use Your Existing PASPORT Sensors** (see pages 25-45) and add the UI-5100 Voltage Sensor (page 23) for high speed sampling of circuits and the UI-5101 Sound Sensor (page 22) to detect sound waves.
- **SPARK LXi:** Choose the SPARK LXi if you want to use your PASPORT sensors without computers or if you need to collect data outside.



550 Universal Interface
UI-5001 (see page 16)



 **SPARK LXi**
PS-3600A (see page 46-47)

Interfaces

Use an interface to connect sensors to your computers or mobile devices running PASCO software.

AirLink®

PS-3200



The AirLink is the most cost-effective way to wirelessly connect PASPORT sensors.

Connect one PASPORT sensor via Bluetooth® or through a USB connection. USB cable included.

Order Information

AirLink Interface PS-3200

SPARKlink® Air

PS-2011



Connect two PASPORT sensors via Bluetooth® or through a USB connection. Also includes dedicated ports for the included temperature and voltage probes. USB cable included.

Order Information

SPARKlink Air Interface PS-2011

SPARK LXi

PS-3600A



Designed for use with wired and wireless sensors, the SPARK LXi can simultaneously accommodate up to five wireless sensors. It also includes two ports for blue PASPORT sensors, plus two ports for the included Fast Response Temp Probe and the Voltage Probe.

Order Information

SPARK LXi Datalogger PS-3600A

550 Universal Interface

UI-5001



The 550 Universal Interface is fast, flexible, and powerful while staying affordable. The 550 has half the ports and many of the great features of our 850 Universal Interface in a smaller package, with Bluetooth® and USB connectivity.

Order Information

550 Universal Interface UI-5001

850 Universal Interface

UI-5000



The 850 Universal Interface is the most powerful science education lab interface in the world, with the most ports, highest sampling rates, and the most powerful functionality and future expandability. It can also replace several pieces of lab instrumentation, which represents great value.

Order Information

850 Universal Interface UI-5000

Interface Comparison

Compare the features and capabilities and see which interface works best in your lab.



	AirLink PS-3200	SPARKlink Air PS-2011	SPARK LXi PS-3600A	550 Universal Interface UI-5001	850 Universal Interface UI-5000
PASPORT Ports	1	2	2	2	4
Built-in Temp and Voltage	No	Yes	Yes	No	No
Analog Inputs	0	0	0	2 (± 10 V, optional gain voltage 10x, 100x)	4 (± 20 V, optional gain voltage 10x, 100x, 1000x)
Digital Inputs	0	0	0	2	4
Connects via USB	Yes	Yes	Yes	Yes	Yes
Connects via Bluetooth	Yes	Yes	Yes	Yes	No
Rechargeable battery for cordless operation	Yes	Yes	Yes	No (AC adapter only)	No (AC adapter only)
Works with PASCO Capstone Software	Yes	Yes	No	Yes	Yes
Works with SPARKvue Software	Yes	Yes	Yes	Yes	No
Accepts PASPORT Sensors	Yes	Yes	Yes	Yes	Yes
Accepts ScienceWorkshop Sensors	No*	No*	No*	Yes	Yes
Maximum Sampling Rate	Sensor-dependent <1000 Hz	Sensor-dependent <1000 Hz	Sensor-dependent <5000 Hz	Up to 2 MHz on one channel	10 MHz on two channels simultaneously
Signal Generator	N/A	N/A	N/A	± 8 V, at 400 mA, DC to 100 kHz	#1 ± 15 V at 1 A, DC to 100 kHz #2 & #3 ± 10 V at 50 mA DC to 500 kHz, independent
Included Items	USB Cable	AC adapter, USB cable, fast response temperature probe, voltage probe	AC adapter, USB cable, fast response temperature probe, voltage probe	USB cable, power supply	USB cable, power supply
Expansion Port	No	No	No	No	44-pin port with voltage outputs, analog inputs, and digital I/O channels

* The AirLink, SPARKlink Air, and SPARK LXi can accept most ScienceWorkshop sensors with the proper adapter (see page 48), although they won't have the same high maximum sample rates. One exception is the Sound Sensor (UI-5101), which is not recommended for use with an adapter.

The PASCO 850 Universal Interface: The Ultimate Sensor Interface for Physics and Engineering

Clear the clutter on your lab bench. The 850 Universal Interface combined with PASCO Capstone software can replace multiple expensive pieces of equipment.

An incredible value!



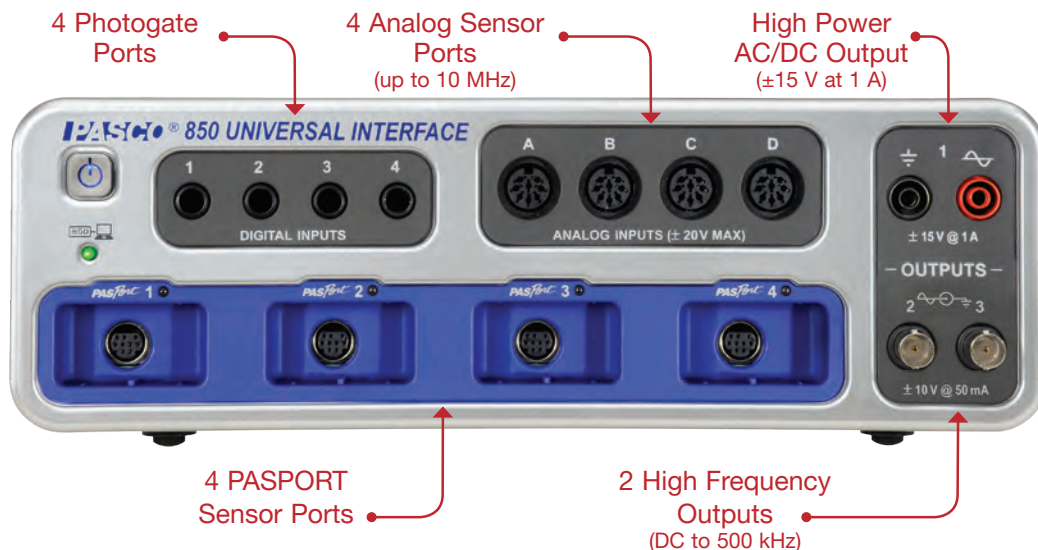
850 Universal Interface



PASCO Capstone Software

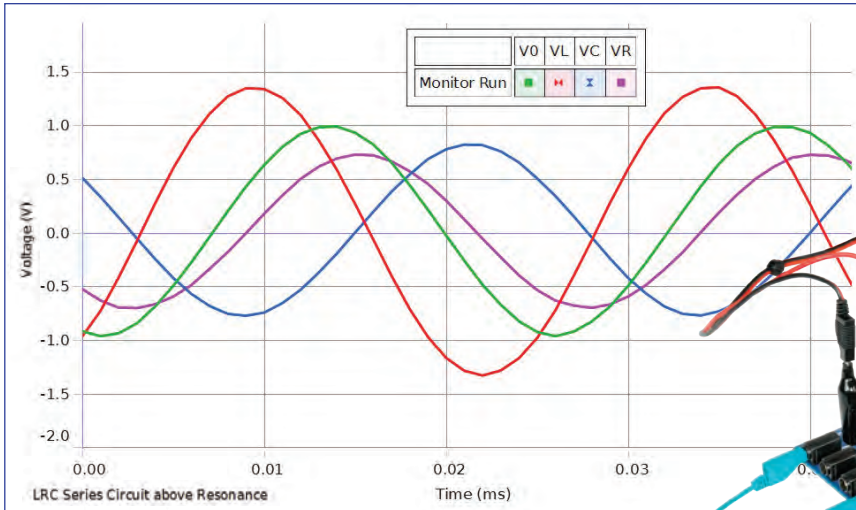


DC Power Supply, Oscilloscope, Digital Multimeter, and Function Generator

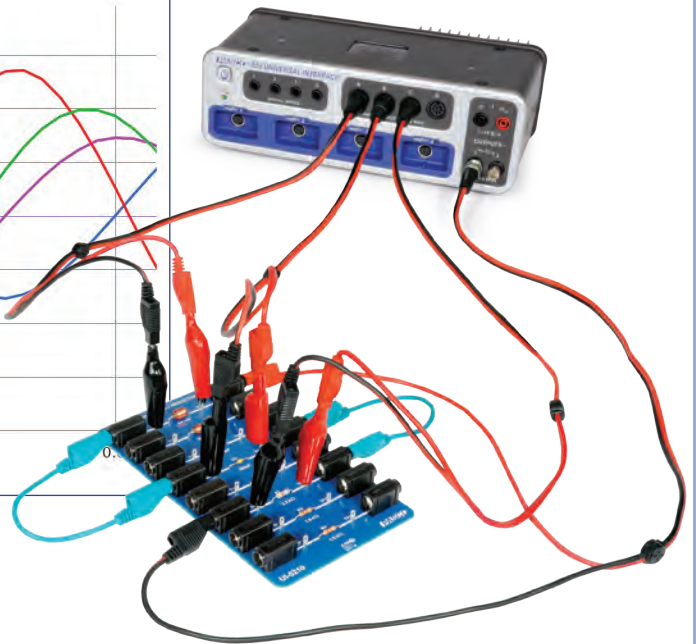


- ▶ **Study AC Circuits:** 10 MHz sample rate on two analog channels simultaneously; two independent high frequency outputs (50 mA at 10 V; DC to 500 kHz)
- ▶ **Power Speakers and String Vibrators:** High power function generator (1 A at 15 V; DC to 100 kHz)
- ▶ **Use Any Sensors You Have:** Compatible with ScienceWorkshop and PASPORT sensors; use at the same time
- ▶ **Explore Modulation:** External trigger input/output for synchronizing multiple 850s
- ▶ **Do 87 Core Physics Experiments:** Check out the Comprehensive 850 Physics Lab Manual (UI-5813; see page 78). Download online at pasco.com/comprehensivephysics
- ▶ **See detailed specifications:** www.pasco.com/850

Order Information	
850 Universal Interface	UI-5000
Required:	
PASCO Capstone Software	pp. 68-71
Recommended:	
BNC Function Generator Output Cable	p. 15
Replacement Part:	
850 Universal Interface Replacement Power Supply	UI-5200



Four Channel Oscilloscope in PASCO Capstone



Dual Independent High Frequency Function Generators

Independent control of frequency, waveform, and amplitude. The voltages across the source, inductor, capacitor, and resistor are displayed in the oscilloscope.

BNC Function Generator Output Cable

UI-5119 (unshrouded) UI-5129 (shrouded)

► Converts the BNC output to two banana cords for the 850's function generators #2 and #3.



Shown in use with the 850 Universal Interface.

Resistor Capacitor Inductor Network

UI-5210

Board components can be used to investigate Kirchhoff's Circuit Laws, Ohm's Law, RC circuits, and A.C. LRC circuit theory with resonant frequencies between 55 kHz and 135 kHz, depending on values used.



Includes

- Two inductors: 6.8 mH, 2.5 mH
- Two capacitors: 3900 pF, 560 pF
- Four resistors: 47 kΩ, 3.3 kΩ, and two 1.0 kΩ.

Shown in use with the 850 Universal Interface.

Order Information

Resistor Capacitor Inductor Network UI-5210

8-Pin DIN Extension Cable

UI-5218

- Use to connect analog sensors to ports A through D on the 850.
- Analog sensors can also be plugged in directly to the 850 ports.



The 1.8 m long Extension Cable allows ScienceWorkshop Sensors to be used even further away from the interface. Multiple cables CAN be used in series. Also works with 750 and 500 interfaces.

Order Information

8-Pin DIN Extension Cable UI-5218

Order Information

BNC Function Generator Output Cable (unshrouded) UI-5119
 BNC Function Generator Output Cable (shrouded) UI-5129

The PASCO 550 Universal Interface...

This powerful interface for Physics connects wirelessly or via USB.

This is the interface with the measurement capability for all types of physics experiments. It features:

- ▶ 2 MHz sampling rate
- ▶ 2 high-speed analog inputs
- ▶ 2 digital inputs for photogates and other timing sensors
- ▶ 2 PASCO PASPORT sensor inputs
- ▶ Signal generator with built-in Voltage and Current sensors

- ▶ Use with other PASPORT interfaces
- ▶ Connect to computers via USB
- ▶ Bluetooth® Low Energy

With the 550, your Physics lab is equipped with high-speed data collection, signal generation and power supply, oscilloscope and FFT displays, timers, and more.



550 Universal Interface Specifications:

2 High-speed Analog Inputs

Measurement Range: ± 10 V differential input
Input Impedance: 1 M Ω
Input Protection: ± 250 V continuous
Selectable Voltage Gain: X1, X10, X100
Resolution: 14-bit, 0.12 mV

2 Digital Inputs

Digital sensors such as Photogates and Time-of-Flight plug directly into the 550 Interface.

- ▶ Compatible with all ScienceWorkshop digital sensors
- ▶ Sensor Connect Detection
- ▶ 0-5 V TTL
- ▶ Bi-directional

2 PASPORT Inputs

Compatible with PASCO's complete line of more than 80 PASPORT sensors.

- ▶ Sample rates depend on sensors

Signal Generator

Waveforms: sine, triangle, square wave, positive and negative ramps, DC

Frequency Range: 0.001 Hz to 100 kHz; 1 mHz resolution

Amplitude Range: ± 8 V

Resolution: 1.33 mV, 12-bit DAC.

Max Output Current: 400 mA at 8 V, over-current detection

Selectable Voltage Limit

Selectable DC Offset

Frequency Sweep Function

Measure Output Current, Voltage, Frequency, Peak Amplitude

Order Information

550 Universal Interface	UI-5001
Required:	
PASCO Capstone Software	pp. 68-71
OR	
SPARKvue Software	pp. 72-73

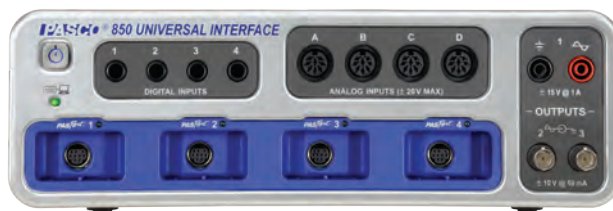
Choose the Universal Interface that is right for you.

The 550 Universal Interface

is fast, flexible, and affordable, and it has all the power you need to ignite student learning in your lab. The 550 is equipped with high-speed data collection, signal generation and power supply, FFTs, timers, and more. (If you have tablets, this is the interface you need.)

The 850 Universal Interface

has all the speed and power you need for your most demanding physics experiments. And it can replace most of the equipment in your physics lab including oscilloscopes, power supplies, timers, and function generators, multi-meters, and more.



Specs:	550 Universal Interface	850 Universal Interface
Sampling Rate:	Up to 2 MHz on one channel	10 MHz on two channels simultaneously
Connection:	Connect to computers or tablets* via USB or Bluetooth® * iPad®, Chromebook™, and Android™ tablets require SPARKvue®	Connect to computers via USB
Signal Generator:	±8 V at 400 mA, DC to 100 kHz	#1: ±15 V at 1 A, DC to 100 kHz #2 and #3: ±10 V at 50 mA, DC to 500 kHz, independent
Analog Input:	±10 V, optional voltage gain 10x, 100x	±20 V, optional voltage gain 10x, 100x, 1000x
Compatibility:	Works with all PASPORT and ScienceWorkshop sensors and works with other PASPORT interfaces	Works with all PASPORT and ScienceWorkshop sensors and works with other PASPORT interfaces
Ports:	2 high-speed analog inputs + 2 digital inputs for photogates and other timing sensors + 2 PASCO PASPORT sensor inputs	Twice the number of ports as the 550
Software:	PASCO Capstone™, SPARKvue	PASCO Capstone™

Labs and configuration files available: pasco.com/capstoneexperiments

Included Labs:

- ▶ Mechanics
- ▶ Fluids
- ▶ Rotation
- ▶ Structures
- ▶ Materials
- ▶ Thermodynamics
- ▶ Electricity
- ▶ Magnetism
- ▶ Waves
- ▶ Optics
- ▶ Quantum

Each lab includes:

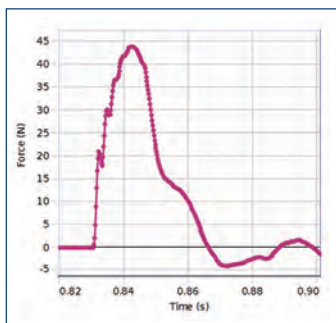
- ▶ Word® document file
- ▶ PASCO Capstone configuration file
- ▶ Image files
- ▶ Sample data

See pages 80-81 for more 550 Physics Labs

Advantages of Using Analog Sensors with the 550 and 850 Universal Interfaces

The 550 and 850 Universal Interfaces are called “Universal” because they are capable of using ScienceWorkshop (analog) sensors as well as PASPORT sensors. Although the PASPORT sensors are the newer digital line of sensors, there are advantages to using the analog technology in the ScienceWorkshop sensors. Here are a few examples:

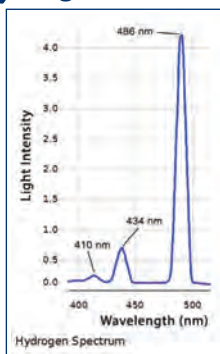
1. High Speed Collision with the Force Sensor (CI-6537); see page 20.



A cart colliding with a Force Sensor equipped with a clay bumper was recorded using a 5000 Hz sampling rate. Details of the clay's collapse can be seen in the data.



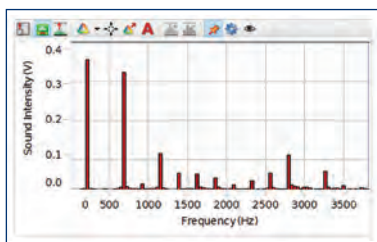
2. High Gain Detecting the Violet Hydrogen Lines with the High Sensitivity Light Sensor (CI-6604); see page 24.



This light sensor has a high gain that, when combined with the interface gain, allows even the dimmest of the Balmer series to be detected.



3. High Resolution Sound FFT Spectrum of a Clarinet Note with the Sound Sensor (UI-5101); see page 22.

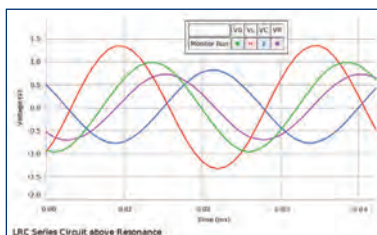


Now with Auto-ID

This FFT of a note being played on a clarinet was captured at a sample rate of 20 kHz. The waveform can also be seen on an oscilloscope in Capstone software.



4. High Synchrony LRC Circuit with the Voltage Sensor (UI-5100); see page 23.



Now with Auto-ID

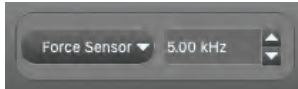
This oscilloscope display in PASCO Capstone shows the voltages across several components of an LRC circuit. The sample rates required for this can be as high as 10 MHz.



Students learn about experimental instrumentation through hands-on equipment assembly and sensor settings that affect measurement quality.

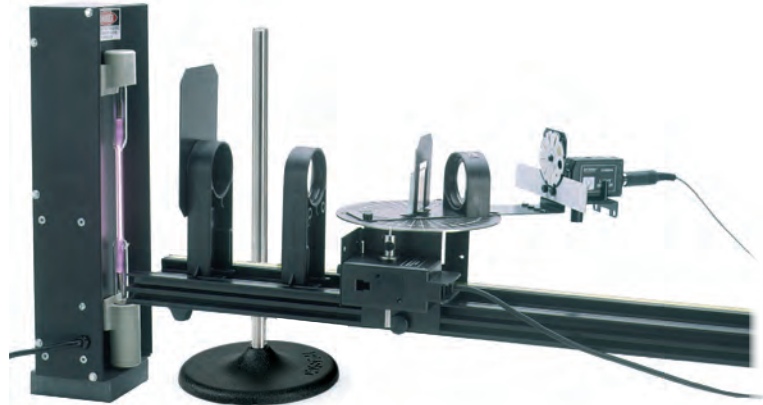
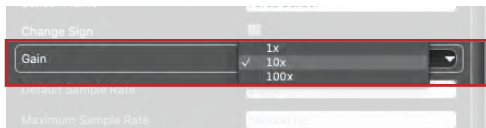
1. Sampling Speed

Set the sampling rate high enough to capture the time-detail of the phenomenon being measured.



2. Voltage Gain

Changing the gain of an analog sensor increases the resolution over a smaller voltage range.



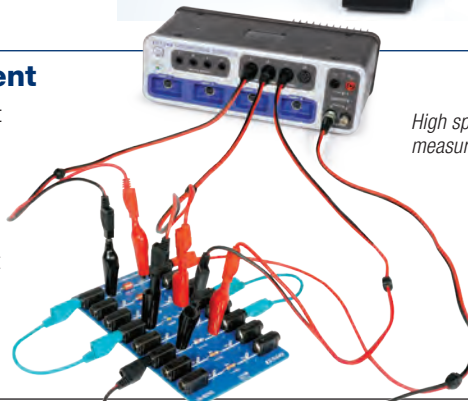
3. Voltage-Based Measurements

Analog sensing is based on voltage measurements. Understanding how devices convert physical changes like temperature, pressure, material deformation, and vibrations into voltage helps students understand the science behind their instrumentation.



4. Measurement Alignment

High speed voltage and current measurements in LRC circuits require that all measurements are synchronized on the same clock to ensure data integrity, and the accurate measurement of phase relationships.



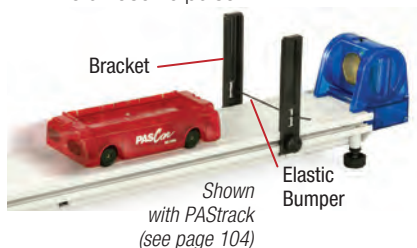
High speed voltage and current measurements in LRC circuits.

Motion and Force

Elastic Bumper

ME-8998

The Elastic Bumper protects the Motion Sensor from the carts, but doesn't interfere with the ultrasonic pulse.



Includes:

- Two pairs of brackets
- 10 meters of elastic material

Order Information

Elastic Bumper ME-8998

Cart Adapter Accessory

ME-6743

The Cart Adapter Accessory allows the Motion Sensor and many other sensors to be mounted to a Dynamics Cart or a PAScar.



Mounting a Motion Sensor on a cart is ideal for the study of relative motion. The adjustment knob on the bracket allows the Motion Sensor to face any direction.

Includes:

- Two M5 thumb screws to attach to cart
- 1/4"-20 screw at center

Order Information

Cart Adapter Accessory ME-6743

Motion Sensor II

CI-6742A

PASCO's digital ScienceWorkshop Motion Sensor II is used to measure position, velocity and acceleration. Ultrasonic pulse-ranging technology has a switch-selectable Standard Beam or Narrow Beam to reject false signals and produce cleaner data. The Motion Sensor sits firmly on a desktop or easily mounts to a rod stand or PASCO Dynamics Track.



Connector:

Dual stereo phone plug for 850, 550, and ScienceWorkshop interfaces.

Order Information

Motion Sensor II CI-6742A
 Recommended:
 Motion Sensor Guard SE-7256
 Motion Sensor Bracket PS-2546
 Cart Adapter Accessory ME-6743
 Accessory Cable CI-6748
 Allows CI-6742A to be used with CBL/EA100.

Motion Sensor Guard

SE-7256

Use this wire guard to protect the Motion Sensor when dropping objects from above.



Order Information

Motion Sensor Guard SE-7256

Motion Sensor Bracket

PS-2546

This magnetic bracket allows a Motion Sensor to be easily hung from a drop ceiling. Simply screw the bracket into the 1/4"-20 threads on the sensor and use the included adjustment nut to hold the sensor in the desired orientation.



The bracket can also be used to hold the Motion Sensor on vertical surfaces such as filing cabinets and magnetic whiteboards.

Order Information

Motion Sensor Bracket PS-2546

Rotary Motion Sensor

CI-6538

Measure angle and angular velocity or measure distance and linear velocity using the rack or the pulley. This sensor is also bi-directional, indicating the direction of motion.



Specifications:

Resolution: 1°/0.087 mm and 0.25°/0.022 mm (software selectable)

Maximum Speeds: 13 rev/sec at 1° resolution (360 data points/revolution); 3.25 rev/sec at 0.25° resolution (1440 data points/revolution)

Optical Encoder: Bidirectional, indicates direction of motion

Connector: Dual stereo phone plug for 850, 550, and ScienceWorkshop interfaces

Order Information

Rotary Motion Sensor CI-6538
 Recommended:
 Linear Motion Accessory CI-6688A
 3-Step Pulley CI-6693

Force Sensor

CI-6537

PASCO's durable, reliable Force Sensor has been designed specifically for the student physics lab. Its wide-range, high-frequency response and a low noise transducer help generate excellent impulse graphs, smooth harmonic motion data, and more. The sensor's special strain gauge consistently generates the same output for the same force and is designed to minimize side loads. Damping materials reduce vibrations caused by collisions without affecting results. Any dynamics cart accessories can be mounted on top of the Force Sensor.



Specifications:

Force Range: ±50 N

Resolution: 0.03 N or 3.1 grams

Zero (Tare) Function: Push-button

Force-overload Protection: Mechanical stop prevents forces of more than 50 N from damaging the sensor

Pin Configuration: 8-pin DIN plug mounts on standard 12.7 mm support rods

Maximum Sample Rate: Depends on interface

Order Information

Force Sensor CI-6537

Photogate Head

ME-9498A

The Photogate Head monitors the motion of objects passing through its gate, counting events as the object breaks the infrared beam.



Specifications:

- Photogate Width:** 7.5 cm
- Fall Time:** < 50 ns
- Spatial Resolution:** < 1 mm
- Timing Resolution:** 0.1 millisecond
- Connector:** Stereo phone plug

Order Information

Photogate Head	ME-9498A
Recommended:	
Photogate Stand	ME-9805

Accessory Photogate

ME-9204B

Includes both a Photogate Head and a Photogate Stand for flexible experiment design. The Photogate Stand is also sold separately.



Order Information

Accessory Photogate	ME-9204B
Photogate Stand	ME-9805

Photogate & Pulley System

ME-6838A



Specifications:

- Pulley Rotational inertia:** 1.8×10^{-6} kg m²;
- Pulley Coefficient of friction:** $< 7 \times 10^{-3}$;
- Pulley Diameter:** 5 cm, mass 5.5 g
- Photogate Width:** 7.5 cm; fall time < 50 ns;
- Photogate Spatial resolution:** < 1 mm
- Timing Resolution:** 0.1 millisecond
- Product Connector:** Stereo phone plug

Order Information

Photogate & Pulley System	ME-6838A
--------------------------------	----------

Time-of-Flight Accessory

ME-6810A

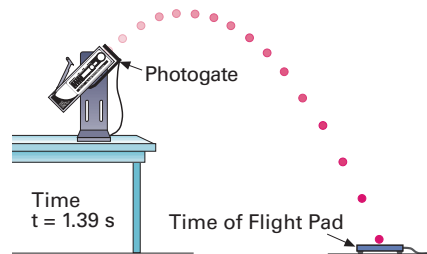


Applications:

- ▶ Conduct freefall experiments
- ▶ Use with all PASCO launchers
- ▶ Horizontal Velocity is Constant
- ▶ Horizontal Distance (two Photogate Heads needed)
- ▶ Time-of-Flight Versus Initial Velocity

The Time-of-Flight Accessory is designed primarily for freefall or projectile experiments. When an object hits the plate, a signal is sent to the interface.

Note: When used with the Projectile Launcher, a photogate is used to start the timer and the 20' extension cable is recommended.



Order Information

Time-of-Flight Accessory	ME-6810A
--------------------------------	----------

Phone Jack Extender Cable

PI-8117



This six meter phone jack-to-phone jack extension cord can be used with any Photogate/Timing accessory.

Order Information

Phone Jack Extender Cable (20' cable)	PI-8117
---	---------

G-M Tube/Power Supply

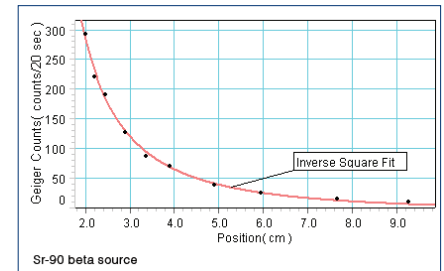
SN-7927A



The G-M Tube/Power Supply senses alpha, beta and gamma radiation. Power for the tube is supplied through the connection to an interface that supplies an operating voltage of +5 V.

Specifications:

- Sensitivity:** Beta, gamma, alpha
- Count Detection:** Audio signal
- Window Thickness:** 1.5 to 2 mg/cm², mica
- Starting/Operating Voltage for Tube:** 450 VDC/500 VDC
- Dead Time:** 90 μs
- Gas Filling:** Neon, Argon, and Halogen



The number of counts per time interval drops off as the distance between the detector and the radioactive source is increased.

The G-M Sensor can be attached directly to the rack on a Rotary Motion Sensor to measure the real-time count rate as a function of distance from the source.

Order Information

G-M Tube/Power Supply	SN-7927A
Recommended for use with SPARKlink Air, AirLink or SPARK LXI:	
PASPORT Digital Adapter	PS-2159

Pressure/Sound/Electrometer

Sound Sensor with Microphone

UI-5101

- ▶ Measures sound waveform
- ▶ Auxiliary microphone on wire

The Sound Sensor houses a sensitive microphone designed to measurements the relative intensity of sound and to display audio waveforms of sound levels between 45 and 100 dB, when used in conjunction with the 550 or 850 Universal Interface and PASCO software.

Applications:

- ▶ Measure basic sound intensity
- ▶ Measure speed of sound measurement
- ▶ Measure beats
- ▶ Study the doppler effect
- ▶ Conduct voice studies
- ▶ Learn musical instrument overtones

Specifications:

Frequency Response: 20 to 9,000 Hz

Decibel Range: 45 to >100 dB

Signal-to-Noise Ratio: < 60 dB

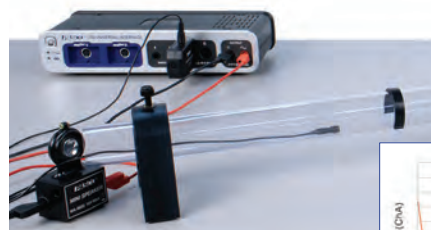
Amplification: Two stages condition low-level signals

Pin Configuration: 8-pin DIN plug on case

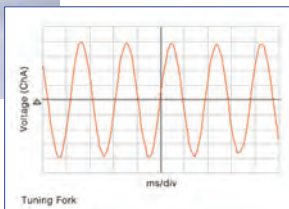
Sensor ID: Auto-identification on 550/850 Interfaces



Also see the new Wireless Sound Sensor on page 54.



The included auxiliary microphone can be used to probe a resonance tube.



Includes:

- Auxiliary Microphone (UI-5102)
- 8-Pin DIN Extension Cable
- Sensor Mounting Rod

Order Information

Sound Sensor with Microphone.....UI-5101

Replacement:

Auxiliary MicrophoneUI-5102

Temperature Sensor

CI-6605A

- ▶ Rugged sensor

PASCO's Stainless Steel Temperature Sensor offers a superior range, resolution and accuracy.

Specifications:

Temperature Range: -35°C to +135°C

Accuracy: ±0.5°C

Resolution: 0.05°C

Pin Configuration: 8-pin DIN plug



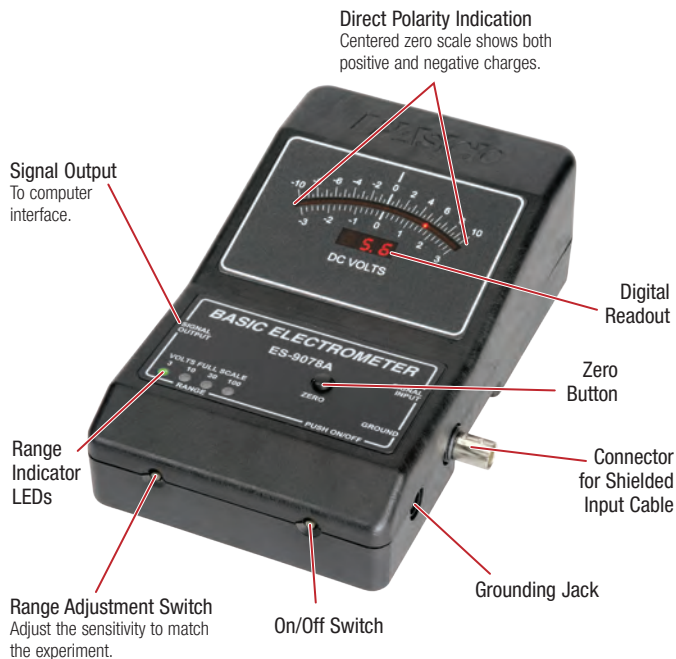
Order Information

Temperature SensorCI-6605A

Basic Electrometer

ES-9078A

- ▶ For 550/850 and ScienceWorkshop Interfaces



The PASCO Basic Electrometer is a quantitative electroscopes, measuring the polarity and magnitude of charged objects. With almost infinite input resistance (10¹⁴ ohm), the Electrometer is a high-impedance voltmeter, draining almost no charge from the object it is measuring.

Features:

- ▶ **Center-Zero Meter:** Polarity is indicated directly.
- ▶ **Switch-Selectable Ranges:** 3, 10, 30 and 100 VDC. LED lights indicate the range in use.
- ▶ **Zeroing Switch:** Removes all charge from the input and brings the meter to zero.
- ▶ **Automatic Shutoff:** Turns off about 3 hours after turned on (or used in any way).
- ▶ **Output Compatible with PASCO Interfaces:** The interface cable included with the electrometer connects directly to an analog channel on a ScienceWorkshop interface, and connects to a PASPORT interface through an Analog Adapter. This enables the output signal from the electrometer to be recorded, displayed, and analyzed by the data acquisition software.
- ▶ **Battery Operation:** 4 "AA" cells included. Range indicator lights flash when batteries need to be replaced.

Includes:

- Shielded input cable to connect the Electrometer to the Faraday Ice Pail or other source of charge
- Grounding cable with clip
- Interface cable
- Instruction and experiment manual

Order Information

Basic Electrometer.....ES-9078A

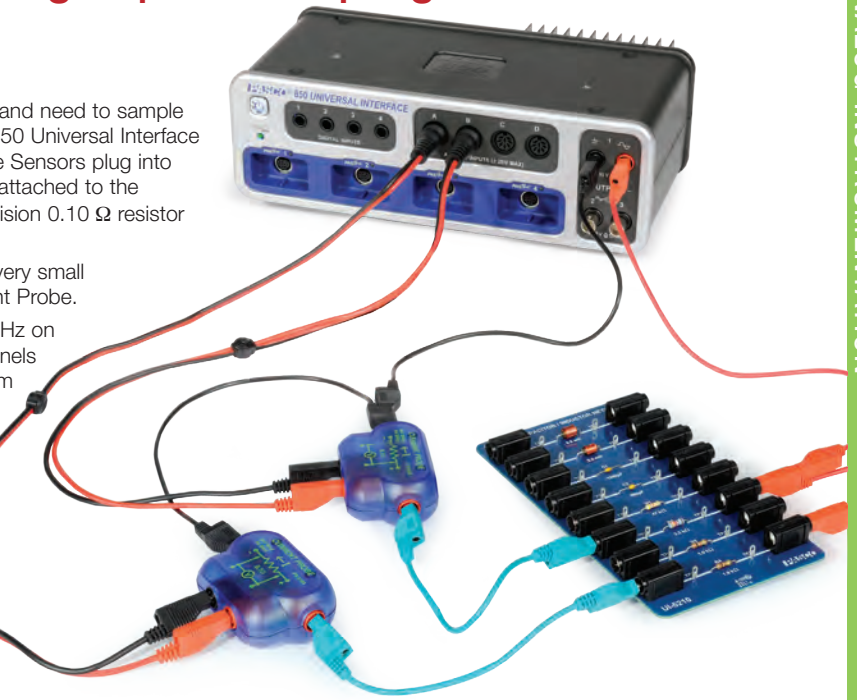
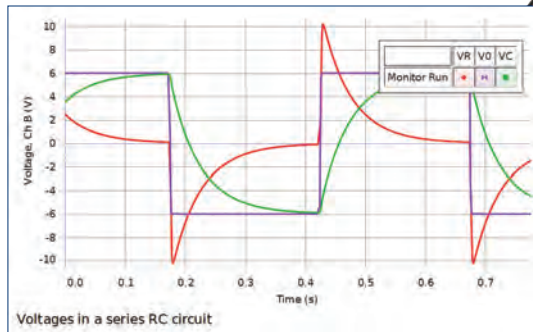
For 550/850 Interfaces and High Speed Sampling:

Voltage Sensor UI-5100/UI-5110 Current Probe PS-2184

When you're measuring voltage and current in AC circuits and need to sample fast, these sensors can sample as fast as 10 MHz on an 850 Universal Interface and up to 2 MHz on a 550 Universal Interface. The Voltage Sensors plug into the analog ports of these interfaces. The Current Probe is attached to the Voltage Sensor to measure the voltage drop across a precision $0.10\ \Omega$ resistor and outputs the resultant current calculation.

Since the 850 Interface analog gain can be set to $\times 1000$, very small currents ($0.024\ \text{mA}$ resolution) can be read with the Current Probe.

The 850 Universal Interface can measure at a rate of 10 MHz on two channels simultaneously; 1 MHz on three or four channels simultaneously. The 550 Universal Interface has a maximum sample rate of 2 MHz on one channel; 1 MHz on two channels simultaneously.



The high speed of the 850 Universal Interface, in Scope Mode, allows the examination of time varying voltages in an RC circuit to verify that Kirchoff's loop theorem holds even when voltage is not constant.

Voltage Sensor

UI-5100 (unshrouded)
UI-5110 (shrouded)



This voltage sensor plugs into any analog channel on a ScienceWorkshop Interface, the 850 Universal Interface, and the 550 Universal Interface. The voltage range and frequency response depend on the interface. When the Voltage Sensor is plugged into either the 550 or 850 Universal Interface, the sensor is automatically recognized.

Specifications:

Voltage Range with 850 Interface:
 $\pm 20\ \text{V AC/DC}$ (850 Interface)

Voltage Range with other interface:
 $\pm 10\ \text{V AC/DC}$ (other than 850)

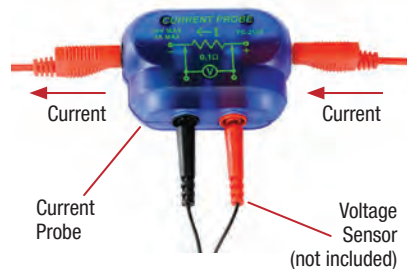
Product Pin Configuration: 8-pin DIN plug. Probe ends are standard banana plugs. Two alligator clip adapters included.

Order Information

Voltage Sensor (unshrouded) UI-5100
Voltage Sensor (shrouded) UI-5110

Current Probe

PS-2184



The PS-2184 attaches to any PASCO voltage sensor to allow the measurement of current between $-4\ \text{A}$ and $+4\ \text{A}$. The probe contains a precision $0.10\ \Omega$ resistor and allows the precise measurement of the voltage drop across the resistor.

Specifications:

Resistor: $0.10\ \Omega$, $3.0\ \text{W}$, 1.0%

Maximum Current: $4\ \text{A}$

Maximum Voltage Without Damage:
 $30\ \text{V}$

Terminals: $4\ \text{mm}$ Banana Jacks

Maximum Sample Rate:
Depends on interface

Order Information

Current Probe PS-2184

Current Sensor

CI-6556



The Current Sensor determines the current through it by measuring the voltage across the internal $1.00\ \Omega$ resistor. Up to $1.5\ \text{A}$ can be measured.

Specifications:

Maximum Current Input: $1.5\ \text{A}^*$

Maximum Differential Voltage: $1.5\ \text{V}^*$

Maximum Common Mode Voltage: $10\ \text{V}$

Resolution: $5\ \text{mA}$ ($1\times$ gain), $0.5\ \text{mA}$

Pin Configuration: 5-pin DIN on box
 * DC or AC RMS (root mean square)

Order Information

Current Sensor CI-6556

Light/Magnetic Field

Light Sensor

CI-6504A



Applications:

- ▶ Measure relative light intensities in daylight (even monitor a solar eclipse)
- ▶ Compare light intensity vs. distance
- ▶ Study interference/diffraction/polarization

PASCO's Light Sensor is ideal for indoor and outdoor relative light intensity experiments. It can be used in a lighted room for most experiments.

Specifications:

Sensing Element: Si PIN photodiode

Spectral Response: 320 nm to 1100 nm

Gain Levels: 100x, 10x, 1x, switch-selectable

Output Voltage: 0 V to 5 V

Pin Configuration: 5-pin DIN plug on case

Maximum Light Intensity Levels (lux):

Approximate Lux 5, 50, 500

Resolution: 0.0001 lux maximum

Order Information

Light Sensor CI-6504A

High-Sensitivity Light Sensor

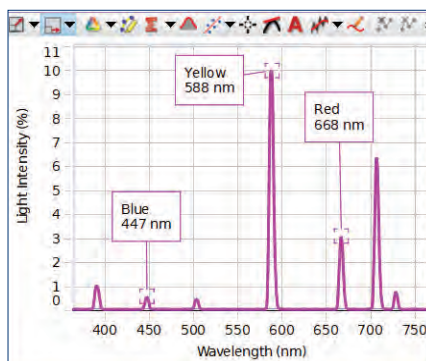
CI-6604



Applications:

- ▶ Spectrophotometry
- ▶ Interference and diffraction patterns
- ▶ Measure light intensity vs. distance

The High-Sensitivity Light Sensor is designed for experiments involving low light level conditions.



Helium spectrum recorded using the High Sensitivity Light Sensor and the OS-8539 Educational Spectrophotometer System.

Specifications:

Sensing Element: Si PIN photodiode

Spectral Response: 320 nm – 1100 nm

Gain Levels: 100x, 10x, 1x, switch-selectable

Resolution: 10 μ lux at the highest gain level.

Gain Level: 100X

Gain Level: 10X

Gain Level: 1X

Maximum Sample Rate: Interface dependent

Output Voltage: 0V to 5V

Order Information

High-Sensitivity Light Sensor CI-6604

Magnetic Field Sensor

CI-6520A

- ▶ Measures radial or axial fields
- ▶ High sample rate



Also see the new Wireless 3-Axis Magnetic Field Sensor on page 56.

PASCO's Magnetic Field Sensor is sensitive enough to detect Earth's magnetic field. Its application in the physics lab includes measuring and plotting fields in single or Helmholtz coils, solenoids, electromagnets and magnets.

Features

- ▶ **Measures radial or axial fields:** Two switch-selectable Hall Effect sensors measure either radial or axial fields.
- ▶ **Tare button:** Zeroing or nulling out existing fields is accomplished by just pushing the Tare button.
- ▶ **Three switchable ranges of sensitivity:** Full scale ranges of 10, 100 and 1,000 gauss.
- ▶ **7.5 cm Probe:** Sensors are mounted at the end of a fully encapsulated 7.5 cm long probe.

Specifications:

Sensitivity:

\pm 10 gauss (100X Gain),

50 mG resolution, 1 G Accuracy

\pm 100 gauss (10X Gain),

50 mG resolution, 10 G Accuracy

\pm 1000 gauss (1X Gain),

500 mG resolution, 100 G Accuracy

Measurement Modes: Axial and Radial

Probe Length: 7.5 cm

Pin Configuration: 8-Pin DIN plug on case

Order Information

Magnetic Field Sensor CI-6520A

Replacement:

Zero Gauss Chamber EM-8652

Zero Gauss Chamber

EM-8652

This double-walled, high permeability metal chamber produces a zero gauss field within the chamber. By placing the Magnetic Field Sensor probe into the chamber and pushing the "Tare" button, the sensor may be zeroed. Highly recommended for measurement of Earth's magnetic field.



Order Information

Zero Gauss Chamber EM-8652

Digital PASPORT Sensor Index

PASPORT Sensors:

- ▶ Have digital outputs that allow multiple measurements per channel with reduced noise
- ▶ Compatible with all current PASCO interfaces, as well as discontinued PASPORT interfaces

Sensor Description	Product #	Page #
Analog Adapter	PS-2158	48
Angle Sensor	PS-2139	39
Breath Rate	PS-2187	41
Charge	PS-2132	37
Chemistry Sensor, Advanced	PS-2172	45
Current, High	PS-2193	36
Current Probe	PS-2184	36
Digital Adapter	PS-2159	48
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Spectrometer, Wireless	PS-2600	60
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Temperature - Fast Response	PS-2135	33
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Temperature - Non-Contact	PS-2197	34
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PASPORT Sensor Extension Cable

PS-2500



The PASPORT Sensor Extension Cable extends the distance a PASPORT sensor can reach by 2 m. Two cables CANNOT be connected together or used on a sensor that already has a cable.

Order Information

PASPORT Sensor
Extension CablePS-2500

8-Pin DIN Extension Cable

UI-5218



The 1.8 m long Extension Cable allows ScienceWorkshop Sensors to be used further away from the interface. Multiple cables can be used in series. It is compatible with the 500, 750 (discontinued), and 850 Interfaces.

Order Information

8-Pin DIN Extension CableUI-5218

Smart Gate

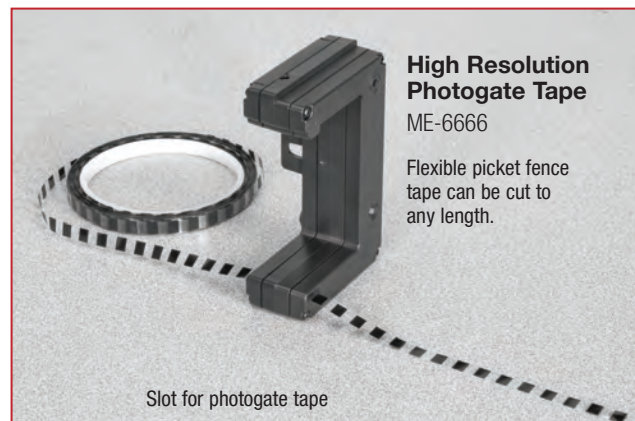
Smart Gate... *It's four photogates in one!*

PS-2180

- ▶ Dual Photogate beams
- ▶ Photogate Tape Slot
- ▶ Daisy-chain auxiliary Photogate or Time-of-Flight

Also see the
Wireless
Smart Gate
on page 52.

The Smart Gate connects directly to any PASPORT interface, and has an auxiliary port to daisy-chain to an additional Photogate. Can be used with a cart picket fence, clamp on super pulley, and flexible Photogate Tape.



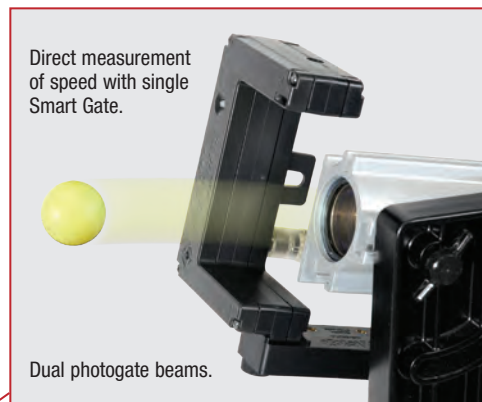
**High Resolution
Photogate Tape**
ME-6666

Flexible picket fence
tape can be cut to
any length.

Slot for photogate tape



Auxiliary port for Time-of-Flight
or other photogates

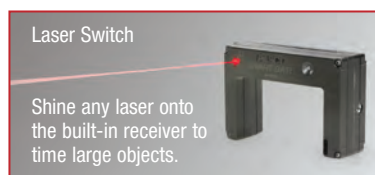


Direct measurement
of speed with single
Smart Gate.

Dual photogate beams.



Connects directly to a PASPORT
interface.



Laser Switch

Shine any laser onto
the built-in receiver to
time large objects.



Includes:

- Smart Gate
- PASPORT Cable
- Interface Cord



Order Information

Smart Gate	PS-2180
Recommended:	
Time-of-Flight Accessory	ME-6810A
Photogate Tape, High Resolution (30 m)	ME-6666
Required:	
PASPORT Interface	

Smart Gate System

PS-3701

Needs only one PASPORT connection.
Photogate daisy-chains to Smart Gate.

Includes:

- Smart Gate PS-2180
- Photogate Head ME-9498A



Order Information

Smart Gate System	PS-3701
-------------------------	---------

Smart Gate Pulley System

PS-3702

The Super Pulley attaches directly to the Smart Gate, providing a simple, low-friction system to measure position, velocity and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments.

Includes:

- Smart Gate: PS-2180
- Super Pulley: ME-9450A
- 45 cm Stainless Steel Rod: ME-8736



Order Information

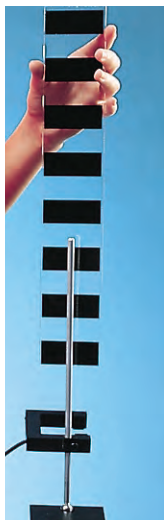
Smart Gate Pulley System	PS-3702
--------------------------------	---------

Picket Fence

ME-9377A

Conduct freefall experiments by dropping this Picket Fence through the PASCO Photogate.

The distance from the leading edge of each black bar to the leading edge of the next black bar is 5.0 cm. The Picket Fence has eight black bars and is 40 cm long.



Order Information

Picket Fence ME-9377A

Cart Picket Fences (2 Pack)

ME-9804



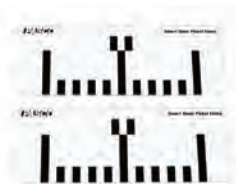
Order Information

Cart Picket Fences (2 Pack) -- IDS ME-9804

Picket Fences (Smart Timer) (Set of 2)

ME-8933

See Smart Timer on pages 116-117.



Order Information

Picket Fences (Smart Timer) ME-8933

Photogate Tape, High Resolution (30 m)

ME-6666

Flexible Mylar picket fence tape can be cut to any length. Tape slides into a Smart Gate to more accurately measure the motion of a cart.

Slide the photogate tape through the slot to measure position, velocity, and acceleration. The band spacing on the tape is 1 cm from edge to edge.



Order Information

Photogate Tape, High Resolution (30 m) ME-6666
Recommended:
Smart Gate PS-2180

Photogate Head

ME-9498A

The Photogate Head monitors the motion of objects passing through its gate, counting events as the object breaks the infrared beam.



Specifications:

Photogate Width: 7.5 cm

Fall Time: < 50 ns

Spatial Resolution: < 1 mm

Timing Resolution: 0.1 millisecond

Connector: Stereo phone plug

Order Information

Photogate Head ME-9498A
Recommended:
Photogate Stand ME-9805

Time-of-Flight Accessory

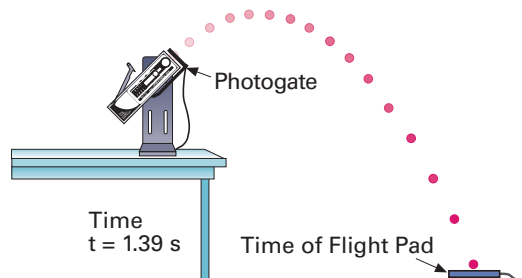
ME-6810A

The Time-of-Flight Accessory is designed primarily for freefall or projectile experiments. When an object hits the plate, a signal is sent to the interface. Note: When used with the Projectile Launcher, a photogate is used to start the timer and the 20' extension cable is recommended.



Applications:

- ▶ Conduct freefall experiments
- ▶ Use with all PASCO launchers
- ▶ Horizontal Velocity is Constant
- ▶ Horizontal Distance (two Photogate Heads needed)
- ▶ Time-of-Flight Versus Initial Velocity



Order Information

Time-of-Flight Accessory ME-6810A

Phone Jack Extender Cable

PI-8117

This six meter phone jack-to-phone jack extension cord can be used with any Photogate/Timing accessory.



Order Information

Phone Jack Extender Cable PI-8117

Motion

PASPORT Motion Sensor

PS-2103A

The PASPORT Motion Sensor is used to measure the position, velocity, and acceleration of a target. The Motion Sensor can be set on a desktop, mounted to a rod stand, or attached to a PASCO Dynamics Track.

**Specifications:****Minimum Range:** 0.15 meters**Maximum Range:** 8 meters**Resolution:** 1 mm**Maximum Sampling Rate:** 250 Hz**Transducer Rotation:** 360°**Narrow Near/Far Switch Settings:** For distances up to 2 meters to reject false target signals or ignore air track noise.**Standard Near/Far Switch Settings:** For longer distances up to 8 meters.**Cable Length:** 1.8 meter**Mounting Options:** Non-skid rubber feet for table mount**Order Information**

PASPORT Motion Sensor	PS-2103A
Recommended:	
Motion Sensor Guard	SE-7256
Motion Sensor Bracket.....	PS-2546
Cart Adapter Accessory.....	ME-6743

Motion Sensor Guard

SE-7256

Use this wire guard to protect the Motion Sensor when dropping objects from above.

**Order Information**

Motion Sensor Guard	SE-7256
---------------------------	---------

Motion Sensor Bracket

PS-2546

This magnetic bracket allows a Motion Sensor to be easily hung from a drop ceiling. Simply screw the bracket into the 1/4"-20 threads on the sensor and use the included adjustment nut to hold the sensor in the desired orientation.

**Order Information**

Motion Sensor Bracket.....	PS-2546
----------------------------	---------

Cart Adapter Accessory

ME-6743

The Cart Adapter Accessory allows the Motion Sensor and many other sensors to be mounted to a Dynamics Cart or a PAScar.

**Order Information**

Cart Adapter Accessory.....	ME-6743
-----------------------------	---------

PASPORT Rotary Motion Sensor

PS-2120A

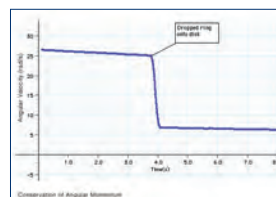


The PASPORT Rotary Motion Sensor is used to measure position and motion within physics labs. It measures position, velocity, and acceleration, both angular and linear, with incredible resolution and accuracy. The maximum spin rate of 30 rev/sec and bi-directional orientation enables the PASPORT Rotary Motion Sensor to facilitate the performance of most motion experiments.

How it Works: The 6.35 mm diameter, dual ball-bearing shaft extends from both sides of the unit, providing an excellent platform for rotational experiments. The rod clamp, which can be attached to three sides of the sensor, allows the unit to be mounted in almost any orientation. A three-step pulley and a mount for the PASCO Super Pulley make torque experiments easier than ever before.

Specifications:**Three-step Pulley:** 10 mm, 29 mm, and 48 mm diameters**Sensor Dimensions:** 10 cm x 5 cm x 3.75 cm, 6.35 mm diameter shaft**Rotary Motion Resolution:** 0.09° (0.00157 rad)**Linear Motion Resolution:** 0.0078 mm**Maximum Rotation Rate:** 30 revs/sec**Rotary Motion Optical Encoder:** Bidirectional to indicate the direction of motion; 4000 divisions/rev

Conservation of Angular Momentum



The angular speed of the disk decreases when the ring is dropped onto the disk.

**Order Information**

PASPORT Rotary Motion Sensor	PS-2120A
Recommended:	
Linear Motion Accessory	CI-6688A
3-Step Pulley for Rotary Motion Sensor.....	CI-6693

Linear Motion Accessory

CI-6688A

**Includes:**

- Rod Clamp
- Solid aluminum rack

Order Information

Linear Motion Accessory	CI-6688A
-------------------------------	----------

PASPORT High Resolution Force Sensor

PS-2189

- ▶ 0.002 N resolution
- ▶ Dynamic over-sampling

The PASPORT High Resolution Force Sensor offers a higher resolution than the PS-2104. It features a variable over-sampling rate that reduces measurement noise at lower sampling rates. The digital design minimizes drift, ensuring that the tare holds for hours. You can use this force sensor as a pan balance for long-term experiments, such as investigating the evaporation of liquids, like alcohol or liquid nitrogen, and the sublimation of dry ice.

Specifications:

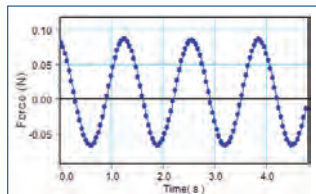
Range: ± 50 N

Measurement Resolution: 0.002 N

Zero (Tare) Function: Push-button

Max Sample Rate: 1000 Hz; 5000 Hz for the 550 and 850 interfaces

Force Overload Protection: Up to 75 N



Graph shows force data for the oscillation of a mass and spring system.

The High Resolution Force Sensor has 10 times the resolution of the PS-2104, and can measure changes in force of less than 0.01 N.

The digital design of the PS-2189 results in very little drift, ensuring that the tare will hold for hours. You can use this force sensor as a pan balance for long-term experiments, like investigating the evaporation of liquids such as alcohol or liquid nitrogen, and the sublimation of dry ice!

Order Information

PASPORT High Resolution Force Sensor PS-2189
Shown in use with:
Mass and Hanger Set..... ME-8979 p. 201
IDS Spring Kit ME-8999 p. 171

Force Sensor Balance Stand

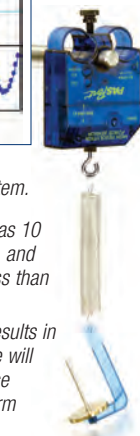
CI-6460

Includes:

- Metal Force Sensor Stand
- Pan Balance

Order Information

Force Sensor Balance Stand CI-6460



PASPORT Force Sensor

PS-2104

- ▶ Binocular force beam minimizes side force measurements

The sensor includes an overload stop in the force beam and a polycarbonate, plastic case to protect it from damage. Finger holes are provided for handheld use, but the sensor can also be mounted directly to a PASCO Dynamics Cart or a 0.5" rod stand.

Applications:

- ▶ Measure force exerted by an oscillating mass
- ▶ Measure force during elastic and inelastic collisions
- ▶ Measure force of a swinging pendulum

Specifications:

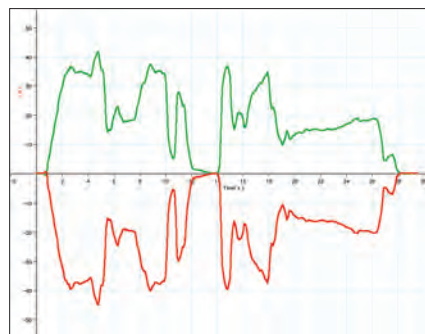
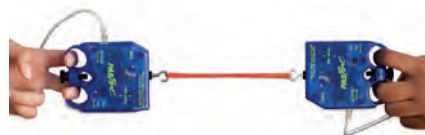
Range: ± 50 N

Resolution: 0.03 N

Zero (Tare) Function: Push-button

Max Sample Rate: 1000 Hz; 5000 Hz for the 550 and 850 interfaces

Force Overload Protection: Up to 75 N without damage



This graph displays Newton's Third Law during a "Tug of War" experiment.

Order Information

PASPORT Force Sensor PS-2104
Replacement:
Force Sensor Track Bracket ME-6622
Rocket Engine Test Bracket ME-6617

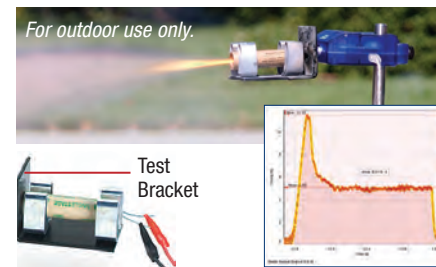


Rocket Engine Test Bracket

ME-6617

- ▶ A perfect supplement for rocketry studies

With the Rocket Engine Test Bracket attached to a Force Sensor (ScienceWorkshop or PASPORT), students can measure and graphically display the impulse of Estes™ and other model rocket engines. A perfect supplement for rocketry studies. Accommodates rocket engine sizes A, B, C and D.



Order Information

Rocket Engine Test Bracket ME-6617

Bumper Accessory Set

ME-9884

Includes:

- Stiff Spring
- Light Spring
- Empty Cup (2)
- Modeling Clay



Order Information

Bumper Accessory Set ME-9884

Magnetic Bumper Set

ME-9885A

Includes:

- Magnetic Bumper (2)



Order Information

Magnetic Bumper Set ME-9885A

Force Sensor Track Bracket

ME-6622

Includes:

- Spring Bumpers (2) (different spring constants)
- Magnetic Bumper
- Rubber Bumper
- Clay Cup for Inelastic Collisions (clay included)
- #0 Phillips Head Screwdriver (to attach to Force Sensor)



Order Information

Force Sensor Track Bracket ME-6622

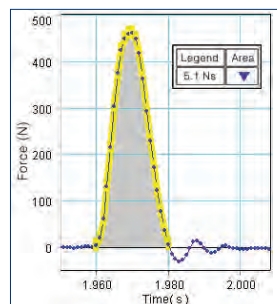
Force Platform

PASPORT Force Platform

PS-2141

- ▶ Rugged design
- ▶ Force overload protection
- ▶ Large jumping and landing surface

The sturdy, glass-filled nylon platform is supported by four force beams that measure the total force acting on the platform. You can use the Force Platform to measure the static weight of a structure or person, as well as the dynamic, vertical force created when moving or jumping. The platform can be placed on a floor or tabletop to measure vertical force, and mounted to a wall to measure horizontal force.



Impulse data for a bouncing playground ball.



Applications:

- ▶ Determine hang time by jumping from and landing on the platform
- ▶ Measure impulse and maximum force
- ▶ Measure the normal force acting on a person riding an elevator
- ▶ Use two Force Platforms to investigate Newton's Third Law
- ▶ Use a Motion Sensor and a ball to compare the impulse and change in momentum as the ball collides with the platform

Specifications:

Range: -1100 N to +4400 N

Force Overload Protection: up to 6600 N (1500 lb, 1700 N or 375 lb per beam)

Platform Size: 35 cm x 35 cm

Zero (tare) Function: Push-button

Max Sample Rate: 1000 Hz (2000 Hz with the 850 Interface)

Resolution: 0.1 N

Mass: 4 kg (without handles)

Order Information

PASPORT Force Platform..... PS-2141

Recommended:

Handle Set, Force Platform..... PS-2548

PASPORT 2-Axis Force Platform

PS-2142

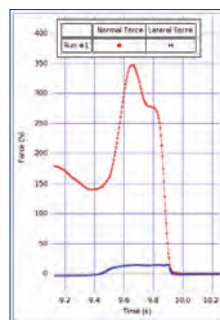
- ▶ Large jumping and landing surface

The 2-axis Force Platform has a second plate that rides on rollers on the base force platform to measure the force parallel to the platform. There are a total of five force beams: four corner beams to measure the normal force and a fifth beam to measure the parallel (sideways) force.



Applications:

- ▶ Measure the sideways force during a broad jump
- ▶ Measure the normal and parallel forces on a wall as a ladder leans against the wall
- ▶ Measure the normal and parallel forces as a person walks or runs across the platform
- ▶ Pull an object across the platform and measure the normal and frictional forces



The normal and parallel forces are recorded as the girl jumps off the platform.



Developed in cooperation with Nancy Beverly, Associate Professor of Physics at Mercy College, Dobbs Ferry, New York.

Specifications:

Range: -1100 N to +4400 N

(in normal direction)

-1100 N to +1100 N

(in parallel direction)

Platform Size: 35 cm x 35 cm

Platform Mass: 6.4 kg (without handles)

Zero (tare) Function: Push-button Force Overload Protection

Max Sample Rate: 1000 Hz (2000 Hz with the 850 Interface)

Resolution: 0.1 N

Order Information

PASPORT 2-Axis Force Platform..... PS-2142

Recommended:

Handle Set, Force Platform..... PS-2548

Handle Set, Force Platform

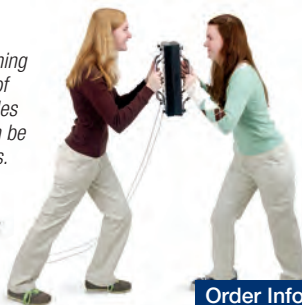
PS-2548

Confirm Newton's Third Law by pushing on a Force Platform using two sets of handles (available separately). Handles bolt onto the Force Platform and can be mounted on either side or both sides.



Includes:

- Sturdy metal handles (2)



By standing on a 2-Axis Force Platform while pushing against the wall with a 1-Axis Force Platform, a real-life statics problem can be analyzed.



Order Information

Handle Set, Force Platform..... PS-2548

Force Platform Structure Bracket

ME-6988A

Includes:

- Brackets (2)
- Screws (4)



Order Information

Force Platform Structure Bracket..... ME-6988A

Two ranges of load cells

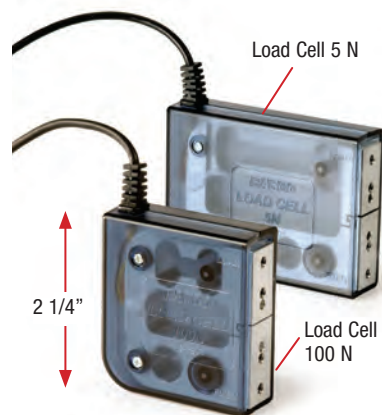
Load Cell 100 N

PS-2200

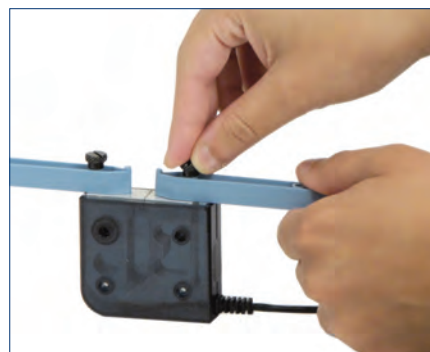
Load Cell 5 N

PS-2201

Also see the Wireless Load Cell on page 53.



Load cells are available in two different ranges: ± 100 N and ± 5 N. Both types of load cells can be used with the same amplifier in any combination. The semi-transparent case lets students see the strain gauge and beam inside.



I-Beams key into the load cell and are fastened with thumb screws.

PS-2200 Specifications:

Range: ± 100 N

Accuracy: $\pm 1\%$ (± 1 N)

Resolution: 0.02 N

Safe Overload: ± 150 N

PS-2201 Specifications:

Range: ± 5 N

Accuracy: $\pm 1\%$ (± 0.05 N)

Resolution: 0.001 N

Safe Overload: ± 7.5 N

Order Information

100 N Load CellPS-2200
5 N Load CellPS-2201

PASPORT Load Cell Amplifier

PS-2198



This Load Cell Amplifier can accommodate up to six load cells and utilizes a single PASCO interface port to connect to a computer's USB port. Students can insert up to six load cells at various points of their structures to extensively analyze their bridges. The Amplifier is compatible with both 5 and 100 N Load Cells, and features a maximum data sampling rate of 500 Hz per port.

Shown in use with Structures systems Truss Set (ME-6990). See page 157



The top two numbers are the left and right diagonals and the bottom two numbers are the left and right horizontal forces.

Includes:

- PASPORT Load Cell Amplifier (PS-2198)
- Instruction manual

Order Information

PASPORT Load Cell AmplifierPS-2198
Required:
100 N Load CellPS-2200
5 N Load CellPS-2201

PS-2199 Includes:

- Load Cell Amplifier
- 100 N Load Cell (4)
- Instruction Manual



Order Information

Load Cell and Amplifier SetPS-2199

PASPORT Dual Load Cell Amplifier

PS-2205



Includes:

- Dual Load Cell Amplifier
- Load Cell 100 N

PS-2206 Includes:

- Load Cell Amplifier (2-port)
- 100 N Load Cell



Order Information

PASPORT Dual Load Cell AmplifierPS-2205
PASPORT Load Cell and Dual Amplifier SetPS-2206

Measure bridge deflection with a Displacement Sensor

PASPORT Displacement Sensor

PS-2204

The Displacement Sensor measures the travel of a spring-loaded indicator as a bridge is loaded with weight. The PASPORT Sensor plugs into the included Digital Indicator, which has its own digital LED readout and can be used as a standalone device. To record your data, simply plug the PASPORT sensor into an interface.



Specifications:

Maximum Travel: 10 mm

Maximum Sample Rate: 5 Hz

Resolution: 0.013 mm (0.0005 in)

Includes:

- Sensor
- Bracket
- Dial Gauge



Order Information

PASPORT Displacement SensorPS-2204
Shown in use with:
Hooked Mass SetSE-8759 p. 197
Small "A" BaseME-8976 p. 186
Stainless Steel Rod,
60 cm ThreadedME-8977 p. 186

PASPORT Absolute Pressure Sensor

PS-2107

The Absolute Pressure Sensor measures the gas pressure in a container or the surroundings. Includes a 20 cc syringe and quick-connect tubing for investigating the Gas Laws. The sensor's wide range makes it an excellent general purpose pressure device.

Applications:

- ▶ Measure chemical reaction rates
- ▶ Verify Gas Laws (Ideal, Charles', Boyle's)
- ▶ Study Vapor Pressure vs. Temperature

Specifications:

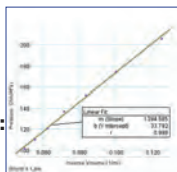
Range: 0 to 700 kPa

Accuracy: ± 2 kPa

Resolution: 0.1 kPa

Maximum Sample Rate: 200 Hz

Repeatability: 1 kPa



The Absolute Pressure Sensor is used in a Boyle's Law experiment in which a syringe is compressed.



Order Information

PASPORT Absolute Pressure SensorPS-2107

PASPORT Dual Pressure Sensor

PS-2181

The Dual Pressure Sensor is capable of reading two absolute pressures, one gauge pressure, or one differential pressure. Dynamic variable over-sampling automatically reduces the measurement noise at low sampling rates. Sample rates up to 1000 Hz make studies of both transient and steady-state pressure possible. Includes quick-connect tubing.

Applications:

- ▶ Measure pressure in Heat Engine (TD-8572).
- ▶ Measure pressure drops in pipes

Specifications:

Maximum Sample Rate: 1000 Hz

Absolute Pressure: 0 to 200 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m², and psi)

Differential Pressure: ± 100 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m², and psi)

Order Information

PASPORT Dual Pressure SensorPS-2181



PASPORT Quad Pressure Sensor

PS-2164



The 4-port Quad Pressure Sensor is capable of reading up to four absolute pressures, two gauge pressures, or two differential pressures. Dynamic variable over-sampling automatically reduces the measurement noise at low sampling rates. Sample rates up to 1000 Hz make studies of both transient and steady-state pressure possible. Includes quick-connect tubing.

Applications:

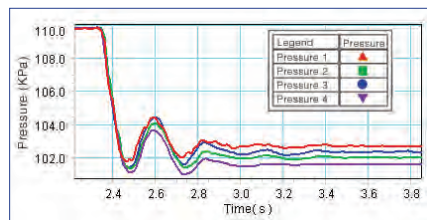
- ▶ Study pressure through a fluid circuit

Specifications:

Absolute Pressure: 0 to 200 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m², and psi)

Differential Pressure: ± 100 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m², and psi)

Maximum Sample Rate: 1000 Hz



The pressure at various points in a Venturi tube decreases as the water flow is turned on. Pressure variability due to cross-sectional area and fluid friction are readily seen in the data.

Order Information

PASPORT Quad Pressure SensorPS-2164
Venturi Tube.....ME-2220 p. 43

PASPORT Absolute Pressure/Temperature Sensor

PS-2146



This combination sensor is specifically designed for studying the Ideal Gas Law. The included thermistor temperature probe has a fast response time and very low thermal mass.

Applications:

- ▶ Extrapolate absolute zero
- ▶ Explore Gas Laws (Ideal, Charles', Boyle's)

Specifications:

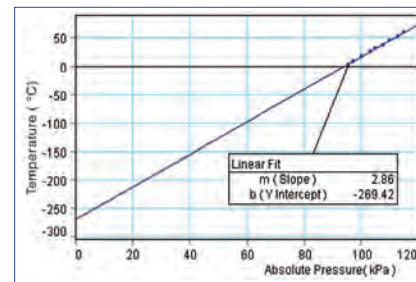
Pressure: 0 to 700 kPa with ± 2 kPa accuracy, 0.1 kPa resolution and 1 kPa repeatability (displays pressure in kPa, N/m², and psi)

Maximum Sample Rate: 100 Hz

Temperature with Included Fast Response Probe: -10 to 70°C

with $\pm 0.5^\circ\text{C}$ accuracy (displays Temperature in $^\circ\text{C}$, K and $^\circ\text{F}$)

Sensor Extension Cable: Included



Extrapolating Absolute Zero



Measure pressure and temperature of air in the sphere.

Order Information

PASPORT Absolute Pressure/ Temperature SensorPS-2146
Absolute Zero Sphere.....TD-8595 p. 206
Ideal Gas Law Apparatus.....TD-8596A p. 206

PASPORT Temperature Sensor

PS-2125

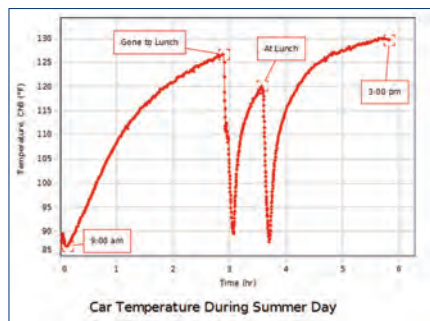
Also see the Wireless Temperature Link on page 55.



PASCO's Stainless Steel Temperature Sensor offers a superior range, resolution and accuracy. It reports temperature (in °C, °F, or K) whether it is immersed in liquids, held in the air, or touching a solid surface.

Applications:

- ▶ Conduct general temperature experiments
- ▶ Measure rapid temperature changes found in endothermic-exothermic reactions
- ▶ Conduct environmental studies



Capstone graph showing the temperature inside a parked car on a summer day. We turned on the air conditioning when we drove to lunch.

Specifications:

- Range:** -35°C to +135°C
- Accuracy:** ±0.5°C
- Resolution:** 0.0025°C
- Maximum Sample Rate:** 10 Hz
- Displays:** °C, K and °F
- Repeatability:** 0.1°C

Order Information

PASPORT Temperature SensorPS-2125

PASPORT Quad Temperature Sensor

PS-2143



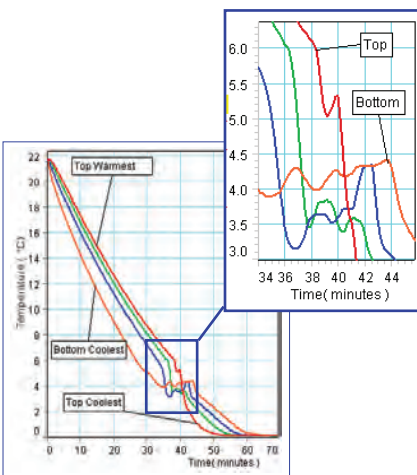
The PASPORT Quad Temperature Sensor can connect up to four Temperature Probes and can be used with our Stainless Steel, Fast Response, and Skin/Surface Temperature probes for a wider variety of temperature measurements in the classroom or field.

Applications:

- ▶ Thermal heat flow (one or two dimension)
- ▶ Compare body temperatures
- ▶ Side-by-side chemical reactions
- ▶ Solar radiation
- ▶ Properties of insulation

Specifications:

- Accuracy:** -35 to +135°C at ±0.5°C
- Displays:** °C, K and °F
- Resolution:** 0.0025°C
- Maximum Sample Rate:** 100 Hz



Four Fast Response Temperature Probes were used to study the temperature in a glass of water at four different levels as the water was cooled.

Includes:

- Two Stainless Steel Temperature Probes (2)
- Three Fast Response Probes (3)

Order Information

PASPORT Quad Temperature SensorPS-2143

Temperature Probes PASPORT Skin/Surface Temperature Probe

PS-2131



- ▶ Flat sensing element ideal for surfaces
- ▶ Quickly reaches equilibrium temperature with surface

Range: -10 to +70°C

Make a temperature profile of the human hand.



Order Information

PASPORT Skin/Surface Temperature ProbePS-2131

PASPORT Fast Response Temperature Probe (3 pack)

PS-2135



- ▶ Accurately measures temperature changes in real time
- ▶ Ideal for small or hard-to-reach spaces
- ▶ Includes 10 Adhesive Patches
- ▶ Adhesive patches hold the Temperature Probe in place.

Range: -30 to +105°C

Order Information

PASPORT Fast Response Temperature Probe (3 pack)PS-2135

PASPORT Stainless Steel Temperature Probe

PS-2153



Range: -35 to +135°C

Order Information

PASPORT Stainless Steel Temperature ProbePS-2153

Order Information

**All of the probes above require one of the following temperature sensors:*
 PASPORT Temperature Sensor PS-2125 p. 33
 PASPORT Quad Temperature Sensor PS-2143 p. 33
 Temperature Sensor CI-6605A p. 22

Temperature

PASPORT Non-Contact Temperature Sensor

PS-2197

- ▶ Non-contact
- ▶ -70°C to 380°C



The Non-Contact Temperature Sensor measures surface temperature by detecting the emitted infrared light. Record the temperature of objects without touching them!

Applications:

- ▶ Compare temperature of hands, skin, face, and clothes
- ▶ Measure the temperature of different outdoor ground surfaces
- ▶ Map the temperature profile of an exterior wall

Specifications:

Range: -70°C to 380°C

Accuracy: $\pm 0.5^{\circ}\text{C}$

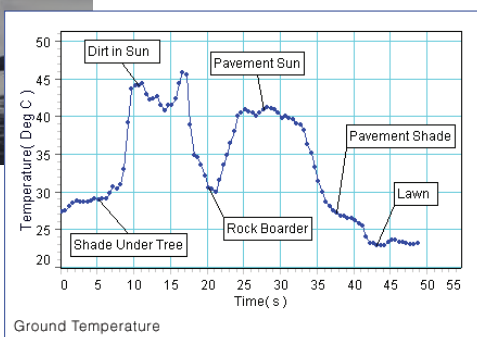
Response Time: Less than 0.1 s

Maximum Sample Rate: 200 Hz

Field of View: $\pm 35^{\circ}$



The student measures the late-morning ground temperature over four distinct surfaces. Starting in the shade under the distant tree, she then crosses bare dirt (in sun), a rock border, pavement, and lawn.



Order Information

PASPORT Non-Contact Temperature Sensor PS-2197
 Shown in use with:
 PASCO Capstone Software pp. 72-75

PASPORT Temperature Type K Sensor

PS-2134

- ▶ Extra-long probe

The PS-2134 is a single channel sensor that uses the same Type K thermocouple probe as the PS-2127 shown on this page. Includes one Type K Thermocouple.



Applications:

- ▶ Measure temperatures down to -200°C
- ▶ Measure temperatures in hard-to-reach places
- ▶ Use in high temperature applications where the narrow tip of the probe can be applied without burning the insulation cover (such as a candle flame)

Specifications:

Temperature Range: -200°C to $+1000^{\circ}\text{C}$

Maximum Sample Rate: 10 Hz

Accuracy: $\pm 3^{\circ}\text{C}$ or 3%, whichever is greater



The Type K Temperature Sensor can be used to measure the temperature of a flame. Works with any industry standard Type K thermocouple.

Order Information

PASPORT Temperature Type K Sensor PS-2134
 Recommended:
 Type K Thermocouple PS-2155

PASPORT High Sensitivity Light Sensor

PS-2176

- ▶ Ideal for low light experiments



The High Sensitivity Light Sensor is designed to perform visible light studies from low intensity spectral studies to daylight. Built-in automatic variable oversampling reduces noise.

Applications:

- ▶ Spectrophotometry
- ▶ Interference and diffraction patterns
- ▶ Measure light intensity vs. distance

Specifications:

Sensing Element: Si PIN photodiode

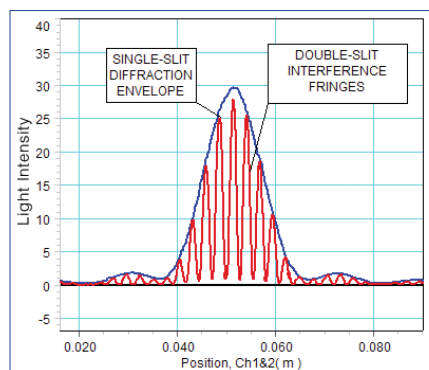
Spectral Response: 320 nm to 1100 nm

Gain Levels: 10,000x, 100x, 1x, switch selectable

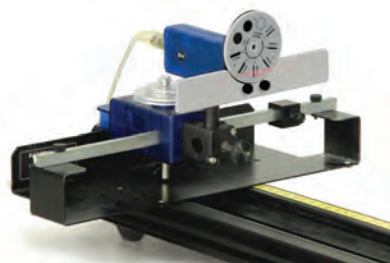
Approximate Lux Ranges: 0 to 1, 0 to 100, 0 to 10,000

Maximum Sample Rate: 1000 Hz

Resolution: ± 0.01 Lux at 1000 Hz on 0 to 100 scale; ± 0.0005 Lux at 5 Hz on 0 to 100 scale



Computer scan of a single-slit and double-slit having the same slit width.



Order Information

PASPORT High Sensitivity Light SensorPS-2176

PASPORT Infrared Light Sensor

PS-2148

- ▶ For heat studies



The Infrared Light Sensor is sensitive in the infrared portion (up to 40,000 nm) of the spectrum, but also detects the visible spectrum. It can detect the radiation from a person's hand. The response is linear over its entire frequency range.

Applications:

- ▶ Measure blackbody radiance
- ▶ Perform Leslie's Cube experiments
- ▶ Measure solar radiance
- ▶ Evaluate heat flow into or out of the sensor
- ▶ Simulate a non-contact temperature sensor

Specifications:

Measure Intensity: in Watts/Meter

Maximum Sample Rate: 100 Hz

Spectral Response: 580 to 40,000 nm

Built-in Thermistor: to measure the temperature of the "cold" side of the thermopile in $^{\circ}\text{C}$, $^{\circ}\text{F}$ or K

Order Information

PASPORT Infrared Light SensorPS-2148

PASPORT Broad Spectrum Light Sensor

PS-2150

- ▶ For use with Spectrophotometer
- ▶ Ideal for Blackbody Spectrum



The Broad Spectrum Light Sensor is designed specifically for use with our Educational Spectrophotometer System OS-8539 and Prism Spectrophotometer Accessory OS-8543 for Blackbody experiments. The Broad Spectrum Light Sensor uses a thermopile and window combination that respond to both the near infrared and visible light necessary for the Blackbody experiment.

Applications:

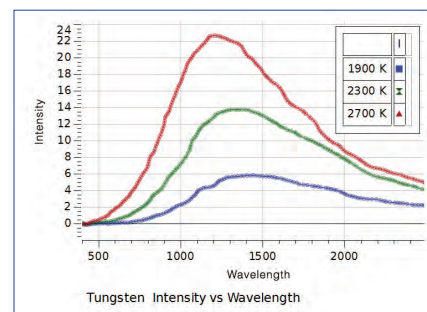
- ▶ Blackbody Experiment

Specifications:

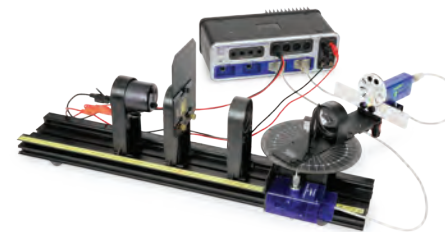
Sensing Element: BaF_2 window, xenon gas-filled thermopile

Spectral Response: 300 to 10,000 nm

Maximum Sample Rate: 100 Hz



The classic textbook diagram of the intensity versus wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the blackbody curve shifts as the source temperature is lowered.



Order Information

PASPORT Broad Spectrum Light SensorPS-2150

Voltage/Current

PASPORT Voltage-Current Sensor

PS-2115



Also see the
Wireless Current
and Voltage
Sensors on
page 57.

The PASPORT Voltage-Current Sensor combines voltage and current sensors in one case. It can simultaneously measure voltage, current, and power, then display the collected data in the form of a digital display or graph. An audible beep can be heard when overload protection shuts down the sensor, alerting teachers and keeping students safe. The sensor will automatically reset after the high current is removed.

Applications:

- ▶ Study circuit properties for both circuits in series and parallel
- ▶ Ohm's Law
- ▶ Measure power used by an electrical device
- ▶ Indirectly measure the resistance of any circuit element
- ▶ Measure the voltage and current associated with RC and LRC circuits

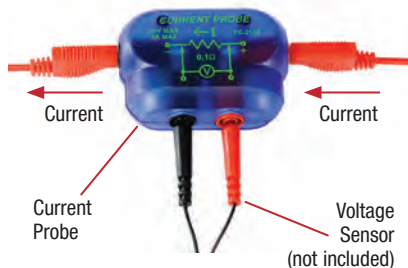
Specifications:**Voltage Range:** ± 10 V**Voltage Resolution:** 0.005 V**Current Range:** ± 1 A**Current Resolution:** 0.5 mA**Current Channel Series Resistance:** 0.6 ohms, < 0.9 ohms at room temperature**Maximum Common Mode Voltage:** 10 V**Maximum Sample Rate:** 1000 samples/sec**Voltage Input Impedance:** 2 M Ω **Order Information**

PASPORT Voltage-Current Sensor.....	PS-2115
Recommended:	
Alligator Clip Leads (Set of 10)	EM-8634

PASPORT Current Probe

PS-2184

The PS-2184 attaches to any voltage sensor to allow the measurement of current between -4 A and +4 A. The probe contains a precision 0.10 ohm resistor and allows the precise measurement of the voltage drop across the resistor.

**Specifications:****Resistor:** 0.10 Ohm, 3.0 W, 1.0%**Maximum Current:** 4 A**Maximum Voltage Without Damage:** 30 V**Terminals:** 4 mm Banana Jacks**Maximum Sample Rate:** Depends on interface**Order Information**

Current Probe	PS-2184
---------------------	---------

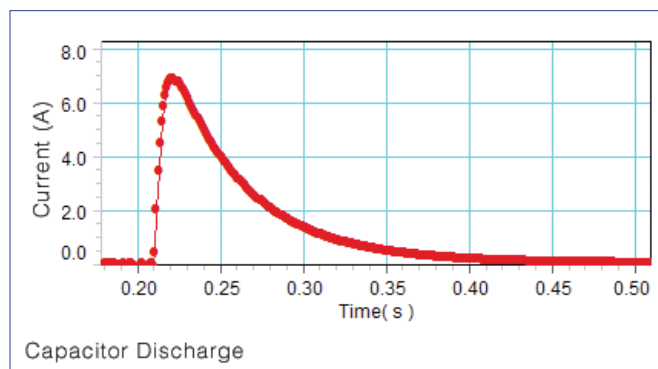
PASPORT High Current Sensor

PS-2193

- ▶ 10 Amp
- ▶ Over-current LED



The High Current Sensor has a low (0.01 Ω) resistance sensing element, can measure up to 10 A, and has an LED over-current indicator. Dynamic variable over-sampling greatly reduces the measurement noise at low sample rates.

Specifications:**Current Range:** ± 10 A, resolution of 0.5 mA**Sensing Element Series Resistance:** 0.01 Ω **Maximum Common Mode Voltage:** 10 V**Maximum Continuous Current Without Damage:** 12 A**Maximum Continuous Overvoltage Without Damage:** ± 40 V**Maximum Sample Rate:** 1000 samples/second

The capacitor is charged with a power supply to 10 volts, and then discharged through the Air Core Solenoid. The graph of the data shows the effect of the coil's inductance on the rise time of the current.

**Order Information**

PASPORT High Current Sensor	PS-2193	
Recommended:		
Capacitor (0.025 F, 2 Pack)	EM-8632	p. 229
Knife Switches	EM-8815	p. 227
Air Core Solenoid	SE-7585	p. 237

PASPORT Galvanometer

PS-2160



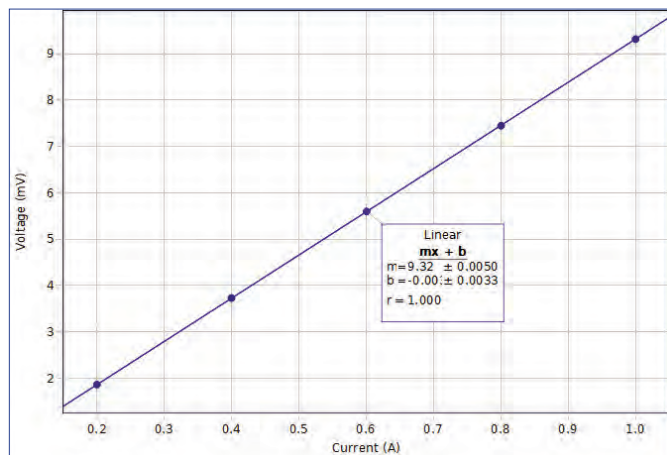
The Galvanometer Sensor is designed to measure small voltages with high resolution. Dynamic variable over-sampling greatly reduces the measurement noise at low sampling rates. Shunt resistors are included to allow measurement of current.

Specifications:

Voltage Range: ± 2000 mV, resolution of 0.1 mV

Maximum Sample Rate: 1000 Hz with other interfaces

Input Impedance: 1 M Ω



Galvanometer Sensor can measure the voltage drop across a short piece of wire. A linear fit of voltage versus current yields the resistance of 0.0093 Ω for the wire.



By using a shunt resistor, the Galvanometer Sensor can be used to measure current.

Includes:

- BNC-to-banana plug cable
- BNC-to-banana jack adapter
- 0.1 Ω and 10 Ω resistors

PASPORT Charge Sensor

PS-2132

- ▶ Ideal for Electrostatics



The Charge Sensor is designed for experiments in electrostatics such as inductive charging, charge production/distribution, and charge on a capacitor. The sensor features automatic scaling, eliminating the need for a gain switch. Designed with highly efficient input over-voltage protection, the Charge Sensor is virtually "blow-out" proof and will provide many years of use in the student lab.

When used with the Faraday Ice Pail, the Charge Sensor can measure the total charge on an object by the induction method.

The Charge Sensor can also be used as a high impedance voltmeter (10^{12} Ω). It includes a 0.9 m shielded cable with alligator clips to eliminate stray fields.

Applications:

- ▶ Measure charge by induction
- ▶ Quantify the charge on a capacitor plate
- ▶ Discover the charge distribution on a conducting sphere

Specifications:

Charge Range: ± 0.1 μC

Voltage Range: ± 10 V

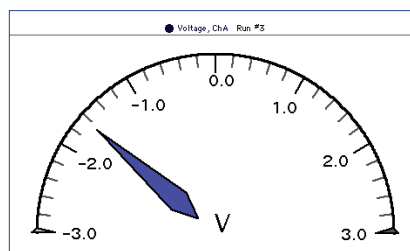
Input Resistance: 10^{12} Ω

Maximum Input Voltage: 150 V

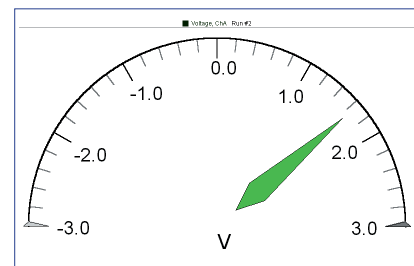
Maximum Sample Rate: 100 Hz

Input Connector: BNC

Input Cable: 0.9 m length; shielded with alligator termination



The Charge Sensor measures equal yet opposite charge on two objects.



Order Information

PASPORT Charge Sensor..... PS-2132

Recommended:

Faraday Ice Pail ES-9042A p. 215

Order Information

PASPORT Galvanometer..... PS-2160

Recommended:

Alligator Clip Leads (Set of 10) EM-8634

Magnetic Field

PASPORT Magnetic Field Sensor

PS-2112

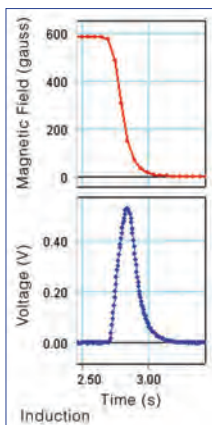


Also see the
Wireless 3-Axis
Magnetic Field
Sensor on
page 56.

The Magnetic Field Sensor provides magnetic field measurement in a compact package. The sensor at the tip of the probe measures magnetic field strength along the axis of the probe.

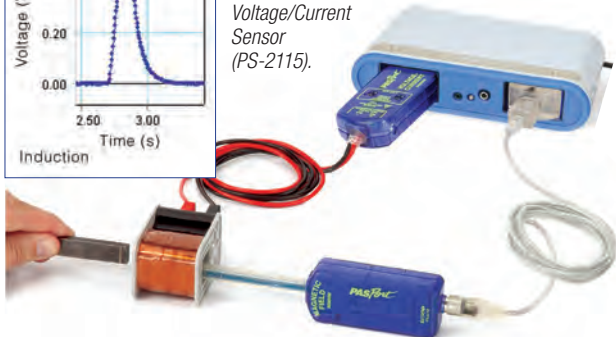
Applications:

- ▶ Study the field strength of bar magnets and electromagnets
- ▶ Understand the field strength of a solenoid
- ▶ Measure the field strength of a Helmholtz coil

Specifications:**Range:** ± 1000 gauss**Accuracy:** ± 3 gauss or 5% of reading, whichever is greater at 25°C (after four minute warm-up)**Resolution:** 0.1 gauss (0.01% full-scale)**Maximum Sample Rate:** 20 Hz**Repeatability:** 0.05%

As the magnet is removed from the coil, a voltage is induced in the coil. The graph shows both the sudden decrease in magnetic field, as well as the voltage curve using a Voltage/Current Sensor.

Shown with: SPARKlink Air (PS-2011), Coil (3200 turn; SF-8613), Bar Magnet (EM-8620), and Voltage/Current Sensor (PS-2115).

**Order Information**

PASPORT Magnetic Field Sensor PS-2112
Recommended:
Zero Gauss Chamber EM-8652

Zero Gauss Chamber

EM-8652

This double-walled, high permeability metal chamber produces a zero gauss field within the chamber. By placing the Magnetic Field Sensor probe into the chamber and pushing the "Tare" button, the sensor may be zeroed. Highly recommended for measurement of Earth's magnetic field.

**Order Information**

Zero Gauss Chamber EM-8652

PASPORT 2-Axis Magnetic Field Sensor

PS-2162

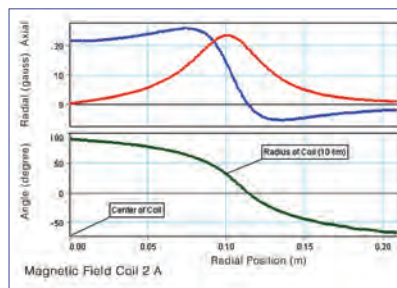
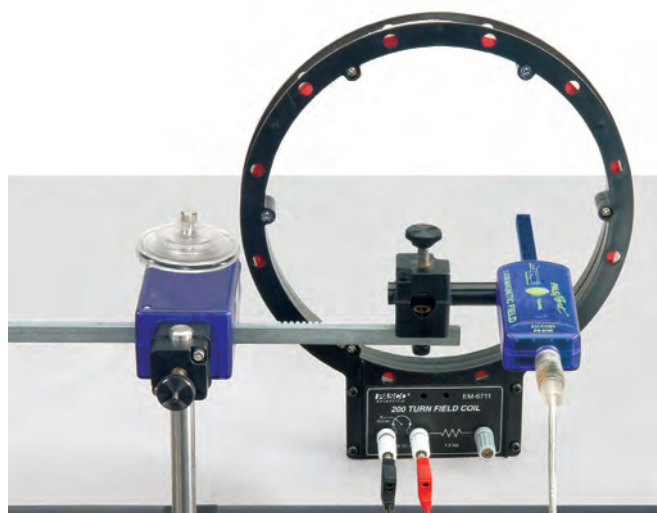
- ▶ Measures radial and axial fields
- ▶ Tare button



Measure radial and axial fields simultaneously. Dynamic variable oversampling greatly reduces noise at low sample rates.

Applications:

- ▶ Measure Earth's magnetic field.
- ▶ Measure magnetic field (magnitude and direction from a coil or a bar magnet).

Specifications:**Range:** ± 1000 gauss**Accuracy:** 5% of reading at 25°C (after four minute warm-up and Tare using Zero Gauss Chamber)**Resolution:** 0.01 gauss at 10 Hz**Maximum Sample Rate:** 1000 Hz**Repeatability:** 0.05%

Magnetic field is measured from the center out to twice the radius of the coil. The angle of the resultant field is calculated.

Order Information

PASPORT 2-Axis Magnetic Field Sensor PS-2162
Recommended:
Zero Gauss Chamber EM-8652
Linear Motion Accessory CI-6688A

p. 28

Human Arm Model

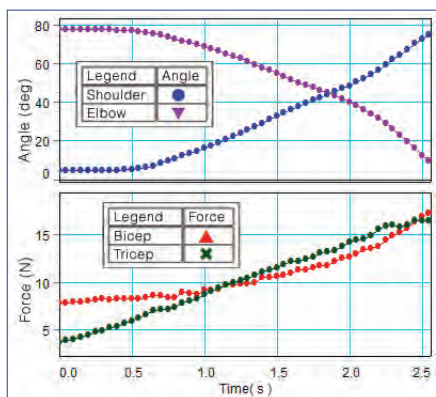
PS-2611

- ▶ Working model of the human arm
- ▶ Associate tricep/bicep muscle action with arm motion
- ▶ Measure torque resulting from lifting weights
- ▶ Actually throws a ball

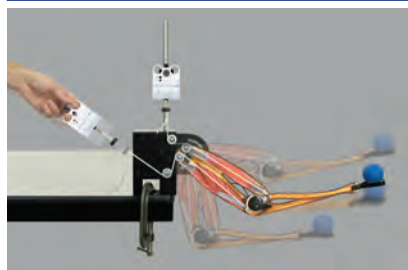


The Human Arm Model simulates the muscles and motion of an actual human arm. To activate the arm motion, students pull on the cord with a Force Sensor. Changes in position are measured at the shoulder and elbow using the two built-in potentiometers plugged into one Angle Sensor (PS-2139), included with PS-2611. From this information, the torque applied when lifting an object can be determined. Also, students can evaluate the work done by the arm in throwing a ball and the resulting kinetic energy delivered to the ball.

The Arm can perform many types of motion such as extending and lifting an object, curling, or throwing a ball overhand. Different arm muscles are activated depending on which pulleys are selected. Static force measurements can also be made to see how the muscle tension changes at various arm positions.



Angles and Forces During Extension: The upper graph shows the angles of the elbow (violet trace) and the shoulder (blue) as the arm is extended as shown in the picture below. Shown in the lower graph, the bicep tension (red) has little change at first and then rises sharply as the arm reaches out, while the tricep tension (green) rises steadily.



Includes:

- Human Arm Model
- Angle Sensor PS-2139



PASPORT Goniometer Sensor

PS-2137

- ▶ Accurately measures joint movements
- ▶ Flexible mounting options for hip, knee, and elbow
- ▶ Flexible mounting options



The PASPORT Goniometer Sensor allows students to use their own bodies to contextualize physics. The Goniometer can be connected to knee, hip, or elbow joints to measure angle changes throughout a variety of movements. It can be used to measure the angular position, velocity, and acceleration of an arm or leg.

The PS-2137 includes one Angle Sensor (PS-2139) and one Goniometer Probe with a Velcro connection kit. An add-on Goniometer Probe (PS-2138) must be purchased to measure the motion of two joints simultaneously.

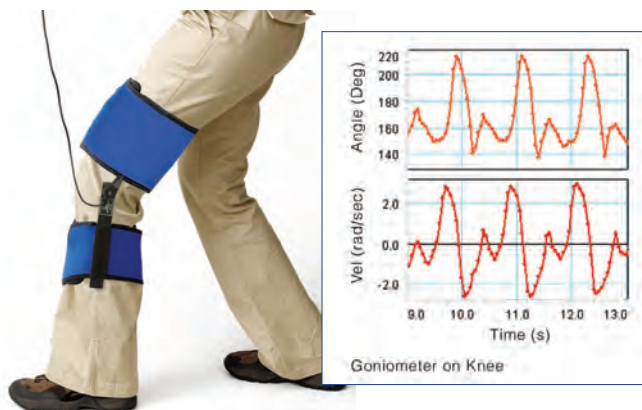
Specifications:

Range: 0 to 340°

Accuracy: ±1° (calibrated), ±3° (uncalibrated)

Resolution: 0.1°

Maximum Sample Rate: 500 Hz



Developed in cooperation with Nancy Beverly, Assistant Professor of Physics at Mercy College, Dobbs Ferry, New York.

See page 143 for more information.

Order Information

PASPORT Goniometer Sensor.....	PS-2137
Recommended:	
PASPORT Goniometer Probe.....	PS-2138

Also available separately: PASPORT Angle Sensor

PS-2139

The Angle Sensor measures angle by measuring resistance. It has two ports to accept two Goniometers (PS-2137) or the two probes in the joints of the Human Arm (PS-2611).



Order Information

PASPORT Angle Sensor	PS-2139
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Order Information

Human Arm Model.....	PS-2611	
Required for force measurement:		
Wireless Force Acceleration Sensor.....	PS-3202	p. 53

Physiology

PASPORT EKG Sensor

PS-2111

The EKG Sensor measures electrical signals produced by the heart. As cardiac muscle depolarization and repolarization occur, the EKG trace graphically illustrates the beating of the heart. The sensor comes with 100 self-adhesive conductive patches that are easily removed from the skin after use.

**Applications:**

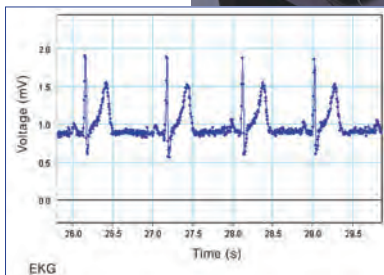
- ▶ Generate a personal EKG graph
- ▶ Compare EKG graphs before and after mild exercise

Specifications:**EKG Waveform Voltage:** 0 to 4.5 mV**EKG Waveform Resolution:** 4.5 μ V**EKG Waveform Sample Rate:**

50 to 200 samples per second (sps)

EKG Waveform Default Sample Rate:

200 samples per second (sps)

Heart Rate (Beats) Range: 47 to 250 beats per minute (bpm)**Heart Rate (Beats) Resolution:** 1 beat per minute (bpm)

Note: The EKG Sensor has been designed for educational purposes only and is not suitable for medical diagnoses.



Additional EKG Electrode Patches (CI-6620) may be ordered separately.

Order Information

PASPORT EKG Sensor PS-2111
 EKG Sensor Electrode Patches CI-6620

PASPORT Spirometer

PS-2152

With our Spirometer Sensor, students can easily measure flow rate, pressure, and lung volume, making it perfect for human physiology courses. The mouthpiece and sensor are designed for the safe and accurate measurement of both airflow out (expiration) and airflow in (inspiration). This sensor uses disposable mouthpieces for student safety and includes two. Extras are available in convenient packs of ten.

**Applications:**

- ▶ Compare a student's airflow before and after exercise
- ▶ Investigate the lung volume of athletes vs. non-athletes
- ▶ Compare smokers vs. non-smokers
- ▶ Conduct respiratory experiments
- ▶ Determine total lung capacity

Features:

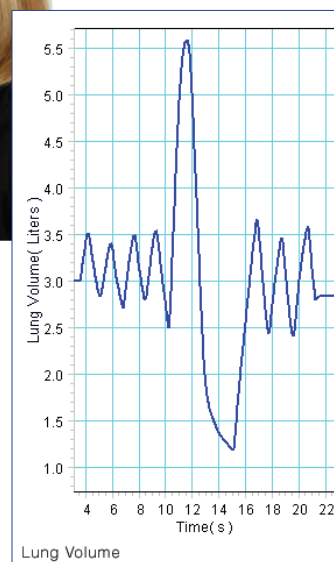
- Displays volume in liters
- Minimal resistance to air flow
- Bi-directional air flow
- Sample Rate Range: 50 to 100 Hz



Measuring lung capacity



Replaceable mouthpiece clips

**Order Information**

PASPORT Spirometer PS-2152
 Spirometer Mouth Piece Replacements (10) PS-2522

PASPORT Breath Rate Sensor

PS-2187

- ▶ Works while exercising



Also see the Wireless Blood Pressure Sensor on page 61.

The Breath Rate Sensor measures breath rate by sensing the pressure change within a standard, disposable dust mask. It generates consistently stable output, even when used during exercise. The sensor's tubing connects to the disposable pressure clips that fasten to the sides of the mask.

Applications:

- ▶ One reading every breath
- ▶ Running average over last four breaths



A graph showing a student's breath rate before, during, and after exercise

Includes:

- Sensor with Tubing
- Pressure Clips (10)
- Masks (10)



PASPORT Ethanol Sensor

PS-2194



The PASPORT Ethanol Sensor measures the concentration of gaseous ethanol up to 3%. In biology and environmental science labs, students can learn about anaerobic respiration by measuring the production of ethanol by bacterial or yeast fermentation. Physics and chemistry students can begin to explore combustion and thermodynamics. Connect your students to the study of respiration and alternative energy sources with the PASPORT Ethanol Sensor.

Note: This is a gas sensor – it should not be submerged into liquids. If exposed to gases with ethanol concentrations above the recommended maximum of 3% the sensor element will be depleted.

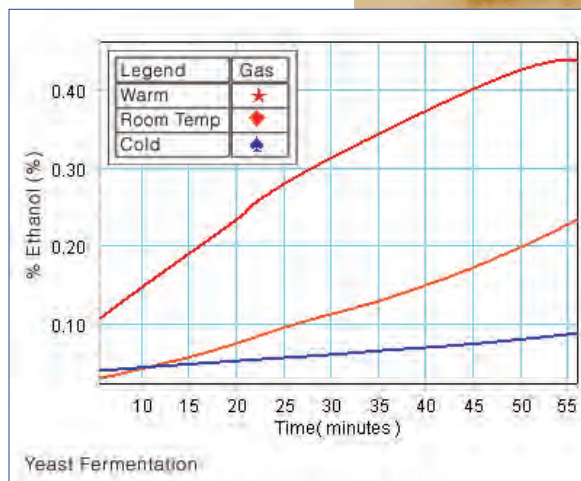
Specifications:

Accuracy: 20% of reading

Range: 0% to 3% gaseous ethanol



Students can vary environmental conditions such as temperature and determine the impact on the rate and type of cellular respiration taking place. In this example, as the temperature increases, the rate of ethanol production is also increasing.



Order Information

PASPORT Ethanol SensorPS-2194
 Shown in use with:
 EcoChamberME-6667
 Heater StirrerPS-3401

Order Information

PASPORT Breath Rate SensorPS-2187
 Breath Rate Sensor Clips 10 packPS-2568
 Breath Rate Sensor Disposable Masks (10 pack)PS-2567

Environmental

PASPORT Thermocline Sensor

PS-2151

At last, students can measure temperature as a function of depth in local streams and lakes. PASCO's Thermocline measures depth automatically — no need to read markings on a cable and enter data manually. Weighted housing provides depth measurement stability in fast-flowing streams.

**Applications:**

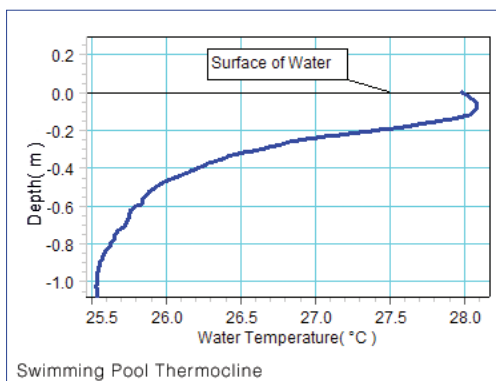
- ▶ Study thermoclines in fresh and salt water environments
- ▶ Create depth profiles for streams, small rivers, shorelines, and swimming pools
- ▶ Study ocean tides

Specifications:

Depth-sensing Element Range: 0 m to 10.5 m
Depth-sensing Element Accuracy: 0.15 m (in fresh water after barometric pressure compensation)
Depth-sensing Element Resolution: 0.03 m
Temperature-sensing Element Range: 0°C to 100°C
Temperature-sensing Element Accuracy: $\pm 1.5^\circ\text{C}$
Temperature-sensing Element Maximum Sample Rate: 10 Hz



The temperature of the water in a pond is measured as a function of depth.

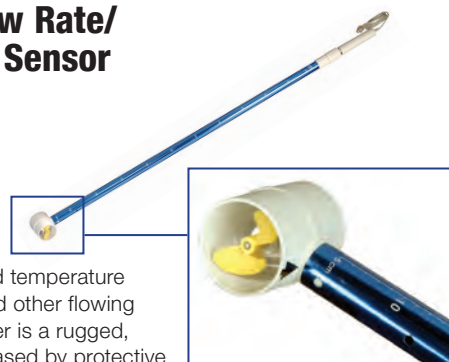
**Order Information**

PASPORT Thermocline Sensor.....PS-2151

PASPORT Flow Rate/ Temperature Sensor

PS-2130

PASCO's Flow Rate Sensor allows students to measure the rate of movement and temperature of streams, rivers, and other flowing systems. The propeller is a rugged, single-piece unit encased by protective material — no more losing pieces at the bottom of the stream.

**Applications:**

- ▶ Determine sediment transport rate for a stream or other body of water
- ▶ Measure and compare flow rate at various locations in a stream
- ▶ Compare the characteristics of one stream to another

Specifications:

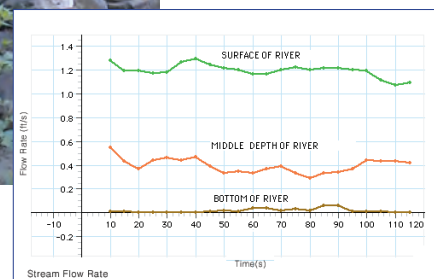
Flow Range: 0 m/s to 3.5 m/s
Accuracy: 0.1 ft/sec
Pulse Frequency: 8.62 pulse/linear foot
Unit options: meter/sec; feet/sec; total pulses
Probe Length: 3 to 7 ft. with Telescoping Tube (Probe is 7 ft when fully expanded)
Temperature Range: -10°C to 50°C
Maximum Length: 1.8 m (6 feet) Telescoping handle to reach deep levels
Maximum Sample Rate: 20 Hz

Features:

- ▶ Exclusive built-in temperature sensor conveniently measures temperature at the same point as flow rate
- ▶ Revolutions of a magnet on the submersible impeller are counted and converted to linear flow rate measurements in ft/sec or m/s
- ▶ Telescoping Handle to reach deep levels



Graph shows the flow rates at the top (green), middle (orange), and bottom (brown) of a stream.

**Order Information**

PASPORT Flow Rate/Temperature Sensor.....PS-2130

PASPORT Dual Pressure Sensor

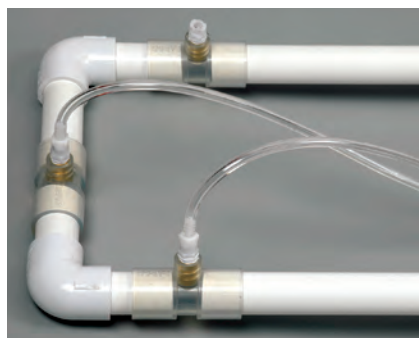
PS-2181



The Dual Pressure sensor is capable of reading two absolute pressures, one gauge pressure, or one differential pressure. Dynamic variable over-sampling automatically reduces the measurement noise at low sampling rates. Sample rates up to 1000 Hz make studies of both transient and steady-state pressure possible. Includes quick-connect tubing.

Applications:

- ▶ Measure pressure in Heat Engine (TD-8572). See page 207.
- ▶ Measure pressure drops in pipes



Instrument your pipe network with the Pressure Taps connected to the Dual Pressure Sensor (PS-2181).

Specifications:

Maximum Sample Rate: 1000 Hz

Absolute Pressure: 0 to 200 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m², and psi)

Differential Pressure: ±100 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m², and psi)

Order Information

PASPORT Dual Pressure Sensor.....PS-2181

Pressure Taps (Set of 5)

ME-2224A



Order Information

Pressure Taps (set of 5)..... ME-2224A

General Flow Sensor

PS-2222

The General Flow Sensor determines the fluid velocity of air or water by measuring the difference in pressure between the two input tubes. The Venturi Tube or Pitot Tube must be connected to the General Flow Sensor to collect data. The type of fluid (air or water) being used is selected using PASCO software.

Applications:

- ▶ The Venturi Tube is used in a pipe network carrying water or air.
- ▶ The Pitot Tube is used in an open water channel or air.

Specifications:

Pressure Range: 0 to 50 kPa

Pressure Accuracy: ±2.5% of Full Scale (0 to 85°C)

Resolution: 0.2% of Full Scale

Venturi Range: 0 to 84 gpm (water); 0 to 773 gpm (air)

Venturi Accuracy: ±2 gpm (water); ±2.5 cf/min (air)

Pitot Range: 0 to 9.98 m/s (water); 0 to 92.1 m/s (air)



Venturi Tube

ME-2220

The Venturi Tube is made of clear PVC so the water can be seen flowing through it. It has a constriction and two pressure ports with tubing attached. The Venturi Tube is connected to the General Flow Sensor by the matching couplers. The General Flow Sensor measures the difference in fluid pressure between the two different cross-sectional areas and the software does a calculation to convert this pressure difference into a velocity or volumetric flow rate. The Venturi Tube slip joints are designed to be glued into any 3/4" PVC pipe network.



Pitot Tube

ME-2221

The Pitot Tube is designed to be placed in the air flow or water flowing in a channel. The General Flow Sensor, connected to the Pitot Tube, measures the pressure difference between the fluid inlet and the static side taps of the Pitot Tube and the software calculates the fluid velocity from the pressure difference.



See pages 182-183 for more applications.

Order Information

General Flow Sensor with Venturi Tube.....PS-2225
 General Flow Sensor with Pitot TubePS-2226
 Required:
 PASPORT Interface..... p. 12-13
 PASCO Capstone Software..... p. 68-71
 Also available separately:
 General Flow Sensor.....PS-2222
 Venturi Tube.....ME-2220
 Pitot Tube.....ME-2221

Environmental

PASPORT Salinity Sensor

PS-2195

The PASPORT Salinity Sensor works with the 10X Salinity Sensor Probe to measure salinity, conductivity, and temperature. The sensor determines salinity based on electrical conductivity. The sensor has a built-in calculation to compensate for the change in conductivity due to temperature change based on the Practical Salinity Scale (PSS).



The Salinity Sensor measures the electric current through a solution between the two platinized platinum electrodes in the Salinity Sensor Probe. The current through the solution is due to the movement of ions, so the higher the concentration of ions in the solution, the higher its conductivity. A voltage (AC) is applied across the two electrodes in the tip of the probe and the measured current is proportional to the conductivity of the solution.

Applications:

- ▶ Explore the salinity of local water sources.
- ▶ Explore the interrelationship of salinity, temperature, and conductivity.
- ▶ Measure the change in the salinity of saltwater as the water evaporates.

Examples of Water Salinity:**Fresh Water:** <0.5 ppt**Brackish Water:** 0.5 to 30 ppt**Saline Water:** 30 to 50 ppt**Ocean Water:** 35 ppt**Brine:** >50 ppt**Specifications:****Conductivity Range:** 1,000 to 100,000 μ S**Temperature Range:** 0 to 50°C**Salinity Range:** 1 to 55 ppt \pm 1% (with calibration)**Sample Rate (Maximum):** 50 Hz**Temperature Compensation:** \pm 0.5 ppt from 0 to 45°C at 33 ppt**Cell Constant:** 10X**Order Information**

PASPORT Salinity Sensor PS-2195

Recommended:

PASPORT Sensor Extension Cable PS-2500

PASPORT Water Quality Colorimeter

PS-2179

This PASPORT Water Quality Colorimeter is designed specifically to support the chemical analysis of water samples using PASCO's ezSample Snap Vial water quality test kits (sold separately).

Includes built-in calibration curves for determining the concentration of ions in a solution for (ions listed on this page). Simple to use in the field, and students avoid direct contact with chemicals!

Specifications:**Measurable Ranges:**

ezSample Snap Vials (Colorimetric)	
Iron	1.5 to 8 mg/l
Nitrate	0.25 to 2 mg/l
Ammonia	0.20 to 3 mg/l
Phosphate	0.20 to 8 mg/l
Chlorine	0.50 to 6 mg/l

ezSample Field Titrators

Total Hardness	20 to 200 mg/l
Dissolved CO ₂	10 to 100 mg/l
Alkalinity	10 to 100 mg/l

Operating Temperature: 0° to 40°C**Order Information**

PASPORT Water Quality Colorimeter PS-2179

Available Test Kits: (30 tests per kit)

ezSample Snap Vials (Colorimetric):

ezSample Snap Vial - Iron	EZ-2331
ezSample Snap Vial - Nitrate	EZ-2333B
ezSample Snap Vial - Ammonia	EZ-2334A
ezSample Snap Vial - Phosphate	EZ-2337
ezSample Snap Vial - Chlorine	EZ-2339A

ezSample Field Titrators

ezSample Field Titrator - Total Hardness EZ-2338

ezSample Field Titrator - Carbon Dioxide EZ-2341

ezSample Field Titrator - Alkalinity EZ-2340

*

WARNING! This product can expose you to chemicals including ethylene glycol, which is known to the State of California to cause birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

**

WARNING! This product can expose you to chemicals including phenolphthalein, which is known to the State of California to cause cancer, and methanol, which is known to the State of California to cause birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

PASPORT Soil Moisture Sensor

PS-2163

The Soil Moisture Sensor measures the water content of soil and reports it in percent. It can be used to conduct experiments in environmental science, agricultural science, horticulture, and biology.

**Applications:**

- ▶ Measure the loss of soil moisture over time due to evaporation and plant uptake
- ▶ Evaluate optimum soil moisture content for various species of plants
- ▶ Monitor soil moisture content to control irrigation in greenhouses

Specifications:**Sensor Range:** 0 to 45% volumetric water content in soil**Sensor Probe Length:** 5.5 cm**Sensor Probe Cable Length:** 5 m**Accuracy:** \pm 4%**Resolution:** 0.1%**Power:** 3 mA at 5 V DC**Operating Temperature:** -40 to 60°C**Default Sample Rate:** 10 samples per second**Order Information**

PASPORT Soil Moisture Sensor PS-2163

PASPORT pH Sensor

PS-2102

Also see the
Wireless
pH Sensor
on page 58.



PASCO's pH Sensor measures the hydronium ion concentration in a solution and reports it as a pH value. This sensor is well-suited for a variety of activities where testing or monitoring acidity is important.

Applications:

- ▶ Titrate an acid into a base
- ▶ Investigate the chemistry of buffers
- ▶ Monitor water quality

Specifications:

Range: 0 to 14 (probe-dependent)

Accuracy: ± 0.1 (after calibration)

Resolution: 0.01

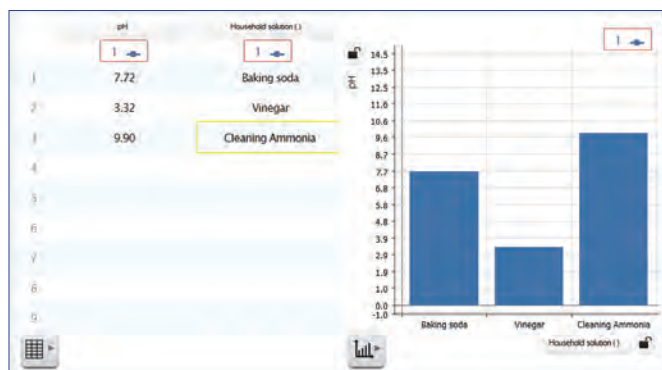
Electrode: Gel-filled Ag-AgCl combination electrode

Maximum Sample Rate: 50 Hz

Temperature Range: 5°C to 60°C



pH vs. Volume
graph



Order Information

PASPORT pH SensorPS-2102

Recommended:

pH ElectrodePS-2573

Advanced Chemistry Sensor

PS-2172



The Advanced Chemistry Sensor measures pressure, temperature, pH, and conductivity. It can measure parameters individually or simultaneously for labs pertaining to electrolytes, acid-base reactions, gas laws, thermochemistry, thermometric and conductometric titrations, and more!

Applications:

- ▶ Exploring Gas Laws
- ▶ Hess's Law
- ▶ Properties of Buffers
- ▶ Rate of Decomposition of Hydrogen Peroxide
- ▶ Intermolecular Forces

Specifications:

Temperature*: -35°C to +135°C, $\pm 0.5^\circ\text{C}$

pH*: 0 to 14, ± 0.1 (with calibration)

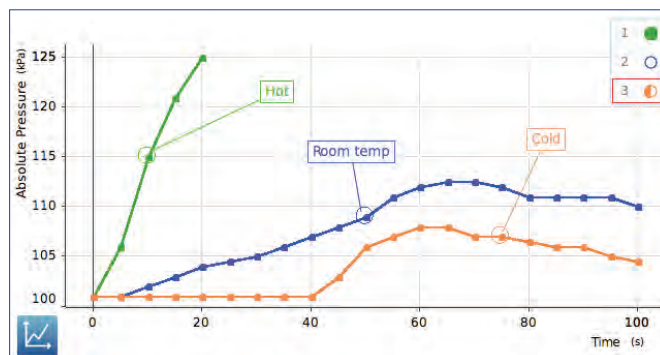
Absolute Pressure: 20 to 400 KPa

Voltage: -2000 mV to +2000 mV

Maximum Sample Rate: 100 Hz

Temperature Range: 5°C to 60°C

*Ranges are probe-dependent.



Determine the effect of temperature on the rate of a reaction.

Includes:

- Stainless Steel Temperature Probe
- pH Probe
- Conductivity Probe
- Built-in Pressure Sensor
- 60 cc syringe, tubing and quick-release connectors

Order Information

Advanced Chemistry SensorPS-2172

SPARK LXi Datalogger

Built for student use both indoors and outdoors.



SPARK LXi
PS-3600A



PASPORT
Sensor Port

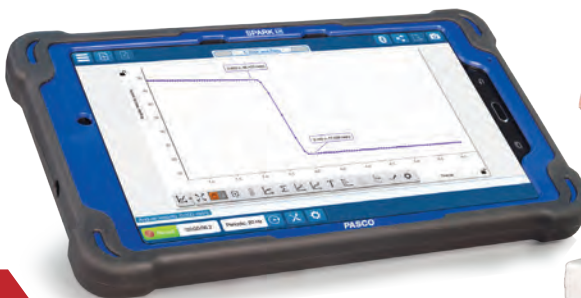
Voltage Port

Temperature Port

PASPORT
Sensor Port

The LXi also has built-in ports for the included temperature and voltage probes.

Simultaneously connect up to five PASCO wireless sensors.



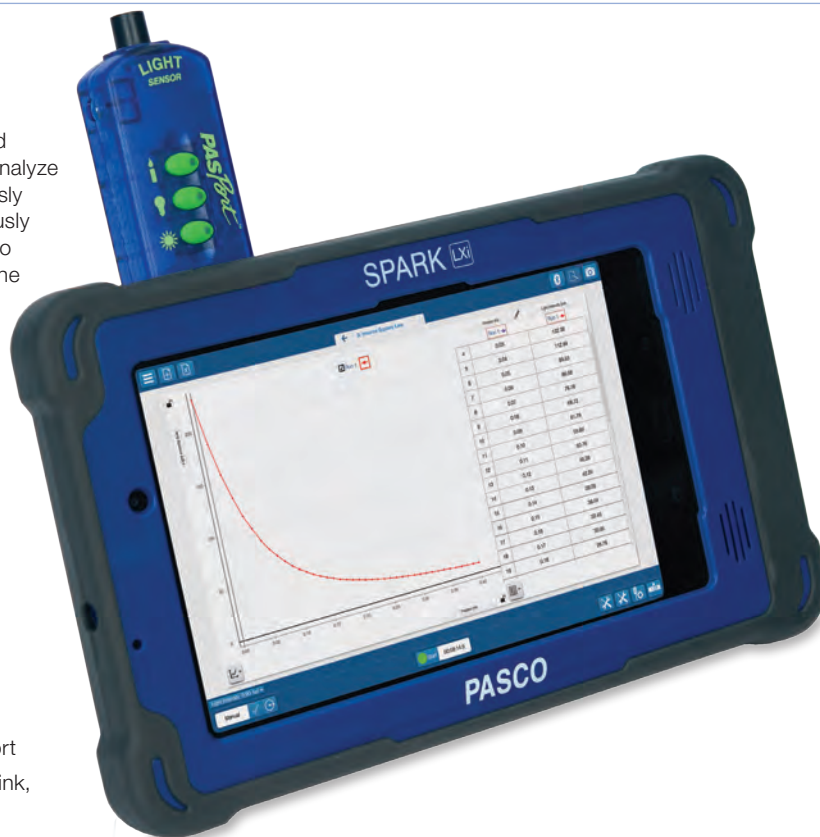
SPARK LXi Datalogger

PS-3600A

The SPARK LXi Datalogger is a Bluetooth, handheld datalogger that enables students to connect wired and wireless sensors, collect data, generate graphs, and analyze results. It is durable, splash-proof, and works seamlessly with PASCO sensors. The SPARK LXi can simultaneously accommodate up to five wireless sensors, includes two ports for PASPORT sensors, as well as two ports for the included Fast Response Temperature Probe and Voltage Probe. It can be used with PASCO Wireless sensors, PASPORT sensors and an AirLink, SPARKlink® Air, and the 550 Universal Interface.

Features:

- ▶ Ruggedized case for indoor/outdoor and wet/dry lab use
- ▶ 8" full-color capacitive touchscreen (1280 x 800 pixels)
- ▶ Simultaneously connects up to 5 PASCO Wireless Sensors
- ▶ SPARKvue® in-app proximity pairing
- ▶ Includes 2 PASPORT ports
- ▶ Includes Voltage Probe and port
- ▶ Includes Fast Response Temperature Probe and port
- ▶ Can connect more PASPORT sensors with the AirLink, SPARKlink Air, and 550 Universal Interface
- ▶ Installed software: PASCO SPARKvue, MatchGraph, and Spectrometry; Microsoft Office Suite; Google Suite
- ▶ Android operating system
- ▶ Wi-Fi, Bluetooth®, and USB connections
- ▶ Can export data to third-party apps
- ▶ Operates online or offline
- ▶ Front and back cameras
- ▶ Accelerometer
- ▶ Microphone and speaker
- ▶ GPS



Order Information

SPARK LXi Datalogger	PS-3600A
Recommended:	
SPARK LXi Charging Station	PS-3602
Replacement Parts:	
PASPORT Voltage Probe	PS-2165
PASPORT Fast Response Temperature Probe (3 pack)	PS-2135

SPARK LXi Charging Station

PS-3602

These convenient charging stations have a wire rack to hold the dataloggers and multiple charging cables, so a complete set of SPARK LXi dataloggers can be charged from one power connection to the wall. The charging station is built into a Grannells case (size F3).

- ▶ PS-3602 can simultaneously charge up to six SPARK LXi dataloggers.

Dimensions: 312 x 427 x 300 mm



Order Information

SPARK LXi Charging Station	PS-3602
----------------------------------	---------

AirLink Interface

PS-3200



The AirLink connects PASPORT sensors to a Mac or Windows computer, Chromebook, iPad, tablet, or smartphone via Bluetooth or USB connection. The USB cable is included.

Includes:

- USB cable

Order Information

AirLink Interface PS-3200

10-Port USB Charging Station

PS-3501



The 10-Port USB Charging Station enables you to charge up to 10 wireless sensors via USB cable (included with sensors).

Includes:

- AC Power cable

Order Information

10-Port USB Charging Station PS-3501

PASPORT Digital Adapter

PS-2159

- ▶ Required for counting and timing sensors
- ▶ Allows digital ScienceWorkshop sensors to be used with PASPORT interfaces



The Digital Adapter is required when photogates, timing and counting sensors are used with any PASPORT interface. Each Digital Adapter accommodates two sensors at once. Each port on the Digital Adapter automatically detects a connection and initiates a selection of pre-configured or user-defined options. Several Digital Adapters can be used simultaneously when required.

Specifications:

Resolution for Counting and Timing Devices: 2 μ s

Resolution for Motion Sensors: 1 μ s

Input: Two 1/4" stereo phone jacks

Order Information

PASPORT Digital Adapter PS-2159

SPARKlink Air Interface

PS-2011



The SPARKlink® Air allows students and teachers to connect any of our 70+ PASPORT sensors to their device via USB or Bluetooth®. This device allows students to collect data using a desktop or laptop running SPARKvue or PASCO Capstone software, or with a Bluetooth iOS or Android device running the SPARKvue app.

Includes:

- AC Adapter
- USB Cable
- Fast Response Temperature Probe
- Voltage Probe

Order Information

SPARKlink Air Interface PS-2011

Requires:

PASCO Capstone Software p. 68-71

SPARKlink Air Charging Station

PS-2577

Conveniently store and charge up to five SPARKlink Air interfaces with a single power source.



Order Information

SPARKlink Air Charging Station PS-2577

PASPORT Analog Adapter

PS-2158

- ▶ Use your black ScienceWorkshop sensors with blue PASPORT interfaces

- ▶ No need to buy new sensors

Use an Analog Adapter to connect ScienceWorkshop sensors with an 8-pin or 5-pin DIN connector such as:

- Colorimeter (CI-6747)
- Current (CI-6556)
- Force (CI-6537)
- Force, Economy (CI-6746)
- Infrared (CI-6628)
- Light (CI-6504A)
- Light, High-Sensitivity (CI-6604)
- Light, UVA (CI-9784)
- Magnetic Field (CI-6520A)
- Pressure Sensor-Absolute (CI-6532A)
- Sound (CI-6506B)
- Temperature (CI-6605A)
- Temperature, High Accuracy (CI-6525)



Order Information

PASPORT Analog Adapter PS-2158

PASCO's Wireless Sensor Family

Our rugged, low-cost wireless sensors connect directly to computers, Chromebooks, and mobile devices to allow students to quickly collect data, leaving more time for analyzing and interpreting data.

In Logging mode, wireless sensors collect data to their onboard memory for hours, days, weeks or even months at a time without needing to be connected to a computer, tablet, Chromebook or smartphone. When the experiment has concluded, simply connect the sensor to a device running PASCO software and download all the measurements it recorded.

Wireless Physics Sensors

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Smart Cart

Smart Cart 

ME-1240 (red)

ME-1241 (blue)

- ▶ Your mechanics lab on wheels
- ▶ Built-in wireless force, position, and acceleration sensors

The patented Smart Cart is the ultimate tool for studying kinematics, dynamics, Newton's Laws, and more. It is based on a durable ABS body with nearly frictionless wheels, just like our high quality PAScars. Now, we've added built-in sensors that measure force, position, velocity, and acceleration. The versatile Smart Cart can collect measurements on or off a track and transmit the data wirelessly over Bluetooth. In essence, it is a wireless dynamics cart that combines all the necessary sensors, without requiring any additional hardware.

Smart Carts are ideal for studying mechanics topics, such as kinematics and dynamics. The built-in load cells enable two Smart Carts to visually demonstrate Newton's Third Law with ease. Additionally, built-in sensors for force and acceleration enable students to investigate Newton's Second Law in minutes. Smart Carts truly are a physics lab on wheels, and now you can own the most advanced physics cart ever created, all without the restrictions of cables.

**Applications:**

- ▶ Kinematics
- ▶ Newton's Laws
- ▶ Impulse
- ▶ Conservation of Momentum
- ▶ Elastic and Inelastic Collisions
- ▶ Conservation of Energy
- ▶ Simple Harmonic Oscillators
- ▶ Magnetic damping
- ▶ Determining g using acceleration on an incline
- ▶ And much more!

U.S. Patent Number
10,481,173

**Specifications:**

- Force Range:** ± 100 N
- Force Resolution:** 0.1 N
- Force Accuracy:** $\pm 1.0\%$
- Force Maximum Sampling Rate:** 2.0 kHz
- Position Resolution:** ± 0.2 mm
- Max Velocity:** ± 3.0 m/s
- Velocity Max Sample Rate:** 500 Hz
- Acceleration Range:** ± 16 g
- Acceleration Max Sample Rate:** 500 samples/second
- Max Rotational Speed Sampling Rate:** 500 samples/second
- Max Wireless Range:** 30 m (unobstructed)
- Maximum Measurable Rotation Rate (Gyro):** ± 245 deg/second
- Mass Without Accessories:** 245 g
- Patent No.:** 10481173
- Magnetic Bumper Mass:** 23.6 g

Includes:

- Hook
- Rubber bumper
- Magnetic bumper
- USB cable for charging

Order Information

Smart Cart (Red)	ME-1240
Smart Cart (Blue)	ME-1241

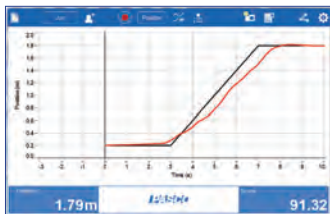
Wireless Motion Sensor

PS-3219

The Wireless Motion Sensor connects via Bluetooth or USB to your device, and uses ultrasound to measure the position, velocity, and acceleration of objects. This enables students to take turns measuring themselves, while the class observes their motion materializing as a graph in real time. The sensor can detect objects ranging from 15 cm to 4.0 m away, and without cables to get in the way, students can explore handheld and ceiling-mounted applications.



The Wireless Motion Sensor works with our free MatchGraph! software. It is an ideal way to teach the concepts of motion graphing, interpreting graphs, and rate of change or slope.



Specifications:

- Range:** 0.15 to 4 m
- Resolution:** 1 mm
- Maximum sample rate:** 100 Hz
- Transducer rotation range:** 180°
- Rechargeable battery:** Lithium-polymer
- Connectivity:** Direct USB or via Bluetooth (Bluetooth 4.0)

Order Information

Wireless Motion Sensor	PS-3219
Recommended:	
MatchGraph! Software	See page 74

Motion Sensor Guard

SE-7256

Use this wire guard to protect the Motion Sensor when dropping objects from above.



Order Information

Motion Sensor Guard	SE-7256
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Motion Sensor Bracket

PS-2546

This magnetic bracket allows a Motion Sensor to be easily hung from a drop ceiling. Simply screw the bracket into the 1/4"-20" threads on the sensor and use the included adjustment nut to hold the sensor in the desired orientation.



The bracket can also be used to hold the Motion Sensor on vertical surfaces such as filing cabinets and magnetic whiteboards.

Order Information

Motion Sensor Bracket.....	PS-2546
----------------------------	---------

Cart Adapter Accessory

ME-6743

The Cart Adapter Accessory allows the Motion Sensor and many other sensors to be mounted to a Dynamics Cart or a PAScar.



The adjustment knob on the bracket allows the Motion Sensor to face any direction.

Order Information

Cart Adapter Accessory.....	ME-6743
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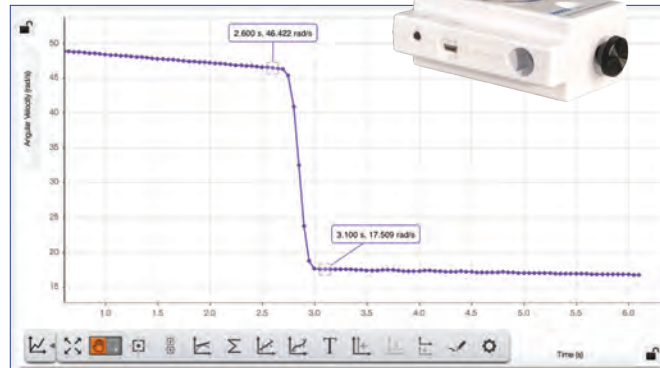
Wireless Rotary Motion Sensor

PS-3220



The Wireless Rotary Motion Sensor measures angle, angular velocity, and angular acceleration, as well as their linear equivalents. The included three-step pulley allows different torques to be applied, rotating a rigid system at different rates of acceleration. The included rod-mounting holes let you orient the sensor for different experiments. The Wireless Rotary Motion Sensor connects directly to your devices via Bluetooth or USB.

Show that angular momentum is conserved. The Wireless Rotary Motion Sensor records the angular velocity as a ring is dropped on a spinning disk.



Specifications:

- Angle resolution:** 0.18° (0.00314 radian)
- Linear resolution:** 0.0157 mm (with 5 mm pulley radius)
- Three-step pulley:** 10, 29, and 48 mm diameter
- Shaft diameter:** 6.35 mm
- Maximum rotation rate:** 30 revolutions per second
- Optical encoder:** 2000 divisions/rev, bidirectional
- Rechargeable battery:** Lithium-polymer
- Logging:** Yes
- Connectivity:** Direct USB or via Bluetooth 4.0

Order Information

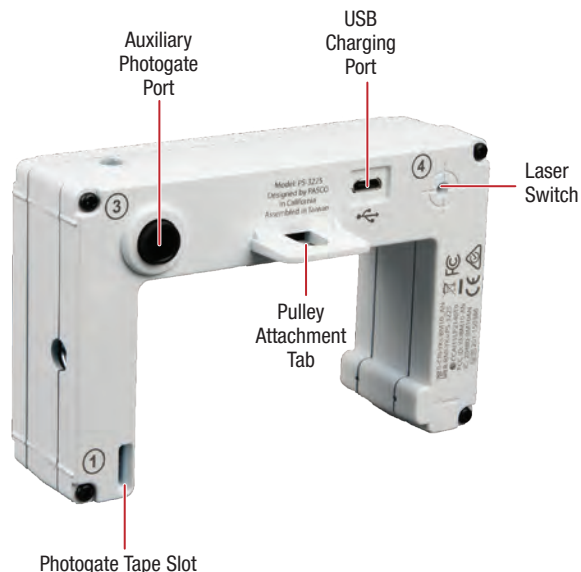
Wireless Rotary Motion Sensor	PS-3220
Shown in use with:	
Rotational Inertia Accessory	ME-3420 p. 174

Physics Sensors

Wireless Smart Gate 

PS-3225

- ▶ Dual photogate beams
- ▶ Laser switch
- ▶ Photogate tape slot
- ▶ Auxiliary photogate/Time-of-Flight port
- ▶ USB and Bluetooth®
- ▶ Rechargeable



The Wireless Smart Gate has all the features of the wired Smart Gate. It has dual photogate beams spaced at 1.5 cm to accurately measure speed. The built-in laser switch (when used with any laser) allows you to time objects too large to fit through the standard photogate. Pass Photogate Tape through the photogate slot to measure the movement of objects. The auxiliary port is for adding an additional photogate head or Time-of-Flight Accessory.

We do not recommend using two Wireless Smart Gates in the same experiment unless the measured times are relatively long (greater than one-half second) since synchronization is limited to 2 ms.

Specifications:**Logging:** Yes**Battery:** Rechargeable Lithium-Polymer**Connectivity:** Direct USB or via Bluetooth 4.0**Order Information**

Wireless Smart GatePS-3225

Wireless Acceleration/Altimeter 

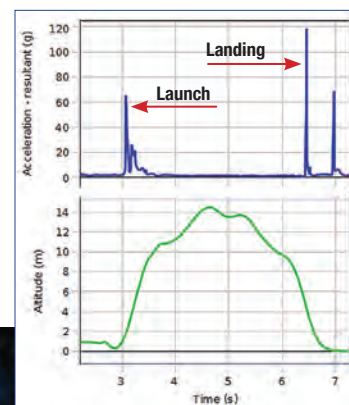
PS-3223

- ▶ 3-axis accelerometer
- ▶ 3-axis gyroscope
- ▶ Altimeter
- ▶ Rubberized case



The Wireless 3-Axis Acceleration/Altimeter can remotely log acceleration in three dimensions and altitude, making it ideal for recording roller coaster rides.

The Wireless 3-Axis Acceleration/Altimeter is launched by a stretched rubber band that is connected to one of many attachment holes in the rubberized case. The graph shows the resultant acceleration (measured in g's) and the altitude for the four-second flight.

**Specifications:****Accelerometer Ranges:** ± 16 g, ± 100 g, ± 200 g, ± 400 g**Measurements:** Acceleration (3 axes and resultant); Altitude; Angular velocity (3 axes)**Logging:** Yes**Battery:** Coin Cell**Connectivity:** Bluetooth 4.0**Order Information**

Wireless Acceleration/AltimeterPS-3223

Wireless Force Acceleration Sensor

PS-3202

- ▶ Freedom from wires
- ▶ Measures force, acceleration, and rotation



Capable of simultaneously measuring force, acceleration, and rotational velocity, this sensor is ideal for experiments involving rotating platforms, moving carts, spring oscillations, collisions, and impulse. The wireless design offers improved measurement accuracy by eliminating cords that affect data collection. Students can use the finger-holes for handheld applications, or mount it onto a cart or rod for more complex experiments.

Features:

- ▶ Bluetooth and USB connectivity
- ▶ Logging
- ▶ ± 50 N force sensor
- ▶ 3-axis accelerometer (± 16 g)
- ▶ 3-axis gyroscope
- ▶ Finger-holes
- ▶ Built-in rod clamp

Specifications:

Force Range: ± 50 N

Force Resolution: 0.03 N

Accuracy: 0.1 N

Acceleration Range: ± 16 g

Angular Rotation Rate Range: up to ± 2000 degrees per second

Battery: Rechargeable lithium-polymer

Logging: Yes

Bluetooth: BT 4.0



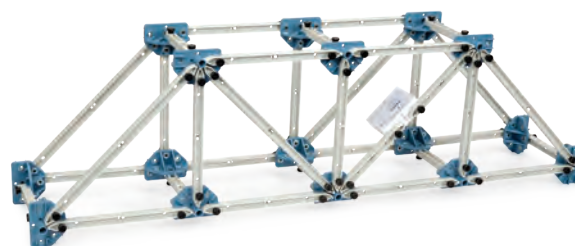
Includes:

- Hook attachment
- Rubber bumper attachment
- Cart/bracket thumbscrew
- Rechargeable lithium-polymer battery
- USB cable

Wireless Load Cell and Accelerometer

PS-3216

- ▶ Measures loads in structures
- ▶ Built-in 3-axis accelerometer measures bridge vibrations



Learn more about PASCO Structures on pages 144-152.

The Wireless Load Cell and Accelerometer is designed to measure loads in all PASCO Structures Systems. It is particularly useful for measuring vibrations because it includes an accelerometer and has no wires to impede movement.

Specifications:

Load Cell Range: ± 50 N

Load Cell Resolution: 0.03 N

Load Cell Accuracy: 0.1 N

Load Cell Maximum Sample Rate: 2 kHz

Acceleration Range: ± 16 g (three axis)

Acceleration Maximum Sample Rate: 500 Hz

Measurements: Force; Acceleration (3 axes and resultant)

Logging: Yes

Battery: Rechargeable Lithium-Polymer

Connectivity: Direct USB or via Bluetooth 4.0

Order Information

Wireless Load Cell and AccelerometerPS-3216

Shown in use with:

Building Better Bridges KitME-3581

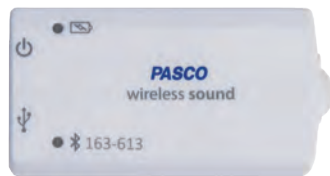
Order Information

Wireless Force Acceleration Sensor.....PS-3202

Physics Sensors

Wireless Sound Sensor 

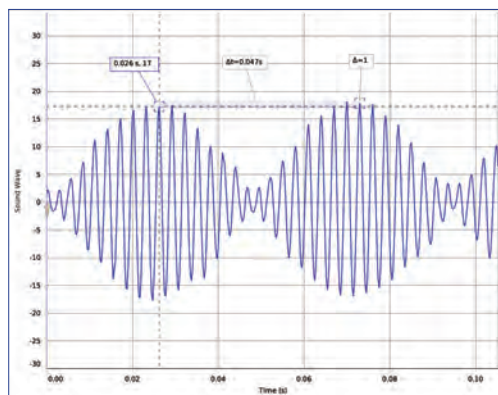
PS-3227



The PS-3227 Wireless Sound Sensor is two sensors in one wireless package: a sound wave sensor capable of measuring changes in relative pressure level as a function of time and a sound level sensor with both dBA and dBC weighted scales.

Sound Wave Sensor: The Sound Wave Sensor measures relative changes in sound pressure level as sound waves are incident on the sensor. With graphs of sound wave measurements versus time, students can explore and analyze wave properties like wave shape, wave speed, amplitude, frequency, wavelength, and much more. Students can use this sensor to explore superposition of waves and beat frequencies, while also exploring standing wave harmonics, and the presence of overtones. Sound wave measurements work beautifully with the scope and FFT displays in both SPARKvue and Capstone, and the Wireless Sound Sensor is capable of measuring sound wave data wirelessly at sample rates up to 100 kHz.

Sound Level Sensor: The Sound Level Sensor gives you true sound level (intensity) measurements with both dBA and dBC scales. The dBC weighting scale measures the intensity of sounds in a wide range of frequencies within, and outside the frequency range of human hearing. The dBA weighting scale filters some of the sound frequencies from a sound source to more closely match the frequency response of the human ear. The dBA scale is commonly used in the workplace to determine the sound level an employee will experience in typical working conditions. Sound level and noise pollution are key measurements in environmental science. This new sensor gives you a wireless solution to measure sound level with all the capability of a sound level meter, but adds the flexibility of recording data continuously as a function of time.



Easily observe and measure beat frequencies

Specifications:

Microphone Frequency Range: 100 – 15,000 Hz

Sound Wave Maximum Sampling Rate: 100 kHz

Sound Level Range: 50 - 110 dB

Accuracy: ± 2 dB

Response: A or C weighted

Order Information

Wireless Sound SensorPS-3227

//code.Node 

PS-3231

NEW

The //code.Node is a turnkey coding solution that combines real-world sensor inquiry, Blockly coding, and live data displays to drive computational thinking in STEM learning. It includes six interactive sensors and four device outputs that measure and respond to phenomena using code created in SPARKvue or Capstone software.

**Specifications:**

Light Level Sensor Range: Visible Spectrum (400 nm to 700 nm)

Light Level Sensor Sensitivity: Approximately 600 lx to 50,000 lx (not calibrated)

Sound Level Sensor Sensitivity: Approximately 70 dB to 100 dB (not calibrated)

Magnetic Field Sensor Range: ± 50 gauss

Acceleration Sensor Range: 2-axes, $\pm 8g$

Ambient Temperature Range: -25 °C to 40 °C

Ambient Temperature Resolution: 0.05 °C

Ambient Temperature Accuracy: ± 1 °C

Maximum Sample Rate: 50 Hz

Momentary Push Buttons (2): On/Off

Speaker Output Frequency Range: 10 Hz to 10,000 Hz

Multi-color LED: Independently adjust intensity of Red, Green, Blue

Order Information

//code.NodePS-3231

Wireless Pressure Sensor

PS-3203

The Wireless Pressure Sensor allows students to easily collect accurate gas pressure data for a wide range of applications. Included is a 60cc syringe, tubing, and connectors that facilitate experiments such as Boyle's Law or measuring pinch-grip strength. Within PASCO's software, students can easily select their desired units from a list containing kPa, mmHg, inHg, mbar, psi, atm, and torr.



Make accurate and consistent measurements of gas pressure, regardless of ambient conditions. Study the Empirical Gas Laws.

Specifications:

Range: 0-400 kPa

Resolution: 0.1 kPa

Accuracy: ± 2 kPa

Logging: Yes

Max sample rate: 1000 Hz

Bluetooth: BT 4.0

Includes:

- Polyurethane Plastic Tubing, 2 ft
- Tube Connector
- Male Barbed Luer Locks (2)
- Female Barbed Luer Lock
- 60 cc Syringe
- Micro USB Cable (PS-3584)

Order Information

Wireless Pressure SensorPS-3203

Wireless Temperature Sensor

PS-3201

Welcome to the modern thermometer. This sensor transmits live data and allows students to continuously monitor, log, and plot temperature measurements on nearly any device.



Features:

- ▶ Simply pair and go, no cables or adapters to manage
- ▶ Variable sampling rate for capturing small, fast changes or experiments that run for hours, days, or weeks
- ▶ Bluetooth wireless connectivity and long-lasting coin cell battery
- ▶ Logs temperature data directly onto the sensor for long-term experiments
- ▶ Dust, dirt, and sand-proof and water resistant (IP-X7 certified)



Specifications:

Range: -40°C to 125°C

Resolution: 0.01°C

Accuracy: 0.5°C

Logging: Yes

Bluetooth: BT 4.0

The versatile Wireless Temperature Sensor works well, both in the lab and outdoors.

Order Information

Wireless Temperature Sensor.....PS-3201

Wireless Temperature Sensor Link

PS-3222

- ▶ Accepts three types of thermistor temperature probes
- ▶ Includes Fast Response Temperature Probe



Specifications:

Battery life >1 year: Battery life >1 year

Compatible Temperature Probes: Skin/Surface (PS-2131); Fast Response (PS-2135); Stainless Steel (PS-2153)

Range with included probe: -30°C to 105°C

Jack: 3.5 mm stereo

Logging: Yes

Connectivity: Bluetooth 4.0

Order Information

Wireless Temperature Sensor Link.....PS-3222

Compatible Temperature Probes:

PASPORT Skin/Surface Temperature ProbePS-2131

PASPORT Fast Response Temperature Probe (3 pack)PS-2135

PASPORT Stainless Steel Temperature ProbePS-2153

Physics Sensors

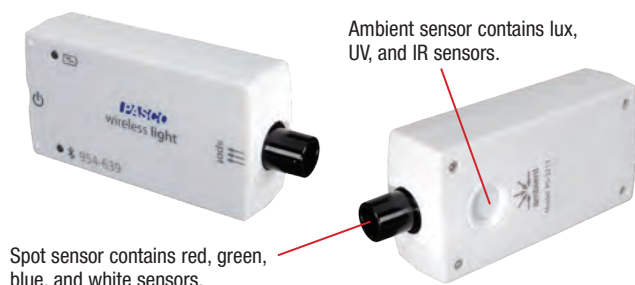
Wireless Light Sensor

PS-3213

- ▶ Four sensors in one
- ▶ Ambient lux
- ▶ Ultraviolet and infrared
- ▶ Detect RGB colors separately
- ▶ Bluetooth 4.0 wireless
- ▶ New enhanced features measure PAR and irradiant light!



The Wireless Light Sensor features two separate apertures - one for ambient light measurements and one for directional light measurements. The ambient sensor measures illuminance and UV Index, while the spot (directional) aperture measures light level and color intensity. Our software displays the relative intensities of Red, Green, and Blue light, then sums them to determine the level of White light. PAR and irradiance are also available as calculated measurements within PASCO Capstone (version 1.8 or later) and SPARKvue software (version 2.6 or later).



Spot sensor contains red, green, blue, and white sensors.



Use the ultraviolet sensor on the back side to measure the amount of UVA and UVB radiation that makes it through sunglasses.

Specifications:

Spectral Response: 300 nm to 1100 nm

Illuminance Range*: 0 to 131,000 lux

Irradiance Range*: 0 to 1362 W/m²

PAR Range*: 0 to 2400 μmol/m²/s

UV Index Range: 0 to 12 (typical in daylight)

RGB and White Light Range: 0 to 100%

Maximum Sample Rate: 2 Hz (ambient); 20 Hz (spot)

Battery: Coin cell

Bluetooth 4.0: Yes

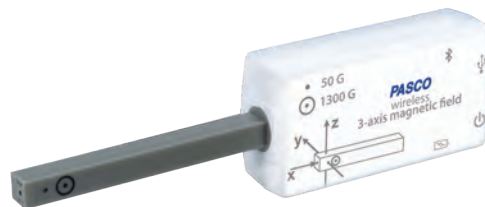
Order Information

Wireless Light SensorPS-3213

Wireless Magnetic Field Sensor

PS-3221

- ▶ Simultaneous measurements on three axes
- ▶ Dual range: ±50 G and ±1300 G
- ▶ Sensitive enough to measure the Earth's magnetic field
- ▶ Measure fields from bar magnets and coils



This 3-Axis Magnetic Field Sensor can sense the Earth's magnetic field and fields from coils and bar magnets. There are two ranges: ±50 gauss and ±1300 gauss. This sensor is primarily for static fields.



Wirelessly measure the magnetic field strength inside a solenoid as a function of current.

Specifications:

Ranges: ±50 G and ±1300 G

Resolution: ±0.01 G (50 G range); ±1 G (1300 G range)

Maximum Sample Rate: 100 Hz

Measurements: Magnetic Field Strength (3 axes and resultant)

Logging: Yes

Battery: Rechargeable Lithium-Polymer

Connectivity: Direct USB or via Bluetooth 4.0

Includes:

- 3-Axis Magnetic Field Sensor
- Sensor Mounting Rod
- USB Charging Cable

Order Information

Wireless Magnetic Field SensorPS-3221

Recommended:

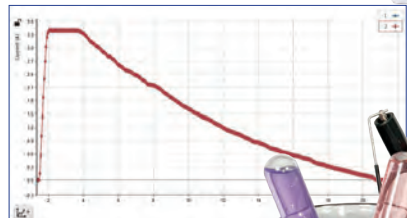
Zero Gauss ChamberEM-8652

p. 38

Wireless Current Sensor

PS-3212

The Wireless Current Sensor's wide current range enables introductory and advanced explorations of the fundamental concepts of electricity and basic circuits.



Features:

- ▶ **Two Ranges:** ± 1.0 A and ± 0.1 A
- ▶ **Resolution:** 0.2 mA at ± 1 A range and 0.02 mA at ± 0.1 A range
- ▶ **Bluetooth® sampling rate of 1.0 kHz**
- ▶ **High-speed sampling via USB**
- ▶ **Remote logging**
- ▶ **Variable sampling rate** for recording small, fast changes or experiments that run for hours, days, or weeks

Includes:

- USB Cable
- Red, Banana-to-alligator-clip
- Black, Banana-to-alligator-clip
- Wireless Current Sensor

Order Information

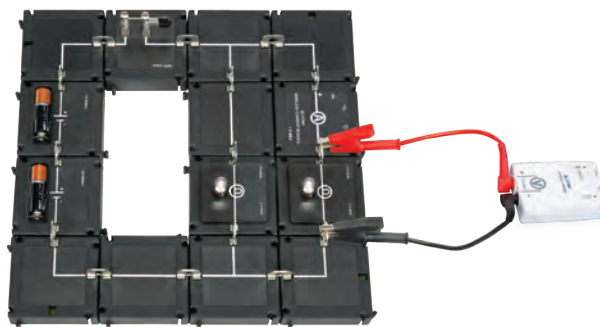
Wireless Current SensorPS-3212

Wireless Voltage Sensor

PS-3211



The Wireless Voltage Sensor is ideal for exploring the fundamental concepts of electricity, voltage, and basic circuits. It measures voltages up to ± 15 V with built-in overload protection, and features high-speed sampling rates when used with a USB. When combined with the Wireless Current Sensor, students can use it to explore Ohm's Law, circuits in series and parallel, and much more.



Features:

- ▶ **Two Ranges:** ± 15 V, ± 5 V
- ▶ **Resolution:** 7 mV (± 15 V range); 2 mV (± 5 V range)
- ▶ **Bluetooth® sampling rate of 1.0 kHz**
- ▶ **High-speed sampling via USB**
- ▶ **Remote logging**

Includes:

- Wireless Voltage Sensor
- USB Cable
- Red, Banana-to-alligator-clip
- Black, Banana-to-alligator-clip

Order Information

Wireless Voltage SensorPS-3211

Wireless Current Sensor Module

EM-3534



Since the Current Sensor Module is in the same form factor as the other modules, it naturally fits in series with the circuit components.

Included in Essential Physics Modular Circuit Kit EM-3536 on pages 218-219.

Specifications:

- Two ranges:** ± 1 A, ± 0.1 A
- Resolution:** 0.2 mA (± 1 A range); 0.02 mA (± 0.1 A range)
- Bluetooth® sampling rate of 1 kHz**
- Higher speed sampling via USB**
- Includes remote logging**

Order Information

Wireless Current Sensor ModuleEM-3534
 Required:
 Modular Circuits pp. 218-219

Chemistry Sensors

Wireless pH Sensor

PS-3204



The Wireless pH Sensor is a must-have for any chemistry, biology, or environmental science course. Equally capable in the lab or field, the sensor eliminates the hassle of cables, reducing spills and improving safety. Don't worry about charging, the sensor has a coin-cell battery that lasts for 2-3 years in most labs and costs about one dollar to replace. The sensor can transmit data in real-time, or store data for hours or days when continuous monitoring is required. The Wireless pH Sensor can perform countless experiments, including acid-base titrations, investigating household chemicals, changes in pH during reactions, water quality studies, and much more.



With the Wireless pH Sensor, students can collect data anywhere!

Easily measure and compare the pH of common acids and bases.



Features:

- ▶ Simply pair and go, no cables or interfaces to manage
- ▶ Compatible with ion-selective electrodes (ISE) and the oxidation reduction probe (ORP)
- ▶ Bluetooth® wireless connectivity and a long-lasting coin cell battery
- ▶ Logs pH data directly onto the sensor for long-term experiments

Specifications:

Range: 0-14 pH

Resolution: 0.02 pH

Accuracy: ± 0.1 pH with calibration

Logging: Yes

Bluetooth: BT 4.0

Temperature Range: 5 °C to 60 °C

Includes:

- Coin cell battery
- Direct-connect BNC pH probe
- Probe storage bottle and solution

Order Information

Wireless pH Sensor.....PS-3204

Flat pH Probe

PS-3514



The Flat pH Probe gives you the freedom to measure what you want, where you want. Study pH levels in different kinds of foods, investigate the pH of common skin and hair care products, and easily collect pH data when doing soil analysis. Can be used on semi-solids by pressing the probe against a moist surface.

Includes:

- Soaker bottle

Order Information

Flat pH Probe.....PS-3514

Required:

Wireless pH Sensor.....PS-3204

Get even more measurements out of the Wireless pH Sensor by using these ORP or ISE electrodes.

Oxidation Reduction Potential Probe

PS-3515

Includes:

- 2m cable



Ion Selective Electrodes



Includes:

- Cable

Order Information

Oxidation Reduction Potential Probe.....PS-3515
Ion Selective Electrodes

Ammonium Ion Selective Electrode.....PS-3516

Carbon Dioxide Ion Selective Electrode.....PS-3517

Calcium Ion Selective Electrode.....PS-3518

Chloride Ion Selective Electrode.....PS-3519

Potassium Ion Selective Electrode.....PS-3520

Nitrate Ion Selective Electrode.....PS-3521

Wireless Conductivity Sensor

PS-3210



The Wireless Conductivity Sensor measures the electrical conductivity of an aqueous solution. It is ideal for investigating the properties of solutions, including total dissolved solids (TDS) for water quality inquiry. Because it is temperature compensated, calibrations are less frequent and can be applied across a range of temperatures. With a range of 0 to 20,000 $\mu\text{S}/\text{cm}$, this sensor can be utilized for chemical, biological, and environmental studies.

Teacher tip: To measure brackish or marine samples, perform a dilution until the measurement falls within the range, then multiply to determine sample conductivity.

Features

- ▶ Measure conductivity and total dissolved solids
- ▶ Automatic temperature compensation
- ▶ Battery life >1 year
- ▶ Remote logging with built-in memory
- ▶ Dust-proof, sand-proof, and water-resistant (1 meter for 30 minutes)



Measure the conductivity of water and other water-based solutions.

Includes:

- Coin cell battery

Order Information

Wireless Conductivity Sensor PS-3210

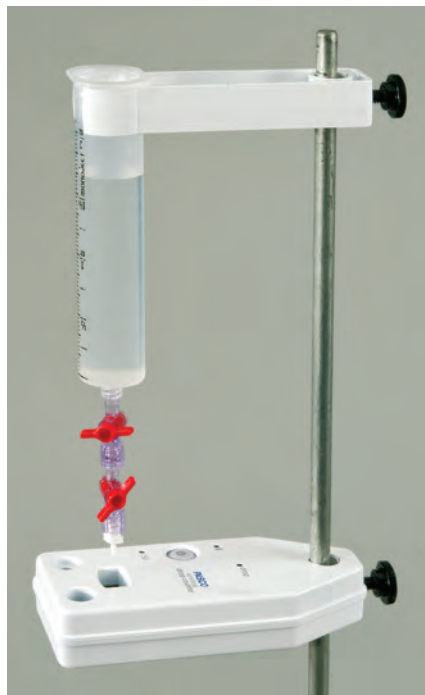
Wireless Drop Counter

PS-3214



The Wireless Drop Counter has a wider (18 x 13 mm) drop window for better drop detection and easier alignment with burettes. It works equally well with large or small, fast or slow drops.

Measures up to 10 drops per second with drops as small as 0.5 mm.



Includes:

- Wireless Drop Counter
- Micro Stir Bar
- Drop Dispenser with Stopcock
- Plastic Dispenser Rod Clamp

Order Information

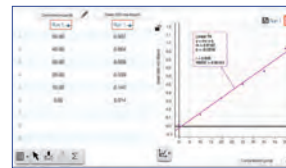
Wireless Drop Counter PS-3214

Wireless Colorimeter & Turbidity Sensor

PS-3215

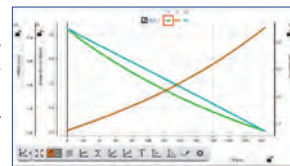
The Wireless Colorimeter simultaneously measures the absorbance and transmittance of six different wavelengths.

The sensor can be used to study Beer's Law (absorbance vs. concentration), enzyme activity, photosynthesis, and the rates of chemical reactions (absorbance vs. time). After a simple calibration, students can quickly begin viewing live measurements as they materialize across the visible spectrum at 650 nm (red), 600 nm (orange), 570 nm (yellow), 550 nm (green), 500 nm (blue), and 450 nm (violet). This sensor also functions as a high-quality turbidimeter for water quality analysis.



Create Beer's Law plots to help students understand the relationship between absorbance and concentration.

Graphically analyze how a reaction changes over time.



Specifications:

Color detection/peak wavelengths:

650 nm (red), 600 nm (orange), 570 nm (yellow), 550 nm (green), 500 nm (blue), 450 nm (violet)

Detector ranges: ± 25 nm from peak

Absorbance: 0-3 Abs units; useful range (0.05 -1.5 Abs)

Transmittance: 0-100%

Turbidity range: 0-400 NTU

Accuracy: $\pm 5\%$ NTU

Includes:

- USB charging cable
- Cuvettes and Caps (9)
- Cuvette Rack (2)
- 100 NTU Calibration Cuvette



WARNING! This product can expose you to chemicals including Formaldehyde, which is known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

Order Information

Wireless Colorimeter & Turbidity Sensor PS-3215

Also available:

Cuvettes and Caps SE-8739

100 NTU Calibration Cuvette SC-3512

Cuvette Rack EC-3590

Chemistry Sensors

Wireless Spectrometer (VIS) 

PS-2600

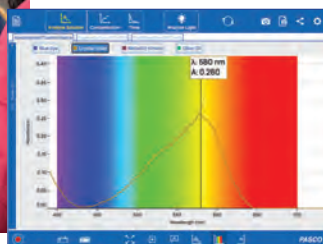
The Wireless Spectrometer from PASCO is specifically designed for modern chemistry, biology, and physics labs. With Bluetooth and USB connectivity, students can quickly connect from their device or computer using the free PASCO Spectrometry Software. With this affordable spectrometer students can gather a full spectrum of data in under one second. After specifying a target wavelength, students can study concentrations (Beer's Law), rates of reactions, or investigate emission spectra using the optional fiber optic cable.

**Applications:**

- ▶ Photosynthesis with DPIP
- ▶ Absorption spectra of plant pigments
- ▶ Concentration of proteins in solution
- ▶ Rate of an enzyme-catalyzed reaction
- ▶ Growth of a cell culture
- ▶ Absorption spectrum of chlorophyll
- ▶ Emission spectra of light from flame tests or other sources
- ▶ Easily identify peak wavelengths for concentration data
- ▶ Study the relationship between concentration and absorbance (Beer's Law)
- ▶ Reaction Kinetics
- ▶ Fluorescence of chlorophyll and other compounds
- ▶ Enzymatic reactions
- ▶ Photosynthesis with algae beads using a pH indicator



Full visible spectrum analysis of solutions with a large digits display helps set the wavelength and see the absorbance.

**Specifications:****Resolution:** 2–3 nm FWHM**Detection Range:** 380–950 nm**Fluorescence Excitation Wavelengths:** 405 nm and 500 nm**Light Source:** LED-boosted tungsten**Bluetooth:** Bluetooth 2.0**Includes:**

- Cuvettes (10)
- Spectrometry Software

Order Information

Wireless Spectrometer (VIS).....PS-2600

Recommended:

Fiber Optics Cable.....PS-2601

p. 292

Wireless Polarimeter 

PS-3237

PASCO's Polarimeter has both Bluetooth® and USB connectivity, so it works on your iPad®, Chromebook™, tablets, and computers. It is ideal for introductory Organic and Biochemistry experiments with chiral compounds.



In this new device, plane polarized light is passed through a sample, which contains a chiral compound, to an analyzer and a detector. The degree of optical rotation of the plane polarized light is based on the type and amount of sample present.

Determine the concentration of a sugar solution based on the optical rotation of plane polarized light.



Optical rotation of sucrose

**Features:**

- ▶ Bluetooth® and USB connectivity
- ▶ 589 nm LED light source
- ▶ $\pm 0.09^\circ$ optical rotation accuracy
- ▶ SPARKvue and Capstone compatible
- ▶ Industry-standard, horizontal polarimeter sample cell (100 mm)

Includes:

- Sample Cell

Order Information

Wireless PolarimeterPS-3237

Wireless Blood Pressure Sensor with Standard Cuff

PS-3218



PASCO's Wireless Blood Pressure Sensor allows students to quickly and easily measure both systolic and diastolic arterial blood pressure (mmHg) as well as heart rate (pulse in bpm). Comparing the digits display for systolic and diastolic pressure with the display of blood pressure from the real-time graph helps students gain a contextual understanding of the physiology of blood pressure.

Applications:

- ▶ Determine effects of exercise on blood pressure and heart rate
- ▶ Compare the blood pressure and heart rate of different students in the class
- ▶ Explore effects of body position on blood pressure & heart rate

Specifications:

Heart Rate Units: beats per minute (bpm)

Heart Rate Range: 36 to 200 bpm

Heart Rate Accuracy: ± 1 bpm

Heart Rate Resolution: 1 bpm

Blood Pressure Units:

millimeters of mercury (mmHg)

Blood Pressure Range: 0 to 375 mmHg

Blood Pressure Accuracy: ± 3 mmHg

Blood Pressure Resolution: 0.05 mmHg

Gauge Pressure Units:

mmHg, N/m², kPa, atm, psi

Gauge Pressure Range: 0 to 375 mmHg

Gauge Pressure Accuracy: ± 3 mmHg

Gauge Pressure Resolution: 0.05 mmHg

Includes:

- Wireless Blood Pressure Sensor
- Standard-size Arm Cuff
- Bladder and pressure release valve



Order Information

Wireless Blood Pressure Sensor with Standard Cuff..... PS-3218

Wireless Exercise Heart Rate Sensor

PS-3207



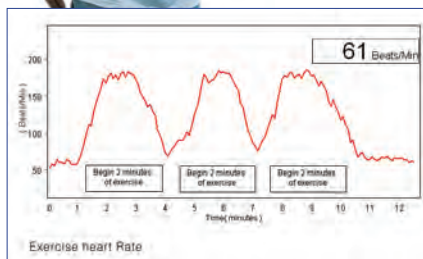
The Wireless Exercise Heart Rate Sensor has a chest strap and will transmit data wirelessly up to 10 m away! The electrode belt fits around the ribcage (worn against the skin for best results, but can be worn over a shirt if saline solution is applied under the electrodes) and wirelessly transmits the cardiac signal to the sensor.

Applications:

- ▶ Compare a student's heart rate before, during, and after exercise
- ▶ Calculate recovery rate after physical activity
- ▶ Determine the effects of mild stimulants (e.g. caffeine)
- ▶ Investigate how heart rate changes when a student sits, reclines, stands or moves suddenly



Graph shows the heart rate as a student alternates between exercising and resting.



Includes:

- Bluetooth® Heart Rate Module
- Coin Cell Battery
- Chest Strap (M-XXL)

Order Information

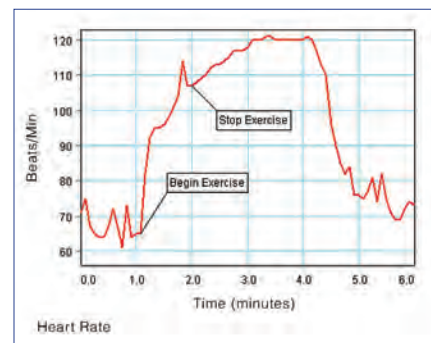
Wireless Exercise Heart Rate Sensor..... PS-3207

Wireless Hand-Grip Heart Rate Sensor

PS-3206



With these wireless hand grips, conducting physiology labs on the cardiovascular system or homeostasis is easier than ever before. Continuously monitor heart rate during exercise, or use the sensor to take initial and final measurements with fast and reliable heart-rate detection.



Includes:

- Hand Grips
- Bluetooth® Heart Rate Module
- Coin Cell Battery

Order Information

Wireless Hand-Grip Heart Rate Sensor..... PS-3206

Biology Sensors

Wireless CO₂ Sensor

PS-3208



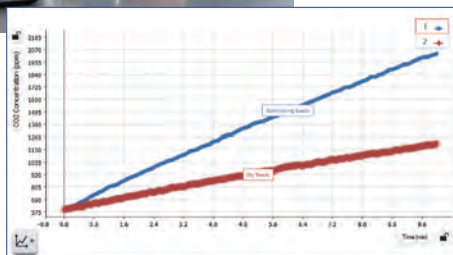
Measure changes in carbon dioxide (CO₂) gas levels quickly and easily with the Wireless CO₂ Sensor. The sensor is temperature compensated and can operate in high humidity environments, like the included sample 250-mL sample bottle. This sensor employs live data to make core labs, such as photosynthesis, cellular respiration, and metabolism experiments engaging and impactful. With the ability to store more than 55,000 data points, this sensor enables studies to run overnight or throughout entire weekends for carbon cycling investigations.



Easily compare respiration/metabolism rates at different conditions.

Includes:

- 250-ml Sampling Bottle
- USB Charging Cable



Order Information

Wireless CO₂ SensorPS-3208

Dissolved CO₂ Waterproof Sleeve

PS-3545



The Wireless CO₂ Sensor can be equipped for aqueous measurements using this semipermeable sleeve. The sleeve is waterproof but allows CO₂ gas to pass through the membrane, creating a headspace around the sensor. Monitor photosynthesis and respiration of aquatic plants or animals with the sample bottle or with other chambers. (Please note: Improper use will void sensor warranty.)

Includes:

- Sleeves (5)
- O-rings (5)



Order Information

Dissolved CO₂ Waterproof SleevePS-3545

Wireless Oxygen Gas Sensor

PS-3217



The Wireless Oxygen Gas Sensor measures gaseous O₂ concentration as well as humidity and air temperature for a range of biology, environmental science, and physiology activities.

The Wireless Oxygen Gas Sensor is accurate and easy to use, making it the perfect sensor to study photosynthesis, respiration, and oxygen cycling in the environment. With remote logging experiments can go beyond the lab period and easily give students hours or days of data for analysis. The Wireless Oxygen Gas Sensor also contains sensors to measure ambient temperature and humidity as well as oxygen gas levels.

Includes:

- USB Charging Cable
- 250-mL Sampling Bottle

Order Information

Wireless Oxygen Gas SensorPS-3217
 Also available:
 Wireless Oxygen Gas Replacement SensorPS-3606

Wireless Oxygen Gas Replacement Sensor

PS-3606



Replacement sensing unit fits inside the wireless Oxygen gas sensor.

Specifications:

- Oxygen percent composition:** within 1%
- Oxygen percent:** 0 to 100%

Order Information

Wireless Oxygen Gas Replacement SensorPS-3606

EcoZone™ System ME-6668

EcoChamber ME-6667

- ▶ Three interconnected EcoChambers (ME-6668) or one stand-alone EcoChamber (ME-6667)
- ▶ Designed for sensor-based measurements

PASCO's EcoZone System is designed to help students model and understand the complex interactions within, and among, different ecosystems. The three clear acrylic EcoChambers are specially designed to accommodate PASCO sensors, making qualitative and quantitative measurements as easy as observing.

With three interconnected chambers, students can model the interaction between three different ecosystems. Choose the traditional terrestrial, aquatic, and decomposition arrangement or create unique biomes to model and measure. Decouple the system for isolated investigations. How does the availability of light affect the ecosystem? Students can create two identical ecosystems and monitor one in light conditions and one in dark.

Opening connects the chambers to allow the interaction between the living and non-living components of each unique ecosystem.



The included cord efficiently wicks water between the chambers.



ME-6667 Includes:

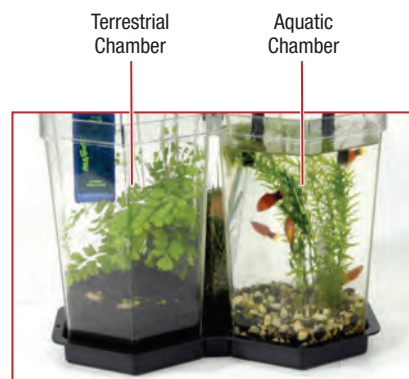
- Acrylic chamber
- Stoppers of various sizes (7)
- Probe stoppers (5)
- 20 cc calibrated syringe
- Sample tube with connector

ME-6668 Includes:

- Three individual EcoChambers with lids
- Custom tray for holding EcoChambers in a connected ecosystem
- Stoppers and connectors
- Cotton wick
- Syringe and plastic tubing



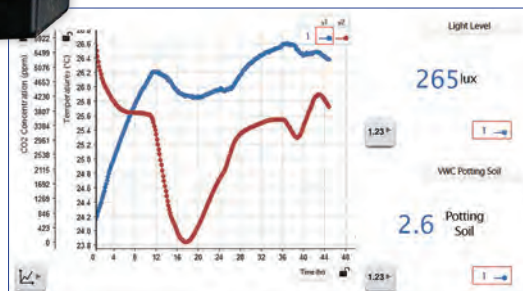
Keep the system closed during chemical testing – use the included syringe to extract water. Or inject pollutants into the system and see how the ecosystem responds.



Cleanup is easy, and the chambers are durable enough to use again and again. The unique design of the PASCO EcoZone System allows you to use your sensors to actively measure a model ecosystem.

For more information on sensors and probes available for use with the EcoZone System, see www.pasco.com/ecozone and scroll down to the Buying Guide.

Decomposition Chamber



Observe the photosynthesis and respiration cycles of the simulated microclimate in the EcoZone and their effect on carbon dioxide.

Order Information

EcoZone System	ME-6668
EcoChamber	ME-6667

Biology & Environmental Sensors

Wireless Optical Dissolved Oxygen Sensor

PS-3224



The Wireless Optical Dissolved Oxygen (ODO) Sensor is ideal for monitoring DO₂ in the lab or field. The Wireless Optical DO Sensor contains three different probes. In addition to the dissolved oxygen sensor, it also includes probes for measuring atmospheric pressure and water temperature. The optical technology is accurate, fast, and does not require stirring, filling solutions, warm-up, or frequent calibration. When equipped with the included cover, the sensor has a waterproof design and is submersible to a depth of 10 m.

A PASCO exclusive feature allows you to log data using the sensor's built-in memory. After collecting data for hours or even days, simply connect the sensor to your device and you're ready to download your data. With this powerful sensor, educators can explore day and night nutrient cycles, changes in metabolic processes, seasonal changes in water quality, and more.

Applications:

- ▶ Teaching field sampling techniques
- ▶ Exploring how temperature influences dissolved oxygen concentrations
- ▶ Measuring net primary productivity
- ▶ Modeling ecosystems
- ▶ Monitoring water quality and investigating watersheds
- ▶ Investigating photosynthesis and cellular respiration in aquatic environments



Specifications:

- Dissolved Oxygen Range:** 0 to 20 mg/L, 0 to 300% saturation
- Accuracy – with user calibration:** ±0.2 mg/L or 1% (whichever is greater)
- Accuracy – out of the box:** ±0.5 mg/L or 3% (whichever is greater)
- Response Time:** 90% in 45 sec
- Measurements:** Concentration (mg/L), Saturation (%), O₂ Gas (in air, qualitative) (%), Temperature (°C)
- Waterproof Depth:** 10 m (30 ft)

Includes:

- USB Cable (for recharging and optional direct connection)
- Protective cover



Order Information

Wireless Optical Dissolved Oxygen Sensor	PS-3224
Recommended:	
Wireless Optical Dissolved Oxygen Sensor Metal Guard	PS-3604
Wireless Optical Dissolved Oxygen Sensor Cap	PS-3605
Shown in use with:	
Photosynthesis Tank	PS-2521B

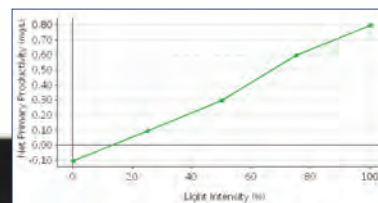
Aquatic Productivity Bottles

ME-6937

The Aquatic Productivity Bottles rest in a rack that provides consistent and reliable light control for quantitative aquatic productivity studies. The identical transparent bottles nest in each of the five rack positions. The custom design of the rack shields the bottles from light by blocking a fixed percentage of light in 25% increments from 0 to 100%.



The Aquatic Productivity Bottles were completely filled with algae solution and the initial dissolved oxygen (DO) concentrations of the solutions were determined with a DO sensor. The bottles were then placed into the rack and the specially molded, light-varying lid was locked into place over the bottles. After 24 hours of incubation in fluorescent light, the bottles were removed from the rack and the DO concentration was again determined with a DO sensor. Using the initial and final readings, students calculated Net Primary Productivity and Gross Primary Productivity.



Net Primary Productivity (mg/L) vs. Light Intensity (%): Notice that for the bottle in the dark, the Net Productivity is negative.

Includes:

- Plastic bottles w/lids (5)
- Case with slotted lid



Order Information

Aquatic Productivity Bottles	ME-6937
Shown in use with:	
Wireless Optical Dissolved Oxygen Sensor	PS-3224

Wireless Weather Sensor with GPS

PS-3209

The Wireless Weather Sensor is an all-in-one instrument for monitoring complex environmental conditions. It houses several sensing elements within a single unit to provide 19 different measurements. Use the sensor in logging mode with the Weather Vane Accessory for long-term monitoring, or use it as a handheld instrument to study microclimates and record ambient conditions relevant to environmental phenomena. You can wirelessly export data to your device for classroom analysis and group activities that are constrained by time. With the built-in GPS, you can collect location data for student investigations and analyze it on the map display, powered by ESRI ArcGIS, within SPARKvue software.



Shown with optional weather vane accessory, sold separately.

Specifications:

Water-resistant: IP-64 splash-proof

Battery: Rechargeable

(Please see pasco.com for detailed specifications.)

Includes:

- USB charging cable

Order Information

Wireless Weather Sensor with GPSPS-3209

Suggested:

Weather Vane AccessoryPS-3553



Measurements

- | | |
|---------|--------------------------|
| Weather | 1. Ambient Temperature |
| | 2. Barometric Pressure |
| | 3. Wind Speed |
| | 4. Wind Direction (true) |
| | 5. Relative Humidity |
| | 6. Absolute Humidity |
| | 7. Dew Point |
| | 8. Wind Chill |
| | 9. Heat Stress Index |
| Light | 10. Ambient Light (lux) |
| | 11. UV Index |
| | 12. PAR |
| GPS | 13. Irradiance |
| | 14. Latitude |
| | 15. Longitude |
| | 16. Altitude |
| | 17. Speed |
| | 18. Magnetic Direction |
| | 19. True Direction |



Weather data colored and viewed on one of several global base maps.

Weather Vane Accessory

PS-3553

Equip your Wireless Weather Sensor for extended environmental monitoring with the Weather Vane Accessory. Once deployed the sensor will freely rotate to capture wind speed and direction, whether you are monitoring data in real time or using the sensor in logging mode to capture hours (or days!) of data for later analysis.

Includes:

- Tripod
- Tripod Adapter
- Weather Vane



Order Information

Weather Vane Accessory PS-3553

Wireless Charging Stations

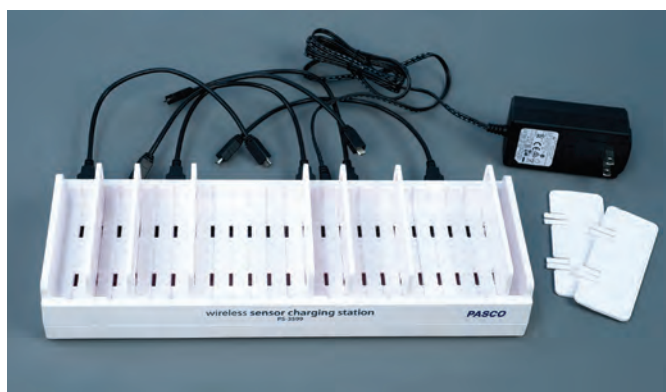
Wireless Sensor Charging Station

PS-3599

- ▶ Charge all types of PASCO wireless sensors
- ▶ Remove partitions to resize sensor bays



This versatile charging station can be configured to fit any size sensor by adding or removing partitions.



Includes:

- Wireless Sensor Charging Station (13 cm x 35 cm)
- Power Adapter
- USB Charging Cables (10)
- Removable Partitions (9)

Order Information

Wireless Sensor Charging StationPS-3599

Make any PASPORT sensor wireless by connecting to an AirLink®

AirLink Interface

PS-3200

The AirLink connects PASPORT sensors to a Mac or Windows computer, Chromebook, iPad, tablet, or smartphone via Bluetooth or USB connection. The USB cable is included.



Order Information

AirLink InterfacePS-3200

Wireless Sensor Packs

- ▶ Includes 8 sensors in each Gratnells® storage tray

Wireless Temperature Sensor Pack

PS-3330

Wireless pH Sensor Pack

PS-3331

Wireless Conductivity Sensor Pack

PS-3332

Wireless Pressure Sensor Pack

PS-3333

Wireless Colorimeter & Turbidity Sensor Pack

PS-3334

Wireless Voltage Sensor Pack

PS-3335

Wireless Current Sensor Pack

PS-3336

Wireless Motion Sensor Pack

PS-3337

Wireless Light Sensor Pack

PS-3338

Wireless Force Acceleration Sensor Pack

PS-3339

Wireless Weather Sensor with GPS Pack

PS-3340

Wireless CO₂ Sensor Pack

PS-3341

Wireless Sound Sensor Pack

PS-3342



Order Information

Wireless Temperature Sensor Pack	PS-3330
Wireless pH Sensor Pack	PS-3331
Wireless Conductivity Sensor Pack	PS-3332
Wireless Pressure Sensor Pack	PS-3333
Wireless Colorimeter & Turbidity Sensor Pack	PS-3334
Wireless Voltage Sensor Pack	PS-3335
Wireless Current Sensor Pack	PS-3336
Wireless Motion Sensor Pack	PS-3337
Wireless Light Sensor Pack	PS-3338
Wireless Force Acceleration Sensor Pack	PS-3339
Wireless Weather Sensor with GPS Pack	PS-3340
Wireless CO ₂ Sensor Pack	PS-3341
Wireless Sound Sensor Pack	PS-3342

Does your Bluetooth need a boost?

USB Bluetooth Adapter

PS-3500

If you are using our wireless sensors and working on an older Mac (without Bluetooth 4.0 connectivity) or if you are using some Windows computers and Chromebooks, you will need a USB Adapter.



See pasco.com/compatibility if you have questions about Bluetooth connectivity.

Order Information

USB Bluetooth Adapter.....PS-3500

Wireless Sensor Storage Trays

► Each tray can store up to 10 wireless sensors.

Wireless Temperature, pH and Conductivity Sensors Storage Tray
PS-3585

Wireless Pressure Sensor Storage Tray
PS-3586

Wireless Colorimeter and Turbidity Sensor Storage Tray
PS-3587

Wireless Voltage and Current Sensors Storage Tray
PS-3588

Wireless Motion Sensor Storage Tray
PS-3589

Wireless Light Sensor and AirLink Storage Tray
PS-3594

Wireless Force Sensor Storage Tray
PS-3595

Wireless Weather Sensor Storage Tray
PS-3596

Wireless Hand-Grip Sensor Storage Tray
PS-3597

Wireless CO₂ Sensor Storage Tray
PS-3598



Order Information

Storage for Wireless Temperature, pH and Conductivity Sensors	PS-3585
Storage Tray for Wireless Pressure Sensors.....	PS-3586
Storage Tray for Wireless Colorimeter and Turbidity Sensor	PS-3587
Storage Tray for Wireless Voltage & Current Sensor	PS-3588
Storage Tray for Wireless Motion Sensor	PS-3589
Storage Tray for Wireless Light Sensor and AirLink	PS-3594
Storage Tray for Wireless Force Sensor	PS-3595
Wireless Weather Sensor Storage Tray	PS-3596
Wireless Hand-Grip Heart Rate Sensor Storage Tray	PS-3597
Wireless CO ₂ Sensor Storage Tray	PS-3598

Gratnells Rolling Carts

EP-3574 (2-column) EP-3575 (3-column)

Gratnells Rolling Carts are the best way to store and transport PASCO sensors and equipment. They can be configured for trays of any size and include large casters with brakes for added stability.

Designed for Gratnells trays, these movable storage rack carts can store up to 8 (2 column) or 12 (3 column) Gratnells F2 trays (sold separately). Each carts comes with either 16 or 24 pairs of runners.

They can be used to store the equipment kits from the Essential Physics or Essential Chemistry curriculum, the storage trays we offer for wireless sensors, or any of the four sizes of empty trays that we offer for everything else you'd like to store.

Assembly is required. Trays not included.



EP-3574:
Stores up to
8 Gratnells F2 trays
24 pairs of runners

Dimensions: 107 cm high,
70 cm wide, 43.5 cm deep

Assembly is required. Trays not included.

EP-3575:
Stores up to
12 Gratnells F2 trays
16 pairs of runners

Dimensions: 107 cm high,
102 cm wide, 43.5 cm deep

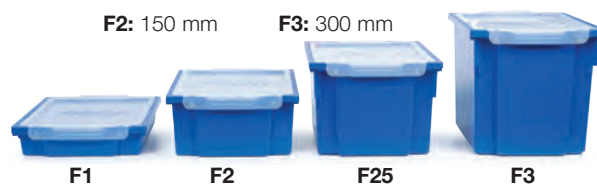
Order Information

Gratnells Rolling Cart (2-column)	EP-3574
Gratnells Rolling Cart (3-column)	EP-3575

Gratnells® Storage Trays with Lids

These empty Gratnells storage trays with lids have a length of 427 mm and width of 312 mm. The depth of each follows:

F1: 75 mm **F25:** 225 mm
F2: 150 mm **F3:** 300 mm



Order Information

Storage Tray (F1) Shallow	PS-3326
Storage Tray (F2) Deep.....	PS-3327
Storage Tray (F25) X-Deep	PS-3328
Storage Tray (F3) Jumbo	PS-3329

Make the switch to **PASCO** capstone™ 2

The Most Advanced Data Collection Software in Science Education

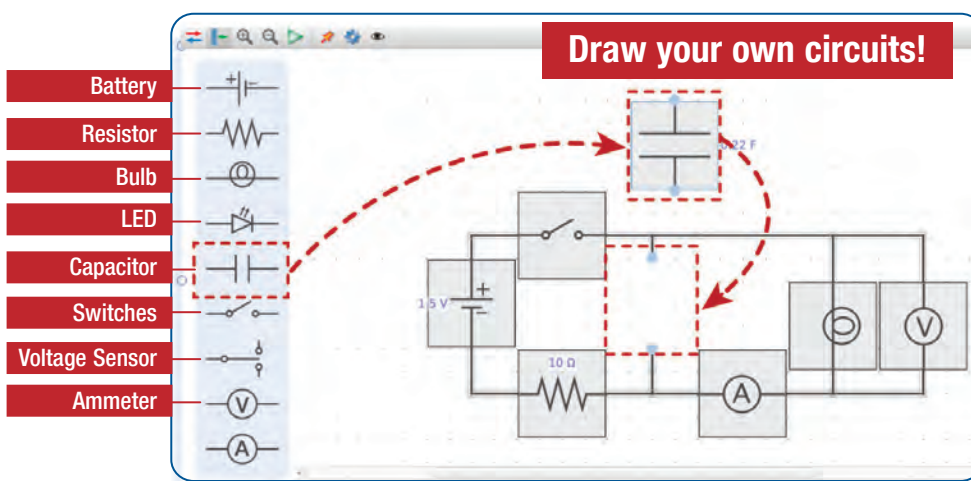
PASCO is pushing the limits of technology, so you can push your students to their potential. Working closely with educators, we continuously develop Capstone™, making improvements and enhancing the teaching features. Capstone is designed to handle large data sets, high-speed sampling, and customized preferences to fit the needs of your lab. A straightforward user interface is approachable for beginners, yet Capstone offers all the capabilities needed for even the most advanced users.

Features in PASCO Capstone 2

Visit pasco.com/capstone for more information.

Circuits Emulation

Reinforce circuit concepts and tackle student misconceptions using circuit visualization.



Combine real-world circuits with simulations, animations, and live measurements.

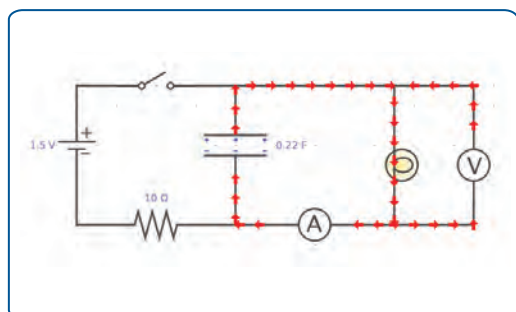
With this tool you can:

- ▶ Construct and modify circuits
- ▶ Show conventional current and electron flow animations
- ▶ Animate circuits with live sensor data

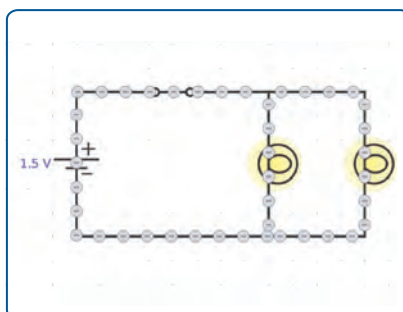
Build your own circuits in Capstone. Drag and drop components and draw wires to connect.

- ▶ Demonstrate series and parallel
- ▶ Charge and discharge capacitors

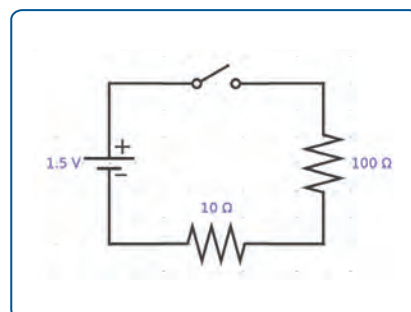
Examples of other circuit emulations



- ▶ Animated conventional current flow
- ▶ Animated capacitor—charge or discharge
- ▶ Edit capacitor values



- ▶ Animated electron flow
- ▶ Connect components in parallel or series

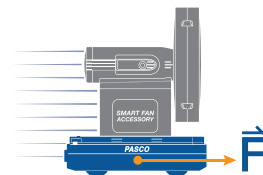


- ▶ Operate switches
- ▶ Edit voltage and resistor values

Blockly Block-based Coding

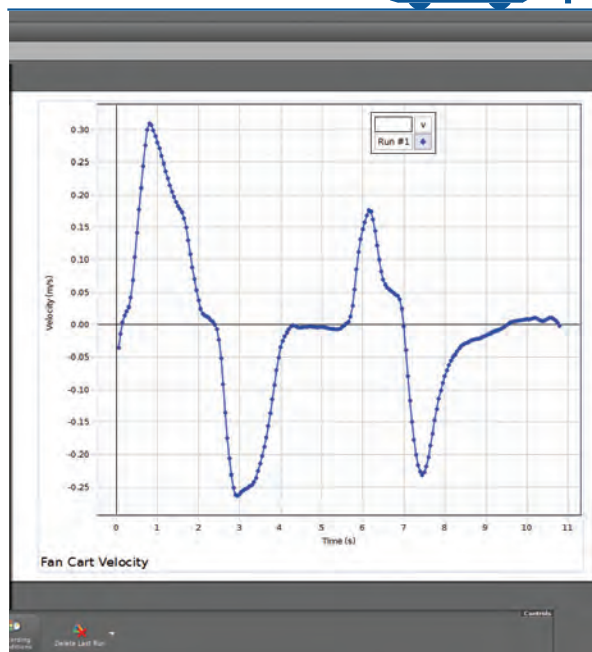
- ▶ Control all PASCO sensors and interfaces
- ▶ Create sense and control programs
- ▶ Control outputs from sensor inputs

Bring computational thinking into your science lab!



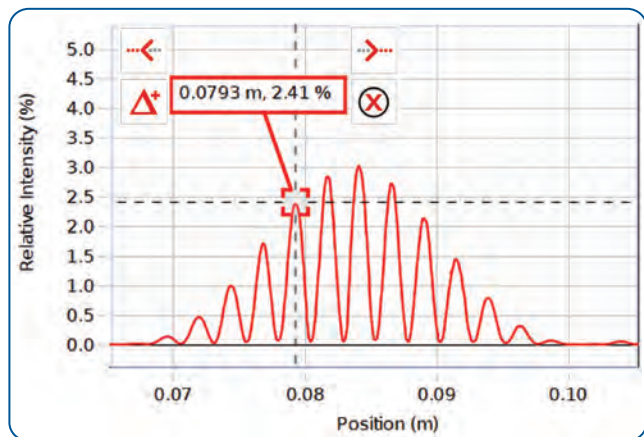
```

Write output voltage Smart Fan Accessory - 0
Sleep in ms 100
set k to -110
set b to 160
set Xo to 0.3
set N to 0
repeat 10000 times
do
change N by 1
set x to Read Measurement Position, Blue - m -
set v to Read Measurement Velocity, Blue - m/s -
set P to k x x - Xo - b x v
Write output voltage Smart Fan Accessory - P -
Write numeric to UED power - P -
Sleep in ms 20
if absolute v 0.1 > and N 100 <
do
set Xo to -1 x Xo -
set N to 0
Write output voltage Smart Fan Accessory - 0
    
```



Graph Pop-up Tools

Quick access to commonly used analysis tools



Visit pasco.com/capstone for more information.

Capstone has all the software tools you need for data collection and analysis. And we continue to add more features, based on input from physics educators just like you!

- ▶ Exclude or delete selected data points from analysis.
- ▶ Create models using the calculator.
- ▶ Calculated columns in tables
- ▶ Error bars
- ▶ Weighted linear fit that takes into account error bars
- ▶ More complex curve fits such as damped sine, Gaussian, sine series, and user-entered fits
- ▶ Smooth data directly on a graph with slider tool.
- ▶ Global preferences settings

Order Information

PASCO Capstone	
Single User License	UI-5401 or UI-5401-DIG
PASCO Capstone	
Site License	UI-5400 or UI-5400-DIG

Download the Free Trial
www.pasco.com/Capstone
 Requires Mac or Windows

TOOLS



Configure PASCO Hardware

Works with PASPORT, ScienceWorkshop, and Wireless Sensors



Photogate Timer Wizard

Easily configure photogates and timing measurements



Data Summary

- ▶ Equations/calculations
- ▶ Fundamental constants
- ▶ Experimental constants
- ▶ Trials and runs



Sensor Calibration Wizard

- ▶ Step by step calibration
- ▶ Many calibration types



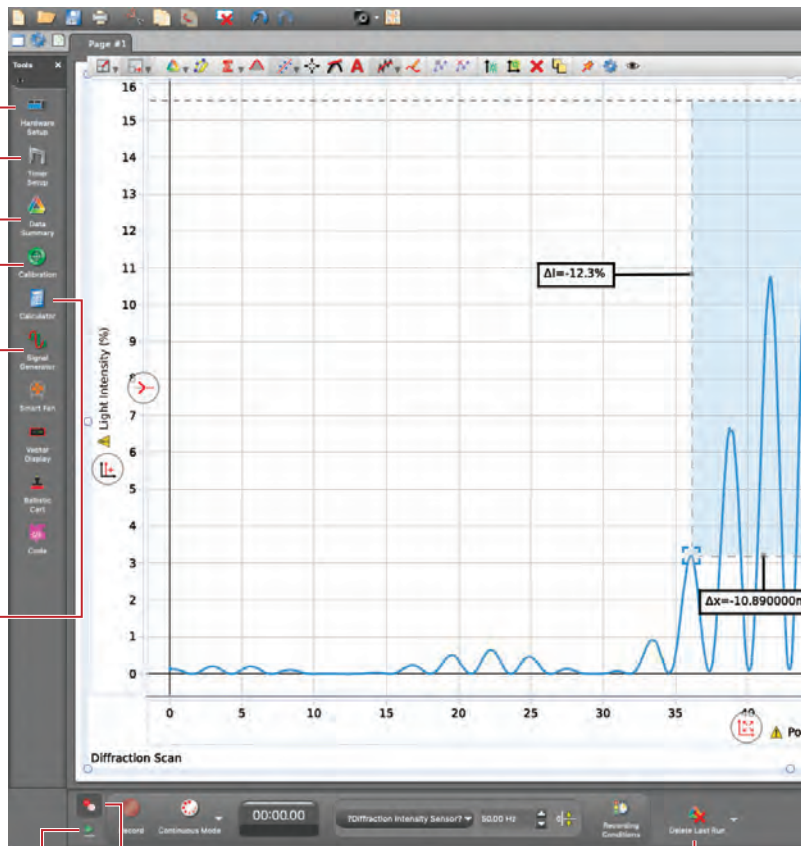
Signal Generator

- ▶ Scan through a range of frequencies
- ▶ Control signal output with a calculation



Calculator

- ▶ Graph modeling
- ▶ Create data sets using sensor data



Calculations	Units
1 Momentum = mass * [Velocity, Red (m/s)]	kg m/s
2 Kinetic Energy = .5 * mass * [Velocity, Red (m/s)]^2	J
3 mass = .250	kg
4	



Replay Your Data

- ▶ Change replay rate
- ▶ Increment by frame
- ▶ Loop playback



Sampling Options

- ▶ Continuous manual sampling
- ▶ Fast monitor mode
- ▶ Independent sensor sampling rates
- ▶ Start/stop conditions
- ▶ Zero sensor

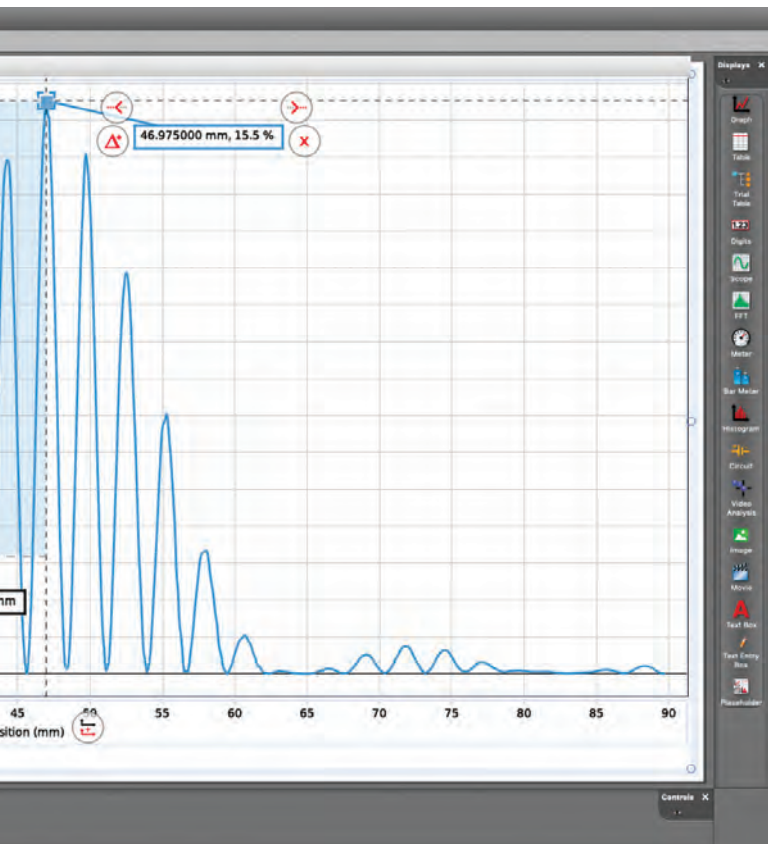
Capstone 2 Includes Video Analysis

Sophisticated scientific calculator has statistics, calculus, filters, logic functions, and special operations such as amplitude and period.

Import video and analyze the motion of objects to measure position, velocity, and acceleration. With this tool you can also:

- ▶ Show velocity and acceleration vectors
- ▶ Use magnifier to identify exact center of an object
- ▶ Use calibration ruler at any time
- ▶ And so much more!

PASCO's
proximity in-app
sensor pairing:
U.S. Patent
Number
10,356,594



DISPLAYS

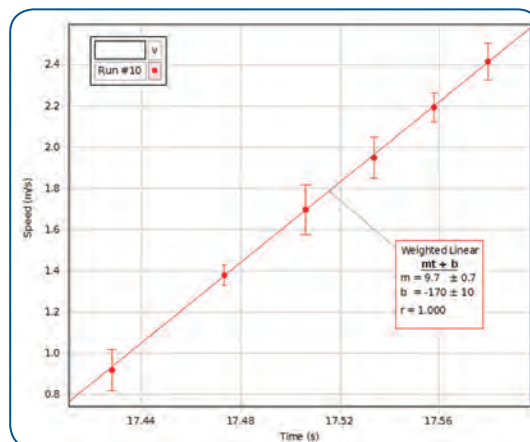
Display Your Data Your Way

- ▶ Graph
- ▶ Table
- ▶ Digits
- ▶ Scope
- ▶ FFT
- ▶ Meters

Graph Tools Include

- ▶ Draw predictions on graphs before taking data.
- ▶ Multiple y-axes and/or multiple plot areas
- ▶ Perform Quick-Calcs on the graph axis to linearize data.
- ▶ Curve-fits report the uncertainties in the parameters.
- ▶ Multi-coordinate tool gives y-values wherever it intersects data.

Error Bars and Weighted Linear Fits



Graph uncertainties using user-entered error bars, absolute error, or percent error. The weighted linear fit incorporates the error bars.

Visit pasco.com/capstone for more information.



Delete Runs

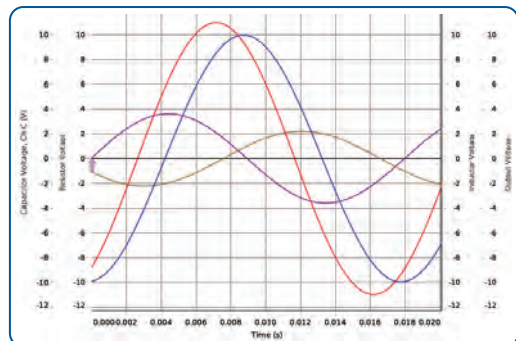
- ▶ Last run only
- ▶ Select from list
- ▶ All runs

Made a mistake?



Just hit
UNDO

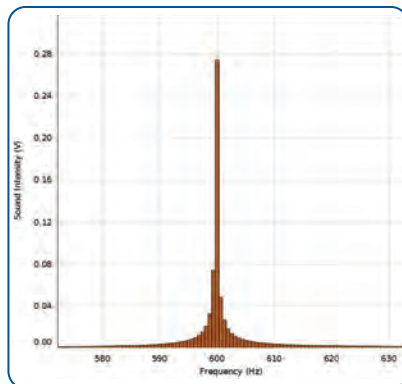
Oscilloscope Display



This display behaves like an authentic digital oscilloscope.

- ▶ Trigger
- ▶ Single trace collection
- ▶ Sample rate tied to time axis scale
- ▶ Set trace offset

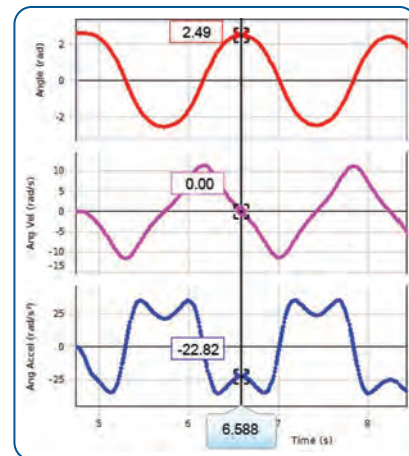
FFT



Display data in the frequency domain to find peak frequency and harmonics.

- ▶ Sample rate tied to axis scale
- ▶ Normalize data
- ▶ Adjust BIN width

Multi-Coordinate Tool



Easily show the relationship between multiple data plots by comparing data values across the time axis.

SPARKvue[®] 4 Software

Award-winning data collection and analysis software for any platform



SPARKvue Software

Award-winning, cross-platform data collection and analysis software



SPARKvue's intuitive design has made it an award-winning tool for collecting and analyzing experimental data. The user-friendly platform optimizes data collection and provides tools for in-depth analysis to provide students with a compact, yet powerful workspace. With the recent release of SPARKvue 4, we've added new features, including a new Welcome screen and Blockly coding. Now, students can use block-based code to sense and control PASCO devices, including any of our wireless sensors.

Designed for All Sciences

Collect data in real time using PASPORT or Wireless sensors.



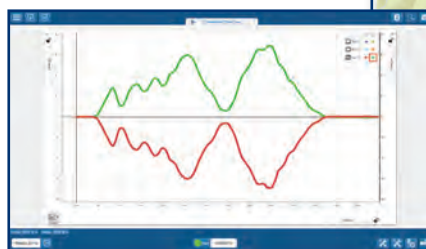
SPARKvue comes installed on every SPARK LXi.



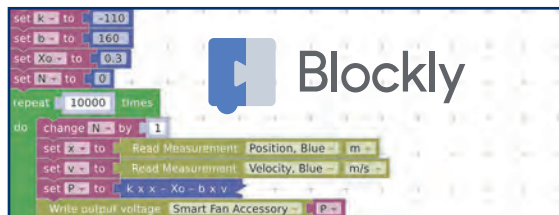
SPARKvue includes interactive data displays that are specific to your activity.



PASCO's
proximity in-app
sensor pairing:
U.S. Patent
Number
10,356,594



Data Collection:



- ▶ **Live Data Bar:** See sensor readings before recording
- ▶ **Periodic sampling:** Automatic sampling at a fixed rate
- ▶ **Manual sampling:** Saves data only when a user specifies
- ▶ **Blockly:** Use code to control sensor and interface data collection
- ▶ **Collaborate:** Start a shared session and stream results in real time

Data Displays:

- ▶ Graph displays with multiple plot areas and axes
- ▶ Digits
- ▶ Meter
- ▶ Data tables
- ▶ FFT
- ▶ Map Display
- ▶ Weather Dashboard
- ▶ Oscilloscope

Try SPARKvue software for FREE. Get Started Today!

The complete version of SPARKvue is now available as a **FREE app** for iPad® and Android™ tablets, Chromebook™, as well as free apps for iPhone and Android phones.



We also offer free 60-day trials for Windows™ and Mac®*. Visit www.pasco.com/downloads

Tools for Data Analysis:



- ▶ **Scale-to-fit:** Adjust axis for optimal data view
- ▶ **Data Selection:** Easily select a portion of data for analysis
- ▶ **Prediction Tool:** Visualize a prediction alongside the data
- ▶ **Smart Tool:** Find data coordinates and calculate delta values
- ▶ **Calculation Tools for Statistics:** Easily obtain statistics such as minimum, maximum, mean values and more
- ▶ **Slope Tool:** Find the slope of a point
- ▶ **Curve Fits:** Various curve fits with goodness of fit values
- ▶ **User Annotation:** Easily add text notes to runs or points
- ▶ **Axes:** Add another y-axis or a new plot with one button

SPARKvue Resources:



- ▶ Video Library: 330+ free videos featuring SPARKvue
- ▶ PASCO Blog: Dozens of fun applications for SPARKvue
- ▶ Experiment Library: 80+ free and downloadable SPARKvue labs
- ▶ FREE webinar training from PASCO professionals on our website
- ▶ On-site Workshops: Personalized professional development
- ▶ Visit www.pasco.com/training-and-development for more information

Cross-Platform Compatibility



SPARKvue



(single user license) PS-2401
(site license) PS-2400

Windows® and Mac®



Order Information

SPARKvue Single User License.....	PS-2401
SPARKvue Site License	PS-2400

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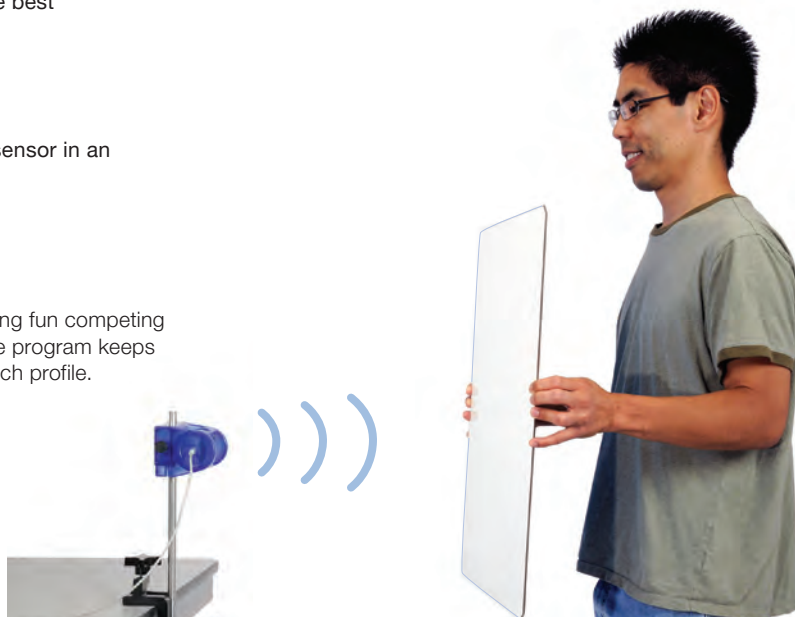
PASCO MatchGraph!

- ▶ Students feel the motion firsthand and learn how to interpret motion graphs! Watch your students compete to get the best match score.
- ▶ The sample graphs to match include both Position vs. Time and Velocity vs. Time.
- ▶ The student moves back and forth in front of a motion sensor in an attempt to match the motion represented on the graph.



High Score	
Name	Score
Lewis	90.78
Ann	90.46
James	75.47
Brett	70.24

Students learn while having fun competing for the highest score. The program keeps track of the scores for each profile.



Select one of the profiles below:

There are nine position profiles to match. The tenth choice allows the students to use the motion sensor without a profile on the graph.

Select one of the profiles below:

The velocity profiles to match correspond to the position profiles.



The students get to see their motion for a few seconds before the matching starts so they can get lined up. Here the black line is the match profile and the red line is the student's attempt to match it.

FREE MatchGraph!™ Software



Go to pasco.com/downloads and click on MatchGraph.

Now works with all Motion Sensors and Smart Carts!

Download FREE MatchGraph! software for Mac® and Windows® computers at pasco.com. Download the free iPad® or Android™ app on the App Store or Google Play.



Order Information

Required:		
Wireless Motion Sensor	PS-3219	p. 51
OR		
PASPORT Motion Sensor	PS-2103A	p. 28
OR		
Motion Sensor II	CI-6742A	p. 20
*Requires a USB or Bluetooth interface; see pages 66.		
OR		
Smart Cart (Red)	ME-1240	p. 50

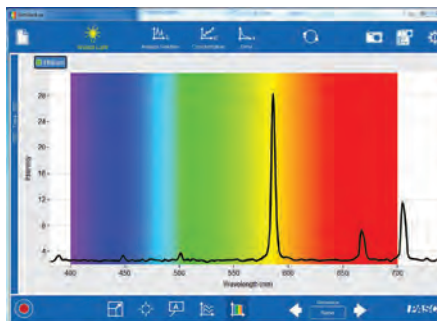
PASCO's Free Spectrometry Software Puts Learning First

PASCO's own software for the PASCO Spectrometer works on iOS®, Android™, Computers, and Chromebooks*

- ▶ Designed by teachers
- ▶ Specialized software specifically targets spectrometry activities
- ▶ Program guides students through the four common types of spectrometer uses
- ▶ Calibration routine is made obvious

The four specially targeted activities are:

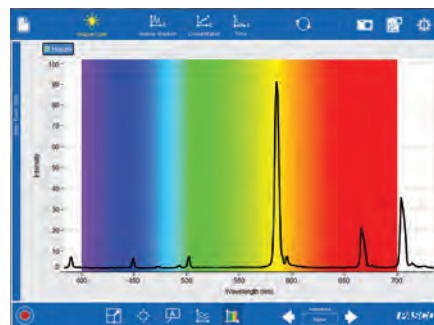
1. Analyze light sources with the optional Fiber Optic Cable.
2. Analyze the absorbance, transmittance, and fluorescence of colored solutions.
3. After the analysis wavelength is set, you can easily create calibration curves and determine the unknown concentration of a solution.
4. Observe the kinetics of a reaction involving a colored solution. Easily create the required graphs (ln(x), 1/x) to determine the order of the reactants.



Helium Spectrum



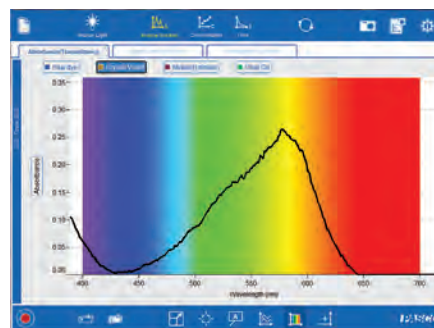
Shown using the optional Fiber Optic Cable.



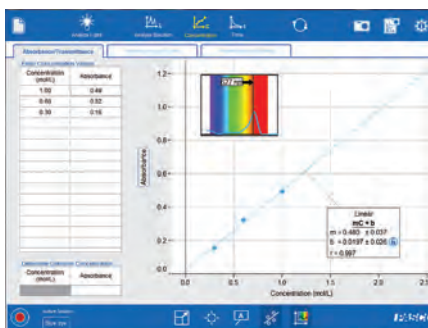
1. Analyze light sources with the optional Fiber Optic Cable.

The Wireless Spectrometer comes with **PASCO's award-winning spectrometry software.**

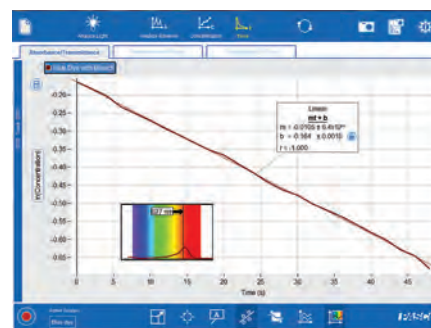
- ▶ Free software for iOS®, Android™, and Mac®
- ▶ Will run on Chromebooks™ with Google Play
- ▶ Designed specifically for introductory spectrometry experiments



2. Full visible spectrum analysis of solutions



3. Create Beer's Law plots to relate absorbance and concentration.



4. Quickly plot calculations of concentrations vs. time to determine the order of the reaction.



Includes

- PASCO Spectrometer
- Cuvettes (10)
- Spectrometry Software



*Our list of compatible Chromebooks is expanding rapidly. Check pasco.com/spectrometer for the latest updates.

Order Information

Wireless Spectrometer (VIS).....PS-2600
 Required for External Light Sources:
 Fiber Optics Cable.....PS-2601 p. 292

Comprehensive 850 Physics System

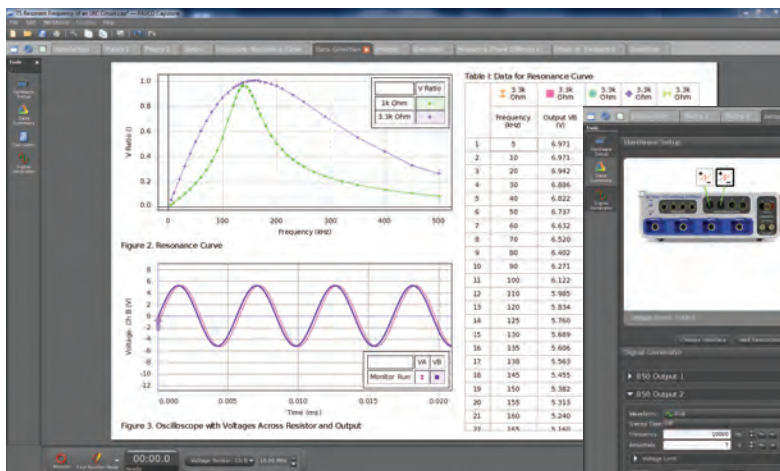
UI-5800D

► Designed for the 850 Universal Interface and PASCO Capstone™ Software

The 850 Comprehensive Physics System consists of 83 experiments and all the equipment and sensors needed to perform these experiments. The experiments cover topics, such as mechanics, waves, optics, thermodynamics, and electromagnetism. The included experiment manual contains instructions written in Word®, a PASCO Capstone electronic workbook, and sample data.

The key to a successful lab is a PASCO Capstone electronic workbook. These workbooks have step-by-step instructions with live, embedded displays, such as graphs, FFTs, oscilloscopes, and meters. They contain the theory, experiment set-up, procedure, data analysis, and questions designed to get the students to think about their results. These electronic workbooks can be easily modified by teachers to fit their individual needs.

NOTE: The 850 Universal Interface (UI-5000) must be purchased separately.



See page 78 for a list of experiments in the included manual. Download free experiments at pasco.com/850experiments

Comprehensive 850 Mechanics Bundle

UI-5801C

(Component of the 850 Comprehensive System UI-5800D)

Includes:

- Force Sensor Track Bracket ME-6622
- Cart Adapter Accessory ME-6743
- Compact Cart Mass (2) ME-6755
- Time-of-Flight Accessory ME-6810A
- Photogate Mounting Bracket ME-6821A
- Mini Launcher ME-6825B
- Dynamics Cart Magnetic Damping ME-6828
- Mini Ballistic Pendulum Accessory ME-6829
- Spring Cart Launcher ME-6843
- PAScar (Set of 2) ME-6950
- Super Fan Cart ME-6977
- Density Set ME-8569A
- Discover Friction Accessory ME-8574
- Large Rod Base ME-8735
- 45 cm Stainless Steel Rod ME-8736
- 90 cm Stainless Steel Rod ME-8738
- Picket Fences (Smart Timer) (2) ME-8933
- Dynamics Track End Stop (2) ME-8971
- Dynamics Track Feet (Pair) ME-8972
- Mass and Hanger Set ME-8979
- Elastic Bumper ME-8998
- IDS Spring Kit (12) ME-8999
- Picket Fence ME-9377A
- Large Table Clamp ME-9472
- 1.2 m Aluminum Dynamics Track ME-9493
- Photogate Head (2) ME-9498A

Equipment

1. Resistor-Capacitor-Inductor Network	UI-5210
2. Voltage Sensor	UI-5100
3. BNC-to-Banana Cord for 850 Output	UI-5119
4. Patch Cords (Set of 5)	SE-7123

Setup

1. Connect the BNC-to-Banana cord to the #2 Signal Generator and connect one end of the 2.5 mm inductor on the circuit to air. Connect the other end of the 500 pF capacitor in series and the 1.0 kΩ in series. Then connect the free end of the sensor.
2. Connect a Voltage Sensor to Channel A on the 850 interface and attach the leads across the resistor, making sure the black cable from the voltage sensor is connected to the grounded side of the resistor.
3. Connect a Voltage Sensor to Channel B on the 850 interface and attach the leads across the leads of the Output #2 cable, making sure the black cable from the voltage sensor is connected to the black side of the signal generator.
4. Open the Signal Generator 850 Output 2 and choose the Sine Wave at a frequency of 30.000 Hz and an amplitude of 1 V. Leave the output on AUTO.



- Pendulum Clamp ME-9506
- Multi-Clamp (2) ME-9507
- Variable Speed Motorized Cart ME-9781
- Centripetal Force Pendulum ME-9821
- PASPORT Motion Sensor (2) PS-2103A
- PASPORT Rotary Motion Sensor PS-2120A
- PASPORT High Resolution Force Sensor (2) PS-2189
- Wireless Acceleration/Altimeter PS-3223
- Pulley Mounting Rod SA-9242
- No-Bounce Pad SE-7347
- Braided Physics String SE-8050
- Comprehensive 850 Physics System Experiment Manual UI-5813
- Rotational Inertia Accessory ME-3420

Order Information

Comprehensive 850 Physics System..... UI-5800D
 Required:
 850 Universal Interface UI-5000 p. 14
 PASCO Capstone™ Software..... pp. 68-71

Want Mechanics Only?

Comprehensive 850 Mechanics Bundle ... UI-5801C

Comprehensive 850 Waves, Optics and Thermodynamics Bundle

UI-5802A (Component of the 850 Comprehensive System UI-5800D)



Includes:

- Sound Sensor with Microphone UI-5101
- Energy Transfer - Calorimeter ET-8499
- Precision Diffraction Slits OS-8453
- Green Diode Laser OS-8458B
- Color Mixer Accessory Kit OS-8495
- Color Mixer OS-8496
- Basic Optics System OS-8515C
- Red Diode Laser OS-8525A
- Polarization Analyzer OS-8533A
- Linear Translator OS-8535A
- Adjustable Focal Length Lens OS-8494
- PASPORT Absolute Pressure Sensor PS-2107
- PASPORT Quad Temperature Sensor PS-2143
- PASPORT High Sensitivity Light Sensor PS-2176
- Sympathetic Resonance Box Set SE-7345
- Banana Plug Cord - Red (5 Pack) SE-9750
- Radiation Cans TD-8570A
- Absolute Zero Sphere TD-8595
- Ideal Gas Law Apparatus TD-8596A
- Resonance Air Column WA-9606
- String Vibrator WA-9857A
- Mini Speaker WA-9605

The experiments for this section require some of the components of the 850 Comprehensive Mechanics UI-5801B.

See page 78 for manual. Download free experiments at pasco.com/850experiments

Comprehensive 850 Electromagnetism Bundle

UI-5803 (Component of the 850 Comprehensive System UI-5800D)



Includes:

- Alnico Bar Magnets (2) EM-8620
- Zero Gauss Chamber EM-8652
- AC/DC Electronics Laboratory EM-8656
- Basic Electrostatics System ES-9080B
- Field Mapper Kit PK-9023
- PASPORT Current Probe (2) PS-2184
- PASPORT 2-Axis Magnetic Field Sensor PS-2162
- Banana Plug Cord Sets, 30 cm Length SE-7123
- Plotting Compass Set (20) SE-8680
- Dip Needle SF-8619
- Voltage Sensor (unshrouded) (4) UI-5100
- BNC Function Generator Output Cable (unshrouded) UI-5119
- Resistor Capacitor Inductor Network UI-5210

The experiments for this section require some of the components of the 850 Comprehensive Mechanics UI-5801B.

See page 78 for a list of experiments in the included manual.

Order Information

Comprehensive 850 Physics System.....	UI-5800D	
Required:		
850 Universal Interface	UI-5000	p. 14
PASCO Capstone Software		pp. 68-71
Also available separately:		
Comprehensive 850 Mechanics Bundle	UI-5801C	
Comprehensive 850 Waves, Optics and Thermodynamics Bundle	UI-5802A	
Comprehensive 850		
Electromagnetism Bundle	UI-5803	
Comprehensive 850 Physics System		
Experiment Manual	UI-5813	

Comprehensive 850 Physics System (UI-5800D)

Includes:

- Comprehensive Mechanics (UI-5801C)
- Comprehensive Waves, Optics, and Thermodynamics (UI-5802A)
- Comprehensive Electromagnetism (UI-5803)

Mechanics 850 System (Includes 850 Universal Interface)

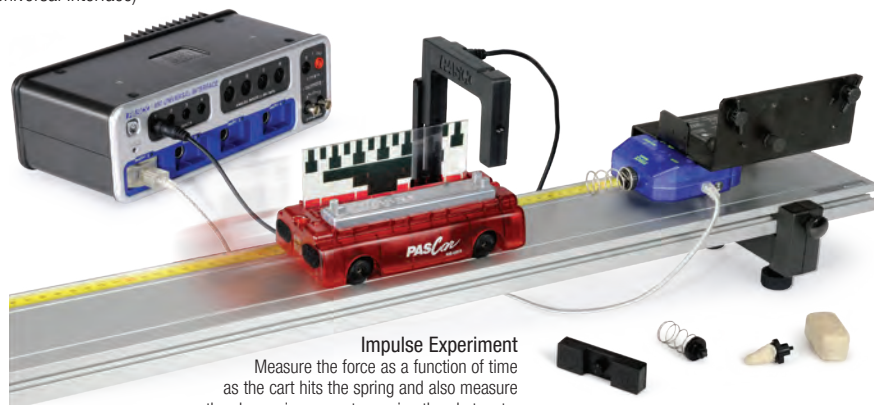
UI-5820

- ▶ Integrates probeware and physics equipment
- ▶ Includes 850 Universal Interface
- ▶ Perform a wide variety of mechanics experiments

When used together, PASCO's probeware and physics apparatus can help students learn the major concepts of mechanics more effectively. The Mechanics 850 System includes the key equipment to perform a wide variety of mechanics experiments.

The new manual has ten complete experiments that take full advantage of the components of this system. This makes it the ideal way to do the essential labs that are standard in all mechanics courses.

PASCO Capstone software (not included) enriches the labs with its interactive displays and analysis tools.



Impulse Experiment

Measure the force as a function of time as the cart hits the spring and also measure the change in momentum using the photogate.

Ten Experiments Included in Manual (UI-5821)

Title	Purpose	Sensors Used
Acceleration Down an Incline	Discover how the acceleration of an object down an incline depends on the angle of incline. Measure the acceleration due to gravity.	Photogate with picket fence
Newton's Second Law	Verify Newton's Second Law by varying the applied force and the mass.	Motion Sensor
Kinetic Friction I	Measure the kinetic coefficient of friction.	Motion Sensor
Kinetic Friction II	Study how the coefficient of kinetic friction depends on the velocity, acceleration, surface area, and weight of the object.	Photogate with pulley
Impulse and Momentum	Measure the impact force of a cart and compare the impulse to its change in momentum.	Force Sensor/ photogate
Conservation of Momentum in Explosions	Verify that momentum is conserved for two carts pushing off from each other.	Two photogates with picket fences
Conservation of Momentum in Inelastic Collisions	Verify that momentum is conserved in inelastic collisions and that kinetic energy is not conserved.	Two photogates with picket fences
Conservation of Momentum in Elastic Collisions	Verify that momentum is conserved in elastic collisions.	Two photogates with picket fences
Conservation of Energy	Show spring potential change into kinetic energy.	Motion Sensor/ photogate with picket fence
Simple Harmonic Motion	Measure the period of oscillation of a spring and mass system and compare it to the theoretical value. Evaluate the effect of changing the mass and spring constants.	Photogate and flag



Includes:

- 850 Universal Interface UI-5000
- PASPORT High Resolution Force Sensor PS-2189
- PASPORT Motion Sensor PS-2103A
- Photogates and Fences Dynamics System ME-9471A
- 1.2 m Aluminum Dynamics Track ME-9493
- Discover Friction Accessory ME-8574
- Force Sensor Track Bracket ME-6622
- Mass and Hanger Set ME-8979
- Super Pulley with Clamp ME-9448B
- Plunger Cart ME-9430
- Collision Cart ME-9454
- Spring Cart Launcher ME-6843
- Smart Fan Accessory ME-1242
- Mechanics 850 System Lab Manual UI-5821

Order Information

Mechanics 850 System.....	UI-5820
Required:	
PASCO Capstone Software.....	pp. 68-71

550 Physics

Universal 550 Physics Experiment Bundle

UI-5830

The 550 Universal Physics System provides a complete set of labs for mechanics, heat, light, sound, and electromagnetism. Each lab consists of student instructions in a Word® document that the instructor can modify as they like, a PASCO Capstone setup file ready for data collection, a Capstone file with sample data, and all the lab equipment required for the experiment. This system was designed to use both wireless and wired sensors, combined with the 550 Universal Interface that serves as a DC power supply and function generator.



Mechanics

Mechanics Includes:

- Rotational Inertia Accessory
- Red and Blue Smart Carts
- 1.2 m Aluminum Dynamics Track
- Friction Block
- Smart Fan Accessory
- Wireless Accelerometer/Altimeter
- Smart Cart Rod Stand Adapter
- Cart Mass (Set of 2)
- Pi Set
- Photogate Mounting Bracket
- Mini Launcher
- Mini Ballistic Pendulum Accessory
- Density Set
- Large Rod Base
- 45 and 90 cm Stainless Steel Rods
- Mass and Hanger Set
- Elastic Bumper
- Spring Kit
- Picket Fence
- Multi Clamps (2)
- Large Table Clamp
- Photogate Head (2)
- Pendulum Clamp
- PASPORT Rotary Motion Sensor
- No-Bounce Pad
- Braided Physics String
- Pulley Mounting Rod
- Bumper Accessory Set
- Super Pulley with Clamp
- Experiment Manual



Heat, Waves, Sound, and Light

Heat, Waves, Sound, and Light Includes:

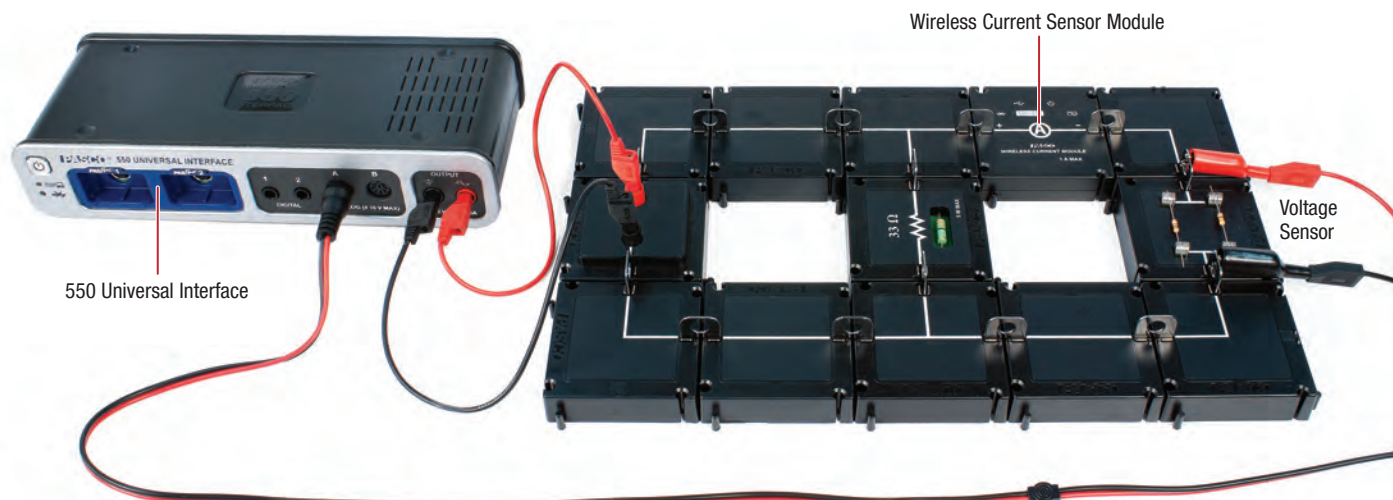
- Sound Sensor
- Calorimeter Cup with Lid (2)
- Tuning Fork Set
- Resonance Air Column
- Mini Speaker
- Basic Optics System
- Precision Diffraction Slits
- Adjustable Focal Length Lens
- Red Diode Laser
- Polarization Analyzer
- Linear Translator
- PASPORT Absolute Pressure Sensor
- PASPORT Quad Temperature Sensor
- PASPORT High Sensitivity Light Sensor
- Red Banana Plug Cord (5 Pack)
- Radiation Cans
- Ideal Gas Law Apparatus



Electromagnetism

Electromagnetism Includes:

- Bar Magnets (2 Pack)
- Modular Circuits Set
- Modular Circuits Expansion Pack
- Charge Sensor
- Wireless Current Sensor Module
- Charge Producers and Proof Plane
- Faraday Ice Pail
- Conductive Spheres
- Electrostatics Voltage Source
- Field Mapper Kit
- Voltage Sensor (2)



In this parallel resistor experiment, the 550 Universal Interface is used as the DC power supply that measures the output voltage and the voltage across the resistors. The Wireless Current Sensor Module is used in-line in the circuit to measure the current in each loop.

550 Universal Physics System Experiment Manual

UI-5831

This complete manual is included with the 550 Universal Physics System (UI-5830). Each experiment consists of student instructions in a Word® document that the instructor can modify as they like, a PASCO Capstone setup file ready for data collection, a Capstone file with sample data, and all the lab equipment required for the experiment. All of this content is provided on a flash drive.

Experiments:

- | | | |
|---|---|---|
| 1. Introduction to Measurement | 23. Work-Energy Theorem: Compare W to ΔE | 43. Reflection |
| 2. Uncertainty and Error Analysis | 24. Conservation of Momentum | 44. Refraction |
| 3. Graph Matching | 25. Impulse and Change in Momentum | 45. Dispersion |
| 4. Instantaneous and Average Velocity and Speed | 26. Ballistic Pendulum | 46. Focal Length of a Concave Mirror |
| 5. Motion with Constant Acceleration | 27. Newton's Second Law for Rotation | 47. Optical Instruments: Telescope and Microscope |
| 6. Equations of Motion for Constant Acceleration | 28. Rotational Inertia | 48. Variation of Light Intensity |
| 7. Acceleration Due to Gravity | 29. Rotational Kinetic Energy | 49. Light Intensity versus Distance |
| 8. Freefall of a Picket Fence | 30. Conservation of Angular Momentum | 50. Polarization: Verify Malus' Law |
| 9. Acceleration on an Inclined Track | 31. Oscillations of Cart and Springs | 51. Brewster's Angle |
| 10. Projectile Range vs. Launch Angle | 32. Physical Pendulum | 52. Diffraction of Light |
| 11. Newton's First Law | 33. Period of a Large Amplitude Pendulum | 53. Electrostatic Charges |
| 12. Newton's Second Law | 34. Archimedes' Principle - Buoyant Force | 54. Electric Field Mapping |
| 13. Force & Acceleration | 35. Transfer of Heat by Radiation | 55. Ohm's Law |
| 14. Inertia and Newton's Second Law | 36. Specific Heat | 56. Series and Parallel Circuits |
| 15. Newton's Third Law | 37. Boyle's Law: P and V of a Gas at Constant T | 57. Kirchhoff's Laws |
| 16. External Force and Newton's Laws | 38. Resonant Modes of Sound in a Tube | 58. RC Circuit |
| 17. Atwood's Machine | 39. Speed of Sound in Air | 59. General Properties of Diodes |
| 18. Friction and Newton's Laws | 40. Superposition of Sound Waves | 60. Magnetic Field Mapping |
| 19. Centripetal, Tangential, and Angular Acceleration | 41. Interference of Sound Waves | 61. Induction - Magnet Through a Coil |
| 20. Conservation of Energy on an Inclined Track | 42. Object and Image Distances for a Thin Lens | |
| 21. Hooke's Law | | |
| 22. Conservation of Energy for a Simple Pendulum | | |

Order Information

Universal 550 Physics Experiment Bundle.....UI-5830
 Universal 550 Physics Experiment ManualUI-5831
 (included in UI-5830)

Advanced Physics 1 Lab Manual

PS-3812-DIG (digital) PS-3812 (print)

This experiment guide covers the latest standards for College Board Advanced Placement Physics.

- ▶ Every lab is based on the College Board Learning Objectives.
- ▶ Data Analysis and Assessment Questions are designed to prepare students for the AP[®] Physics 1 exam
- ▶ Every lab employs the same strategies found in free response questions on the AP[®] exam
- ▶ Includes editable student handouts

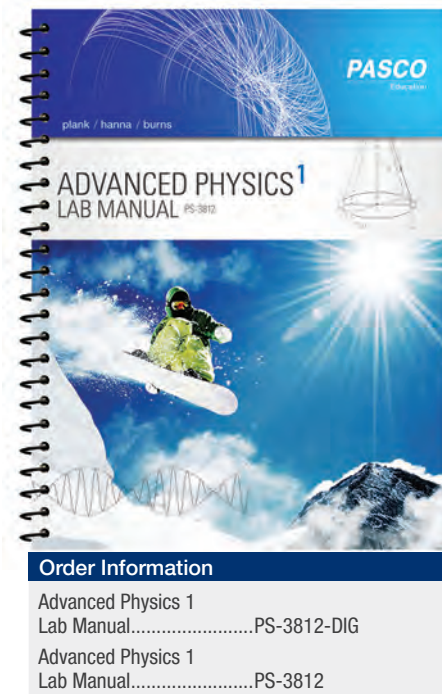
Prepare your students for inquiry investigations in the physics lab. Each lab is presented three ways:

- ▶ Structured
- ▶ Guided inquiry
- ▶ Student designed

You decide which level of inquiry is appropriate for each lab.

Each lab includes teacher resources:

- ▶ Pre-lab discussion and questions
- ▶ Procedural overview
- ▶ Teacher tips
- ▶ Sample data
- ▶ Assessment and synthesis questions
- ▶ Extended inquiry suggestions



Order Information

Advanced Physics 1
Lab Manual.....PS-3812-DIG
Advanced Physics 1
Lab Manual.....PS-3812

ADV PHYSICS 1 EXPERIMENTS	EQUIPMENT		ALIGNMENT	
	LAB	Perform these labs with the PS-3813 Equipment Kit	Add the PS-3814 Expansion Kit to perform all these labs	IB [®] Standards*
1. Graphical Analysis: Motion	●	●	2.1	3.A.1.1, 2, 3
2. Newton's Second Law	●	●	2.2	3.B.1.1, 2, 3, 3.B.2.1
3. Atwood's Machine	●	●	2.2	3.B.1.1, 2
4. Coefficients of Friction	●	●	2.2	3.C.4.1,2
5. Two Dimensional Motion: Projectiles		●	1.3, 2.1	3.E.1.3, 4
6. Conservation of Mechanical Energy	●	●	2.3	5.B.4.1,2
7. Work and Kinetic Energy	●	●	2.3	4.C.2.1, 2
8. Conservation of Momentum		●	2.4	5.D.1.3,5.D.2.2, 4
9. Momentum and Impulse	●	●	2.4	3.D.2.3, 4
10. Rotational Dynamics		●	B.1	3.F.2.1, 2, 3.A.1.3
11. Rotational Statics		●	B.1	3.F.1.1, 2, 3, 4, 5
12. Periodic Motion: Mass and Spring	●	●	4.1, 9.1	3.B.3.1, 2, 3, 4
13. Simple Pendulum	●	●	4.1, 9.1	3.B.3.1, 2, 3
14. Resonance and Standing Waves		●	4.5, B.4	6.D.3.4, 6.D.4.1, 2
15. DC Circuits		●	5.1, 5.2	1.B.1.2, 5.B.9.2, 3, 5.C.3.1

Each lab manual includes video support!

How-to videos are included with the manual, on the PASCO website and on YouTube, and can be installed on your own computers.



Try It!



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 ** AP is a trademark registered and/or owned by the College Board, which was not involved in the production of, and does not endorse, this product.

Advanced Physics 1 Equipment Kit

PS-3813

Includes:

- Smart Cart (Red)
- PAStrack
- Dynamics Track
- End Stop (2 pack)
- Four Scale Meter Stick
- Compact Cart Mass (2)
- Mass and Hanger Set
- Super Pulley Kit
- Black Thread (3 pack)

ME-1240
ME-6960

ME-8971
SE-8695
ME-6755
ME-8979
ME-9433
ME-9875

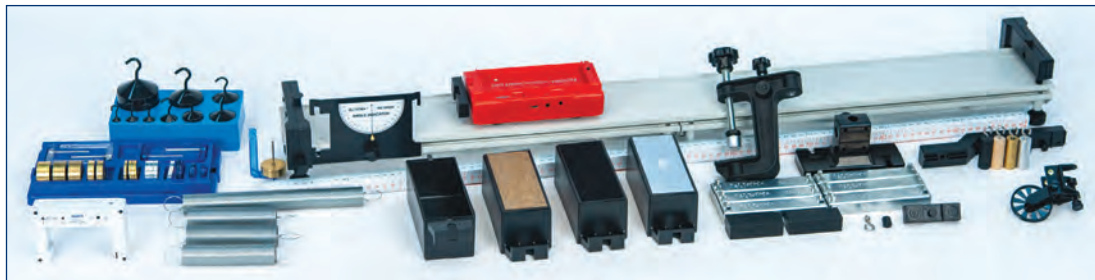
- Stainless Steel Rod, 60 cm (threaded)
- Aluminum Table Clamp
- Wireless Smart Gate
- Right Angle Clamp
- PAScar Cart Mass (3 sets of 2)
- Discover Friction Accessory
- Stainless Steel Rod, 45 cm
- Angle Indicator

ME-8977
ME-8995
PS-3225
SE-9444
ME-6757A
ME-8574
ME-8736
ME-9495A

- Track Rod Clamp
- Bumper Accessory Set
- Smart Cart Rod Stand Adapter
- Stainless Steel Rod, 90 cm
- Demonstration Spring Set
- Hooked Mass Set
- Photogate Pendulum Set
- Pendulum Clamp

ME-9836
ME-9884
ME-1244
ME-8738
ME-9866
SE-8759
ME-8752
ME-9506

This kit contains all of the equipment and sensors needed to perform 9 of the 15 experiments from the Advanced Physics 1 Experiment Guide (PS-3812).



Order Information

Advanced Physics 1 Equipment KitPS-3813

Advanced Physics 1 Expansion Kit

PS-3814

Includes:

- Smart Cart (Blue)
- Pendulum Accessory
- Wireless Rotary Motion Sensor
- Stainless Steel Calipers
- Tension Protractor (2)

ME-1241
ME-8969
PS-3220
SF-8711
ME-6855

- Stainless Steel Rod, 60 cm (threaded)
- Aluminum Table Clamp
- Resonance Air Column
- AC/DC Electronics Laboratory

ME-8977
ME-8995
WA-9606
EM-8656

- Wireless Voltage Sensor
- Wireless Current Sensor
- Photogate Mounting Bracket
- Mini Launcher
- Carbon Paper (100 Sheets)

PS-3211
PS-3212
ME-6821A
ME-6825B
SE-8693

When added to the Advanced Physics 1 Equipment Kit (PS-3813), this kit provides the additional equipment and sensors needed to perform all 15 experiments from the Advanced Physics 1 Experiment Guide (PS-3812).



Order Information

Advanced Physics 1 Expansion KitPS-3814

Just need sensors?

Advanced Physics Sensor Bundle

PS-3818

Includes:

- Smart Cart (Red)
- Wireless Smart Gate
- Smart Cart (Blue)
- Wireless Rotary Motion Sensor
- Wireless Voltage Sensor
- Wireless Current Sensor
- Wireless Pressure Sensor
- Wireless Magnetic Field Sensor

ME-1240
PS-3225
ME-1241
PS-3220
PS-3211
PS-3212
PS-3203
PS-3221



Order Information

Advanced Physics Sensor Bundle.....PS-3818

This bundle contains only the sensors (but not the equipment) needed to perform all the labs from the Advanced Physics 1 Experiment Guide (PS-3812) and the Advanced Physics 2 Experiment Guide (PS-3815).

Advanced Physics 2 Lab Manual

PS-3815-DIG (digital) PS-3815 (print)

This experiment guide covers the latest standards for College Board Advanced Placement Physics 2.

- ▶ Every lab is based on the College Board Learning Objectives.
- ▶ Data Analysis and Assessment Questions are designed to prepare students for the AP[®] Physics 2 exam
- ▶ Every lab employs the same strategies found in free response questions on the AP[®] exam
- ▶ Includes editable student handouts

Prepare your students for inquiry investigations in the physics lab.

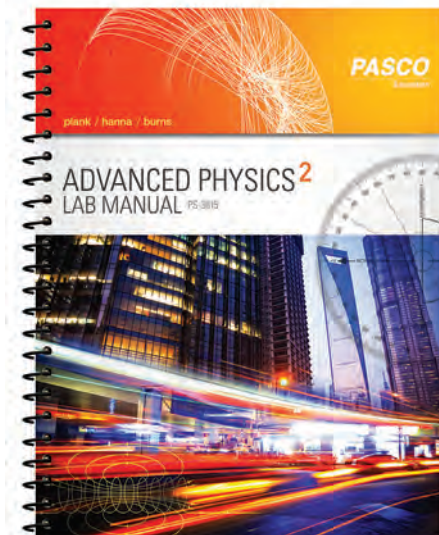
Each lab is presented in three ways:

- ▶ Structured
- ▶ Guided inquiry
- ▶ Student designed

Each lab includes teacher resources.

You decide which level of inquiry is appropriate for each lab:

- ▶ Pre-lab discussion and questions
- ▶ Sample data
- ▶ Procedural overview
- ▶ Assessment and synthesis questions
- ▶ Teacher tips
- ▶ Extended inquiry suggestions



Order Information

Advanced Physics 2
Lab Manual.....PS-3815-DIG
Advanced Physics 2
Lab Manual.....PS-3815

ADV PHYSICS 2 EXPERIMENTS	EQUIPMENT		ALIGNMENT	
	LAB	Perform these labs with the PS-3816 Equipment Kit	Add the PS-3817 Expansion Kit to perform all these labs	IB [®] Standards*
1. Hydrostatic Pressure	●	●	B.3	3.C.4.1, 3.C.4.2
2. Buoyant Force		●	B.3	1.E.1.2, 3.A.3.1, 3.C.4.2
3. Fluid Dynamics	●	●	B.3	5.B.10.1, 5.B.10.3, 5.B.10.4
4. Boyle's Law	●	●	3.2	5.B.7.2, 7.A.3.2, 7.A.3.3
5. Spherical Mirror Reflection	●	●	C.1	6.E.4.1, 6.E.4.2
6. Snell's Law	●	●	4.4	6.E.3.2, 6.E.3.3
7. Focal Length of a Converging Lens	●	●	C.1	6.E.5.1, 6.E.5.2
8. Interference and Diffraction	●	●	4.4, 9.2, 9.3	6.C.3.1
9. Electric Field Mapping		●	5.1, 10.1	2.E.2.1
10. Magnetic Fields		●	5.4	2.D.2.1, 2.D.3.1, 2.D.4.1
11. Magnetic Field Strength		●	5.4	2.D.2.1
12. Electromagnetic Induction	●	●	11.1	4.E.2.1
13. Capacitor Fundamentals		●	11.3	4.E.4.2, 4.E.4.3
14. Series and Parallel Capacitors		●	11.3	4.E.5.3, 5.B.9.5
15. RC Circuits		●	11.3	4.E.5.1, 4.E.5.2, 4.E.5.3
16. Planck's Constant		●	12.1	6.F.3.1, 6.F.4.1

Each lab manual includes video support!

How-to videos are included with the manual, on the PASCO website and on YouTube, and can be installed on your own computers.



Try It!



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Advanced Physics 2 Equipment Kit

PS-3816

Includes:

- Water Reservoir ME-8594
- Wireless Pressure Sensor PS-3203
- Four Scale Meter Stick SE-8695
- Concave/Convex Mirror OS-8457
- Basic Optics Light Source OS-8470
- Optics Track, 1.2 m OS-8508
- Basic Optics Ray Table OS-8465
- Basic Optics Viewing Screen OS-8460
- Geometric Lens Set OS-8466A
- Adjustable Lens Holder OS-8474
- Diffraction Plate OS-8850
- Stainless Steel Rod, 45 cm (2) ME-8736
- Aluminum Table Clamp (2) ME-8995
- Digital Calipers SE-8710
- Three-Finger Clamp (2) SE-9445
- Red Diode Laser Pointer SE-9716C
- Wireless Voltage Sensor PS-3211
- Magnet Wire, 22-Gauge
- Rigid Plastic Tubing, 12-in length, 0.5-in diameter



This kit contains all of the equipment and sensors needed to perform 8 of the 16 experiments from the Advanced Physics 2 Lab Manual.

Order Information

Advanced Physics 2 Equipment KitPS-3816

Advanced Physics 2 Expansion Kit

PS-3817

Includes:

- Smart Cart (Red) ME-1240
- Aluminum Table Clamp ME-8995
- Black Thread (3 pack) ME-9875
- Overflow Can SE-8568
- Right Angle Clamp SE-9444
- Field Mapper Kit PK-9023
- Student Power Supply, 18 VDC, 3 A SE-8828
- Basic Digital Multimeter SE-9786A
- Neodymium Magnets, Solid (16 pack) EM-8648B
- AC/DC Electronics Laboratory EM-8656
- Magnaprobe SE-7390
- Banana Plug Cord-Red (5 pack) (2) SE-9750
- Wireless Magnetic Field Sensor PS-3221
- Wireless Current Sensor PS-3212

Included but not pictured:

- Capacitor, 100- μ F (5)
- Blue LED (450–500 nm)
- Green LED (501–565 nm)
- Yellow/Amber LED (566–620 nm)
- Red LED (621–750 nm)



When added to the Advanced Physics 2 Equipment Kit (PS-3816), this kit provides the additional equipment and sensors needed to perform all 16 experiments from the Advanced Physics 2 Experiment Guide (PS-3815).

Order Information

Advanced Physics 2 Expansion KitPS-3817

Just need sensors?

Advanced Physics Sensor Bundle

PS-3818

Includes:

- Smart Cart (Red) ME-1240
- Wireless Smart Gate PS-3225
- Smart Cart (Blue) ME-1241
- Wireless Rotary Motion Sensor PS-3220
- Wireless Voltage Sensor PS-3211
- Wireless Current Sensor PS-3212
- Wireless Pressure Sensor PS-3203
- Wireless Magnetic Field Sensor PS-3221

This bundle contains only the sensors (but not the equipment) needed to perform all the labs from the Advanced Physics 1 Experiment Guide (PS-3812) and the Advanced Physics 2 Experiment Guide (PS-3815).



Order Information

Advanced Physics Sensor Bundle.....PS-3818

Physics Starter Lab

Physics Starter Lab Station

EP-3579

The Physics Starter Lab Station makes it easy and affordable to begin using sensor-based technology in your physics classroom or at home. Inside the Starter Lab Station are the wireless sensors used to perform 9 kinematics, dynamics, voltage, and circuit lab activities from the Physics Lab Station Investigations Manual. Available separately is the Physics Extension Lab Station (EP-3580) which, when combined with the Physics Starter Lab Station, comprises all the wireless sensors used to perform the 20 labs inside the Physics Lab Station Investigations Manual, plus many of the lab activities found in PASCO's Advanced Physics 1 Lab Manual and Advanced Physics 2 Lab Manual.

Features:

- ▶ Included storage tray and custom insert provide a simple and secure storage solution
- ▶ Portable and easy to transport
- ▶ Record data wirelessly without the hassle of tangled cables
- ▶ Includes digital access to a wide range of lab activities
- ▶ Includes video and other lab resources for at-home and distance learning lab activities

Lab Activities

The Printed Samples Booklet includes 10 student lab handouts taken from PASCO's Physics Lab Station Investigations Manual (right). The combined Physics Starter Lab Station (EP-3579) and Physics Extension Lab Station (EP-3580) comprise the sensors used to perform all 20 labs, plus many of the lab activities found in PASCO's Advanced Physics 1 Lab Manual and Advanced Physics 2 Lab Manual.



Lab	Title	Starter Lab Station
1	Position, Distance, and Displacement	●
2	Newton's 2nd Law	●
3	Crash Cushions	
4	Momentum and Impulse	●
5	Change in Kinetic Energy	●
6	Rotational Dynamics	
7	Measuring the Speed of Sound with an Echo	
8	Ohm's Law	●
9	DC Circuits	●
10	RC Circuits	●

Includes:

- Wireless Motion Sensor PS-3219
- Wireless Force Acceleration Sensor PS-3202
- Wireless Voltage Sensor PS-3211
- Wireless Current Sensor PS-3212
- Grattells Storage Tray with Custom Storage Insert
- Digital Access to PASCO's Physics Lab Station Investigations Manual
- Digital Access to PASCO's Advanced Physics 1 Lab Manual (PS-3812)
- Digital Access to PASCO's Advanced Physics 2 Lab Manual (PS-3815)



Order Information

Physics Starter Lab Station EP-3579

Physics Extension Lab Station

EP-3580

The Physics Extension Lab Station includes five wireless sensors that complement the set of sensors found in the Physics Starter Lab Station (EP-3579). Together, the sensors from the Physics Starter and Extension Lab Stations comprise the sensors needed to perform all 20 lab investigations inside the Physics Lab Station Investigations Manual, plus many of the lab activities found in PASCO's Advanced Physics 1 Lab Manual and Advanced Physics 2 Lab Manual. The Grattells storage tray, included with the Starter Station, comes with storage slots for the Extension Station sensors.



Lab Activities

The Printed Samples Booklet includes 10 student lab handouts taken from PASCO's Physics Lab Station Investigations Manual. Combined, the Physics Starter Lab Station (EP-3579) and Physics Extension Lab Station (EP-3580) comprise the sensors used to perform all 20 labs, plus many of the lab activities found in PASCO's Advanced Physics 1 Lab Manual and Advanced Physics 2 Lab Manual.



Lab	Title	Starter & Extension Lab Station
1	Position, Distance, and Displacement	●
2	Newton's 2nd Law	●
3	Crash Cushions	●
4	Momentum and Impulse	●
5	Change in Kinetic Energy	●
6	Rotational Dynamics	●
7	Measuring the Speed of Sound with an Echo	●
8	Ohm's Law	●
9	DC Circuits	●
10	RC Circuits	●

Includes:

- Wireless Acceleration/Altimeter PS-3223
- Wireless Magnetic Field Sensor PS-3221
- Wireless Rotary Motion Sensor PS-3220
- Wireless Current Sensor PS-3212
- Wireless Smart Gate PS-3225
- Digital Access to PASCO's Physics Lab Station Investigations Manual
- Digital Access to PASCO's Advanced Physics 1 Lab Manual (PS-3812)
- Digital Access to PASCO's Advanced Physics 2 Lab Manual (PS-3815)



Order Information

Physics Extension Lab Station.....EP-3580

Essential Physics Curriculum

This complete physics solution includes Textbook, e-Book, Lab Manual, Digital Teacher Resources, and Equipment!

Essential Physics 3rd Edition is a comprehensive, full-color textbook paired with PASCO equipment. It is the first e-book for physics on the market. The program includes over 100 interactive tools that increase student engagement and understanding.

Essential Physics is focused on practical applications that connect students to the physics of nature as well as technology.

About the program:

- ▶ Rigorous yet accessible design
- ▶ Interactive simulations and equations
- ▶ Lessons follow the 5E design
- ▶ Strong mathematics scaffolding
- ▶ Formative and summative assessment tools
- ▶ Differentiation for ELL students
- ▶ Works with your LMS and Google Classroom
- ▶ Includes 24/7 online access.
- ▶ Aligns to your state standards

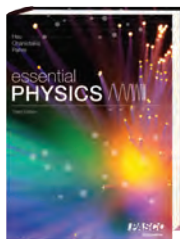


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EP-6323

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Essential Physics 3rd Edition: Student e-Book

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EP-6323-EB1 (1-year license)

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Essential Physics Teacher Resources

EP-6324-DIG

*Essential
Physics
Teacher
Resources*

Essential Physics is multiplatform: iOS, Android™, Chrome™, Windows®, and Mac®!

For more *Essential Physics* information, contact your PASCO Education Specialist.

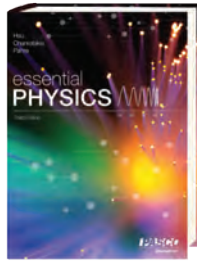
Email sales@pasco.com or phone 800-772-8700 or +1 916-786-3800.

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EP-6323

This hardbound, printed student textbook includes core Physics topics that cover a complete year of instruction. The book content aligns to standards for general physics coursework.



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- ▶ Physical Quantities and Measurement
- ▶ Position and Velocity
- ▶ Acceleration
- ▶ Forces and Newton's Laws
- ▶ Motion in Two and Three Dimensions
- ▶ Circular Motion
- ▶ Static Equilibrium and Torque
- ▶ Work and Energy
- ▶ Conservation of Energy
- ▶ Momentum and Collisions
- ▶ Machines
- ▶ Angular Momentum
- ▶ Harmonic Motion
- ▶ Waves
- ▶ Sound
- ▶ Electricity and Circuits
- ▶ Electric and Magnetic Fields
- ▶ Electromagnetism
- ▶ Light and Reflection
- ▶ Refraction and Lenses
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- ▶ Heat Transfer
- ▶ Thermodynamics
- ▶ Quantum Physics and the Atom
- ▶ Nuclear Physics

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Essential Physics 3rd Edition: Student Textbook EP-6323

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Order Information

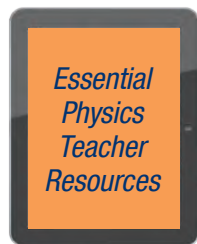
Essential Physics 3rd Edition: Student e-Book
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EP-6324-DIG

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- Teacher Edition flash drive + Student Edition flash drive
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- Teacher e-Book with five-year license
- Student e-Book with five-year license
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EP-6490A

This kit is designed to support all of the sensor-based, hands-on lab investigations within the *Essential Physics* 3rd Edition Curriculum, as well as the *Essential Physics* Student Lab Manual. This kit includes enough equipment for a full year of investigations in a standard, algebra-based physics course.



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- Mini Launcher ME-6825B
- *Essential Physics* Modular Circuits Kit EM-3536
- Simple Machines Engineering Kit EP-3577

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Essential Physics Comprehensive Equipment Kit EP-6490A

Also available:

Standard Equipment Kit *Essential Physics*

EP-3567A

Designed for use with the investigations in *Essential Physics* 3rd Edition, this kit contains everything in the Forces and Motion Kit, as well as the Modular Circuits Kit.

Includes:

- Forces and Motion Kit EP-3576
- *Essential Physics* Modular Circuits Kit EM-3536



Order Information

Standard Equipment Kit: *Essential Physics* EP-3567A

A textbook and an e-book for all your students

What sets *Essential Physics* apart is the complete and interactive e-book. When you purchase the e-book, you get animations, videos, and interactive equations and simulations that bring concepts to life for students. Combined with digital resources for teachers, formative and summative assessment, and equipment for lab investigations, *Essential Physics* forms a seamless learning system for mastering physics.

The e-book's interactive tools include:

31 videos



84 embedded interactive equations

Finding magnitude from vector components

Cartesian coordinates

$$F_x = F \cos \theta$$

$$F_y = F \sin \theta$$

Polar coordinates

$$F = \sqrt{F_x^2 + F_y^2}$$

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

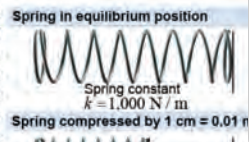
Magnitude

time a force is restrained from acting in such a way that the energy can be released if the restraint is removed. If you use the spring to launch a marble you can see how the potential energy of the spring is converted to kinetic energy of the marble. Compressing a spring creates potential energy because you have to do work against the force of the spring to compress it. A compressed spring stores potential energy as long as it is compressed. This type of potential energy is called **elastic potential energy** because it derives from the elasticity of the steel in the spring. It can be calculated by using equation (9.4).

$$(9.4) E_p = \frac{1}{2} kx^2$$

E_p = elastic potential energy (J)
 k = spring constant (N/m)
 x = displacement from equilibrium (m)

The quantity k in equation (9.4) is called the **spring constant**, which represents the strength of the restoring force exerted by the spring when it is compressed or stretched. The spring constant is a property of the spring itself and is different for every spring or other elastic material. It has units of force divided by distance, because the



Full audio read

f. Create a series of eight successive displacements that would program a robot to move in an octagonal path that is as close as you can get to approximating a circle. The robot should return to its starting point after the eighth displacement. What total distance does the robot move? Calculate the radius of a circle that has this distance as its circumference.

In this interactive element, you create a series of individual displacements and then run the simulation to create the total displacement. This simulation and y.

71 interactive simulations

Kinetic energy is lost in inelastic collisions

There are two basic types of collisions in physics: elastic and inelastic. In an **inelastic collision**, some of the initial kinetic energy of the objects is transformed into heat and/or work to deform the shape of the objects. Auto collisions are nearly always inelastic, because of the damage caused by the impact. In the special case of a **perfectly inelastic collision**, the two objects stick together after impact.

Perfectly inelastic collisions

Before collision

After collision: balls stick together

$v_{1i} = 7 \text{ m/s}$	$v_{2i} = -2 \text{ m/s}$	$v_f = 2.5 \text{ m/s}$
$m_1 = 1 \text{ kg}$	$m_2 = 1 \text{ kg}$	$m_1 + m_2 = 2 \text{ kg}$
$p_{1i} = 7 \text{ kg m/s}$	$p_{2i} = -2 \text{ kg m/s}$	$p_{f,12} = 5 \text{ kg m/s}$

A perfectly inelastic collision is depicted in the illustration above. These collision problems are solved in the same way as any other collision problem, using the conservation of momentum. Moreover, in the perfectly inelastic collision case the **final** velocities of the two objects are set to be equal—because the objects stick together!

Rutherford scattering

Metal foil target: $Z = 79$ Au Gold

Alpha-particles escaping from "gun" at high velocity

Gold atoms: foil "target"

Target foil

Strongly deflected alpha particles: 27

Partially deflected alpha particles: 348

Undelected alpha particles: 397338

Buttons: Run, Print, Reset, Help

31 embedded animations

Summative assessment: The Infinite Test Bank

Section 14-2 Natural frequency and resonance

Self Quiz

Questions: 1 2 3 4 5

Attempts: 0 Score: 0%

1. A pendulum is oscillating with a natural frequency $f = 3 \text{ Hz}$. If the length of the pendulum increases by a factor of 4 what happens to the frequency?

a) increases by a factor of 2

b) decreases by a factor of 4

c) increases by a factor of 4

d) does not change

e) decreases by a factor of 2

Formative assessment

Test your knowledge

Ryan moves to the right with a *positive* velocity of 5 m/s for 1 s, then to the left with a *negative* velocity of -5 m/s for 1 s. What is Ryan's displacement after 2 s?

a. 5 m

b. 10 m

c. 0 m

d. -5 m

Buttons: Show Solution

Essential Physics meets your state standards and supports STEM and NGSS!


The Digital Teacher Resources include lesson plans, slide presentations, student work, and answer keys, all at point-of-use.

5.3 - Springs

Lesson resources:

- Lesson plan: DOC / PDF
- Slide presentation: PPTX / PDF / Notes (PDF)
- Student work: DOC / PDF
- Answers: DOC / PDF
- Video resource: VIDEO

Hooke's law



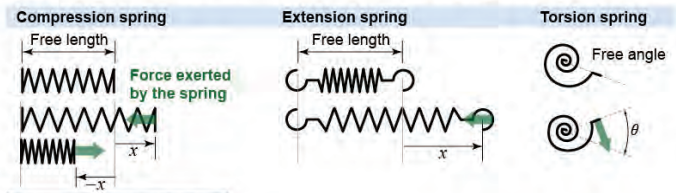
Lesson summary:

The lesson resources correspond to the content on these next four pages. This lesson introduces forces from springs and Hooke's law ($F = -kx$).

Present key content:

Human technology uses springs in many different ways. Show different types of springs.

Types of springs



Compression spring
Free length
Force exerted by the spring
 x

Extension spring
Free length
 x

Torsion spring
Free angle
 θ

Compression, extension, and torsion springs

Hooke's law for springs

(5.4) $F = -kx$

F = restoring force (N)
 k = spring constant (N/m)
 x = displacement from equilibrium (m)

Interactive equation

What is k ?

The the defo

LESSON PLAN

Essential Physics CHAPTER 3

Friction

Content
There are many forms of friction. This lesson introduces the force laws for static friction, kinetic friction, and rolling friction. Students learn the meaning of and typical range of values for the coefficients of friction. In the investigation, students determine the coefficients of static and kinetic friction between two surfaces.

Learning objectives
The student will be able to:
1) calculate friction forces from equation models for static, kinetic, and rolling friction; and
2) solve one-dimensional force problems including friction.

Materials/technology resources

- Slide presentation: "Friction.ppt"
- Investigation: track with feet, friction block, thread, balance, Smart Cart with hook, 250-g cart masses (2)
- SPARKvue file: "OSC Friction.spklab"
- Student work: "FrictionAssignment.pdf"

Lesson resources:

- Lesson plan: DOC/PDF
- Slide presentation: PPTX/PDF/Notes (PDF)
- Student work: DOC/PDF
- Answers: DOC/PDF

Lesson resources:

- Lesson plan: DOC/PDF
- Slide presentation: PPTX/PDF/Notes (PDF)
- Student work: DOC/PDF
- Answers: DOC/PDF

Lesson resources:

- Lesson plan: DOC/PDF
- Slide presentation: PPTX/PDF/Notes (PDF)
- Student work: DOC/PDF
- Answers: DOC/PDF

Investigation 5C: Static Friction

Essential question: What determines the magnitude of the friction force?

Friction is everywhere and can be either helpful or wasteful depending on the situation. In this investigation you will test models of friction against actual measurements to get a sense of how accurate these friction models are.




Table: Coefficient of static friction and kinetic friction

Trial	Max Force (N)	Average Force While Sliding (N)	Mass of Block (kg)	Static Friction Coefficient μ_s	Kinetic Friction Coefficient μ_k
1	11.0	5.08	1.125	0.46	0.21
2	6.25	2.76	0.625	0.45	0.29
3	3.75	1.55	0.375	0.42	0.27

Average value for μ_s : 0.44 Average value for μ_k : 0.26

Friction types:

- Air friction:** comes from air being pushed aside or flowing around surfaces such as the body of a car or the wing of an aircraft.
- Rolling friction:** comes from rolling contact between two surfaces, such as a wheel and the road.
- Sliding friction:** comes from sliding contact between two surfaces, such as the bottom of skis and a snow-covered hill.
- Viscous friction:** comes from liquids being displaced or forced to flow around or through objects such as pipes or boats.

Lesson resources:

- Lesson plan: DOC/PDF
- Slide presentation: PPTX/PDF/Notes (PDF)
- Student work: DOC/PDF
- Answers: DOC/PDF

Essential Physics Student Lab Manual

EP-6326

► Each Comprehensive Physics Investigations manual is printed in a student-consumable format with tear-out pages for every investigation.

This printed, student-consumable Essential Physics Student Lab Manual includes 46 labs that cover a full year of introductory physics. Created by physics teachers, these investigations are an ideal supplement to any algebra-based physics course. Each investigation is tightly integrated with our innovative software, sensors, and equipment.

Investigations and activities in the lab manual cover topics such as:

- Graphs of Motion
- Motion Graphs
- Acceleration
- A Model for Accelerated Motion
- Newton's Second Law
- Hooke's Law
- Static and Kinetic Friction
- Projectile Motion
- Acceleration on an Inclined Plane
- Static Equilibrium
- Work and the Force vs. Distance Graph
- Inclined Plane and the Conservation of Energy
- Work and Energy
- Springs and the Conservation of Energy
- Work Done by Friction
- Design a Crash Barrier
- Conservation of Momentum
- Inelastic Collisions
- Elastic Collisions
- Levers
- Pulleys
- Ramps and Inclined Planes
- Gear Ratios
- Designing Gear Machines
- Torque
- Mechanical Advantage of Gears
- Oscillators
- Resonance
- Waves
- Interference
- Resonance and Sound
- Design a Musical Instrument
- Electricity and Circuits
- Voltage and Batteries
- Design a Lemon Battery
- Resistors and Ohm's Law
- Series and Parallel Resistances
- Electrical Power
- Compound Circuits
- Magnification of Mirrors and Lenses
- Reflection in a Plane Mirror
- Refraction of Light
- Creating Real and Virtual Images with Lenses
- Image Formation for a Convex Lens
- Build a Microscope and Telescope
- Phosphorescence



Essential Physics Teacher Lab Manual Resources

Includes editable documents, PowerPoint presentations, answer keys, and video lab assistance.

Order Information

Essential Physics Student Lab Manual EP-6326
(student-consumable)

Order Information

Essential Physics Teacher Lab Manual EP-6329
Essential Physics Teacher Lab Manual (digital) EP-6329-DIG
Also available:
Essential Physics Teacher Lab Manual -
Electronic Resources EP-6328-DIG

All the Physics Equipment You Need...

Essential Physics Comprehensive Equipment Kit

EP-6490A

Includes:

- Forces and Motion Kit EP-3576
- Essential Physics Waves and Sound Kit EP-3578
- Essential Physics Light, Color & Optics Kit EP-3558
- Mini Launcher ME-6825B
- Essential Physics Modular Circuits Kit EM-3536
- Simple Machines Engineering Kit EP-3577

Each kit includes a Gragnells® Storage Tray



These kits require either SPARKvue or PASCO Capstone software, available at pasco.com/downloads

Order Information

Essential Physics Comprehensive Equipment Kit EP-6490A

Choose the Kits You Need...

Forces and Motion Kit

EP-3576

Forces + Motion Labs

- Graphs of Motion
- Motion Graphs
- Acceleration on a Ramp
- A Model for Accelerated Motion
- Newton's Second Law
- Hooke's Law
- Static and Kinetic Friction
- Projectile Motion
- Acceleration on an Inclined Plane
- Static Equilibrium
- Work and the Force Versus Distance Graph
- Inclined Plane and the Conservation of Energy
- Work and Energy
- Springs and the Conservation of Energy



Smart Cart Demonstration Kit

ME-1272 (with red cart) ME-1273 (with blue cart)

Demonstrate:

- Differences between Velocity and Acceleration
- Independence of Horizontal and Vertical Projectile Motion
- Newton's First Law
- Newton's Second Law
- Newton's Third Law
- Impulse and Force
- Force and Acceleration in Collisions
- Centripetal Acceleration
- Compare Velocity, Acceleration, and Force in Simple Harmonic Motion
- Buoyant Force and Archimedes' Principle



Order Information

Forces and Motion Kit EP-3576

Order Information

Red Smart Cart Demonstration Kit ME-1272
Blue Smart Cart Demonstration Kit ME-1273

Simple Machines Engineering Kit

EP-3577

Simple Machines Labs

- Static Equilibrium
- Levers
- Pulleys
- Gear Ratios
- Designing Gear Machines
- Torque
- Mechanical Advantage of Gears



Essential Physics Modular Circuits Kit

EM-3536

Modular Circuits Labs

- Electricity and Circuits
- Voltage and Batteries
- Design a Lemon Battery
- Resistors and Ohm's Law
- Series and Parallel Resistances
- Electrical Power
- Compound Circuits



Order Information

Simple Machines Engineering Kit EP-3577

Order Information

Essential Physics Modular Circuits Kit EM-3536

Essential Physics Light, Color & Optics Kit

EP-3558

Light, Color & Optics Labs

- Magnification of Mirrors and Lenses
- Reflection in a Plane Mirror
- Refraction of Light
- Creating Real and Virtual Images with Lenses
- Image Formation for a Convex Lens
- Build a Microscope and Telescope
- Phosphorescence



Essential Physics Waves and Sound Kit

EP-3578

Oscillations, Waves & Sound Labs

- Oscillators
- Resonance
- Waves
- Interference
- Resonance and Sound
- Design a Musical Instrument



Order Information

Essential Physics Light, Color & Optics Kit EP-3558

Order Information

Essential Physics Waves and Sound Kit EP-3578

Go to pasco.com for complete kit contents.

The Best Dynamics Systems in the World

PASCO introduced the first dynamics system in 1992... and we have been refining it ever since.

It all started with sturdy aluminum carts:

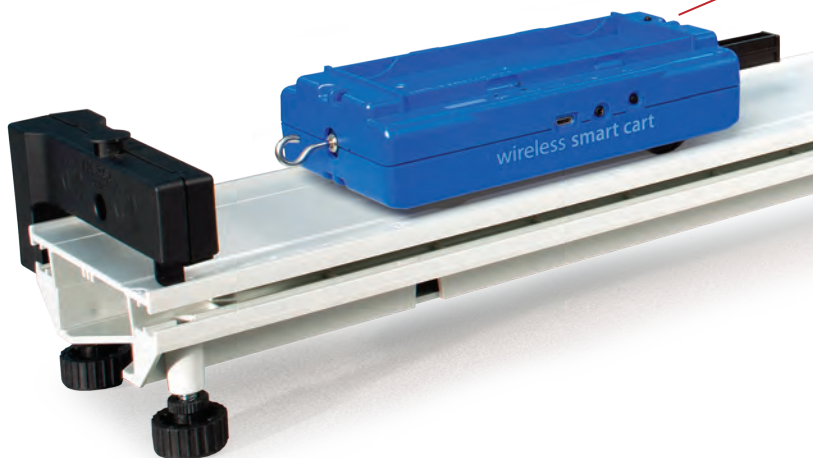
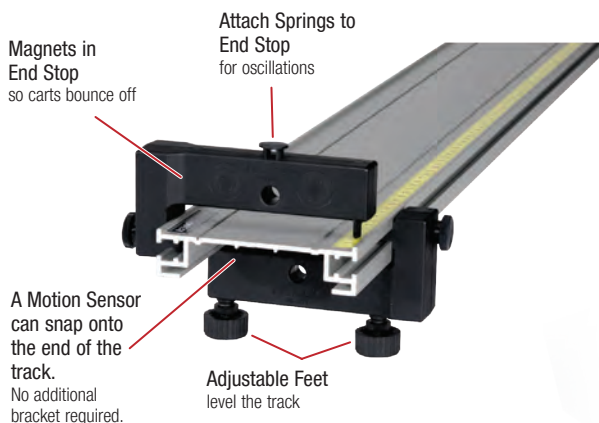


So little friction they will roll off the table if you set them down on their wheels, and so sturdy they will survive the fall!



Spring-loaded, retractable wheels prevent damage and keep your students from skating on them.

Soon, we added an aluminum dynamics track to align collisions:



New technologies led to new innovations...

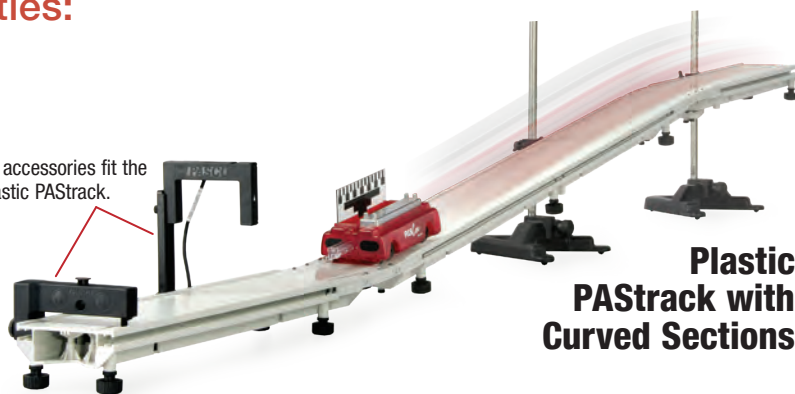
Plastic brought new possibilities:

- ▶ Durable lightweight PAScars
- ▶ Curved track for Conservation of Energy

Plastic PAScars

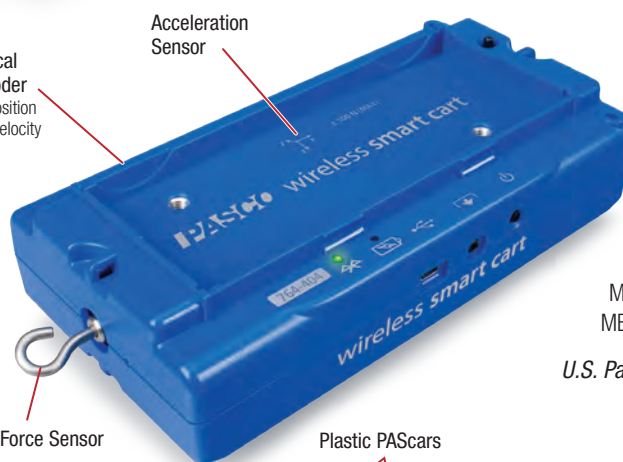


All accessories fit the plastic PATrack.



Plastic PATrack with Curved Sections

Then in 2016, PASCO introduced the Smart Cart, the first fully instrumented dynamics cart.



Smart Cart

ME-1240 (red)
ME-1241 (blue)

U.S. Patent Number 10,481,173

Classic Metal Carts

Plastic PAScars



Smart Carts

Snap together individual sections to make a track as long as you want with PATrack.

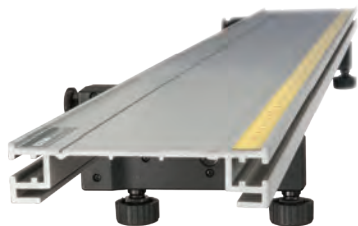
Now, these three types of carts are compatible with both types of tracks, and there are many accessories to complete your lab.

See the next two pages to configure your dynamics system.

How to choose the Dynamics System that's best for you:

1 Select the type of track you want.

Do you want metal or plastic tracks?



Metal Track Advantages

- ▶ Available in 1.2 m or 2.2 m lengths
- ▶ Straight and rigid
- ▶ Supports induced magnetic drag because it's conductive
- ▶ Feet can be placed at any position
- ▶ High-contrast scale



Plastic Track Advantages

- ▶ Add tracks to extend the length
- ▶ Lightweight
- ▶ Supports curved track for hills
- ▶ Built-in feet
- ▶ Storage: 1-meter track disassembles into two 50-cm parts
- ▶ Less expensive

2 Select the type of carts you want.

Do you want metal, plastic or Smart Carts?



Metal Cart Advantages

- ▶ Red and blue for distinguishing in collisions
- ▶ More inertia
- ▶ Sturdy body
- ▶ User-replaceable wheels



Plastic Cart Advantages

- ▶ Red and blue for distinguishing in collisions
- ▶ Least expensive
- ▶ Two string tie positions
- ▶ Plunger has a long throw



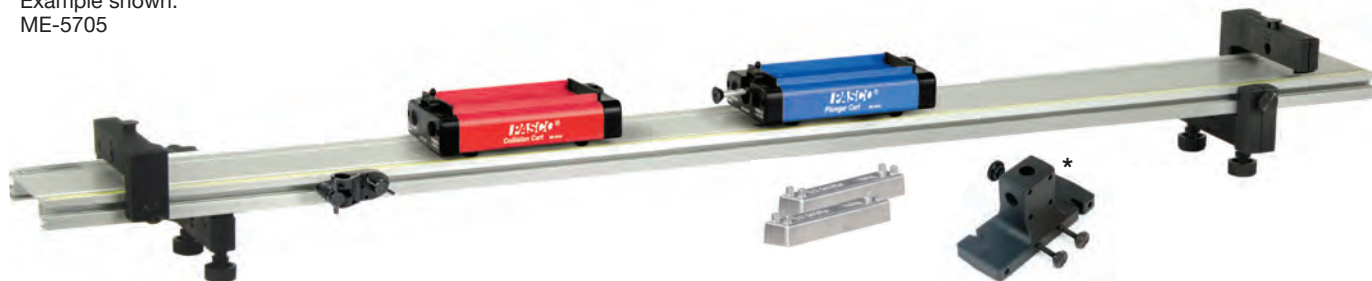
Smart Cart Advantages

- ▶ Red and blue for distinguishing in collisions
- ▶ Completely instrumented with all the sensors you need for dynamics
- ▶ Two string tie positions
- ▶ Bluetooth 4.0 wireless: No interface required

3 Which system is best for you?

Basic System – Just Carts and Track

Example shown:
ME-5705



OR

Standard System – Basic System + Accessory Pack

Example shown:
ME-5715



Basic System Includes

- Track
- 2 Carts
- 2 Feet
- 2 Endstops
- Rod Clamp
- 2 Mass Bars (4 with metal carts)
- Smart Cart Rod Stand Adapter*

Choose your Track and Carts	Plastic Track 1 m	Metal Track 1.2 m	Metal Track 2.2 m
Plastic Carts	ME-5701	ME-5702	ME-5703
Metal Carts	ME-5704	ME-5705	ME-5706
Smart Carts	ME-5707A	ME-5708A	ME-5709A

Standard System Includes

- Track
- 2 Carts
- 2 Feet
- 2 Endstops
- Rod Clamp
- 2 Mass Bars (4 with metal carts)
- Spring Set
- Clamp-on Super Pulley
- Friction Block
- Angle Indicator
- Smart Cart Rod Stand Adapter*

Choose your Track and Carts	Plastic Track 1 m	Metal Track 1.2 m	Metal Track 2.2 m
Plastic Carts	ME-5711	ME-5712	ME-5713
Metal Carts	ME-5714	ME-5715	ME-5716
Smart Carts	ME-5717A	ME-5718A	ME-5719A

*Smart Cart Rod Stand Adapter is only included in Smart Cart Dynamics Systems (ME-5707A, ME-5708A, ME-5709A, ME-5717A, ME-5718A, and ME-5719A)

Smart Cart

Wireless Smart Cart

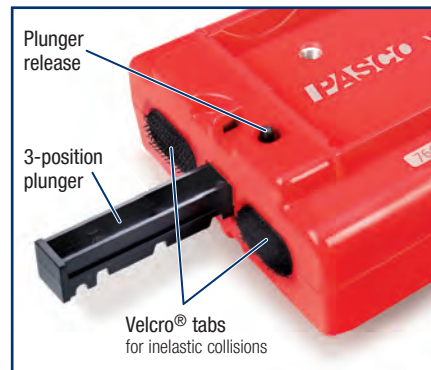
ME-1240 (red) ME-1241 (blue)



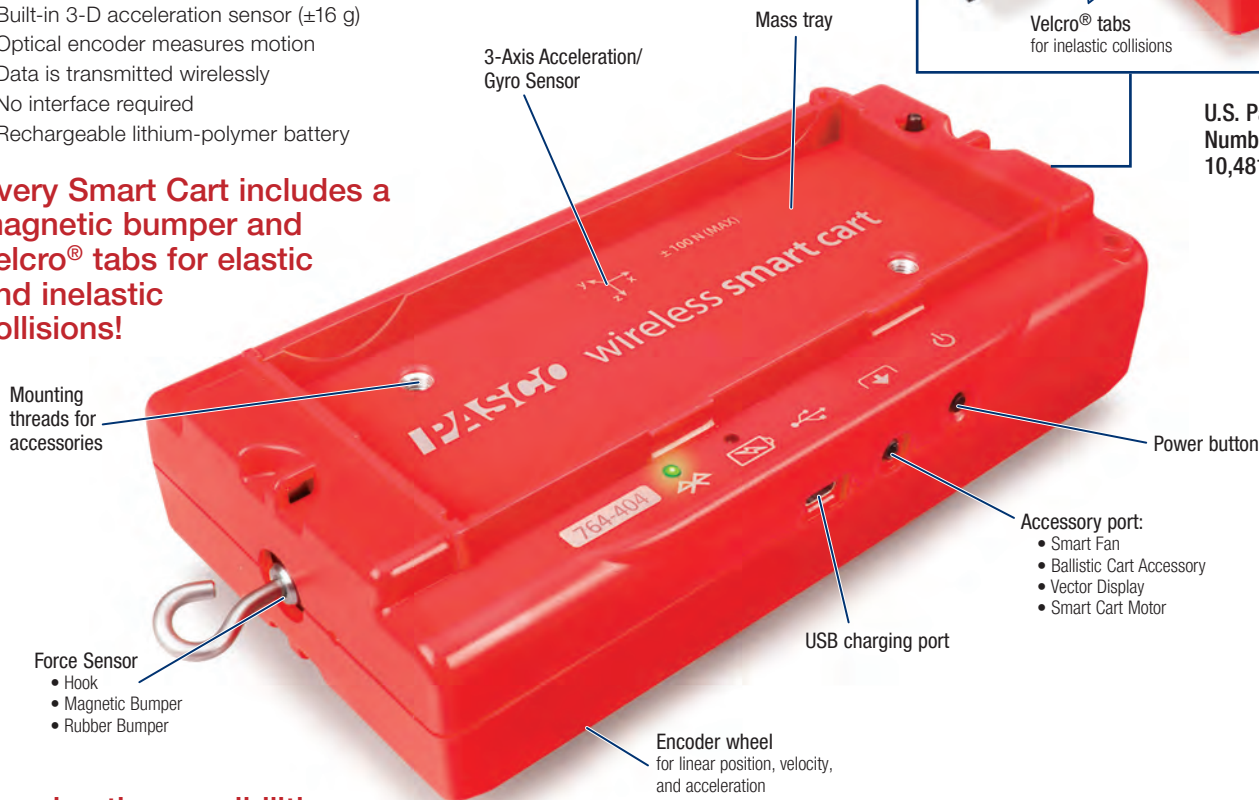
The patented Smart Cart is the ultimate tool for studying kinematics, dynamics, Newton's Laws, and more. It is based on a durable ABS body with nearly frictionless wheels, just like our high quality PAScars. Now, we've added built-in sensors that measure force, position, velocity, and acceleration. The versatile Smart Cart can collect measurements on or off a track and transmit the data wirelessly over Bluetooth. In essence, it is a wireless dynamics cart that combines all the necessary sensors, without requiring any additional hardware.

- ▶ Built-in force sensor (± 100 N)
- ▶ Built-in 3-D acceleration sensor (± 16 g)
- ▶ Optical encoder measures motion
- ▶ Data is transmitted wirelessly
- ▶ No interface required
- ▶ Rechargeable lithium-polymer battery

Every Smart Cart includes a magnetic bumper and Velcro® tabs for elastic and inelastic collisions!



U.S. Patent Number 10,481,173



Imagine the possibilities...



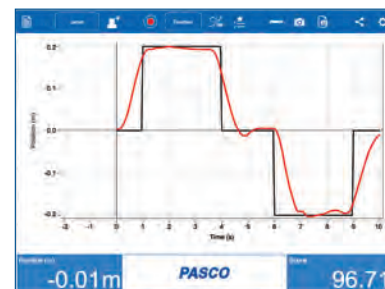
1. Measure cart velocity on a curved track where Motion Sensors cannot work because there is no straight line of sight.

2. Directly measure the tension in the string connected to the Smart Cart.

Hang a mass over a pulley, hold the cart in place, and then let go. When the cart is stationary, the tension is equal to the hanging weight. When the cart accelerates, the tension is less than the hanging weight.

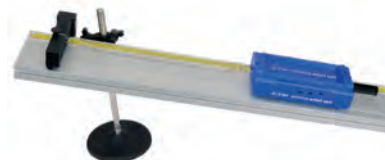


3. Match Position and Velocity vs. Time graphs with FREE MatchGraph Software! pasco.com/downloads



4. Measure oscillations of a cart and spring.

Measure the position, velocity, and acceleration of the cart, and force of the spring.



5. Place the cart on the floor or table.

Measure velocity as cart travels across the floor or table without a track.

Four built-in sensors, one low price, zero additional equipment

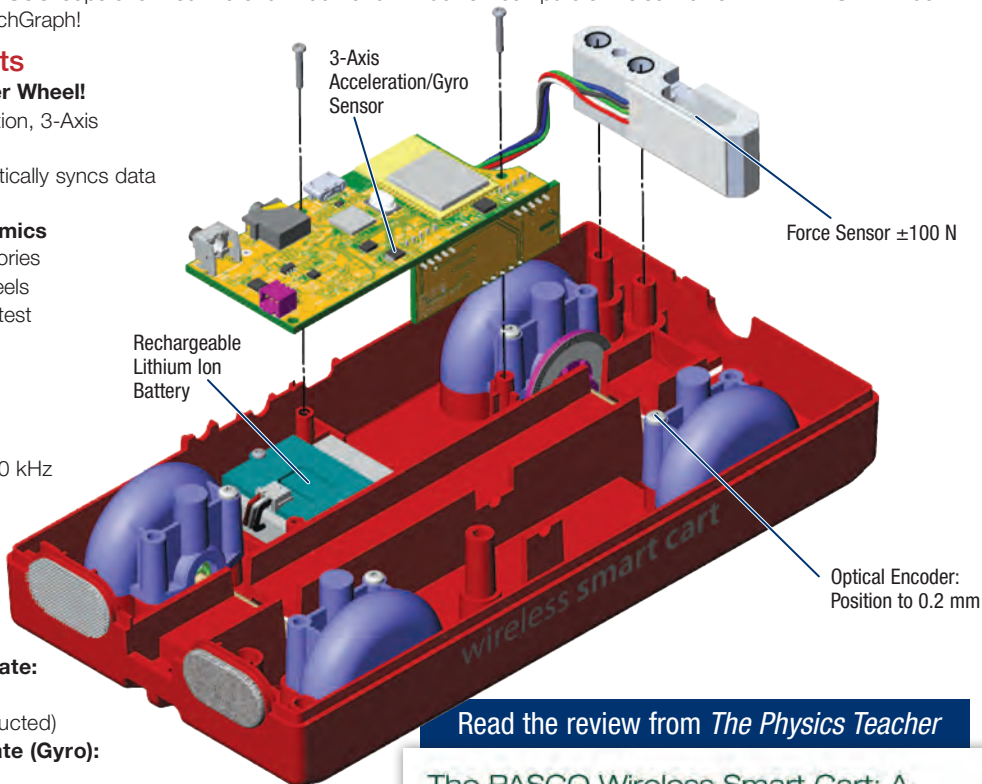
- ▶ Wirelessly measure position, velocity, acceleration (3-axis and resultant), rotation and force, either individually or simultaneously.
- ▶ Use on a tabletop or standard physics dynamics tracks.
- ▶ Wirelessly connect the Smart Cart to your laptop or tablet, and the built-in sensors will measure and transmit data.
- ▶ The Smart Cart is compatible with PASCO Capstone™ software for Mac® and Windows® computers. It also works with FREE SPARKvue® software for mobile devices and MatchGraph!

It's what's inside that counts

- ▶ **Enclosed High-resolution Encoder Wheel!**
- ▶ **4 Embedded Sensors:** Force, Position, 3-Axis Acceleration, 3-Axis Gyroscope
- ▶ **Special Sync Technology:** Automatically syncs data from two Smart Carts to within 2 ms
- ▶ **Compatible with All PASCO Dynamics Systems:** Tracks, carts, and accessories
- ▶ **Ultra-low Friction:** Ball bearing wheels
- ▶ **Rugged Design:** Survives the drop test

Specifications:

- Force Range:** ± 100 N
- Force Resolution:** 0.1 N
- Force Accuracy:** $\pm 1.0\%$
- Force Maximum Sampling Rate:** 2.0 kHz
- Position Resolution:** ± 0.2 mm
- Max Velocity:** ± 3.0 m/s
- Velocity Max Sample Rate:** 500 Hz
- Acceleration Range:** ± 16 g
- Acceleration Max Sample Rate:** 500 samples/second
- Max Rotational Speed Sampling Rate:** 500 samples/second
- Max Wireless Range:** 30 m (unobstructed)
- Maximum Measurable Rotation Rate (Gyro):** ± 245 deg/second
- Mass Without Accessories:** 245 g
- Patent No.:** 10481173
- Magnetic Bumper Mass:** 23.6 g



Read the review from *The Physics Teacher*

The PASCO Wireless Smart Cart: A Game Changer in the Undergraduate Physics Laboratory

Asif Shakur and Rainor Connor, Salisbury University, Salisbury, MD

With the introduction of the Wireless Smart Cart by PASCO scientific in April 2016, we expect a paradigm shift in undergraduate physics laboratory instruction. We have evaluated the feasibility of using the smart cart by carrying out experiments that are usually performed using traditional PASCO equipment. The simplicity, convenience, and cost saving achieved by replacing a plethora of traditional laboratory sensors, wires, and equipment clutter with the smart cart are reported here.

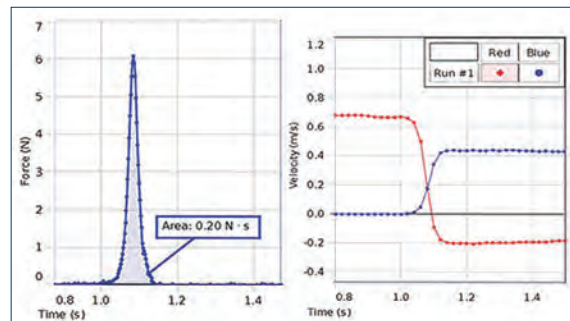
Inelastic collision

We performed a simple inelastic collision experiment to ascertain the feasibility of using the wireless smart cart in an undergraduate laboratory setting. Two similar smart carts (red and blue) were placed on a 1-m PASCO aluminum track. The free PASCO app SPARKvue was installed on an iPhone. The app paired up with the blue cart via Bluetooth and recognized the unique identification sticker on the cart. We gave the blue cart a gentle push in the direction of the stationary red cart. The two carts collided and stuck together on the Vetro pads. The two carts moved together with a slower speed. Note that we only needed one iPhone to pair up with only one cart (blue) in order to draw meaningful conclusions. The velocity and time data (in addition to position, acceleration, and a raft of other data) were wirelessly transmitted by the smart cart to the iPhone as a CSV file (comma separated values). The data were tabulated in an Excel file, and a graph of velocity vs. time is depicted in Fig. 2.



Fig. 1. The PASCO Wireless Smart Cart.

Inelastic Collision Between Equal Mass Carts



Smart Carts can be used to investigate impulse and collisions, as well as velocity and acceleration, motion graphs, Newton's Laws, conservation of momentum, conservation of energy, centripetal force, and much more!

6. Use two Smart Carts for collisions.

Each cart measures its own velocity and force. Will students correctly predict the forces recorded by each cart for these parameters?

- ▶ Use equal masses and unequal masses.
- ▶ Use the same spring bumpers on the Smart Cart force sensors and then change the spring on one Smart Cart to a weaker spring.



The magnetic bumper for the force sensor is included with the Smart Cart.

Go to pasco.com/smartcart

Includes:

- Hook
- Rubber bumper
- Magnetic bumper
- USB cable for charging



Order Information

Smart Cart (Red)	ME-1240	
Smart Cart (Blue)	ME-1241	
Recommended:		
Smart Cart Charging Garage	ME-1243	p. 101
PAScar Cart Mass (set of 2)	ME-6757A	p. 111

Powered Carts

Smart Fan Accessory

ME-1242

- ▶ Provides a Constant Force
- ▶ Hands-off Operation
- ▶ Sense and Control
- ▶ Manual Mode for Non-Smart Carts

What makes this fan so smart?

If you use this fan on a regular cart, you can turn it on and select one of three speeds by pushing the button on the side. But plugging it into a Smart Cart gives this Smart Fan Accessory added capabilities:

- ▶ **Hands-off Operation:** You can turn the Smart Fan on and off wirelessly from your computing device.
- ▶ **Adjust the Thrust:** Move the slider in the software and watch the fan respond.
- ▶ **Reverse the Spin of the Fan:** Input a negative thrust to make the fan blow in the opposite direction.
- ▶ **Set Start and Stop Conditions:** Choose to start the fan when a measurement (such as Position) reaches a certain value. Make the fan stop after a certain time so the cart coasts during part of the experiment.
- ▶ **Sense and Control:** Program the Smart Fan thrust to respond to a calculation based on sensor measurements, for example:

$$\text{Thrust} = -100 * [\text{Position}]$$

- ▶ This will cause the fan to blow harder as the cart moves down the track, causing the cart to reverse. Eventually the fan will reverse when the Position becomes negative, accelerating the cart in the positive direction.

Specifications:

Push-button for on/off: 3 speed settings

Maximum thrust: 0.2 N

Fits all PASCO dynamics carts

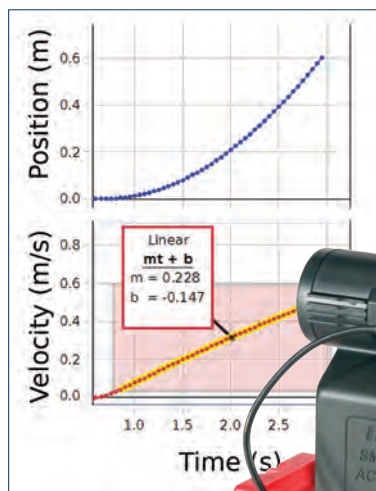
Uses 4 AA batteries (alkaline or rechargeable)

Lithium battery performance: On medium speed, fan slows after 5.2 hrs and stops after 5.6 hrs.

Alkaline battery performance: On medium speed, fan slows after 1 hr and stops after 8.9 hrs.

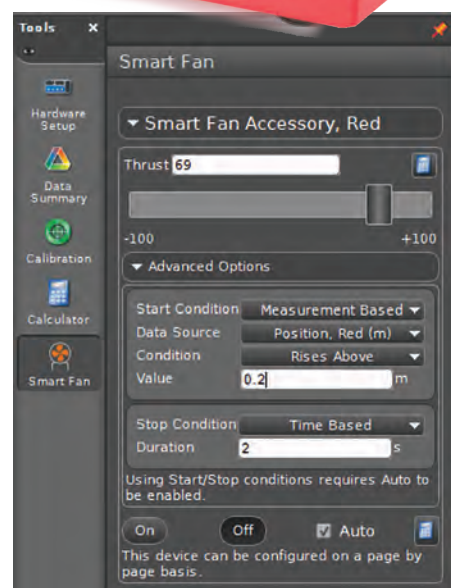
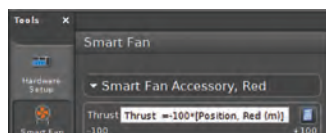
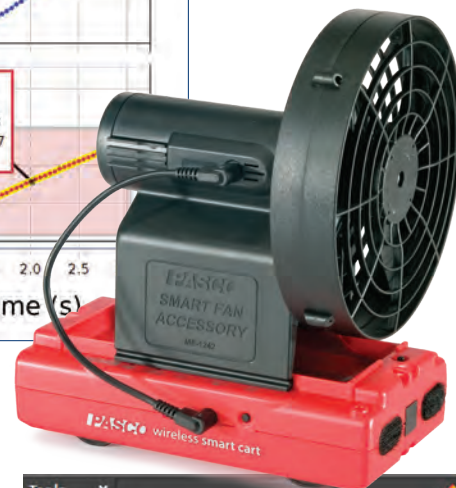
Patent No.: 10482789

Smart Cart required for extended Smart features



Sample data capture of position and velocity.

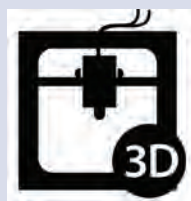
The Smart Fan Accessory becomes smart when plugged into a Smart Cart.



This is the control panel for the Smart Fan in PASCO Capstone software.

Make your fan rotatable:

3D print your own rotating base for the Smart Fan Accessory at pasco.com/diy



Includes:

- Smart Fan Accessory
- Smart Cart Cable (19 cm)
- AA Alkaline Batteries (4)



Order Information

Smart Fan Accessory	ME-1242
Requires:	
Smart Cart or Dynamics Cart	pp. 98, 105
PASCO Capstone Software	pp. 68-71
Suggested:	
Battery Charger and 8 AA Batteries	SE-3570

Smart Cart Vector Display

ME-1246

Helps your students visualize acceleration, force, and velocity... in real time.

The Smart Cart Vector Display adds visual vectors to your Smart Cart for Force, Acceleration, or Velocity. Connect to the Smart Cart's accessory port to visualize vectors in real time! Arrows light up proportional to the sensor reading showing either positive or negative direction and magnitude.

Features

- ▶ Select between Force, Acceleration, or Velocity vectors and watch them in real time.
- ▶ Students can visualize constant acceleration as a cart rolls up and then down an incline.
- ▶ Great for the student lab station or for a physics lecture demonstration!
- ▶ Selectable ranges



The vector display can sit flat in a Smart Cart.



The vector display can mount vertically for classroom demonstrations.



Order Information

Smart Cart Vector Display ME-1246

Smart Cart Charging Garage

ME-1243

Charge up to five Smart Carts at once. Provides storage for the carts and accessory bumpers. Includes power adapter.



Order Information

Smart Cart Charging Garage ME-1243

NEW

Fan Sail

ME-1248

This sail fits into a Smart Cart or Super Fan Cart (ME-6977), so the fan can blow into the sail, demonstrating Newton's Third Law by remaining stationary. When the concave side of the sail faces the fan, the air rebounds off the sail and moves the cart.



Order Information

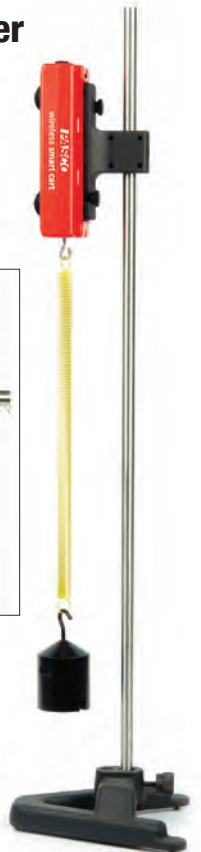
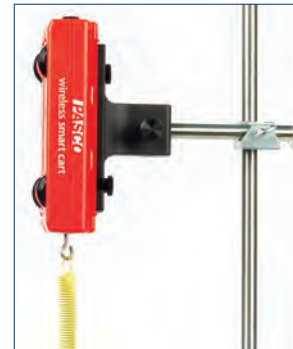
Fan Sail ME-1248

Smart Cart Rod Stand Adapter

ME-1244

This accessory allows the Smart Cart to be suspended from a rod stand. Use the Smart Cart's force sensor to measure the force of an oscillating spring and mass.

The Smart Cart can be mounted directly to a vertical rod or to a horizontal cross-rod.



Screw storage



Order Information

Smart Cart Rod Stand Adapter ME-1244

Smart Ballistic Cart Accessory

ME-1245

- ▶ Updated to take advantage of Smart Cart capabilities
- ▶ Demonstrates the independence of vertical and horizontal motion
- ▶ Works with all PASCO carts
- ▶ Shoots over 50 cm high

The Smart Ballistic Accessory mounts to any PASCO dynamics cart for a classic demonstration on the independence of X and Y motion. A projectile fired from the accessory while a cart is in motion will be caught farther down the track. When mounted to a PASCO aluminum cart, or PAScar, the projectile is launched using a push button timer delay. When connected to a PASCO Smart Cart, the Smart Ballistic Accessory can launch the projectile based on measurements made by the Smart Cart in either SPARKvue or PASCO Capstone software.

How It Works:

Attach the Smart Ballistic Accessory to any PASCO dynamics cart using the captured mounting screws. X-Y adjustments on the top deck of the accessory (red thumb screws) are used to adjust the aim of the launcher. Insert one of the yellow projectiles into the launcher and press down. The launcher is now set to fire.

When attached to any PASCO dynamics cart, press the timer button on top of the Smart Ballistic Accessory. This provides a one second delay before the projectile is launched. After the button is pressed, give your dynamics cart a push. The projectile will fire upwards, and be caught farther down the track.

When attached to a PASCO Smart Cart, connect the accessory cable to the accessory port on the Smart Cart. In either PASCO Capstone or SPARKvue, you can launch the ball by pressing a button in the software. In PASCO Capstone, you can set a particular distance or time at which the ball will launch. Using Blockly coding, in either PASCO Capstone or SPARKvue software, you can set the launch condition to be based on a Smart Cart measurement of position, velocity, or acceleration. Start recording data, and push the Smart Cart. The projectile will fire when the measurement condition is met.

If the cart is moving at a constant velocity, the ball will fall back into the catcher on the cart.

Includes:

- Smart Ballistic Cart Accessory
- Plastic Balls (2)
- USB Charging Cable
- Smart Cart Accessory Cable



Features

- ▶ Compatible with all PASCO dynamics carts.
- ▶ Push button timer for delay for launching the projectile after the cart is pushed.
- ▶ Release mechanism does not affect cart motion or ball flight path.
- ▶ The barrel has X and Y adjustments, so perfect vertical projections can be produced every time.
- ▶ Fires a colored nylon ball 0.5 meters or higher for impressive demonstrations.
- ▶ Connects to the Smart Cart for measurement-based launching conditions.
- ▶ USB rechargeable Li-Ion battery.



Order Information

Smart Ballistic Cart Accessory ME-1245

Requires:

Smart Cart or any other PASCO Cart

Recommended:

Aluminum Dynamics Track with Leveling Feet

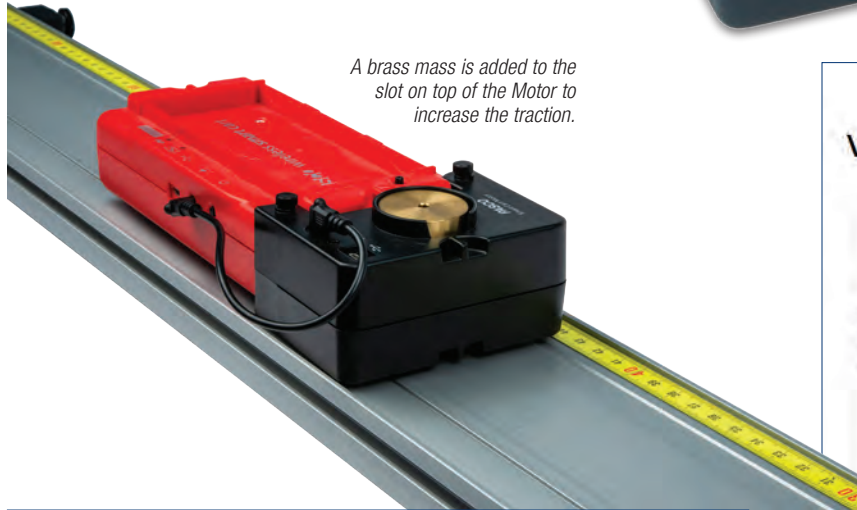
Smart Cart Motor



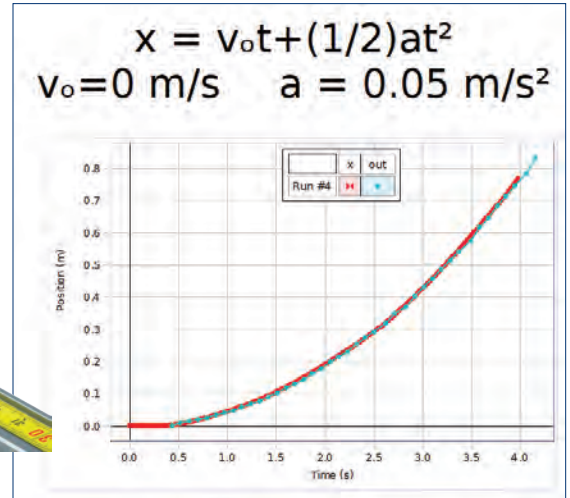
ME-1247

NEW

The Smart Cart Motor is a motor-driven wheel that attaches to the Smart Cart to make it go at a constant velocity, forwards or backwards. In PASCO Capstone or SPARKvue, you can control the motor remotely through its wired connection to the Smart Cart by setting the power on a scale of -100 to +100%.



A brass mass is added to the slot on top of the Motor to increase the traction.

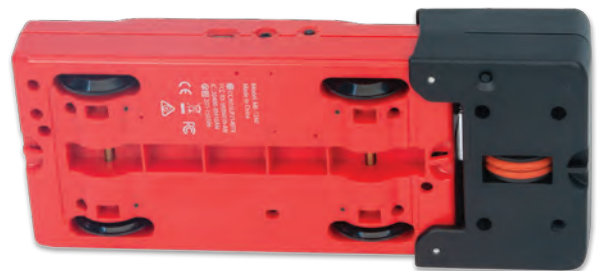


You can program the Smart Cart to follow equations of motion and graph the real-time motion on a plot of the theoretical equation of motion.

```

Code
Blockly Lua
Logic
  set [ ] to 44 motor drive acceleration ??
  sleep for 20 ms
  set x to 0
  set k to 700
  set v0 to 0.15
  set a to -0.05
  set Power to 0
  set t0 to get time in ms
  in number output a enter a
  in text output Eqn enter x = 1/2at^2
  repeat until x <= 0.6
  do
    set t to get time in ms
    set x to v0 * t + 0.5 * a * t^2
    set P to k * x
    change Power by 0.5 * P
    set SmartCartMotorAccessory to Power
    in number output out enter x
  
```

Program with Blockly in Capstone or SPARKvue to make the Smart Cart with Motor follow an equation of motion.



This view of the underside of the Smart Cart with Motor shows the red motor-driven wheel. It can be used on or off a track.

Includes:

- Smart Cart Motor
- Smart Cart Connector Cable
- USB Charging Cable



Order Information

Smart Cart Motor	ME-1247	
Required:		
Smart Cart (Red)	ME-1240	pp. 98-99
OR		
Smart Cart (Blue)	ME-1241	pp. 98-99
Recommended:		
1.2 m Aluminum Dynamics Track.....	ME-9493	p. 105

Smart Cart Accessories

Smart Cart Demonstration Kit

ME-1272 (with red cart) ME-1273 (with blue cart)

The Smart Cart Demonstration Kit comes with either a Red Smart Cart or a Blue Smart Cart and all the accessories you need to perform amazing physics demonstrations in kinematics and dynamics.



Demonstrate:

- ▶ Differences between Velocity and Acceleration
- ▶ Independence of Horizontal and Vertical Projectile Motion
- ▶ Newton's First Law
- ▶ Newton's Second Law
- ▶ Newton's Third Law
- ▶ Impulse and Force
- ▶ Force and Acceleration in Collisions
- ▶ Centripetal Acceleration
- ▶ Compare Velocity, Acceleration, and Force in Simple Harmonic Motion
- ▶ Buoyant Force and Archimedes' Principle



Includes:

- Red Smart Cart (included in ME-1272) OR ME-1240
- Blue Smart Cart (included in ME-1273) ME-1241
- Smart Fan Accessory ME-1242
- Smart Cart Rod Stand Adapter ME-1244
- Smart Ballistic Cart Accessory ME-1245
- Smart Cart Vector Display ME-1246
- PAScar Cart Mass (set of 2) ME-6757A
- Fan Cart Sail
- Storage Tray
- Smart Cart Demonstration Manual



Demo Manual Included!



Order Information

Red Smart Cart Demonstration Kit ME-1272
 Blue Smart Cart Demonstration Kit..... ME-1273

PASCO Dynamics Carts

PAScar

ME-6933 (red) ME-6934 (blue)

Each 250 gram polycarbonate plastic cart includes a spring plunger, magnets and Velcro tabs for collision studies. The PAScars come in red and blue and are compatible with all PASCO Dynamics Tracks and accessories.

Polycarbonate Body
Total mass: 250 g



Order Information	
PAScar Red.....	ME-6933
PAScar Blue.....	ME-6934
PAScar (Set of 2).....	ME-6950
Replacement Supplies:	
Cart Replacement Axles (4 pack).....	ME-6957 p. 112
PAScar Cart Mass (set of 2).....	ME-6757A p. 111

PAStack

ME-6960

Includes:

- Two piece track
- Connector clips (2)
- Leveling feet (6)



Order Information	
PASStack.....	ME-6960

Curved PAStack

ME-6841

Create hills, valleys and inclines. Molded PAStack system has straight and curved sections that just snap together. Connect multiple sets to make a track as long as you want.

Includes:

- Concave-up Curved Piece
- Concave-down Curved Piece
- PAStack Connector Clips (2)



Order Information	
Curved PAStack.....	ME-6841

Classic Aluminum Carts

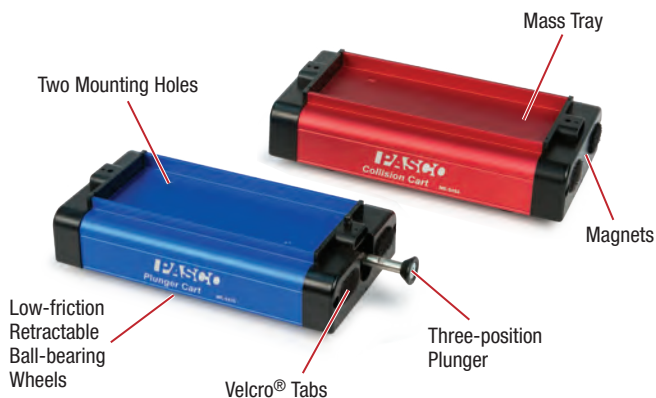
Plunger Cart

ME-9430 (blue)

Collision Cart

ME-9454 (red)

These are the standard carts in thousands of physics labs around the world. With an aluminum body and high-impact ABS plastic end caps, they make dynamics experiments quick to set up and very quantitative. The Classic Carts are compatible with all PASCO Dynamics Tracks and accessories. The plunger cart has a spring loaded plunger for launching.



Order Information	
Plunger Cart.....	ME-9430
Collision Cart.....	ME-9454
Replacement Supplies:	
Cart Replacement Axles (4 pack).....	ME-6957 p. 112
PAScar Cart Mass (set of 2).....	ME-6757A p. 111

Aluminum Starter Tracks



Have 1.2 m length tracks and want to change to 2.2 m?

These aluminum tracks are available in 1.2 m and 2.2 m lengths.

Order Information	
1.2 m Aluminum Dynamics Track.....	ME-9493
2.2 m Aluminum Dynamics Track.....	ME-9779

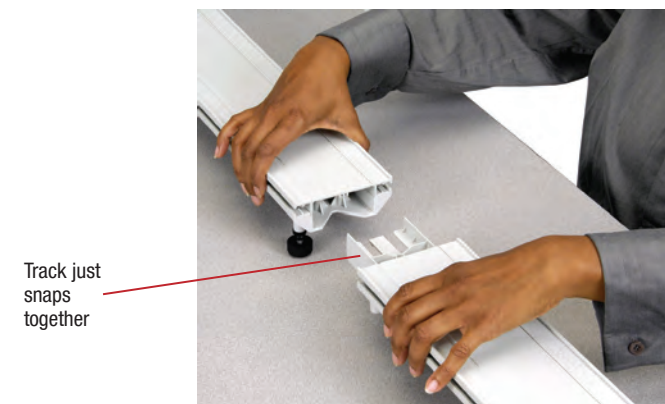
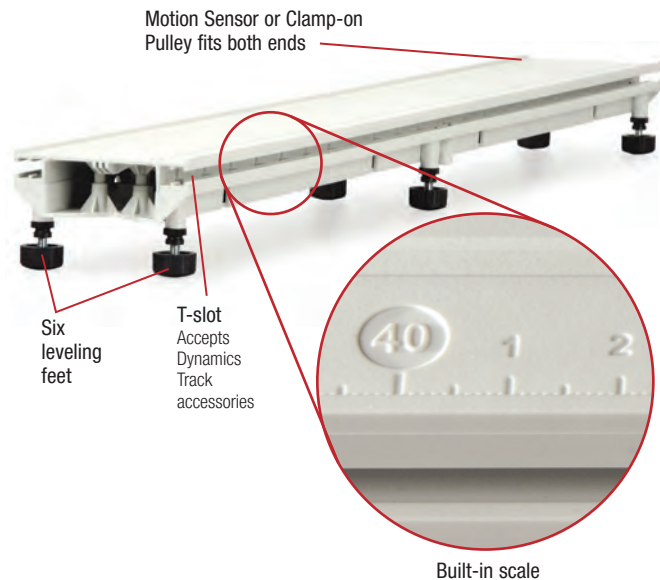
PAstrack

PAstrack

ME-6960

- ▶ 1 m length dynamics track
- ▶ Two-piece molded construction
- ▶ Accepts dynamics track accessories

This two-piece track construction makes storage easy. Snap-on connector clip holds sections straight and rigid. Use the second clip (included) to connect multiple tracks! The track ends are designed to accept the Motion Sensor and Clamp-on Pulley, and the side T-slots accept Dynamic Track accessories, such as photogate brackets and end stops. Track includes six built-in leveling feet.



Includes:

- Two piece track
- Connector clips (2)
- Leveling feet (6)



Order Information

PAstrack.....ME-6960

PAstrack Inclined Plane Accessory

ME-6965

The Inclined Plane Accessory includes the hinge with angle scale and the rubber cord for the rubber bumper. A PAstrack is required to make a complete inclined plane.



Includes:

- Inclined Plane Accessory
- Rubber Cord, 1.5 mm square, 30 m

Order Information

PAstrack Inclined Plane Accessory.....ME-6965
 Required:
 PAstrack.....ME-6960

PAstrack Inclined Plane

ME-6967

The PAstrack Inclined Plane includes the Inclined Plane Accessory (ME-6965) and the PAstrack (ME-6960).



Includes:

- PAstrack Inclined Plane Accessory ME-6965
- PAstrack ME-6960

Order Information

PAstrack Inclined PlaneME-6967

Curved PAStack

ME-6841

- ▶ Attaches to Straight PAStack with same connector clip
- ▶ Put two curved pieces together
- ▶ One concave up and one concave down

Create hills, valleys and inclines. The molded PAStack system has straight and curved sections that just snap together. Connect multiple sets to make a track as long as you want.



Includes:

- Concave-up Curved Piece
- Concave-down Curved Piece
- PAStack Connector Clips (2)

Order Information

Curved PAStack..... ME-6841

Conservation of Energy Experiments

Smart Cart Curved Track System

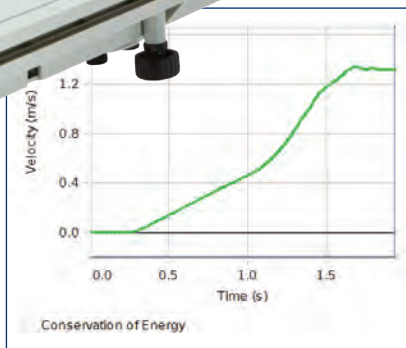
ME-5700B

- ▶ Explore all aspects of the Law of Conservation of Energy
- ▶ Wireless Smart Cart has all the sensors you need
- ▶ Use this system for all other dynamics experiments

This unique system has a curved track that allows your students to build hills and valleys for Conservation of Energy experiments. Data is collected using the sensors onboard the Smart Cart. Unlike when Motion Sensors are used to track the cart, the Smart Cart does not have to be in the direct line of sight of the sensor, so it can go over hills. And, the Smart Cart is wireless, so no extra friction is introduced.



Will the cart be going any faster at the bottom if a mass is added? With the Curved PAStack and a low friction cart, students can investigate conservation of energy to answer that question.



Includes:

- PAStack (2) ME-6960
- Curved PAStack (2) ME-6841
- Track Rod Clamps (4) ME-9836
- Dynamics Track End Stop (Two 2 Packs) ME-8971
- Stainless Steel Rod, 60 cm (threaded) (2) ME-8977
- Round Base with Rod (2) ME-8270
- Small "A" Base (2) ME-8976
- PAScar Cart Mass (set of 2) ME-6757A
- Smart Cart (Red) ME-1240

Order Information

Smart Cart Curved Track System.....ME-5700B
 Required:
 PASCO Capstone Software.....pp. 68-71
 Bluetooth 4.0 compatible computer

The curved and straight track pieces can be combined to form a step, so the cart starts out on a nearly level upper step, travels down the step, and ends on a level straight section. This makes measuring the change in height very easy.

During the experiments, the mass of the cart is varied to see what effect, if any, it has on the results.

Another configuration forms a potential well so the cart oscillates back and forth.

This versatile system can also be used for regular dynamics experiments such as impulse and Newton's Second Law.

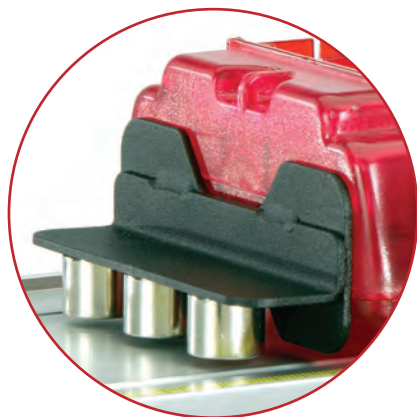
Experiments can be downloaded at pasco.com

Dynamics Systems Accessories

Dynamics Cart Magnetic Damping

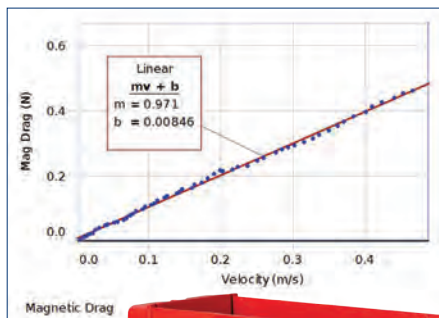
ME-6828

- ▶ Magnets cause eddy currents in aluminum tracks
- ▶ Magnetic drag is proportional to cart speed
- ▶ Damping Accessory connects to cart magnets
- ▶ Slide magnets up/down to adjust amount of drag



Magnetic Damping using the Wireless Smart Cart

Measure the magnetic drag force directly with the Smart Cart's on-board force sensor. The Smart Cart also has an encoder that keeps track of its velocity. This plot of Force vs. Velocity shows the induced magnetic drag is proportional to the velocity.



Includes:

- Bracket
- Magnets
- Keeper

Order Information

Dynamics Cart Magnetic Damping	ME-6828	
Shown in use with:		
Basic Smart Cart Metal Track 1.2 m System	ME-5708A	p. 97
IDS Spring Kit	ME-8999	p. 111

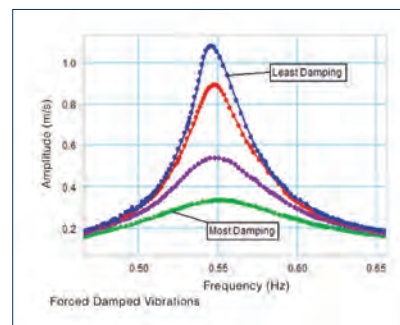
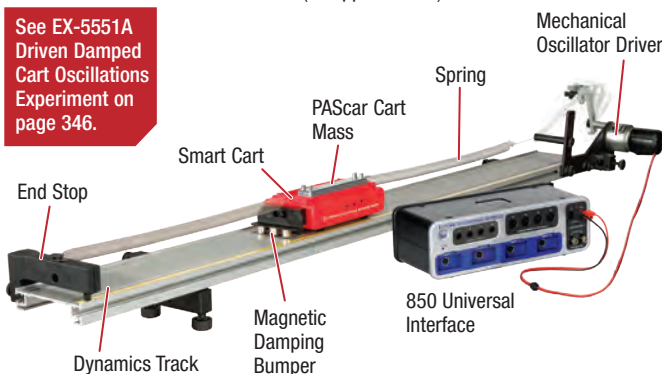
Mechanical Oscillator/Driver

ME-8750

The Mechanical Oscillator/Driver delivers repeatable, low-frequency, high-force sinusoidal motion for harmonic motion experiments. Shown with the Smart Cart Standard Dynamics System (ME-5718), it also works with other Dynamics Systems having a metal track.



See EX-5551A Driven Damped Cart Oscillations Experiment on page 346.



The velocity amplitude is plotted as a function of driving frequency. The four resonance curves show the effect of varying the strength of the magnetic damping.

Specifications:

Sinusoidal Drive: 12 VDC motor
(Frequency: 0.3-3 Hz, Current: 0-0.3 A).

Adjustable Amplitude: Up to 12 cm.

Mounts to Dynamics Track or Rod

Photogate Mounting Holes

Order Information

Mechanical Oscillator/Driver	ME-8750	
Shown in use with:		
Standard Smart Cart Metal Track 1.2 m System	ME-5718A	p. 97
Dynamics Cart Magnetic Damping	ME-6828	
850 Universal Interface	UI-5000	p. 14

Friction Block

ME-9807

- ▶ Two types of material
- ▶ Vary surface area by using it flat or up on its side
- ▶ Hook for attaching a string to pull it
- ▶ Slot for a picket fence or flag for photogate timing

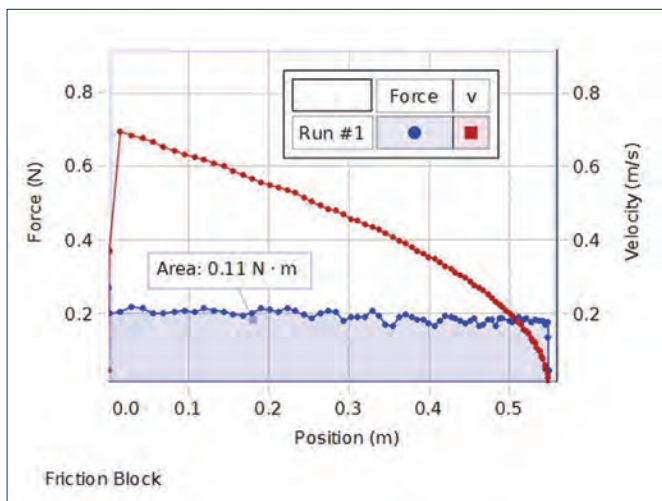


The wooden Friction Block has felt on two sides, so the frictional coefficients for felt or wood can be measured. It also fits into the dynamics cart tray so the cart can run on its wheels, or it can be turned upside down to run on the Friction Block without changing the mass.

Specifications:

Dimensions: 13 cm x 5 cm x 1.7 cm

Approximate Mass: 110 g



The sliding friction block does work on the moving Smart Cart and stops it quickly. The graph above shows the cart velocity and applied friction stopping force vs. the distance travelled by the cart and block. The area under the Force vs. Distance curve gives the work done, and the loss of kinetic energy can be calculated from the velocity.



Order Information

Friction Block.....	ME-9807
Shown in use with:	
Dynamics Track System.....	See pages 96-97
Dynamics Track End Stop (2 Pack).....	ME-8971 p. 111

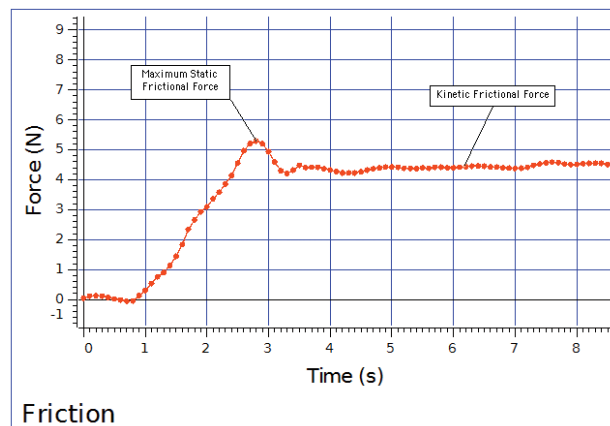
Discover Friction Accessory

ME-8574

See EX-5508
Sliding Friction
Experiment on
page 330.



PASCO's Discover Friction Accessory is unlike any other friction set. The trays are designed to work effectively with PASCO carts and sensors. Using the four trays, students can discover concepts such as coefficient of friction, static friction, kinetic friction and the sliding friction equations. The two trays with identical plastic surfaces can be hooked together to explore the relationship between surface area and sliding frictional forces.



The peak of the graph represents the maximum static frictional force. Once the friction tray begins to move, the kinetic frictional force is evident on the graph.

Features

- ▶ **Compatible:** Can be used with PASCO carts, masses and Force Sensors
- ▶ **Versatile:** Allow students to discover key friction concepts
- ▶ **Easy Storage:** Friction trays are stackable, both for adjusting the pulling height and storage



Includes:

- Friction Tray - Felt
- Friction Tray - Cork
- Friction Tray - Plastic (2)

Order Information

Discover Friction Accessory	ME-8574
Recommended:	
PAScar Cart Mass (set of 2).....	ME-6757A
PAScar (Red).....	ME-6933
PAScar (Blue).....	ME-6934
Force Sensor.....	See pages 20, 29
Dynamics System.....	See pages 96-97

Super Fan Cart

ME-6977

- ▶ Constant force
- ▶ Rechargeable
- ▶ Programmable

Teach every aspect of Newton's Second Law with PASCO's Super Fan Cart.

$$\vec{F}_{\text{Net}} = m\vec{a}$$

Adjust thrust angle to teach about vector forces
Fan turns through 180°

Rechargeable Battery

Lithium/polymer battery runs fan continuously on medium thrust for about 1.5 hours. Recharges in about 1 hour.

Vary the Mass Without Changing the Force

Accessory Mass Tray for Compact Cart Masses (ME-6755).

Retractable Wheels with low friction ball bearings

Adjustable Fan Speed

Apply different forces using three standard settings or the continuously variable setting. Regulated power supply gives constant thrust even as the battery discharges.

String Attachment
Connect two fan carts together to add or subtract forces.

The Net Force Is Zero
Removable sail can be used two ways: When positioned as shown, the sail cancels the forward air flow and there is no thrust. If the sail is reversed, its curved shape reflects the air backwards, causing the cart to move.



Pulse Duration
Program fan to be pulsed on for specific time to demonstrate acceleration only occurs when a force is applied. Includes time delay and auto-repeat option.

Specifications:

Fan Cart Mass: Approximately 0.3 kg

Sail Mass: Approximately 0.1 kg

Regulated Power Supply: Lithium-polymer battery (7.2 volts, 1.25 amp-hour)

Run-time: Runs approximately 1.5 hr on medium thrust

Recharge Time: One hour

Thrust Settings: Approximately 0.04 N on Low, 0.15 N on Medium, and 0.22 N on High

Thrust, Variable: Approximately 0.01 N to 0.23 N

Includes:

- Fan Cart
- Sail
- Charger

Order Information

Super Fan Cart.....	ME-6977	
Recommended:		
PAStrack.....	ME-6960	p. 106
Compact Cart Mass	ME-6755	p. 111
Replacement Part:		
Fan Sail	ME-1248	p. 101

Hooke's Law, Spring Potential Energy, and Work-Kinetic Energy Theorem, all in one cart launcher

Spring Cart Launcher

ME-6843*

- ▶ Affordable cart launcher
- ▶ Hooke's Law
- ▶ Spring potential energy



See EX-5504A Hooke's Law and Energy Stored in a Spring on p. 327

The Spring Cart Launcher provides an economical way to launch carts in a repeatable fashion. It can be used for Hooke's Law, collisions, and for Conservation of Energy. It fits into the bed of a Dynamics Cart or PAScar. To launch the cart, the plunger is pulled through the hole in the new endstop, compressing the spring, and then released. To add repeatability, a second endstop can be used with the supplied pin to hold the plunger at a specified compression position. Three different strength springs are provided with the Spring Cart Launcher. Use with or without probeware.

*NOTE: The Spring Cart Launcher is not compatible with the Smart Cart.

Includes:

- Spring Cart Launcher
- Trigger Pin
- Three Different Strength Springs



Order Information

Spring Cart Launcher.....	ME-6843
Required:	
Dynamics Track System.....	See pages 96-97
Shown in use with:	
Dynamics Track End Stop (2 Pack).....	ME-8971 p. 111
Cart Launcher Springs	ME-6847
(Three different strength springs, two each)	
Compact Cart Mass	ME-6755 p. 111

Constant Speed Buggy

SE-8028A

Turn on the Constant Speed Buggy and watch it go. When it reaches a wall, it flips over and changes directions. This low-cost solution features flashing lights and a sporty appearance. Requires two "C" batteries that are not included. Actual product may vary from picture.

WARNING
CHOKING HAZARD
Small parts. Not for children under 3 years.

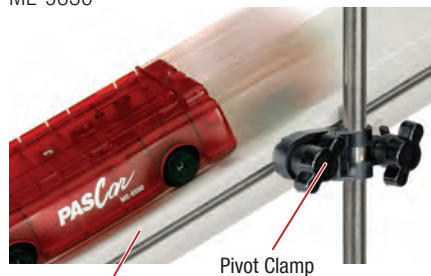


Order Information

Constant Speed Buggy.....	SE-8028A
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Track Rod Clamp

ME-9836



Pivot Clamp

Shown with PAStrack

Track Rod Clamp fastens to the T-slot of a Dynamics Track and accepts 1/2" rod.

Order Information

Track Rod Clamp ME-9836

Dynamics Track Feet (Pair)

ME-8972

A pair of adjustable feet for the classic aluminum tracks included in PASCO Dynamics Systems.



Order Information

Dynamics Track Feet (Pair)..... ME-8972

Dynamics Track End Stop (2 Pack)

ME-8971

A replacement supply for tracks included in PASCO Dynamics Systems.



Order Information

Dynamics Track End Stop (2 Pack) ME-8971

Angle Indicator

ME-9495A

The Angle Indicator fastens to the T-slot of a dynamics track. Hanging plumb-bob indicates angle to 1/2°.



Order Information

Angle Indicator..... ME-9495A
Recommended:
Launcher Plumb Bobs
(12-pack)..... ME-9868A

PAScar Cart Mass (set of 2)

ME-6757A



These 250-gram masses fit in any Dynamics Cart (including the Smart Cart) or the Discover Friction Accessory.

Order Information

PAScar Cart Mass (set of 2).....ME-6757A

Compact Cart Mass

ME-6755

This 250-g mass allows students to change the mass of the Classic Cart or PAScar when a force sensor is mounted in the bed of the cart. It also fits on a cart that has a Spring Cart Launcher (ME-6843) mounted in the bed.



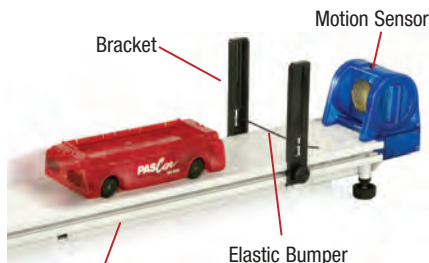
Order Information

Compact Cart Mass ME-6755

Elastic Bumper

ME-8998

The Elastic Bumper protects the Motion Sensor from the carts, but doesn't interfere with the ultrasonic pulse.



Shown with PAStrack

Includes:

- Two pairs of brackets
- 10 meters of elastic material

Order Information

Elastic Bumper ME-8998

Super Pulley with Clamp

ME-9448B



Shown with PAStrack

The Super Pulley with its integral clamp makes setup and alignment easy. The pulley height is fully adjustable, so you can keep the force parallel to the track on an inclined plane.

Includes:

- Super Pulley
- Super Pulley Clamp
- Mounting Screws (2)

Order Information

Super Pulley with ClampME-9448B

IDS Spring Kit

ME-8999



Includes 12 springs (1.6 cm diameter) with approximate spring constants of:

- 3.4 N/m (3 short and 3 long springs)
- 6.8 N/m (3 short and 3 long springs)

Order Information

IDS Spring Kit ME-8999

Harmonic Springs 8 Pack

ME-9803B



Includes eight identical springs: 8 cm long, 3.4 N/M spring constant.

Order Information

Harmonic Springs 8 Pack..... ME-9803B

Photogate Brackets (2 Pack)

ME-9806



ME-8933



ME-9804

Order Information

Photogate Brackets
(2 Pack)– IDS ME-9806
Picket Fences
(Smart Timer)..... ME-8933
Cart Picket Fences
(2 Pack) – IDS ME-9804

Cart Replacement Axles* (4 pack)

ME-6957



*Not suitable
for Smart Carts

Although the ball bearings are designed for many years of use, the bearings may become damaged from dirt and other contaminants. The wheels and axles of the PAScar can be easily replaced by removing the lower section of the car and placing the new wheels in the chassis. A perfect tune-up for a PAScar or GOcar! The wheels of the Classic Carts can also be replaced with the same set of wheels. Contact PASCO's technical support for further assistance.

Order Information

Cart Replacement Axles
(4 pack) ME-6957

Braided Physics String

SE-8050

▶ 30-lb. Test

This braided Dacron® string is tough, resists stretching, and won't unravel. Withstands up to 133 Newtons of force (equivalent to 13.6 kg). Each roll provides 320 meters of string.



Order Information

Braided Physics String SE-8050

Spares Kit - IDS

ME-9823

The Spares Kit contains many of the small parts that can get lost after classroom use. All parts are organized in a convenient case for easy storage.



Includes:

- Cart Bumper Magnets (2)
- Velcro® Hoop and Loop Bumpers (4)
- Dynamics Track Feet Screws (4)
- 1/4"-20 x 9/16" Tee Thumb Screws (4)
- 1/4"-20 x 9/16" Round Thumb Screws (6)
- 1/4"-20 x 3/8" Round Thumb Screws (6)
- 1/4"-20 x 7/32" Square Nuts (20)
- 1/4"-20 Nylon Thumb Nuts (6)
- 6-32 x 3/8" Nylon Thumb Screw (6)
- M5 x 0.8 x 20 mm Nylon Thumb Screw (4)
- 1/4"-20 x 3/8" Set Screws (4)
- Bumper Squares (8)
- Round Rubber Bumpers (4)

Order Information

Spares Kit - IDS ME-9823

Rubber Cord for IDS System (30m Spool)

ME-8986

This rubber cord is used with PASCO's Elastic Bumper, and also fits the Air Track Bumper Set with Holder.



Order Information

Rubber Cord for IDS System
(30m Spool) ME-8986

Use your Rotary Motion
Sensor to track cart motion.

Dynamics Track Mount

CI-6692



The Dynamics Track Mount (CI-6692) is used to mount the Rotary Motion Sensor to the Dynamics Track, allowing it to act as a high resolution, bi-directional Smart Pulley.

Includes:

- Bracket



Order Information

Dynamics Track Mount.....CI-6692

Track String Adapter

ME-6569



When the Track String Adapter is used in conjunction with the Dynamics Track Mount (CI-6692), the Track String Adapter allows a Rotary Motion Sensor to continuously monitor the Dynamics Cart's position. A loop of string wraps around the Rotary Motion Sensor pulley and the ball-bearing pulley, and then it attaches to the cart via a special clip (included).

Includes:

- Bracket with Pulley
- Cart String Clip
- Thread



Order Information

Track String AdapterME-6569

Force Sensor Track Bracket

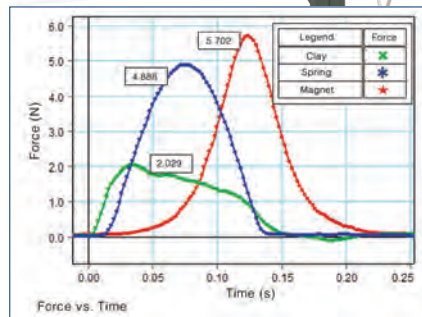
ME-6622

The Force Bracket with bumpers mounts the PASCO Force Sensor directly to a dynamics track. It includes 5 collision attachments for the Force Sensor and conveniently stores each attachment on the bracket itself.

Using any of these attachments, the bracket serves as an excellent support or target for collision studies using the Force Sensor.



Wireless Force Acceleration Sensor (PS-3202) in cart collisions with fixed spring bumper on Force Bracket



Force vs. Time data for a clay, spring, and magnet



Includes:

- Spring Bumpers (different spring constants) (2)
- Magnetic Bumper
- Rubber Bumper
- Clay Cup for Inelastic Collisions (clay included)
- #0 Phillips Head Screwdriver (to attach to Force Sensor)

Order Information

Force Sensor Track Bracket ME-6622

Bumper Accessory Set

ME-9884



This set of bumpers can be used with any PASCO Force Sensor to perform both elastic and inelastic collisions. The standard hook for each Force Sensor can be easily removed and replaced with any of these bumpers. Use a spring and a cup for elastic collisions. Combine two cups with clay to explore inelastic collisions.

Includes:

- Stiff Spring
- Light Spring
- Empty Cup (2)
- Modeling Clay



Order Information

Bumper Accessory Set ME-9884

Magnetic Bumper Set

ME-9885A

This set of magnetic bumpers can be used with any PASCO Force Sensor or Smart Cart to perform elastic collisions without any contact. The bumpers screw directly into the beam of the sensor. They can also be used with the Force Bracket.

Includes:

- Magnetic Bumper (2)



Order Information

Magnetic Bumper Set ME-9885A

Cart Adapter Accessory

ME-6743

The Cart Adapter Accessory allows the Motion Sensor and many other sensors to be mounted to a Dynamics Cart or a PAScar.



Mounting a Motion Sensor on a cart is ideal for the study of relative motion. The adjustment knob on the bracket allows the Motion Sensor to face any direction.

Includes:

- Two M5 thumb screws to attach to cart
- 1/4"-20 screw at center



Order Information

Cart Adapter Accessory ME-6743

Dynamics Systems Measurement

Smart Gate

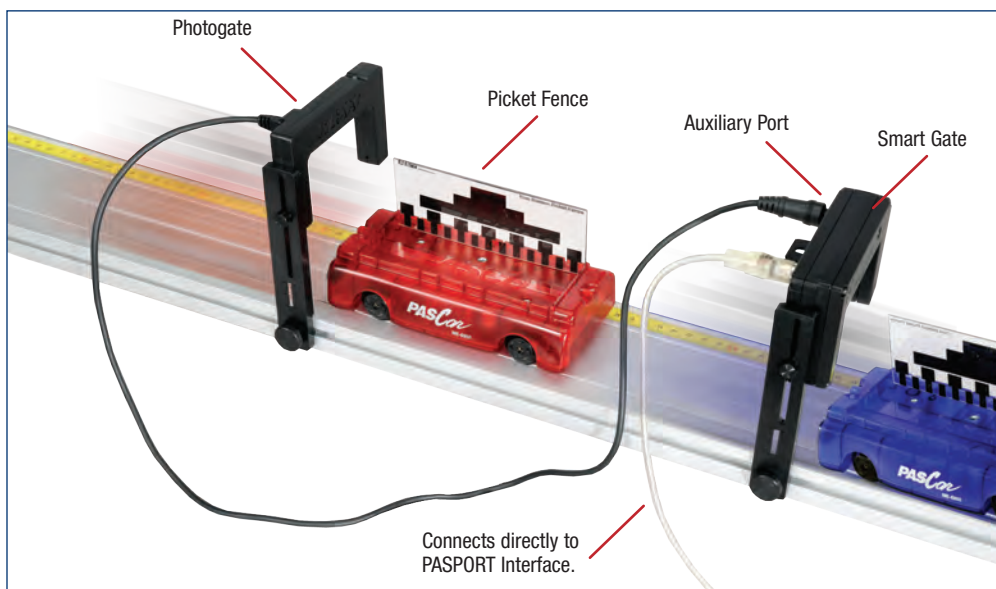
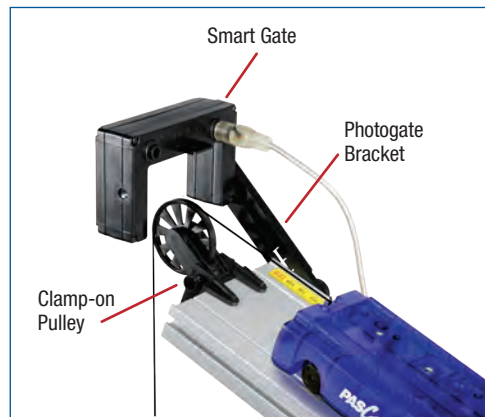
PS-2180

The Smart Gate connects directly to any PASPORT interface, and has an auxiliary port to daisy chain to an additional Photogate. Can be used with cart picket fence, clamp on super pulley, and flexible Photogate Tape.

Wireless Smart Gate

PS-3225

The Wireless Smart Gate has all the features of the Smart Gate (PS-2180), but it connects to your computing device via Bluetooth® or USB; it does not require an interface.



Smart Pulley

Use the Smart Gate and Photogate Bracket with the Clamp-on Super Pulley to create a “smart pulley.”

Double Infrared Beams

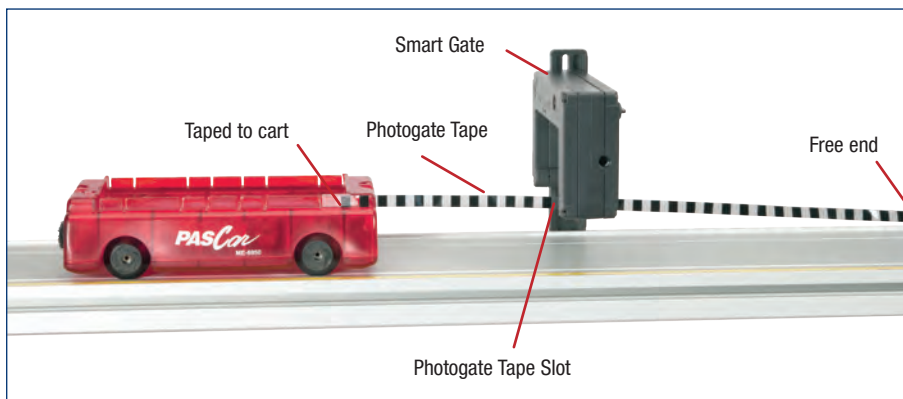
Using the double beam of the Smart Gate, the velocity of the cart can be determined accurately using the front edge of a single flag.

Auxiliary Port

A second photogate is connected to the Smart Gate Auxiliary Port so only one PASPORT port is required for two photogates.

Photogate Tape Slot

The Smart Gate has a special slot through which the Photogate Tape can be threaded. This creates an excellent way of continuously measuring the speed of the cart as it accelerates down the inclined track.



PS-2180 Includes:

- Smart Gate
- PASPORT Cable
- Interface Cord



PS-3225 Includes:

- Wireless Smart Gate
- USB Charge Cable



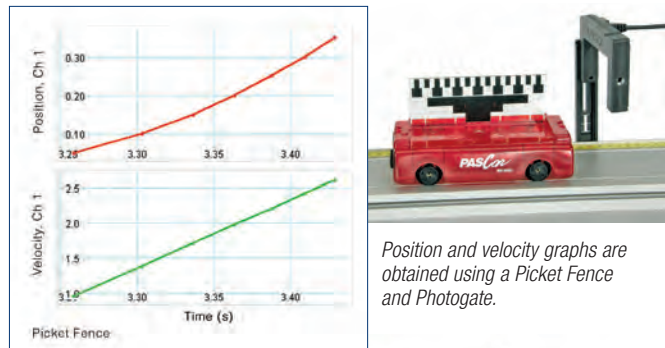
Order Information

Smart Gate	PS-2180	p. 26
Wireless Smart Gate	PS-3225	p. 50
Recommended:		
Photogate Head	ME-9498A	p. 27
Photogate Tape, High Resolution (30 m)	ME-6666	p. 27
Photogate Brackets (2 Pack) – IDS	ME-9806	p. 112
Cart Picket Fences (2 Pack) – IDS	ME-9804	p. 115
Super Pulley with Clamp	ME-9448B	p. 111

Photogates and Fences Dynamics System

ME-9471A

When used with the computer for data recording, display, and analysis, the photogate/pulley timing system can provide a wide range of time, speed, and velocity measurements. The photogates mount to the dynamics track using the provided brackets. The picket fences provided mount directly to the dynamics carts.



Position and velocity graphs are obtained using a Picket Fence and Photogate.

Includes:

- Photogate Heads (2)
- Photogate Brackets (2)
- Picket Fences (2)
- Super Pulley with attachment screw (attaches Super Pulley to Photogate)
- Pulley Mounting Rod

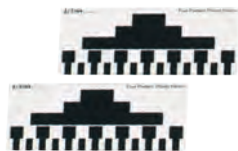


Order Information

Photogates and Fences Dynamics System	ME-9471A	
Individual Components:		
Photogate Head	ME-9498A	p. 27
Photogate Brackets (2 Pack) -- IDS	ME-9806	
Cart Picket Fences (2 Pack) -- IDS	ME-9804	
Super Pulley	ME-9450A	p. 141
Pulley Mounting Rod	SA-9242	p. 141
Required for use with PASPORT interfaces:		
PASPORT Digital Adapter	PS-2159	p. 48

Cart Picket Fences (2 Pack)

ME-9804



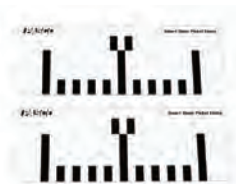
Order Information

Cart Picket Fences (2 Pack) – IDS	ME-9804
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Picket Fences (Smart Timer) (Set of 2)

ME-8933

See Smart Timer on pages 116-117



Order Information

Picket Fences (Smart Timer)	ME-8933
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Photogate Brackets (2 Pack) – IDS

ME-9806

- ▶ Attaches Photogates to PASCO Dynamics Tracks
- ▶ Easily Adjust Photogate Height

The Photogate Bracket allows the Photogate Head to be attached directly to PASCO dynamics tracks. This eliminates the need for separate photogate stands and allows the photogate height to be easily adjusted relative to the track. Includes two Photogate Brackets.



(Photogates not included.)

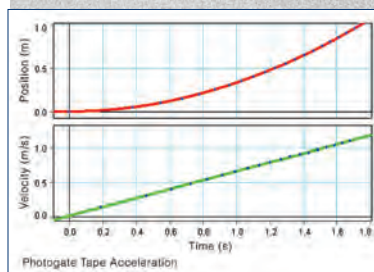
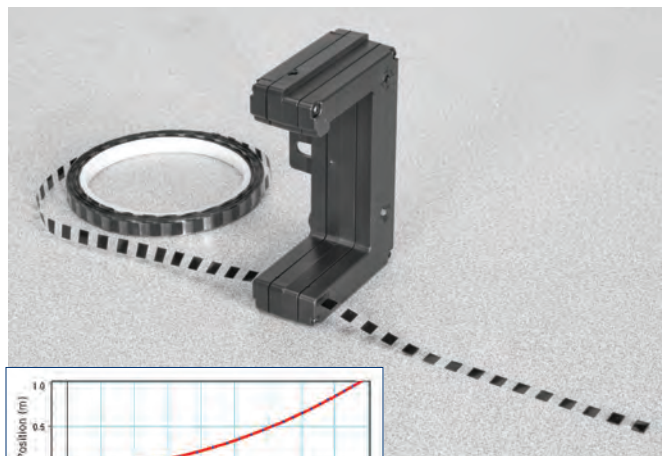
Order Information

Photogate Brackets (2 Pack) – IDS	ME-9806
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Photogate Tape, High Resolution (30 m)

ME-6666

Flexible Mylar picket fence tape can be cut to any length. Tape slides into a Smart Gate to more accurately measure the motion of a cart.



Photogate tape can be used as a picket fence "string" to continuously measure the motion of the cart.

Slide the photogate tape through the slot to measure position, velocity, and acceleration. The band spacing on the tape is 1 cm from edge to edge.

Order Information

Photogate Tape, High Resolution (30 m)	ME-6666	
Required:		
Smart Gate	PS-2180	p. 26
Wireless Smart Gate	PS-3225	p. 52

Timers

The Most Versatile Stand-Alone Timer Available

Smart Timer

ME-8930

- ▶ Portable timer for photogates and smart pulleys
- ▶ Measures time, speed and acceleration
- ▶ Counter for G-M Tubes
- ▶ Crystal-controlled 0.01% accuracy

The ME-8930 Smart Timer works with all PASCO timing devices:

- ▶ Accessory Photogate
- ▶ Photogate/Pulley System
- ▶ Time-of-Flight Accessory
- ▶ Freefall Adapter
- ▶ Laser Switch
- ▶ G-M Tube

Measure Time:

- ▶ One Gate: Returns time from leading edge to leading edge
- ▶ Fence: Returns 10 time values
- ▶ Two Gates: Returns time between two gates
- ▶ Pendulum: Measures pendulum period
- ▶ Stopwatch: Returns time between pressing Start/Stop button

Measure Speed:

- ▶ One Gate: Single object speed using picket fence
- ▶ Collision: Initial and final speeds for one or two carts
- ▶ Pulley: Angular speed

Measure Acceleration:

- ▶ One Gate: Direct measurement of acceleration using picket fence
- ▶ Linear Pulley: Acceleration of string
- ▶ Angular Pulley
- ▶ Two Gates: Object's average acceleration between two photogates

Measure Counts:

- ▶ Three timing intervals
- ▶ Manual mode counts until Stop is pressed
- ▶ Up to 5,000 counts/second
- ▶ Up to 9,999,999 total counts

2-line, 16-character Alphanumeric LCD

- ▶ Top Line: Measurement Description; Bottom Line: Numerical Values



It's as easy as 1-2-3.

1. Measurement

Press this button to select the quantity to be measured: "Time," "Speed," "Accel," "Count" or "Test" will appear on the display.

2. Mode

Press this button to select the type of experimental setup. Each mode is shown in words on the display.

3. Start/Stop

Press Start. The Smart Timer "beeps," and waits for an event to occur. After the event, the Smart Timer displays a result.

Features:

- ▶ **Works with Two Photogates**
- ▶ **More Than Just a Timer:** Measures speed and acceleration as well as time.
- ▶ **Quick Setup:** Turn on the switch, plug in the photogates, and it's ready to use.
- ▶ **Portability or Plug-in:** The battery-operated (four "AA"s) Smart Timer can be used outside the classroom away from power outlets. It can also be operated on the 9 VAC adapter (included).
- ▶ **Calculation Lock-out Switch:** A switch inside the battery compartment disables the speed and acceleration modes. Timing modes are unaffected, and students are required to do their own calculations.

Specifications:

Resolution: 100 μ s

Accuracy: 0.01% of full range of the measured time

Display: 2-line, 16-character, alphanumeric LCD

Inputs: Two 1/4" stereo phone jacks on side panel— TTL compatible

Power Requirements: Four "AA" batteries (not included) or AC adapter (9 VDC, 500 mA) included



Typical Experiments

- ▶ Acceleration Due to Gravity*
- ▶ Newton's Second Law*
- ▶ Conservation of Momentum in Collisions*
- ▶ Rotational Inertia of a Disk & Ring*
- ▶ Acceleration Down an Incline
- ▶ Simple Harmonic Oscillator
- ▶ Oscillations on an Incline
- ▶ Springs in Series and Parallel
- ▶ Projectile Motion Using Photogates
- ▶ Time-of-Flight and Initial Velocity
- ▶ Determining the Acceleration Due to Gravity
- ▶ Counting Radiation with the G-M Tube

*Experiments require accessories listed on pages 21 and 27.



To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Two Photogate Ports



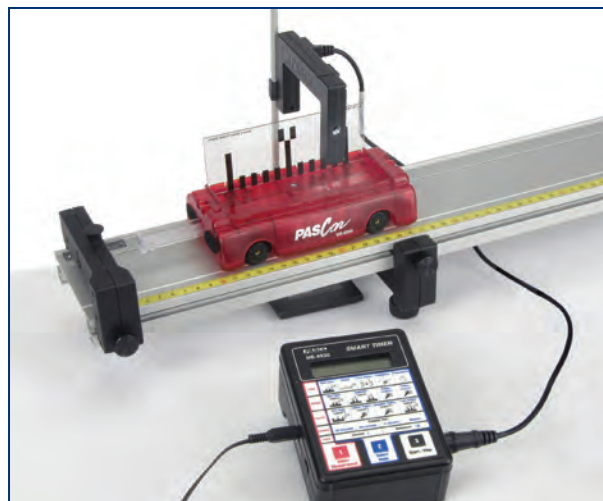
Durable Positive-click Buttons



The microprocessor-based PASCO Smart Timer is the most versatile way to make time, speed, acceleration, and count measurements.



Speed of projectile—In Time: Two Gates mode; determine the speed of a ball fired by a Projectile Launcher through two photogates.



Speed of object through one gate—In Time: One Gate mode; timing begins when the photogate beam is first blocked and continues until the beam is blocked again. Use the fence supplied with the Smart Timer.



Speed before and after collision—In Speed: Collision mode; use two carts and two photogates with a single Smart Timer to measure initial and final speeds of both carts.



Rotary motion—In Acceleration: Linear Pulley mode; the Smart Timer measures the acceleration of the string over the Smart Pulley.

Includes:

- Smart Timer
- Picket Fences (2)
- 9 VAC Adapter
- Lab Manual

Order Information

Smart Timer.....	ME-8930	
Recommended:		
Accessory Photogate	ME-9204B	p. 21
Picket Fences (Smart Timer).....	ME-8933	
Freefall Adapter	ME-9207B	
Photogate & Pulley System	ME-6838A	p. 21
Time-of-Flight Accessory	ME-6810A	p. 21
G-M Tube/Power Supply	SN-7927A	p. 21
Phone Jack Extender Cable	PI-8117	p. 21

Smart Timer Photogate System

ME-8932

The PASCO Smart Timer is among the most versatile and affordable measurement tools available to physics educators. This system includes a PASCO Smart Timer and two Photogates for measuring time, speed, acceleration, and count.

Includes:

- Accessory Photogate (2) ME-9204B
- Super Pulley ME-9450A
- Smart Timer ME-8930
- Picket Fences (Smart Timer) ME-8933
- 9 VAC Adapter and Lab Manual (not shown)



Order Information

Smart Timer	
Photogate System.....	ME-8932

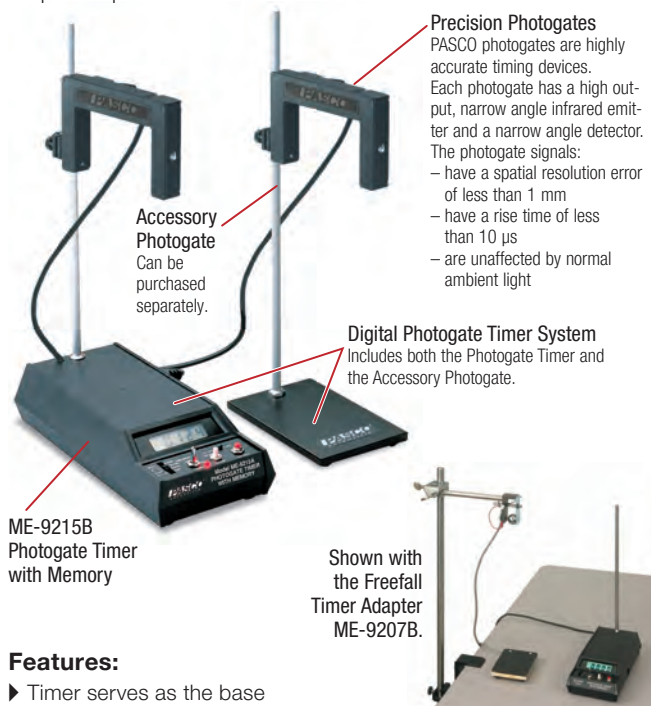
Timers

Digital Photogate Timer System

ME-9403A

- ▶ High accuracy and resolution
- ▶ Four timing modes: gate, pulse, pendulum, and manual stopwatch
- ▶ Built-in memory
- ▶ Two Photogates for measuring time between gates

PASCO Photogates and Digital Timers are used in thousands of physics labs throughout the world because they are rugged and simple to operate.



Features:

- ▶ Timer serves as the base
- ▶ 0.1 ms resolution and 0.01% accuracy
- ▶ Memory Function allows two measurements to be made in rapid succession, such as pre-collision and post-collision velocities
- ▶ Two Photogates for measuring elapsed time between gate interferences
- ▶ Simply turn it on and begin collecting measurements
- ▶ Powered by 4 C batteries (not included) or the 9V AC adapter (included)
- ▶ Manual includes ten ready-to-use experiments

Specifications:

Modes: Gate, pulse, pendulum, manual stopwatch**Resolution:** 0.1 ms (max time 19.9999 s)**Accuracy:** 0.05% of full range of the measured time ± 1 digit**Display:** 5-1/2 digit, 10 mm high LCD**Memory:** Preserves displayed time while new time is measured**Photogate:** 6.5 cm wide; fully adjustable swivel mount; LED trigger indicator; fall time < 10 ns; spacial resolution < 1 mm**Inputs:** Accessory Photogates, or TTL-compatible signals; one photogate jack and a 9-V AC adapter jack (or four "C" size batteries) on back panel

Order Information

Digital Photogate Timer System	ME-9403A
Photogate Timer	ME-9215B
Accessory Photogate	ME-9204B



Compatible with these PASCO products:

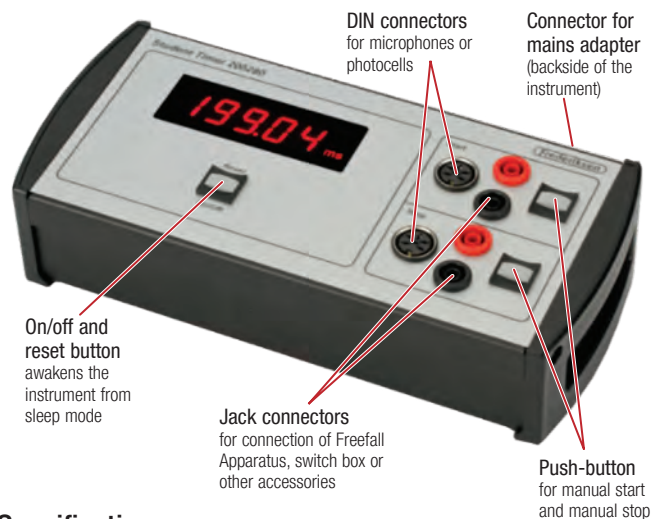
- Time-of-Flight Accessory
- Freefall Timer
- Laser Switch

Freefall Apparatus
Student Timer

SF-7275

- ▶ Use with Freefall Apparatus (SF-7274)
- ▶ Also has manual start/stop
- ▶ Battery-powered

This student timer is designed to perform time measurements using photo cells, microphones, freefall equipment and other mechanical and electronic switches. The timer function can also be activated manually. The student timer is supplied with batteries and a power adapter. The instrument turns itself off automatically after 5 minutes without any activity, both when battery powered and when powered with the power adapter.



Specifications:

Display: 5-digit floating point LED**Resolution:** 0.01 ms**Max. time:** 99999 s

Order Information

Student Timer	SF-7275
---------------------	---------

Tape Timer

ME-9283

- ▶ Crystal-controlled
- ▶ Two frequencies (10 Hz and 40 Hz)
- ▶ Easy-to-read dots

Provides students with a visual demonstration of speed and acceleration. A moving object pulls a paper tape through the timer. The timer prints dots on the tape at equal time intervals. The result is a series of dots on the paper tape, representing the position of the object as a function of time.

From the dots on the tape, the distance traveled can be measured, and the average speed for each time interval can be calculated. Plotting position versus time enables students to determine the average speed. Plotting the average speed for each time interval versus time enables acceleration to be determined.

The paper tape can be attached to air track carts, dynamics carts, falling masses or other objects.

Features:

- ▶ **Two Crystal-controlled, Calibrated Frequencies:** (10 Hz and 40 Hz), accurate to 0.1%. The 40-Hz frequency is ideal for freefall experiments. The slower 10-Hz frequency is best for most dynamics track experiments.

- ▶ **Includes an Internal 9-V Battery, or Use an Optional External 9-V AC Adapter/Power Supply:** A single battery can last for up to a year's worth of normal experiments.

- ▶ **Low Mass, Small-pin Printing Head:** Driven by short millisecond pulses, produces sharp, round dots without smearing.

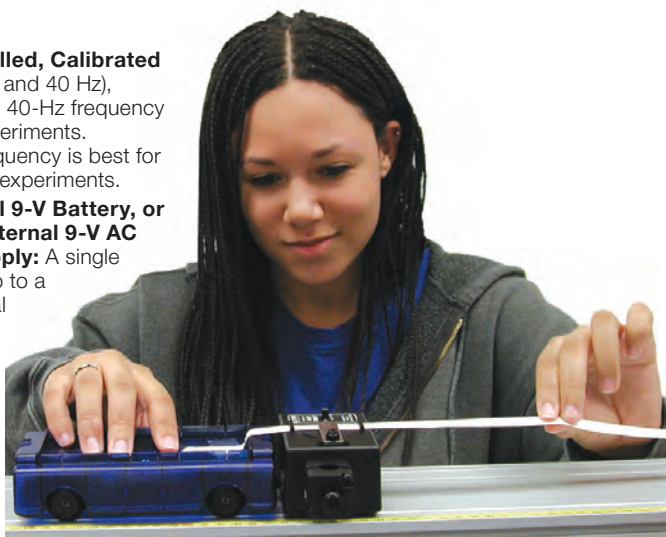
- ▶ **Plain Paper:** Print on 12.5 mm (1/2 inch) wide, plain paper supplied in 150-meter (500 feet) rolls.

- ▶ **Carbon Paper Discs:** Used for printing. The adjustable disc holder allows the printing point to be adjusted, giving a long life to the discs.

- ▶ **Rod Clamp:** Allows the Tape Timer to be mounted on a standard lab stand rod so that the paper path is either parallel or perpendicular to the rod. Rod sizes between 13 mm (1/2 inch) and 9 mm (3/8 inch) are accommodated.

Includes:

- Roll of paper
- Carbon paper discs
- Battery
- Manual (not shown)



PASCO Stopwatch

ME-1234

- ▶ No alarm or clock
- ▶ Memory for stored event times
- ▶ Uses one AA battery
- ▶ Durable buttons

Are you tired of annoying stopwatch alarms going off all day? Are your students stuck in the clock mode and can't get their stopwatch back into the timing mode? Does your stopwatch stop working after changing that little watch battery? The PASCO Stopwatch solves all these problems.

This stopwatch was designed specifically for science timing. The modes of operation are intuitive and complete instructions are included. The buttons are built to last and it uses a single long-lasting AA battery, which is less expensive than a watch battery (and easier to install).



The PASCO Stopwatch fits comfortably in your hand.



The EVENT/RECALL button allows you to view the last time, in case students forget to write down their data. The EVENT/RECALL button is also used to store and recall up to nine event times. For example, record a series of events, such as times at which sandbags were dropped along the gym floor.

Specifications:

LED Display: Visible indoors and outdoors

Two Display Modes: MM:SS.SS (01:25.34) or Decimal Sec (85.34 s)

Precision: 0.01 sec up to 59:59.99 (MM:SS.SS) or 3599.99 s Then 1 sec to 99:59:59 (HH:MM:SS) or 359999 s

Max Number of Event Times: Nine

Auto-off: After one hour idle Can Be Used with a Lanyard (not included)

Can be used: with a lanyard (not included)

Includes: One AA battery and instruction sheet

Order Information

PASCO Stopwatch.....ME-1234
PASCO Stopwatch, 10-pack.....ME-1235

Order Information

Tape Timer..... ME-9283
Recommended:
AC Adapter (9 V, 500mA) 540-007
Tape Timer Supplies..... ME-9284
Includes five rolls of paper (150 m each) and 10 carbon discs.

Air Track

2.0 m Air Track

SF-9214

Variable Output
Air Supply

SF-9216

- ▶ Nearly frictionless linear motion
- ▶ Two meters long
- ▶ Complete accessories included

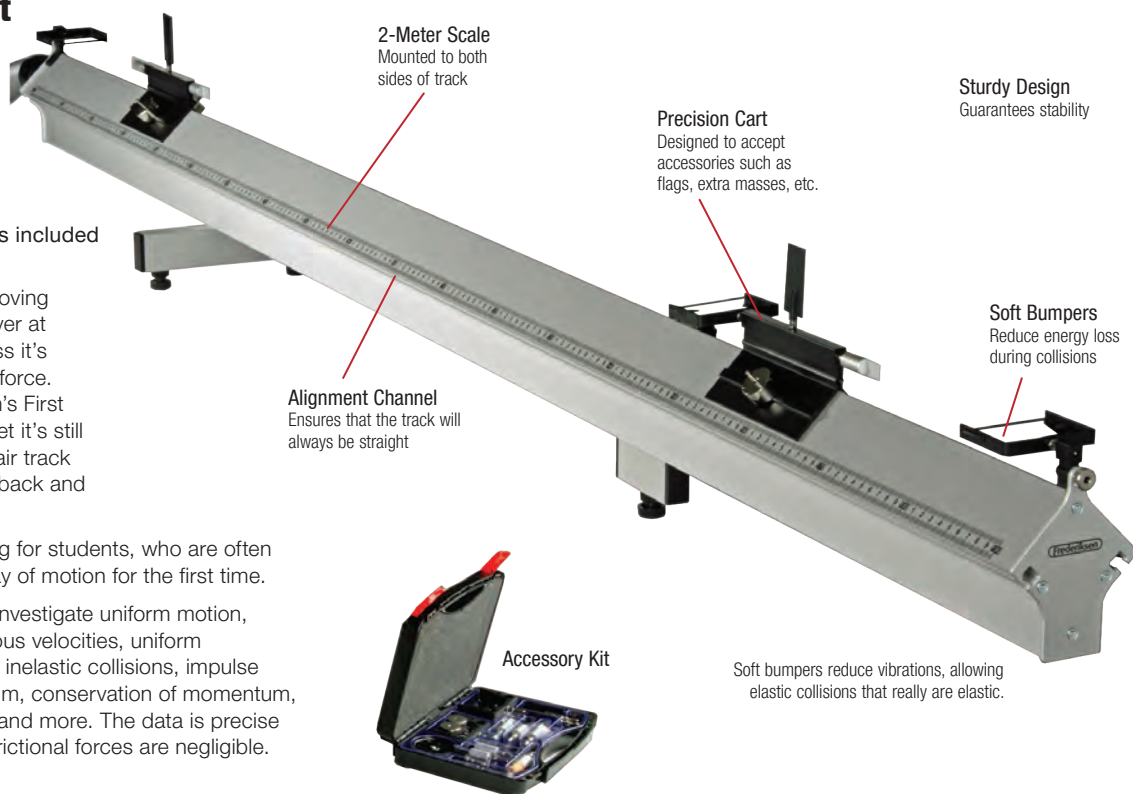
It's simple physics—a moving object will continue forever at a constant velocity unless it's acted on by an external force. To the physicist, Newton's First Law is second nature. Yet it's still fascinating to watch an air track glider moving endlessly back and forth on an air track.

It's even more fascinating for students, who are often seeing this simple display of motion for the first time.

Add a timing system to investigate uniform motion, average and instantaneous velocities, uniform acceleration, elastic and inelastic collisions, impulse and change in momentum, conservation of momentum, conservation of energy, and more. The data is precise and unambiguous and frictional forces are negligible.

Compared to other air tracks, the PASCO Air Track is:

- ▶ **Longer:** The full 2-meter length provides more room for experimenting (yet it still fits on a standard lab table).
- ▶ **Straighter:** Guaranteed straight to within 0.04 mm over its entire 2-meter length. If your air track should ever become misaligned, return it to us and we will realign it for free.
- ▶ **Tougher:** The track is a large square aluminum extrusion with 3 mm thick walls that are further strengthened by a supporting U-channel. This construction preserves straightness and allows for accurate realignment.
- ▶ **Quieter:** When using PASCO's Air Supply (SF-9216 Sold Separately) this system is exceptionally quiet (allows the air to be adjusted), and the variable flow to the perfect amount for each experiment. (Too little air causes friction; too much air causes energy loss due to glider "flutter.")
- ▶ **Versatile:** The PASCO Air Track comes with a large set of accessories
- ▶ **Precision Cart:** Designed to easily accept accessories such as flags, extra masses, etc.
- ▶ **2-Meter Scale:** Mounted to both sides of track.
- ▶ **Soft Bumpers:** Reduce energy loss during collisions.
- ▶ **Alignment Channel:** Ensures that the track will always be straight.



2-Meter Scale
Mounted to both
sides of track

Precision Cart
Designed to accept
accessories such as
flags, extra masses, etc.

Sturdy Design
Guarantees stability

Soft Bumpers
Reduce energy loss
during collisions

Alignment Channel
Ensures that the track will
always be straight

Accessory Kit

Soft bumpers reduce vibrations, allowing
elastic collisions that really are elastic.

Specifications:

Length: 2 m (working distance 1.9 m)

Base: Three-point with bilateral leveling screws

Millimeter Scales: 2 meters long on each side

Includes:

- Gliders (2): 13 cm long; 170 g; with rubber-band bumpers
- Glider Flags (2): 25 mm
- Glider Masses (4): 50 g
- Glider Bumper (3)
- Inelastic Collision Kit:
Needle with wax-filled receptacle
- Constant Acceleration Kit:
Ball-bearing pulley, glider hook,
mass hanger (2 g) and
five acceleration masses:
two 1 g; one 2 g; one 5 g; one 10 g
- Storage Case



Order Information

2.0 m Air Track SF-9214

Required:

Variable Output Air Supply..... SF-9216

Recommended:

Replacement Parts..... see opposite page

Air Track Accessory Kit

SF-9295



A set of accessories comes with every PASCO Air Track. All that's needed is a timing system. The pieces of the set may be ordered separately.

Order Information

Air Track Accessory Kit.....	SF-9295
Recommended:	
Glider Kit.....	SF-9224
Air Supply Hose for	
Air Track (2m)	SF-9298
T-Adapter and Hose –	
Air Track	SF-9217

Variable Output Air Supply

SF-9216



The PASCO Air Supply is exceptionally quiet. Its variable output lets students match the air flow to the experiment. A 2-meter hose is included. By adding the T-Adapter and Hose (SF-9217), the Air Supply can operate two PASCO Air Tracks at the same time.

Note: This Air Supply produces 36 cfm at 0.122 psi for use with the Precision Air Track SF-9214. If used with another track, the total area of the air flow holes must be greater than 2.6 cm², or the supply may overheat.

Order Information

Variable Output Air Supply.....	SF-9216
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Rubber Cord for IDS System (30m Spool)

ME-8986



This rubber cord is used with PASCO's Elastic Bumper, and also fits the Air Track Bumper Set With Holder.

Order Information

Rubber Cord for IDS System (30m Spool).....	ME-8986
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Air Track Accessories and Replacement Parts

The Air Track includes accessories for standard air track experiments, from simple acceleration to elastic and inelastic collisions. To add more advanced experiments, a variety of additional accessories are available.

Included in the SF-9295 Kit

(Each item may be ordered separately. The number in parentheses indicates how many of each item is included in the Accessory Kit.)

Mass/Hanger Set (1)

SF-6300



Bumper Set with Holder (3)

SF-6301



Bumper Set Air Track (3)

SF-6302



Inelastic Collision Needle (1)

SF-6303



Wax Receptacle (1)

SF-6304



Glider Hook (1)

SF-6305



Glider Mass (4)

SF-6307



Ball Bearing Pulley (1)

SF-6308



Photogate Flags (25 mm) (2)

SF-6311



Not Included in the SF-9295 Kit

(Must be ordered separately.)

Glider

SF-6306



Fixed End Stop

SF-6313



Adjustable End Stop

SF-6309



Glider Kit

(see photo below)
SF-9224

Air Supply Hose (2m)

SF-9298



Additional Glider Kit

SF-9224



Includes:

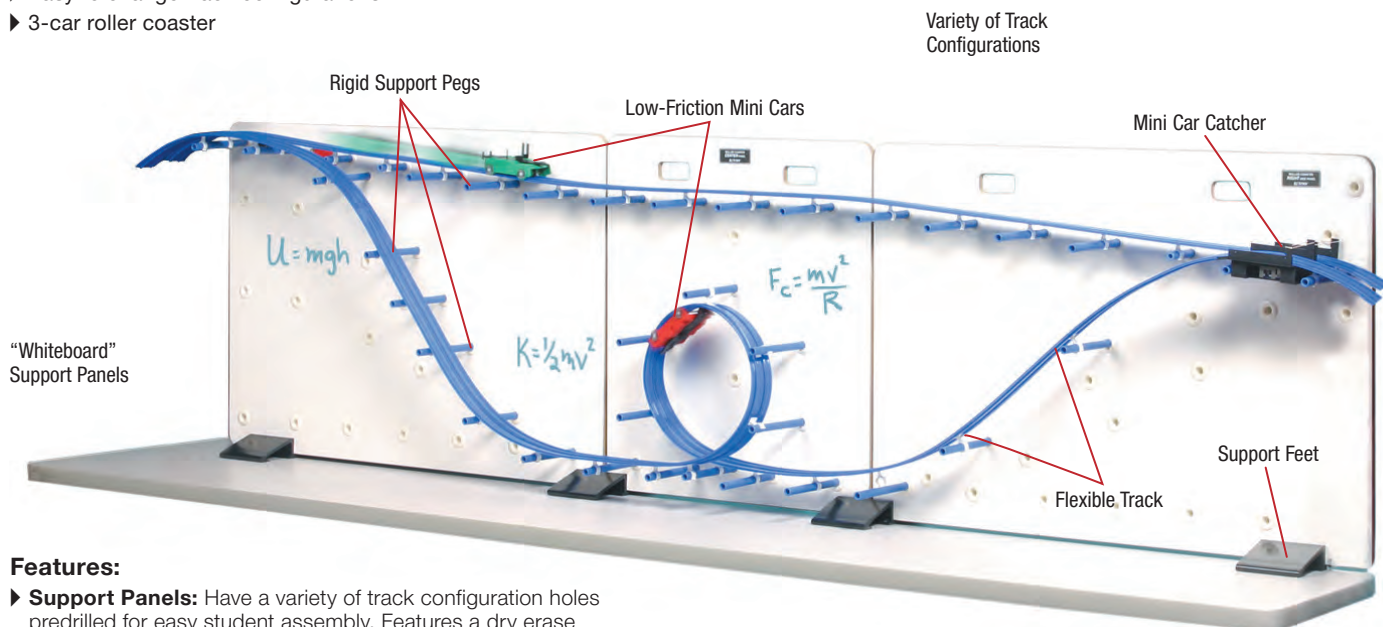
- Glider
- 50 g Masses (2)
- Bumper with Holder
- Bumper Blade

Roller Coaster

Roller Coaster Complete System

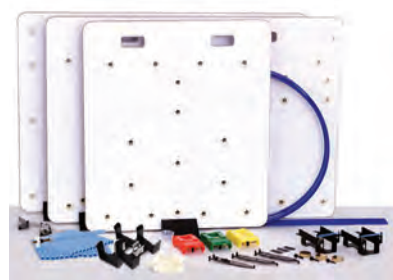
ME-9812

- ▶ Quantitative studies of Energy Conservation
- ▶ Easy to change track configurations
- ▶ 3-car roller coaster



Features:

- ▶ **Support Panels:** Have a variety of track configuration holes predrilled for easy student assembly. Features a dry erase surface so calculations can be performed at the point of interest on the track.
- ▶ **Mini Cars:** Have low-friction ball bearings and ABS construction to withstand repeated impacts. One red, one yellow and one green Mini Car included. Each car includes a slot for a supplied photogate flag, cup/mass holder and cup. The body of the car extends just far enough below the wheels to protect them should the car leave the track.
 - ▶ The Roller Coaster's Mini Cars are low friction, yet rugged; mass can be added to the cars on top or in the ballast position.
 - ▶ Bumpers mount on Mini Cars to allow rubber band or clay collisions. Also used to couple Mini Cars into a train.
- ▶ **Ballast Mass:** Can be added to the mass tray of a Mini Car or hidden under a Mini Car to increase the energy without changing the car's appearance.
- ▶ **Flexible track:** Guides carts on their path, yet is flexible enough to form loops and hills, or can be rolled out flat on a table. Easily attaches to the support pegs using the twist-on track clips. Long pegs allow two tracks side-by-side for comparison.
- ▶ **Probeware Compatible:** Threaded support pegs and Mini Car photogate flags allow photogates to be used at many positions around the track to measure velocity and acceleration.



Includes:

- Support panel (3 sections)
- Support feet (4)
- Flexible track (9.1 meters)
- Mini Cars (3)
- Support pegs for track (43)
- Photogate support pegs (4)
- Track clips (50)
- Mini Car catcher (2)
- Mini Car starter bracket (2)
- Mini Car collision accessory (3)
- Mini Car photogate flags (3)
- Water cup (3)
- Mini Car ballast mass (3)
- Photogate brackets (4)
- Track couplers (2)

Applications:

- ▶ **Conservation of Energy:** Release the Mini Car and measure its velocity and height at several points along the track. Use these values to calculate total energy of the Mini Car. Frictional losses are less than 5%.
- ▶ **Constant Acceleration:** Several straight inclined sections can be used to measure and demonstrate constantly accelerated motion.
- ▶ **Projectile Motion/Conservation of Energy:** Use the initial height of the Mini Car to determine its speed as it flies off the end of the track. Using this speed and height above the ground when it leaves the track, predict where the Mini Car will land.
- ▶ **Multi-car Train:** Mini Cars can be coupled to form a train and the velocity of each car can be measured with a photogate and a Smart Timer. The velocities are not the same.
- ▶ **Brachistochrone:** A Mini Car traveling between two points along a brachistochrone path takes less time compared to the straight line path.

Order Information

Roller Coaster Complete System.....	ME-9812	
Recommended:		
Photogate Head	ME-9498A	p. 27
Photogate Brackets (2 Pack) – IDS.....	ME-9806	p. 115
Spares Kit – Roller Coaster	ME-9815	
Mini Cars (Set of 3)	ME-9813	
Roller Coaster Track.....	ME-9814	
Smart Timer.....	ME-8930	p. 116

Loop-the-Loop

SE-7591

How high do you have to start the ball to make it go over the loop? Students use Conservation of Energy to determine how much potential energy is needed to have enough speed to make it around the loop.

Specifications:

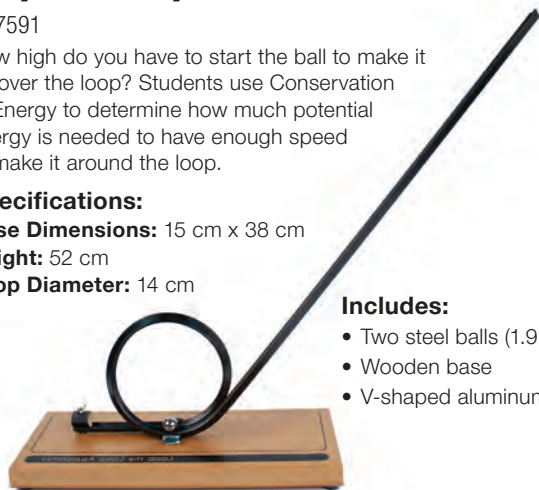
Base Dimensions: 15 cm x 38 cm

Height: 52 cm

Loop Diameter: 14 cm

Includes:

- Two steel balls (1.9 cm dia.)
- Wooden base
- V-shaped aluminum track

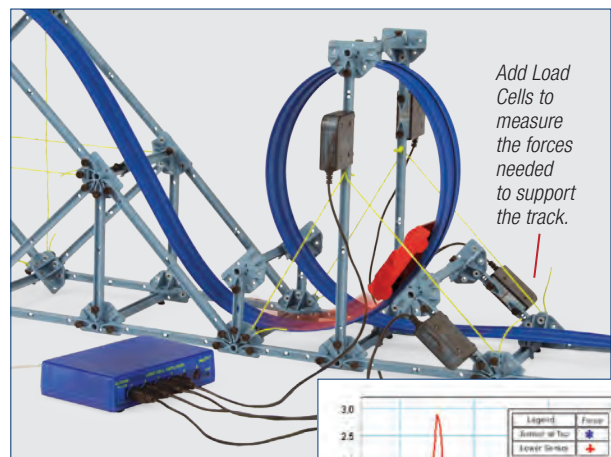


Order Information

Loop-the-Loop.....SE-7591

Design your own roller coaster with PASCO's Structures System.

PASCO's Structures System allows students to design and build their own roller coaster for detailed studies of conservation of energy and centripetal force. The flexible track is perfect for building hills, valleys and even a loop! Car with low-friction, ball-bearing wheels minimizes energy losses. Measure the speed of the car using photogates or a Motion Sensor.



Add a loop to your roller coaster

Investigate the effect of changing the size and shape.

Graph shows support forces exerted on the track as the car goes up and over the loop.

Order Information

Large Structures Set..... ME-7003 p. 150-151
 Shown in use with:
 Load Cell and Amplifier Set..... PS-2199 p. 31
 Accessory Photogate ME-9204B p. 21

Amusement Park Physics Kit

ME-9426A

- ▶ Extend your lab into the "real world"
- ▶ Complete kit for 15 students
- ▶ Developed in conjunction with AAPT*

They might lose their notes. They might even lose their nerve. But in one day at an amusement park, students will also gain a real "gut-level" appreciation for Newton's Laws. Using this kit, students don't observe a dynamics cart. They are the dynamics cart. This is the only kit that is:

- ▶ Approved by the safety officers of major amusement parks across the USA.
- ▶ Student-tested in amusement parks by hundreds of schools.
- ▶ Teacher-tested in hundreds of Amusement Park Physics Workshops.
- ▶ Made with a metal coil spring for the Vertical Accelerometer (far more accurate than the commonly used rubber band).



Students experience the thrill of scientific investigation.

Photo courtesy of Paramount's Great America.

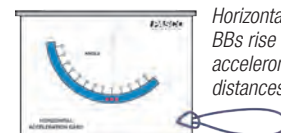
Includes:

- Brass Hanging Weights (19)
- Springs* $k = 3 \text{ N/m}$ (16)
- Plastic Tubing (2.5 m)
- Plastic Tubes, 30 cm long (16)
- Plastic Tube End Caps (32)
- Bumper Stickers (16)
- Horizontal Accelerometer
- Cards (16)
- Push Pins (5)
- No. 3 Paper Clips (17)
- Cotton String
- Metal Balls (60)
- Straws (16)
- Wire Ties
- Vinyl Tape
- Rubber Bands #117 (32)
- Rubber Bands #19 (6)
- Plastic Storage Bags (16)
- Instruction Manual

*Additional accelerometer springs may be purchased separately. See order information below.



Vertical Accelerometer: The stretch of the spring measures the vertical acceleration in "g's."



Horizontal Accelerometer: The angle to which the BBs rise measures the horizontal acceleration. This accelerometer doubles as a sextant to measure distances by triangulation.

Order Information

Amusement Park Physics Kit (15 Pack)ME-9426A
 Recommended:
 Accelerometer Springs (16 Pack)ME-8734
 Scissors, pliers, masking tape, clear plastic tape

Hovercraft

Hovercraft

ME-9838

- ▶ Students experience Newton's Laws
- ▶ Durable nylon skirt
- ▶ Rubber bumper
- ▶ Optional cordless air supply

Our Hovercraft follows the classic design, with a rugged nylon skirt attached around a 1.2 m wood platform. Students can easily ride on the Hovercraft to experience firsthand the kinematics of frictionless motion.

How It Works

The nylon skirt is stretched around the wood platform and tightened using a steel wire.

The center of the skirt

is attached to the bottom of the wood platform. A custom rubber bumper is placed around the circumference of the wood platform. The bumper helps secure the skirt and also provides a soft cushion around the edge of the Hovercraft. A high-volume air source is used to force air through the platform and into the skirt. After sitting on the platform, the air source is turned on and the skirt inflates. Small holes in the skirt allow the air to escape, while providing the higher pressure needed to lift the rider. A built-in level helps students center their weight on the Hovercraft.

A Cordless Air Source (SE-8806) is orderable separately (below). In addition, most leaf blowers provide enough air flow to support the Hovercraft.

The PASCO Hovercraft is capable of supporting up to 300 lbs and comes completely assembled.



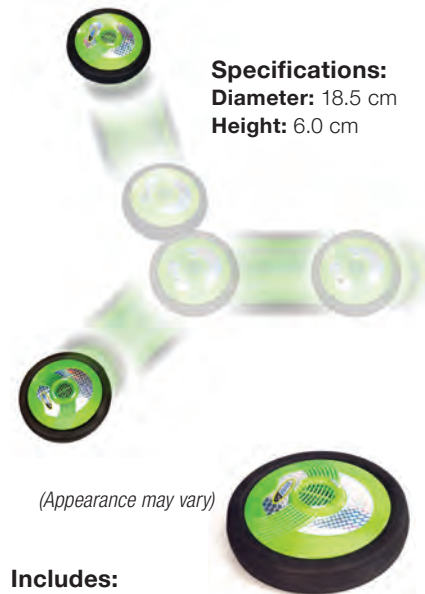
*Air source
not included.*

Hover Puck

SE-7335B

- ▶ Hovers on a cushion of air
- ▶ Ideal for inertia activities

The Hover Puck glides on a self-generated cushion of air across any smooth surface, including low-pile carpet. The rubber bumper provides protection for the puck and other objects during collisions. Each puck includes four "AA" batteries.



Specifications:
Diameter: 18.5 cm
Height: 6.0 cm

(Appearance may vary)

Includes:

- Hover Puck
- Four "AA" Batteries

Order Information

Hover Puck SE-7335B

Recommended:

PASPORT

Motion Sensor PS-2103A p. 28

Motion Sensor II CI-6742A p. 20

Wireless Motion

Sensor PS-3219 p. 51

Cordless Air Source

SE-8806



Includes:

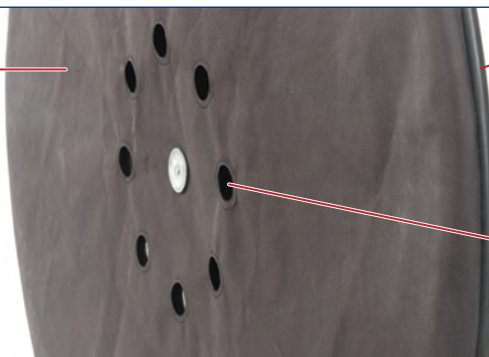
- Rechargeable Battery
- Charging Adapter

Order Information

Cordless Air Source SE-8806

Double-Reinforced Nylon Skirt

stretched around the wood platform and tightened using a steel wire prevents failure under high pressure loads.



Custom Rubber Bumper is stretched securely around the circumference of the wood platform.

Air Holes allow air to escape, providing high pressure to lift the student.

Includes:

- Wood platform (1.2 m diameter, 1.9 cm thick)
- Nylon skirt with mounting hardware
- Rubber bumper
- Liquid level
- Connection hose for air source



Order Information

Hovercraft ME-9838

Recommended:

Cordless Air Source SE-8806

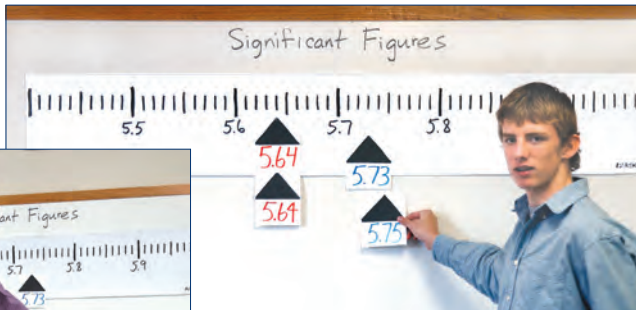
Significant Figures Set

ME-9850

- ▶ Connects measurements to Significant Figures
- ▶ Includes materials for one student group
- ▶ Detailed activity manual

The series of activities included in the Significant Figures Set emphasize the connection between measurements and significant figures. Students work through a number of situations in which they experience the concepts of accuracy and precision. Through these activities, students learn the importance of the measuring tool and its role in the uncertainty of measurements. For each activity, student groups are asked to place their measurements and/or calculations along a demonstration number line. The groups can then share their results with the entire class during discussions and presentations.

The Number Line and Data Pointers are laminated for use with dry erase markers.



The Ball Drop activity gives students experience with accuracy and precision.



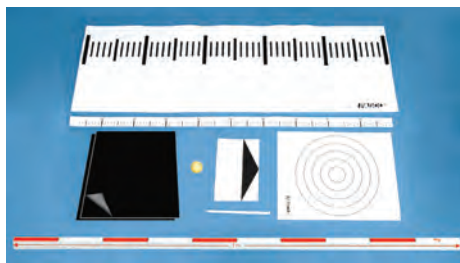
The Four-Scale Meter Stick is an important part of the Significant Figures Kit as it includes four scales of varying precision.

Perform These Experiments:

- ▶ **Ball Drop:** Students toss small balls on a bulls-eye to discover the relationship between technique and measurements. In addition, the concepts of accuracy and precision are explored.
- ▶ **“Forced Error” Measurements:** Students use a meter stick that has inaccurate markings to take measurements to reinforce that precise measurements are not always accurate.
- ▶ **Mass/Length Measurements:** Students use a balance or Four-Scale Meter Stick with imprecise scales to limit the certainty in their measurements.
- ▶ **Area/Volume/Density Calculations:** Students use a variety of measuring devices to calculate the area, volume, and density of various objects.

Includes:

- Yellow Nylon Ball
- Paper Bullseye (2)
- Carbon Paper (100 Sheets)
- Four Scale Meter Stick
- Number Line
- Data Pointer
- Meter Stick Label
- Balance Label



Order Information

Significant Figures Set.....ME-9850

Discover Pi Set (10 pack)

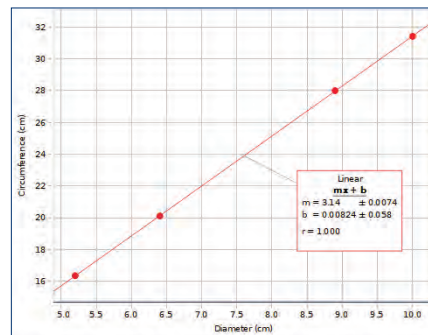
ME-6819A

- ▶ Students discover the meaning of Pi
- ▶ Pi circles stack together for easy storage



The student reads the circumference directly from the transparent tape wrapped around the pi circle.

The Discover Pi Set allows students to derive the meaning of pi directly from their measurements. This activity transforms pi from a constant with unknown origin to a fundamental characteristic of all circular objects.



The slope of the circumference vs. diameter graph is equal to π

Includes:

- Each pack includes 4 Pi Circles: 5.2, 6.4, 8.9, 10.0 cm diameter
- Transparent Measuring Tape

Order Information

Discover Pi Set (10 pack) ME-6819A

Gravity & Freefall

Discover Freefall System

ME-9889

- Determine g
- Investigate air resistance dependence on mass, volume, cross-sectional area

PASCO's Discover Freefall System can be used to drop almost any small object by attaching a small steel washer with a small adhesive pad (both are included in the system). Using an electric switch, timing is started automatically, just as the object is dropped. And the Time-of-Flight Pad stops timing when the object strikes it.

Students can investigate the effect of air resistance on acceleration. In addition, students can drop objects of the same size but different mass to study how object mass affects terminal velocity during freefall. The drop box has a magnetic mount for attaching to metal frames in ceilings.

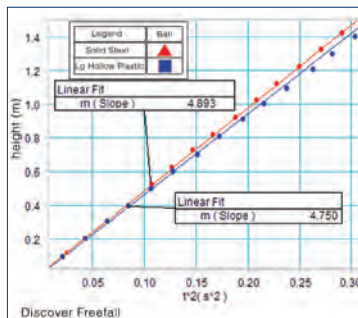


Set includes six different balls

This system can also accept the Target Accessory, ME-6854, to perform the shoot-the-target demonstration. See page 131.

**Includes:**

- Drop box
- Control cable
- Control box
- AC adapter
- Time-of-Flight receptor pad
- Timer Switch
- Release washers (10)
- Release labels for attaching washers to object (50)
- Small nylon ball
- Large plastic ball
- Golf ball
- Hollow golf ball
- 1" steel ball
- 5/8" steel ball



When the switch is pressed, the ball is dropped and the time of fall is measured for various balls. The graph shows height vs time-squared data for the 1 inch steel ball and the large hollow plastic ball. The slope of the line (equal to $1/2 g$) gives an acceleration for the steel ball of 9.79 m/s^2 . Note that the acceleration of the large hollow ball is considerably smaller and that its data is not linear.



Shown in use with rods and clamps sold on pages 186-189. The Drop Box also has built-in magnets to fasten directly to the ceiling.



Any small object can be dropped with the Discover Freefall System by attaching a washer to the object with an adhesive pad (both included).

The Discover Freefall System also works with the 850, PASPORT, or any ScienceWorkshop Interface. Shown here using a Digital Adapter.

Order Information

Discover Freefall System.....	ME-9889	
Required:		
Smart Timer.....	ME-8930	p. 116
or 850/550 Interface.....		p. 14-17
Recommended:		
Freefall Balls Accessory.....	ME-9890	p. 193
Rods and Clamps.....		p. 186-189

Free Fall Apparatus

SF-7274

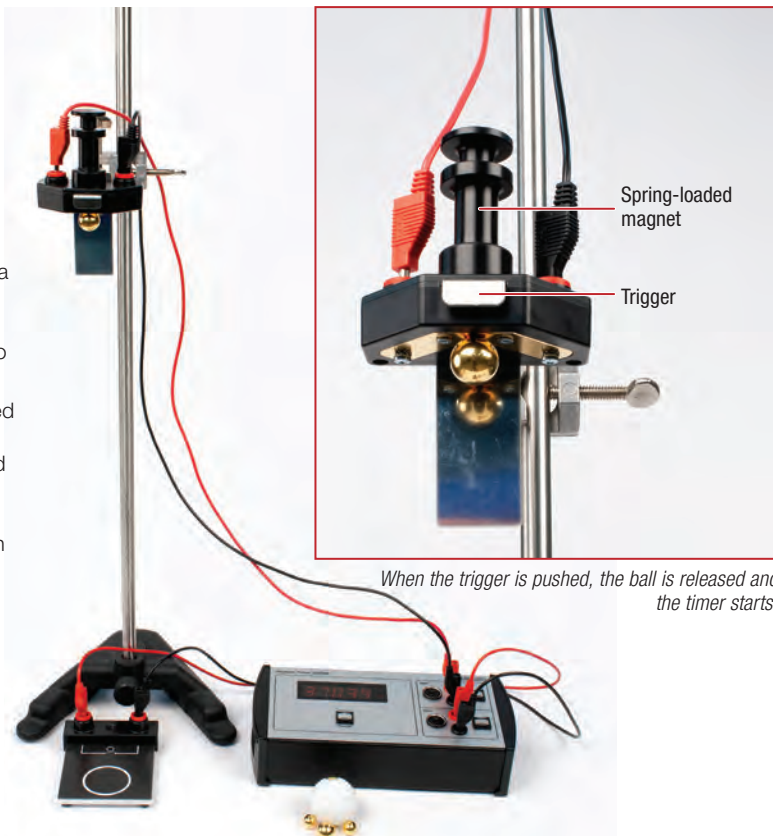
- ▶ Drop ball from rest and time the fall
- ▶ Explore effect of air drag on two different size balls with the same mass
- ▶ Precise and straight-forward device for measuring free fall

The acceleration of gravity g can be computed by measuring the drop distance and the fall time. The apparatus consists of a release mechanism that also acts as the start switch, a switch plate that acts as the stop switch, and conducting balls. The release mechanism and the switch plate are both connected to the Student Timer (not included).

The release mechanism has two contact plates that are shorted when the conducting ball being measured is in place and ready to drop. The steel ball is held in place by a spring-loaded neodymium magnet. Pushing the trigger will cause the ball to drop away from the contact plates, thus opening the counter start circuit just as the fall begins. When the ball hits the switch plate, the timer is stopped.



When the ball hits the switch plate, the timer stops.



When the trigger is pushed, the ball is released and the timer starts.

Order Information

Free Fall Apparatus	SF-7274	
Required:		
Student Timer	SF-7275	p. 118
Small "A" Base	ME-8976	p. 186
120 cm Stainless Steel Rod	ME-8741	p. 186
2 Meter Patch Cord Set	SE-9415A	p. 228
Replacement:		
Replacement Free Fall Balls	SF-7280	

Includes:

- Magnetic release mechanism with mirror
- Switch plate
- Four gold-plated steel balls (diameters 12 mm and 16 mm)
- Ping pong ball with same mass as 12 mm steel ball



Freefall Adapter

ME-9207B

When the steel ball is dropped from the release mechanism, the computer automatically starts timing. When the ball hits the receptor pad, timing stops. Timer measurements of "g" are accurate and repeatable.



Maximum distance of fall is 2 m.

Freefall Timer Adapter shown in use with the Smart Timer. The Smart Timer records the elapsed time from when the ball is dropped until the ball hits the receptor pad.

Includes:

- Ball release mechanism with stereo phone plug and receptor pad
- Four steel balls (1.9 cm, 1.6 cm diameter)



Order Information

Freefall Adapter	ME-9207B	
Required:		
Large Table Clamp	ME-9472	p. 189
Multi-Clamp	ME-9507	p. 188
90 cm Stainless Steel Rod	ME-8738	p. 186
Photogate Timer	ME-9215B	p. 118
Smart Timer	ME-8930	p. 116
or 850/550 Interface		p. 14-17

Launchers

Projectile Launcher

ME-6800

- ▶ Accurate
- ▶ Durable
- ▶ High Repeatability



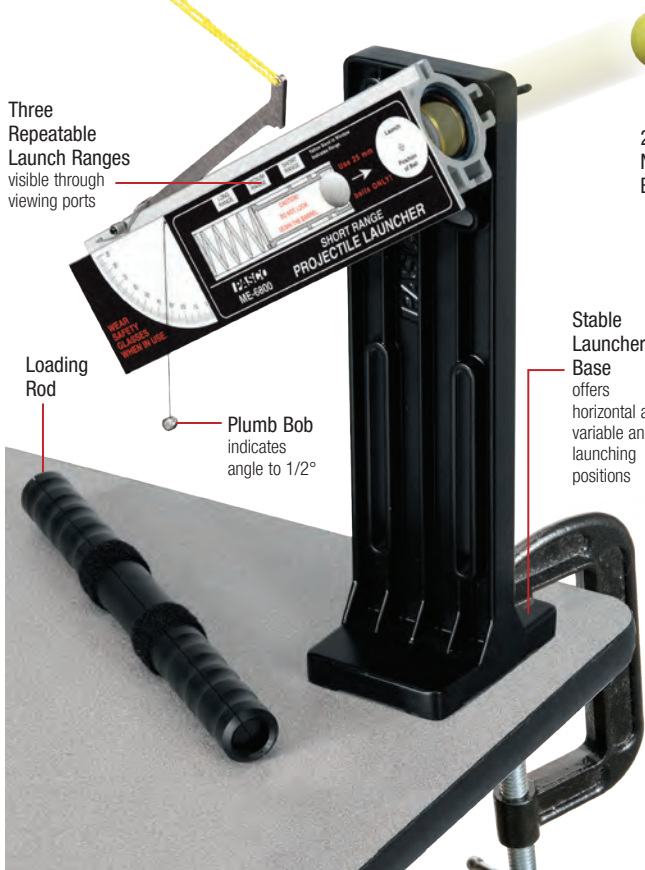
Three Repeatable Launch Ranges visible through viewing ports

2.5 cm Nylon Balls

Loading Rod

Plumb Bob indicates angle to 1/2°

Stable Launcher Base offers horizontal and variable angle launching positions



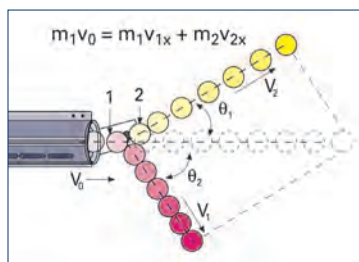
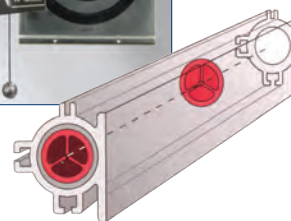
Unique Sights

Shoot-the-Target

The "gun" is aimed directly at the target. Although the target "drops" the moment the projectile is fired, the ball still hits the target since the ball falls with the same acceleration.



Two bore sights simplify aiming the launcher.



The 2-D Collision Accessory (included with all PASCO launchers) allows the study of **Conservation of Momentum** in two dimensions. Use the points of impact with the floor of each of the two balls to determine relative velocities and angles.

Specifications:

Ranges: 1.2, 3, 5 m

Launch Angles: 0 to +90°

Launcher Length: 21 cm

Features:

- ▶ **Variable Launch Speed:** For short range or longer range experiments.
- ▶ **Fixed Firing Height at Any Launch Angle:** Firing height of ball is same for any launch angle.
- ▶ **Unique Piston Design:** Minimizes projectile spin to ensure repeatability of impact position.

Includes:

- Projectile Launcher
- Launcher Base
- Projectile Balls (2)
- Loading Rod
- Safety Glasses
- 2-D Collision Accessory
- Manual

Order Information

Projectile Launcher.....	ME-6800	
Shown in use with:		
Shoot-the-Target.....	ME-6853	p. 131
Photogate Mounting Bracket.....	ME-6821A	p. 133
Smart Gate.....	PS-2180	p. 26
Recommended:		
Time-of-Flight Accessory.....	ME-6810A	p. 133
Large C Clamp (6 Pack).....	SE-7285	p. 133
Plumb Bobs (10 Pack).....	SE-8728	p. 133

Launcher Spares Kit

ME-6802

Contains spare equipment for the PASCO Projectile Launcher.

Includes:

- Loading Rod (10)
- 2-D Collision Accessory (2)
- Plastic Balls (10)
- Sights (5)
- Angle Indicator (1)
- Plumb Bobs (12)
- Thumbscrew to attach launcher to base (10)



Order Information

Launcher Spares Kit.....ME-6802

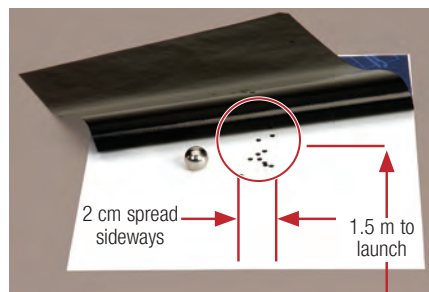
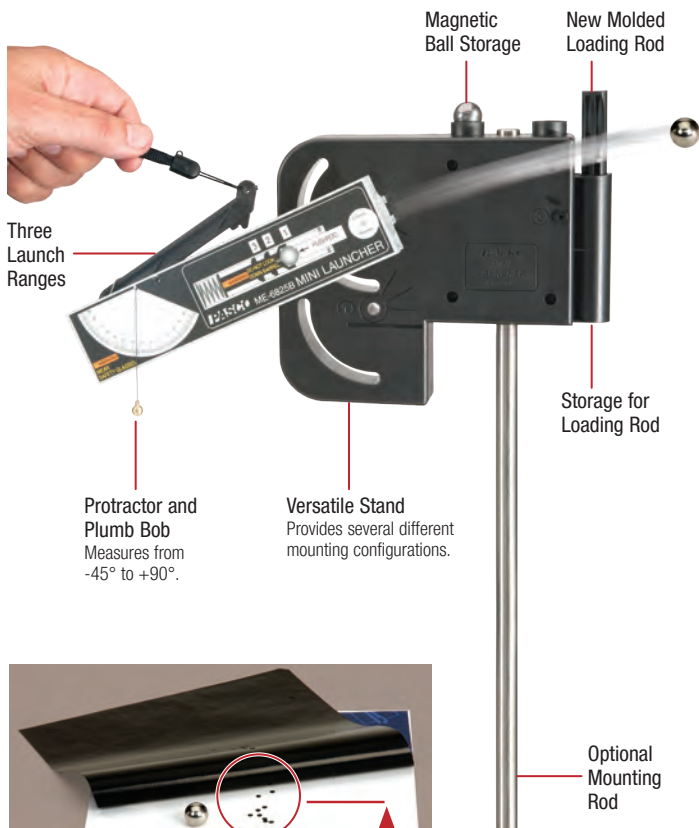
Mini Launcher

ME-6825B

- ▶ Ideal for tabletop projectile experiments
- ▶ Fires at downward angles
- ▶ Low cost

Bracket features include:

- ▶ Magnetic ball storage
- ▶ New plunger storage
- ▶ Labeled shooting positions



Typical pattern for Mini Launcher –
Ball was launched 10 times off 1 m high table at 30° angle. All 10 shots landed within 5 cm diameter circle.

2-D Collision



The 2-D Collision Accessory (included with all PASCO launchers) allows the study of **Conservation of Momentum** in two dimensions.



Shoot from tabletop level!



Negative launch angle!

Unique stand design allows ball to be launched from tabletop height. The ball lands on the table at the same height from which it was launched.

Magnetic Piston holds ball in place for launching at downward angles.

Specifications:

- Range:** 0.5, 1, 2 m
- Launch Angle:** 0 to +90° and 0 to -45°
- Launcher Length:** 18 cm

Mini Launcher Spares Kit

ME-6824

Includes several spare parts for Mini Launcher.

Includes:

- Loading Rod (10)
- 2-D Collision Accessory (2)
- Steel Balls (10)
- Angle Indicator
- Plumb Bobs (12)
- Thumbscrew to attach launcher to base (10)



Order Information

Mini Launcher Spares Kit.....ME-6824

Includes:

- Launcher Base
- Loading Rod
- 2-D Collision Accessory
- Steel Ball Projectile, 16 mm (2)
- Safety Glasses
- Manual
- Mini Launcher

Order Information

Mini Launcher.....	ME-6825B	
Recommended:		
Photogate Mounting Bracket.....	ME-6821A	p. 133
Smart Gate.....	PS-2180	p. 26
Time-of-Flight Accessory.....	ME-6810A	p. 133
Large C Clamp (6 Pack).....	SE-7285	p. 133
45 cm Stainless Steel Rod.....	ME-8736	p. 186
Plumb Bobs (10 Pack).....	SE-8728	p. 133
Carbon Paper (100 Sheets).....	SE-8693	p. 133
30 Meter Measuring Tape.....	SE-8712A	p. 192

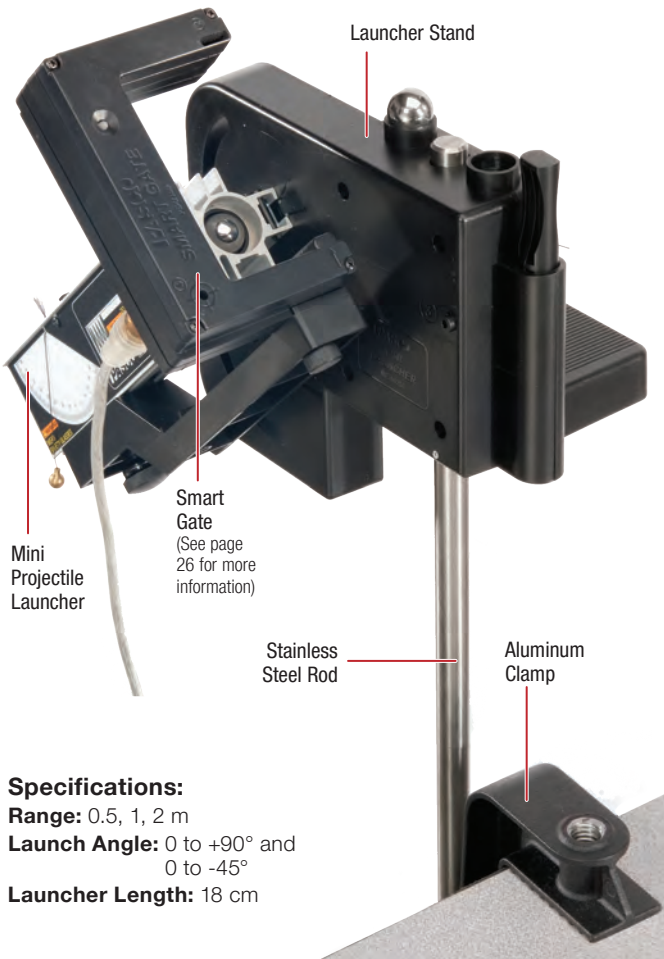
Launchers

Projectile Launcher Smart Gate System

ME-6798

- ▶ Vary height
- ▶ Vary launch speed
- ▶ Vary angle
- ▶ Measure accurately with Smart Gate

With this combination, your students can study projectile motion and measure the initial speed with one economical Smart Gate, since it has two built-in photogate beams. The Mini Launcher and Smart Gate make the setup simple: Just clamp the launcher to the table and slide the Smart Gate on. All the components needed are included, even the rod and clamp.

**Specifications:****Range:** 0.5, 1, 2 m**Launch Angle:** 0 to +90° and
0 to -45°**Launcher Length:** 18 cm**Includes:**

- Smart Gate with Mounting Bracket
- Launcher with Mounting Stand
- Steel Balls (2) with Loading Rod
- 2-D Collision Accessory
- Aluminum Table Clamp
- 45 cm Stainless Steel Rod

**Order Information**

Projectile Launcher Smart Gate System ME-6798

Shown in use with:

Time-of-Flight Accessory ME-6810A p. 131

Required:

PASPORT Interface

**Add optional
Time-of-Flight***Daisy-chain
Time-of-Flight
to Smart Gate.**Smart Gate
connects directly
to a PASPORT
interface.***Projectile Launcher Wireless
Smart Gate System**

ME-6796

Choose this wireless option to eliminate cables between the computer and the projectile launcher. The Wireless Smart Gate has all the features of the Smart Gate (PS-2180), but it connects to your computing device via Bluetooth or USB; it does not require an interface.

**Includes:**

- Wireless Smart Gate with Mounting Bracket
- Launcher with Mounting Stand
- Steel Balls (2) with Loading Rod
- 2-D Collision Accessory
- Aluminum Table Clamp
- 45 cm Stainless Steel Rod

Order Information

Projectile Launcher Wireless

Smart Gate System.....ME-6796

Shoot-the-Target

ME-6853

- ▶ Demonstrate independence of x- and y-motion
- ▶ For use with all launchers

The PASCO Shoot-the-Target Accessory, in combination with a projectile launcher, demonstrates that acceleration is constant for all objects in freefall, regardless of initial velocity. A target is initially suspended near the ceiling, and a projectile launcher is aimed directly at it. As soon as the projectile is shot from the launcher, the target is released. The projectile hits the target as it falls, proving that both objects accelerate downward at the same rate.

Before it falls, the target is attached to the drop box by a permanent magnet so it can hang indefinitely, even when the drop box is not powered. A photogate detects the projectile as it leaves the launcher and triggers the drop box. The drop box releases the target by driving a current through a coil that cancels the field of the permanent magnet.

The "gun" is aimed directly at the target. Although the target "drops" the moment the projectile is fired, the ball still hits the target since the ball falls with the same acceleration.

Includes:

- Drop Box & Control Box
- Control Cable
- Target ME-6852
- Photogate Head & Bracket
- AC Adapter (9 VDC, 500 mA)



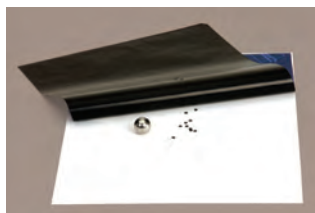
Order Information

Shoot-the-Target	ME-6853	
Recommended:		
Projectile Launcher	ME-6800	p. 128
Mini Launcher.....	ME-6825B	p. 129

Carbon Paper (100 Sheets)

SE-8693

Carbon paper is ideal for marking the position of an object as it strikes the floor or other surface.



Order Information

Carbon Paper (100 Sheets)	SE-8693
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Time-of-Flight Accessory

ME-6810A

- ▶ For use with all PASCO launchers

Includes:

- Time-of-Flight Accessory
- Instruction Manual
- Experiment Guide



Order Information

Time-of-Flight Accessory	ME-6810A
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Launcher Accessories

Drop Shoot Accessory

ME-9859

- ▶ Simultaneously drops one ball and launches a second ball horizontally
- ▶ Prove the independence of x- and y-motion
- ▶ Mounts on PASCO projectile launchers (short- and long-range)

The Drop-Shoot Accessory is an easy-to-use tool that helps students better understand the independence between the horizontal and vertical motion of a projectile. Connect the accessory to either the short or long range projectile launchers, hang one ball from the magnet and fire away. The fired ball strikes the hanging ball, causing one ball to shoot horizontally at the same instant the other ball falls straight down. Both balls hit the ground at the same time, regardless of the fired projectile's muzzle velocity, provided the Projectile Launcher is level. This device also provides an interesting demonstration of Conservation of Momentum in collisions.

When the (included) hollow steel ball is used, the two balls are both fired horizontally at two different speeds. A Photogate and Time-of-Flight Accessory can also be used to directly measure time of flight.

Includes:

- Drop-Shoot Bracket
- 2.5 cm Steel Balls (2)
- 2.5 cm Hollow Steel Ball
- Mounting Hardware
- Loading Rod



When the solid ball hits the hanging solid ball, the hanging ball shoots out horizontally, while the ball shot out of the launcher drops straight down.



Either the solid steel ball or hollow steel ball is hung by a magnet.

Order Information

Drop Shoot Accessory.....	ME-9859	
Required:		
Projectile Launcher.....	ME-6800	p. 128

Ball Ramp

SE-7596

- ▶ Use for Projectile Motion
- ▶ Use for 2-D Collisions

This apparatus consists of a curved track with a base at one end. On the base is a support to hold a ball at the proper height for a center-to-center collision with a second ball rolling down the track. The track is level so collision occurs only in the horizontal plane, simplifying calculations.

Includes:

- 25 cm one-piece track
- 3 balls (12 mm diameter):
2 steel, 1 glass
- Plumb bob



Order Information

Ball Ramp.....	SE-7596
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Drop-Shoot Demo

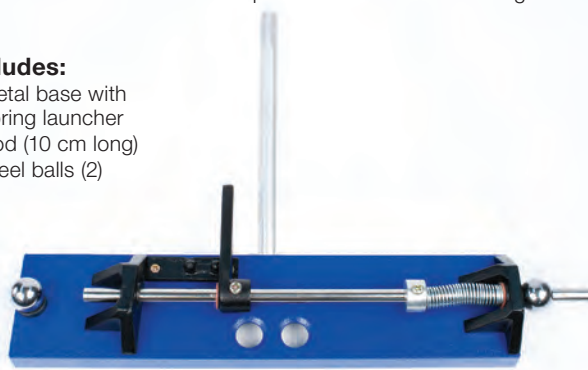
SE-7592

- ▶ Demonstrates the independence of horizontal and vertical components of projectile motion

Releasing the spring causes one ball to drop directly down while the other is projected horizontally. Listen and you'll hear that both hit the floor at the same time! The Drop-Shoot Demo is 25 cm long.

Includes:

- Metal base with spring launcher
- Rod (10 cm long)
- Steel balls (2)



Order Information

Drop-Shoot Demo.....	SE-7592
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Time-of-Flight Accessory

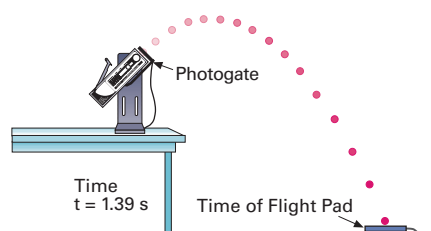
ME-6810A

► For use with all PASCO launchers

The Time-of-Flight Accessory is designed primarily for freefall or projectile experiments. When an object hits the plate, a signal is sent to the interface.



Note: When used with the Projectile Launcher, a photogate is used to start the timer and the 20' extension cable is recommended.



Includes:

- Time-of-Flight Accessory
- Instruction Manual
- Experiment Guide

Order Information

Time-of-Flight Accessory ME-6810A

Photogate Mounting Bracket

ME-6821A



Mount one or two photogates on any Projectile Launcher. Compatible with Photogate Heads below.



Order Information

Photogate Mounting BracketME-6821A
 Photogate HeadME-9498A p. 27
 Accessory PhotogateME-9204B p. 21
 Smart GatePS-2180 p. 26
 Wireless Smart GatePS-3225 p. 52

Small Steel Balls (10 pack)

ME-9872



These 1.6 cm diameter steel balls are used with the Mini Launcher (ME-6825).

WARNING
CHOKING HAZARD
 Contains small balls. Not for children under 3 years.

Order Information

Small Steel Balls (10 pack) ME-9872

Steel Balls (4 pack)

ME-9864



WARNING
CHOKING HAZARD
 Contains small balls. Not for children under 3 years.

Purchase this 4 pack of 2.5 cm diameter balls for use with PASCO Short or Long-Range Projectile Launchers (ME-6800 or ME-6801).

Order Information

Steel Balls (4 pack) ME-9864

Plastic Balls (10 Pack)

ME-6822



WARNING
CHOKING HAZARD
 Contains small balls. Not for children under 3 years.

Extra brightly colored balls are available for the Projectile Launcher. Diameter is 2.5 cm (1 in.).

Order Information

Plastic Balls (10 Pack) ME-6822

Spherical Mass Set

ME-8968



WARNING
CHOKING HAZARD
 Contains small balls. Not for children under 3 years.

This set includes four balls with a diameter of 2.5 cm each, but features various masses, including a hollow steel ball, solid steel ball, plastic ball and aluminum ball.

Order Information

Spherical Mass Set ME-8968

Launcher Sights

ME-9865



Purchase this 5 pack of aiming sights as a replacement for the Short-Range or Long-Range Projectile Launchers.

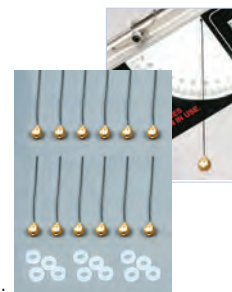
Order Information

Launcher SightsME-9865

Launcher Plumb Bobs (30 pack)

ME-9868A

This kit includes 12 brass plumb bobs and 12 washers to replace lost or broken parts from any of PASCO's projectile launchers.



Order Information

Launcher Plumb Bobs (12-pack) ME-9868A

Large C Clamp (6 Pack)

SE-7285

These rugged clamps are perfect for attaching a variety of objects to a table. Size 10 cm (4 inch).



Order Information

Large C Clamp (6 Pack)SE-7285

Plumb Bobs (10 Pack)

SE-8728



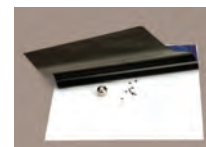
Order Information

Plumb Bobs (10 Pack)SE-8728

Carbon Paper (100 Sheets)

SE-8693

Carbon paper is ideal for marking the position of an object as it strikes the floor or other surface.



Order Information

Carbon Paper (100 Sheets)SE-8693

Ballistics

Ballistic Pendulum

ME-6830

- ▶ Extremely accurate: $\pm 2.5\%$ of predicted values
- ▶ Both elastic and inelastic experiments
- ▶ Projectile launcher experiments
- ▶ Now includes ME-6800 bracket!

This classic physics experiment combines the laws of Conservation of Momentum and Conservation of Energy to determine the muzzle velocity of the projectile. Only simple mass and distance measurements are required to make this determination.

How It Works

A projectile is fired into a pendulum, causing it to rise.

Using the projectile mass, the pendulum mass, and the rise in pendulum height, students can calculate the gravitational potential energy of the system.

Since the potential energy is equal to the pendulum's kinetic energy at the lowest point, students can calculate the speed of the pendulum at impact.

Applying the Law of Conservation of Momentum, the projectile's speed is easily calculated.

An additional mounting bracket is included to perform the full range of projectile launcher experiments.



Already own a PASCO Projectile Launcher?

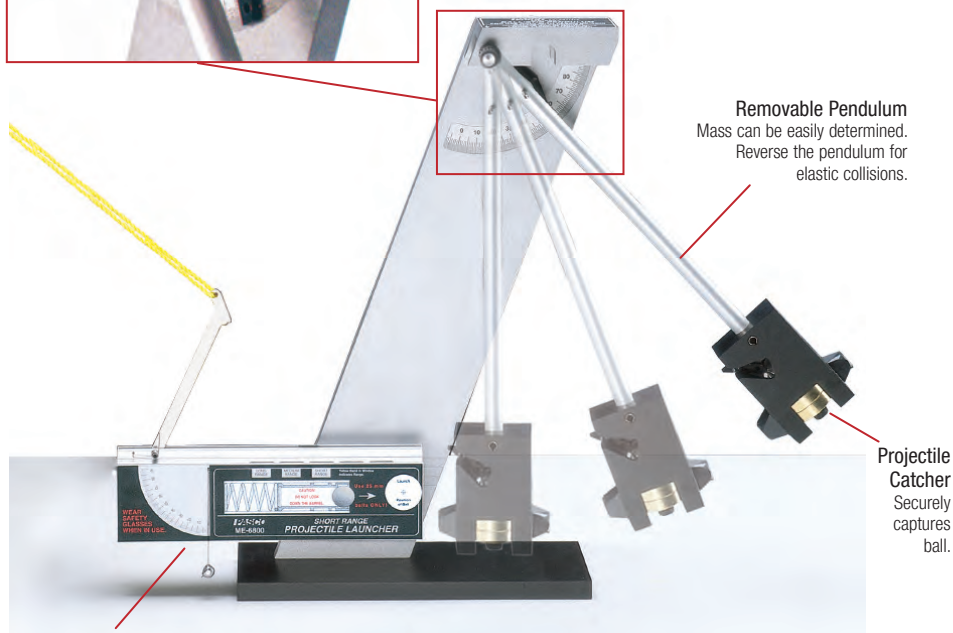
The base and pendulum assembly can be purchased separately.

See Ballistic Pendulum (No Launcher) in the order block for more information.



Unique Angle Measurement Design

Easily measures pendulum angle to 0.5° .
Low friction gives repeatable results.



Projectile Launcher
Durable with three repeatable launch settings.

Removable Pendulum

Mass can be easily determined.
Reverse the pendulum for elastic collisions.

Projectile Catcher
Securely captures ball.

Add Masses

Two 50 g masses (included) can be added to change the pendulum mass and rotational inertia.

Features:

- ▶ **Repeatable:** The three velocity settings on the Projectile Launcher produce consistent velocities.
- ▶ **Accurate:** The $0\text{--}80^\circ$ angle measurement scale resolves to 0.5° , leading to experimental results within 2.5% of predicted values.
- ▶ **Removable Pendulum:** Remove the pendulum to determine its mass and center of mass, let it swing freely for rotational inertia calculations, or mount it backwards for elastic collision experiments.
- ▶ **Ball and Pendulum Masses:** This set includes two, 50 g pendulum masses, as well as two steel and two plastic balls.
- ▶ **Projectile Launcher:** Mount the Projectile Launcher on the other side of the base to give students access to its accessories.
- ▶ **Unique Angle Measurement:** The PASCO Ballistic Pendulum pushes a low friction, low mass pointer to the highest point. It remains there, permitting an accurate measurement.

Includes:

- Ballistic Pendulum (without launcher)
- Projectile Launcher
- Projectile Launcher Base
- 2.5 cm Plastic Balls (2)
- 2.5 cm Steel Balls (2)
- Masses (2)
- 2-D Collision Accessory
- Safety Glasses (2)
- Operations and Experiment Manual



Order Information

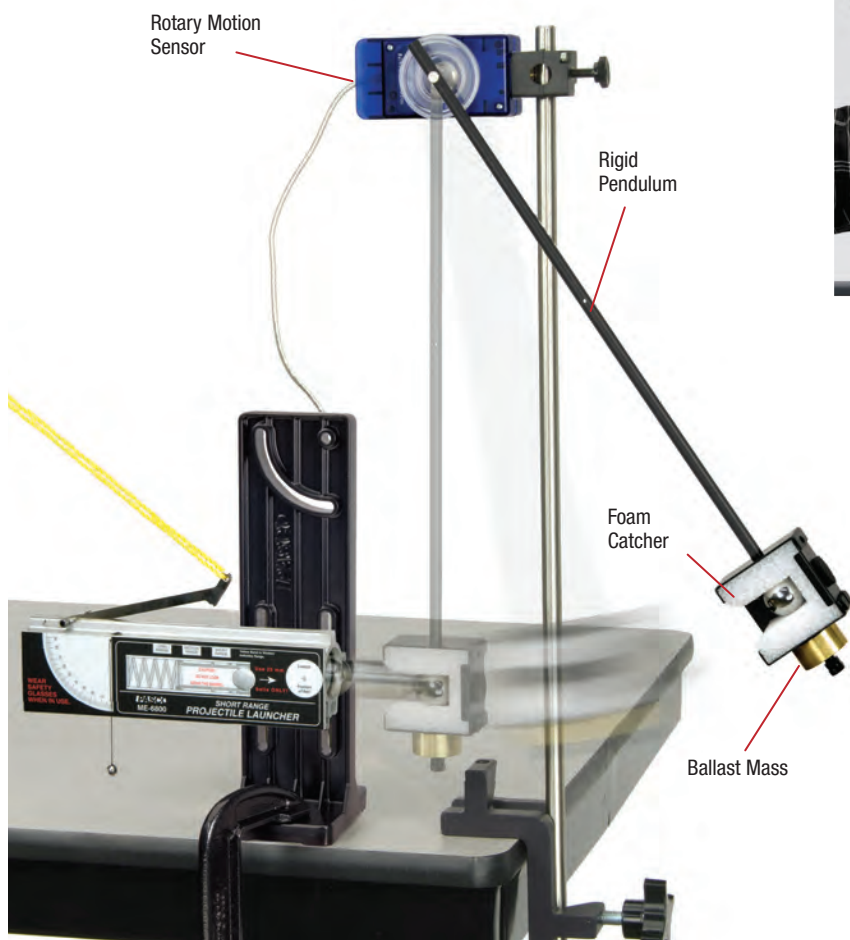
Ballistic Pendulum	ME-6830	
Ballistic Pendulum (without launcher)	ME-6831	
Recommended:		
Spherical Mass Set	ME-8968	p. 133
Shoot-the-Target	ME-6853	p. 131
Time-of-Flight Accessory	ME-6810A	p. 131
Large C Clamp (6 Pack)	SE-7285	p. 133

Ballistic Pendulum Accessory

ME-9892

- ▶ Both are accessories to the Rotary Motion Sensor
- ▶ For elastic and inelastic experiments
- ▶ Low cost

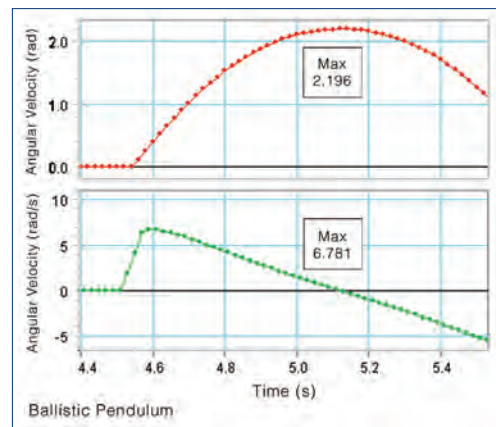
Both of these ballistic pendulum accessories use a Rotary Motion Sensor to measure the speed of the catcher assembly immediately after the collision, as well as the maximum height to which the pendulum swings. The Rotary Motion Sensor can also be used to measure the rotational inertia of the pendulum for a detailed study of the collision using conservation of angular momentum.



Mini Ballistic Pendulum Accessory

ME-6829 (for use with the ME-6825B Mini Launcher on page 129)

Turn your PASCO Launcher into a Ballistic Pendulum using the Rotary Motion Sensor. Combine this accessory with the Mini Launcher and a Rotary Motion Sensor to study ballistic pendulums, momentum and energy.



Rotary Motion Sensor (required for use) allows measurement of instantaneous velocity of catcher immediately after collision, as well as total angle of rotation of the pendulum arm.

Both accessories include:

- Pendulum Arm with Catcher
- Ballast Mass
- Steel Ball



Order Information

Ballistic Pendulum Accessory.....	ME-9892	
Recommended:		
Projectile Launcher	ME-6800	p. 128
PASPORT Rotary Motion Sensor	PS-2120A	p. 28

Order Information

Mini Ballistic Pendulum Accessory	ME-6829	
Recommended:		
Mini Launcher.....	ME-6825B	p. 129
PASPORT Rotary Motion Sensor	PS-2120A	p. 28

Statics

Pulley Demonstration System

SE-8685

- ▶ Demonstrate the mechanical advantage of single or combination pulleys
- ▶ Complete stand-alone pulley apparatus
- ▶ Simple setup

Features:

- ▶ **Stable Base:** Easily attach two threaded 81 cm rods to the sturdy base. An eye-hook and capstan are included to demonstrate an entire pulley system.
- ▶ **Comprehensive:** Contains everything needed to effectively display the usefulness of pulleys, including slotted masses and mass hangers.
- ▶ **Several Pulley Types:** Reveal the benefits of single pulleys, tandem pulleys, quadruple pulleys and even the 4-step pulley. Combine several of them for an efficient pulley system.



Set up a double pulley and a single pulley, each with a 200 g mass. Simultaneously pull the string of each from the same vertical height down to the base. Observe that the mass of the single pulley moves twice as high as the double pulley with twice the force.



Includes:

- 20 cm x 81 cm base with eye-hook and capstan
- Threaded 81 cm rods (2)
- Clamps (2)
- Horizontal rod
- Hook collars (8)
- 90° clamp
- Single pulleys (2)
- Triple-tandem pulleys (2)
- Quadruple pulleys (2)
- Four-step pulley
- Slotted masses (13)
- Mass hangers (6)

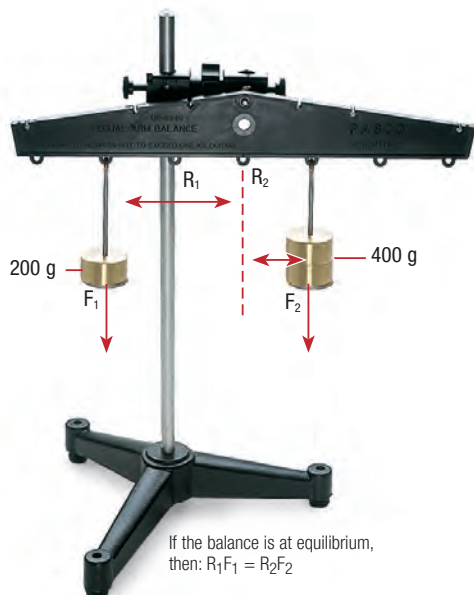


Equal Arm Balance

ME-8949



The Equal Arm Balance was specially designed to simplify the study of torques. This balance has a ball-bearing pivot.



If the balance is at equilibrium, then: $R_1F_1 = R_2F_2$

With 200 g and 400 g masses placed as shown above, the balance remains in equilibrium.

Specifications:

Total length: 34 cm

Maximum weight exerted on balance arm:: 1 kg or 10 N



Includes:

- Balance Arm with Ball-Bearing Pivot

Order Information

Equal Arm Balance..... ME-8949

Required:

Mass and

Hanger Set..... ME-8979 p. 197

Order Information

Pulley Demonstration SystemSE-8685

Super Pulley Force Table

ME-9447B

- ▶ High accuracy
- ▶ Easy, compact storage
- ▶ Inexpensive!

Adjustable height

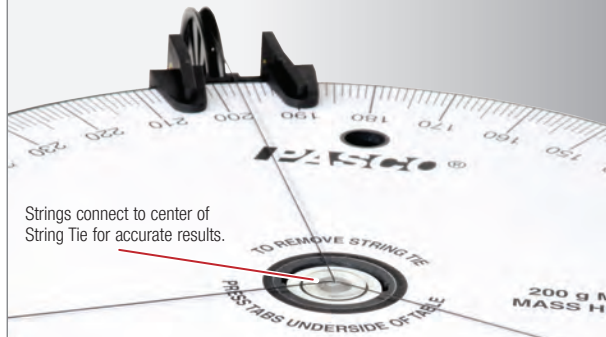
The swivel feature of the pulleys can virtually eliminate parallax for more precise angle measurements.



Built-in Scale
Measure angles quickly and accurately.

String Tie

String Tie is captured to make setup of hanging masses easy, but it freely floats over bulls-eye pattern to clearly show even small changes in equilibrium.



Compact, Easy Storage



Improved leg storage

The screw-in legs snap under the table for easy storage.

Improved stacking

Stacked tables are keyed together to eliminate slipping. Now you can store all your Force Tables in one convenient stack!



Change the mass by 1/2 gram or an angle by 1/2 degree and see an immediate change in the equilibrium.

Mass and Hanger
(sold separately)

Includes:

- 25 cm diameter table with detachable legs
- Adjustable Super Pulleys with clamps (3)
- Spool of thread

Mass and Hanger Set is sold separately.



Order Information

Super Pulley Force Table.....	ME-9447B	
Required:		
Mass and Hanger Set.....	ME-8979	p. 197
Additional Pulleys:		
Super Pulley with Clamp.....	ME-9448B	p. 141

Statics

Tension Protractor

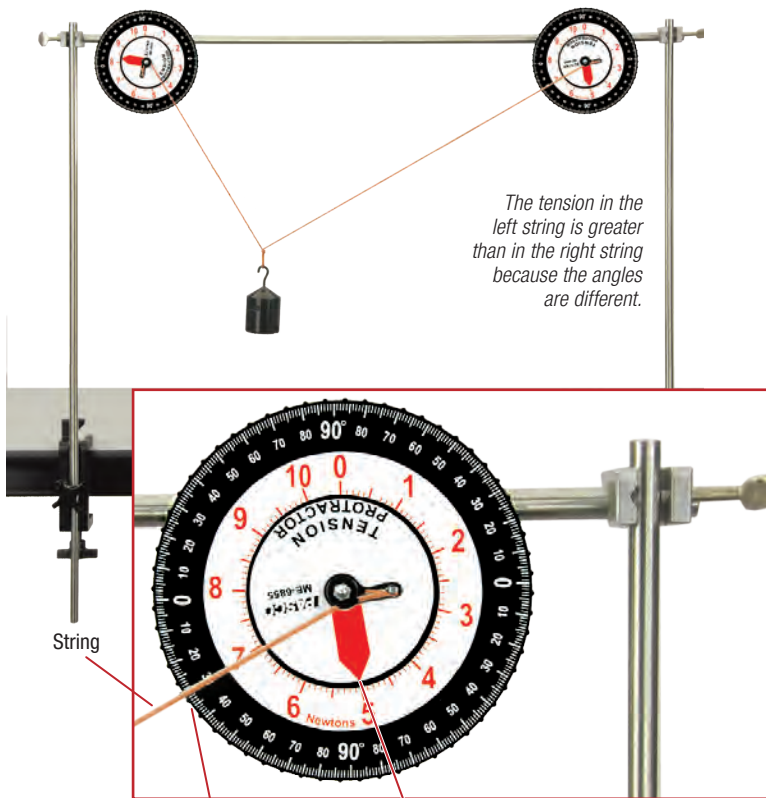
ME-6855

- ▶ Measure tension and angle with one device
- ▶ Large scale for viewing demonstrations
- ▶ Zero-adjust for torsion spring scale
- ▶ Built-in rod clamp

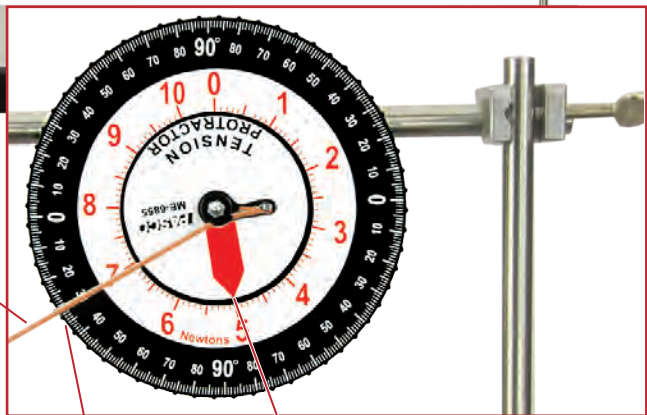
The Tension Protractor is a spring scale and a protractor integrated into one device. Perfect for static equilibrium experiments, the rotary dial indicates the tension in the string and the angle is read where the string passes over the degree scale on the outer ring. Since the Tension Protractor is supported on a rod, it has an advantage over other spring scales that tend to weigh down the string, changing the angle.

The string is wrapped once around a small pulley that is spring-loaded. The torsion spring scale is carefully calibrated at the factory and can be zeroed by the user using the thumb screw on the back. The red arrow that indicates tension is color-coded to match the Newton scale.

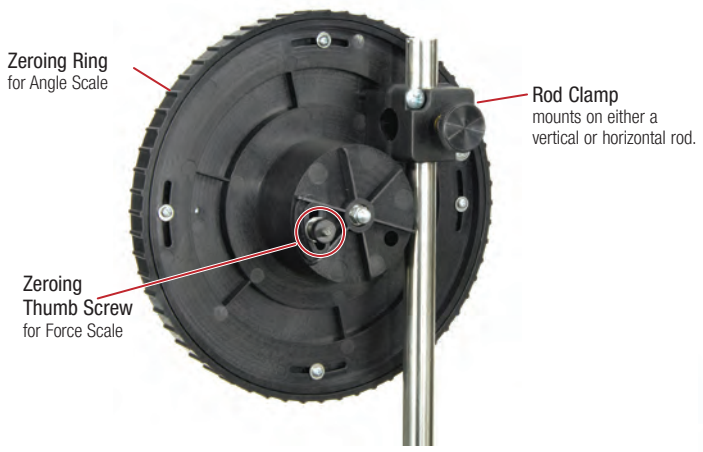
Even if the mounting rod is not plumb, the Tension Protractor's degree scale can be adjusted to read 90 degrees vertically by rotating the outer ring until the string with a hanging mass aligns with 90 degrees.



The tension in the left string is greater than in the right string because the angles are different.



30° angle reading Arrow indicates tension reading (5.0 N)



Zeroing Ring for Angle Scale
 Rod Clamp mounts on either a vertical or horizontal rod.
 Zeroing Thumb Screw for Force Scale

Specifications:

- Force Range:** 0 N to 10 N
- Smallest Force Division:** 0.1 N
- Force Accuracy:** $\pm 4\%$ of Reading
- Angle Range:** -90° to $+90^\circ$
- Smallest Angle Division:** 1°
- Diameter:** 15 cm

- Includes:**
- One Tension Protractor



A 50 gram mass hangs vertically from the Tension Protractor: The tension reads 0.5 N as expected and the outer degree scale is dialed to align the 90° mark with the string. This compensates for unlevel tables or bent rods.

Order Information

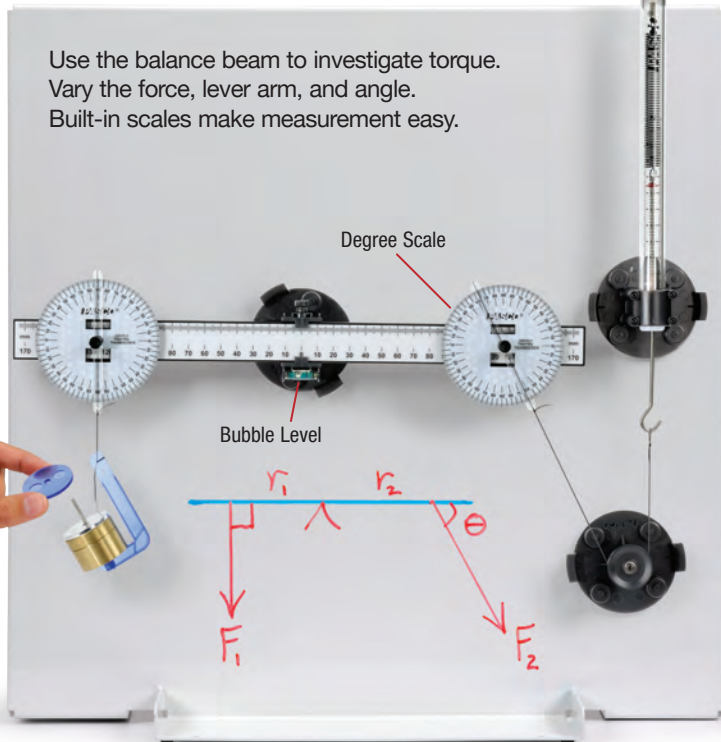
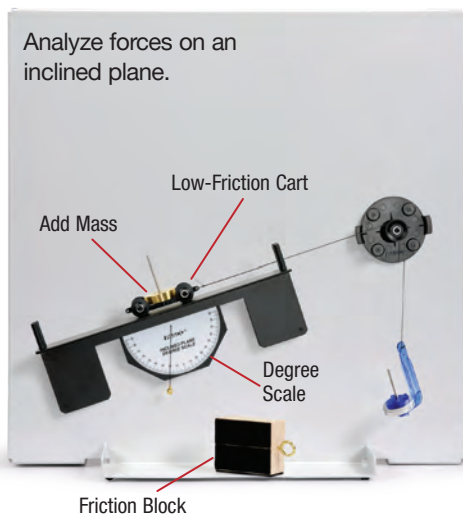
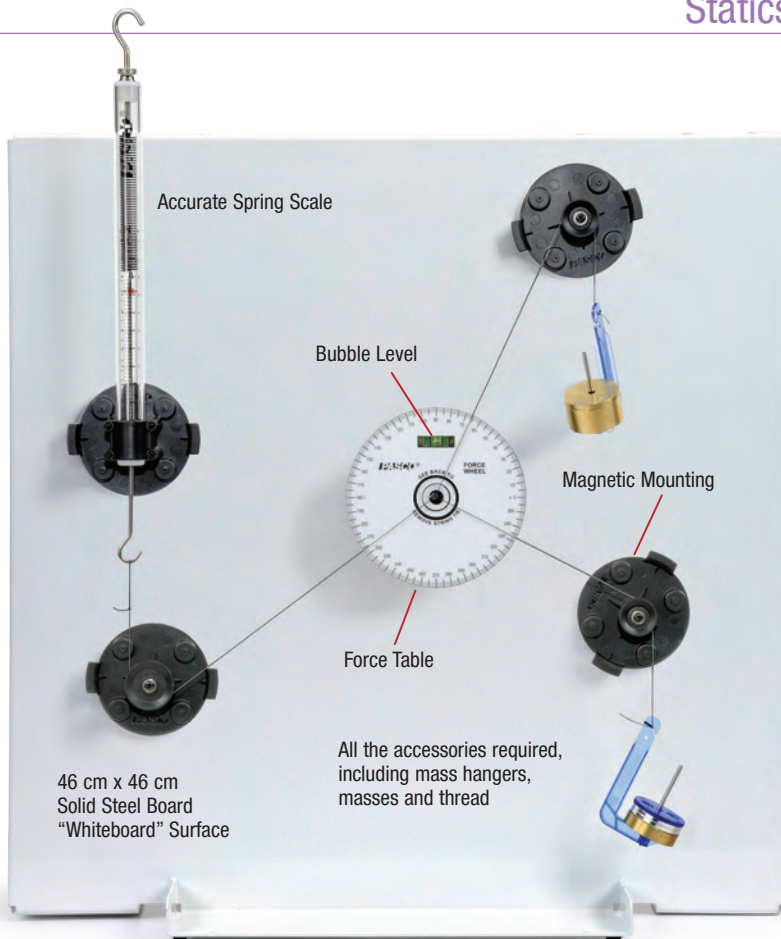
Tension Protractor.....	ME-6855	
Recommended:		
Large Table Clamp	ME-9472	p. 189
90 cm Stainless Steel Rod	ME-8738	p. 186
Multi-Clamp.....	ME-9507	p. 188
Hooked Mass Set.....	SE-8759	p. 197

Statics System

ME-9502

- ▶ Everything required for 15 experiments
- ▶ Comprehensive — from vector addition to simple machines
- ▶ Easy Setup — magnetic mounting

The Statics System is a versatile lab system designed for demonstrating the basic concepts of vector forces, torques, center of mass, simple machines, and more. When combined with the ME-9503 Statics Board (sold separately), the Statics System doubles in width, making it ideal for demonstrations.



Easy Storage

Store magnetic components on back of experiment board.

Includes:

- Experiment Board
- Components
- Mass Set
- Comprehensive Manual with 16 Copy-Ready Experiments



Order Information

Statics System.....	ME-9502
Additional Equipment:	
Statics Board	ME-9503
Spring Scale	ME-9824A
Statics Spares Package	ME-9504

Simple Machines

Essential Physics Forces and Machines Teacher Resources

EP-6483

- ▶ A single teacher guide is all you need to outfit your class or lab.
- ▶ Complete with guided inquiry lab activities, suggested answers, and much more
- ▶ Requires the Simple Machines Engineering Kit
- ▶ Every lesson has accompanying teacher resources including PowerPoint slide sets to help deliver the lesson content

Questions are embedded throughout the activities. Other features include sequencing and key-term challenges. Opportunities to predict outcomes prior to data collection and post-lab multiple choice questions help to make a seamless connection between lectures and labs. And the lab activities are correlated to state and national standards.



Order Information

Essential Physics Forces and Machines
Teacher Resources EP-6483

Simple Machines Engineering Kit

EP-3577

Our Simple Machines Engineering Kit engages students in a wide range of physics, physical science, and engineering concepts. Two triple-pulley blocks make it easy to build machines with mechanical advantage up to 6:1. Build all three classes of levers with our pair of 20-cm levers, or combine gears, levers, and pulleys together to show how rotating machines work. The *Essential Physics Forces and Machines Teacher Resources* (available separately) include 11 lessons designed to be delivered in conjunction with this kit.

Includes:

- 10 N Metal Spring Scales (2)
- Tripod Stands & Crossrail (2)
- Universal Spring Hanger (2)
- Right-angle Connector with Pulley (2)
- Fixed Triple Pulley Block (1)
- Hanging Triple Pulley Block (1)
- Friction Block (1)
- Quick-attach Gear Hubs (4)
- Gear Spacers (12)
- 20 cm Levers (2)
- 60 Tooth Spur Gears (2)
- 40 Tooth Spur Gears (2)
- 20 Tooth Spur Gears (3)
- 20 cm-diam. Large Pulleys (2)
- Weights (1)
- String (1)
- Gratnells® Storage Tray (1)



Order Information

Simple Machines Engineering Kit EP-3577

Tripod Stand

EP-3572

Includes:

- 68.6 cm extruded aluminum vertical rail
- Wide tripod base with aluminum legs and rubber feet
- Includes 5 sliding 14-20 inserts, already installed



Order Information

Tripod Stand EP-3572

Weight Set

EP-3563

Includes:

- 2 mass hangers
- Fender washer masses



Order Information

Weight Set EP-3563

Super Pulley

ME-9450A

- ▶ 20 N max load
- ▶ Nearly frictionless
- ▶ Durable



The PASCO Super Pulley is the standard in physics labs. Its low-friction design produces excellent results. The precision spacing of the 10 spokes makes it ideal for photogate monitoring with PASCO's computer interfaces and photogate systems.

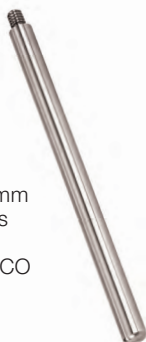
Order Information

Super Pulley ME-9450A

Pulley Mounting Rod

SA-9242

This 14 cm long stainless steel mounting rod is 9.5 mm (3/8 in.) in diameter and fits most standard laboratory clamps, including the PASCO Universal Clamp. It has a standard 1/4"-20 thread.



Order Information

Pulley Mounting Rod SA-9242

Smart Gate Pulley System

PS-3702

The Super Pulley attaches directly to the Smart Gate, providing a simple, low-friction system to measure position, velocity and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments.



Includes:

- Smart Gate (1) PS-2180
- Super Pulley (1) ME-9450A
- 45 cm Stainless Steel Rod (1) ME-8736

Order Information

Smart Gate Pulley System..... PS-3702

Super Pulley with Mounting Rod

ME-9499

This Super Pulley is mounted on a rigid plastic mounting rod (12.7 mm diameter, 14 cm long) and fits most standard laboratory clamps.



Order Information

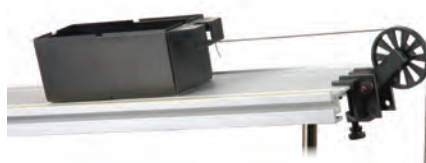
Super Pulley With Mounting Rod ME-9499

Super Pulley with Clamp

ME-9448B



Upgrade your force table and inclined plane experiments. The Super Pulley with its integral clamp makes setup and alignment easy. The pulley height is fully adjustable, so you can skim the top of a force table for parallax-free readings. Yet you can keep the force parallel to the track on an inclined plane, as shown in the photo below. Fits tables up to 2.0 cm (13/16 in.) thick.



Order Information

Super Pulley with Clamp ME-9448B

Mounting Rods (10 pack)

ME-9483

These rigid plastic pulley handles (14 cm long, 1.27 mm diameter) screw into a Super Pulley.



Order Information

Mounting Rods (10 pack) ME-9483

Photogate & Pulley System

ME-6838A

The Super Pulley attaches directly to a Photogate Head, providing a simple, low-friction system to measure position, velocity and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments.



Order Information

Photogate & Pulley System ME-6838A

Atwood's Machine

SA-9241



Two Super Pulleys mounted on a 6.4 cm long rod produce a classic, low-friction introduction to Newton's Second Law. The instruction sheet fully describes both the experiment and the theory.



Includes:

- 2 Pulleys
- 1 Connecting Rod

Order Information

Atwood's Machine SA-9241

Human Applications

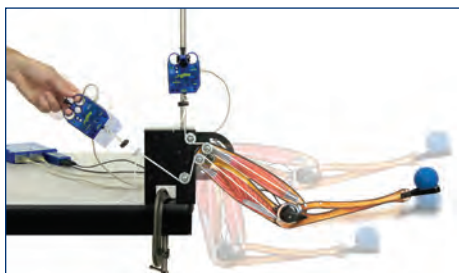
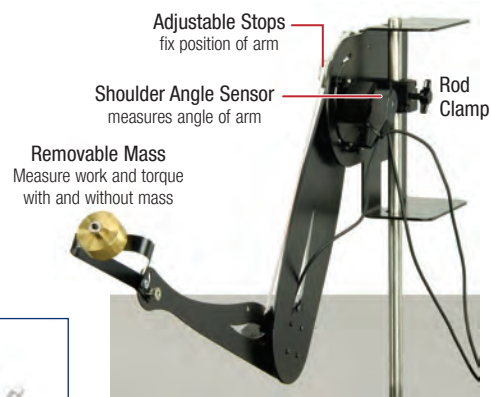
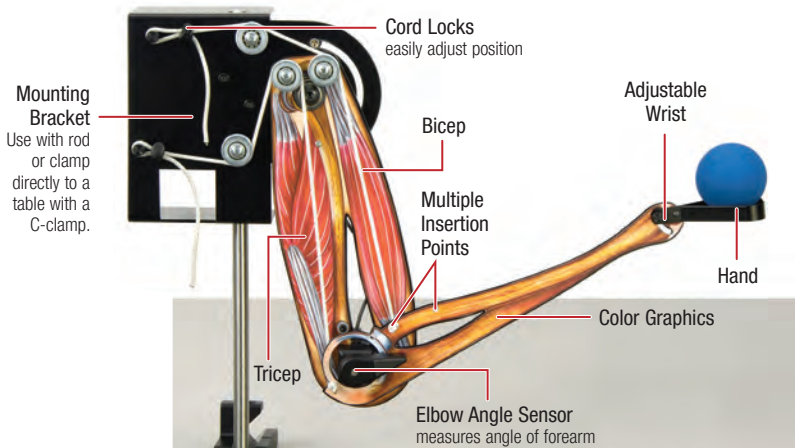
Human Arm Model

PS-2611

- ▶ Working Model of the Human Arm
- ▶ Associate Triceps/Biceps Muscle Action with Arm Motion
- ▶ Measure Torque Resulting from Lifting Weights
- ▶ Actually Throws a Ball

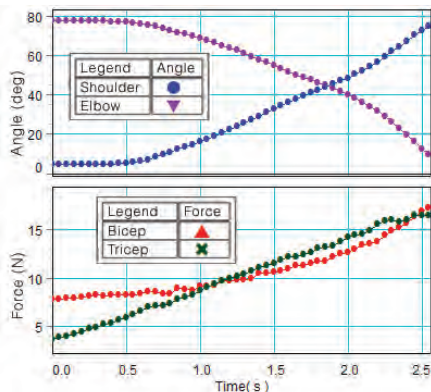
The Human Arm Model simulates the muscles and motion of an actual human arm. To activate the arm motion, students pull on the cord with a Force Sensor. Changes in position are measured at the shoulder and elbow using the two built-in potentiometers plugged into one Angle Sensor (PS-2139), included with PS-2611. From this information, the torque applied when lifting an object can be determined. Also, students can evaluate the work done by the arm in throwing a ball and the resulting kinetic energy delivered to the ball.

The Arm can perform many types of motion such as extending and lifting an object, curling, or throwing a ball overhand. Different arm muscles are activated depending on which pulleys are selected. Static force measurements can also be made to see how the muscle tension changes at various arm positions.



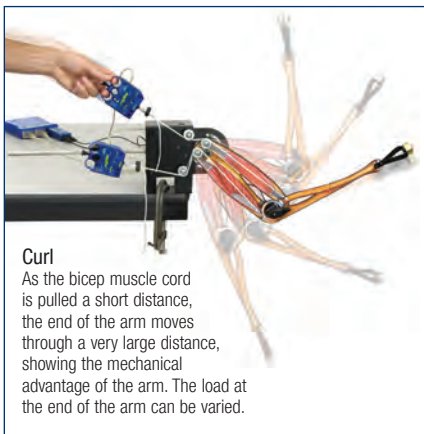
Extension

As the tricep muscle is pulled with a Force Sensor, another fixed Force Sensor records the tension in the bicep muscle cord.



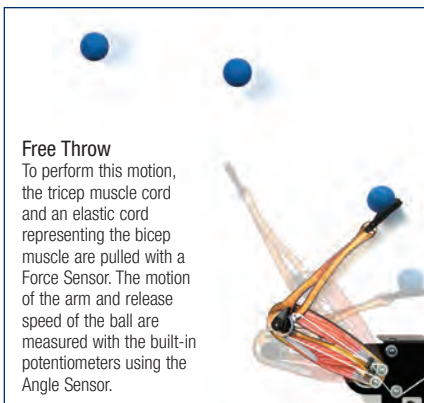
Angles and Forces During Extension

The upper graph shows the angles of the elbow (violet trace) and the shoulder (blue) as the arm is extended as shown in the picture above. Shown in the lower graph, the bicep tension (red) has little change at first and then rises sharply as the arm reaches out, while the tricep tension (green) rises steadily.



Curl

As the bicep muscle cord is pulled a short distance, the end of the arm moves through a very large distance, showing the mechanical advantage of the arm. The load at the end of the arm can be varied.



Free Throw

To perform this motion, the tricep muscle cord and an elastic cord representing the bicep muscle are pulled with a Force Sensor. The motion of the arm and release speed of the ball are measured with the built-in potentiometers using the Angle Sensor.

Includes:

- Arm
- Angle Sensor
- Removable Mass
- Cord & Cord Locks
- Mounting Bracket with Rod
- Force Sensor Mounting Rod
- Rubber Ball



Order Information

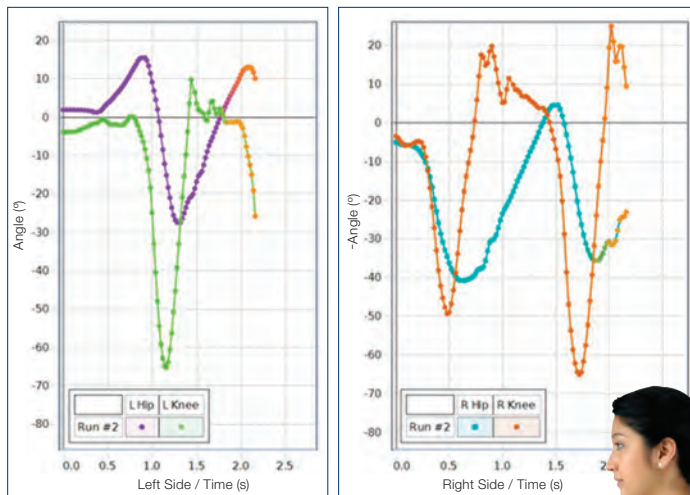
Human Arm Model	PS-2611	
Required:		
“C” Clamp or Large Table Clamp		
PASPORT		
Force Sensor	PS-2104	p. 29
850 Universal		
Interface	UI-5000	p. 14

Goniometer

PS-2137

- ▶ Accurately measures joint movements
- ▶ Flexible mounting options for hip, knee, and elbow

The SPARKlink Air Interface is used here with two Angle Sensors, part of the PS-2137 Goniometer System. The data is sent via Bluetooth® to a desktop computer and displayed live with the video being recorded by a web cam.



Data shows position of both left and right knee and hip joints during walking.

Capture data remotely!

The SPARKlink Air Interface records the sensor data and sends it to the computer via Bluetooth.



Goniometer Probes

The probes are fastened in place using the blue Velcro® straps and can be positioned to measure the motion of the knee, hip, or elbow.

Specifications:

Range: 0 to 340°

Accuracy: ±1° (calibrated), ±3° (uncalibrated)

Resolution: 0.1°

Maximum Sample Rate: 500 Hz

Includes:

- Goniometer Probe
- Angle Sensor
- Velcro Straps



Order Information

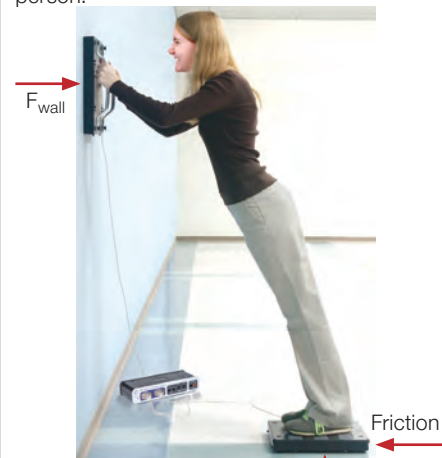
Goniometer Sensor	PS-2137	
Recommended:		
SPARKlink Air	PS-2011	p. 48
Additional Goniometer Straps	PS-2547	
Additional Goniometer Probe	PS-2138	p. 39



Forces on the Human Body

- ▶ Measure forces on human body
- ▶ 1-axis and 2-axis force platforms
- ▶ Precise and fast

Explore the forces exerted on the human body in everyday situations, sports, and large-scale physics experiments. The force platforms are designed to measure large forces, such as the weight of a person.



By standing on a 2-Axis Force Platform while pushing against the wall with a 1-Axis Force Platform, a real-life statics problem can be analyzed.



Confirm Newton's Third Law by pushing on a Force Platform using two sets of handles (available separately). Handles bolt onto the Force Platform (1-axis or 2-axis) and can be mounted on one or both sides.

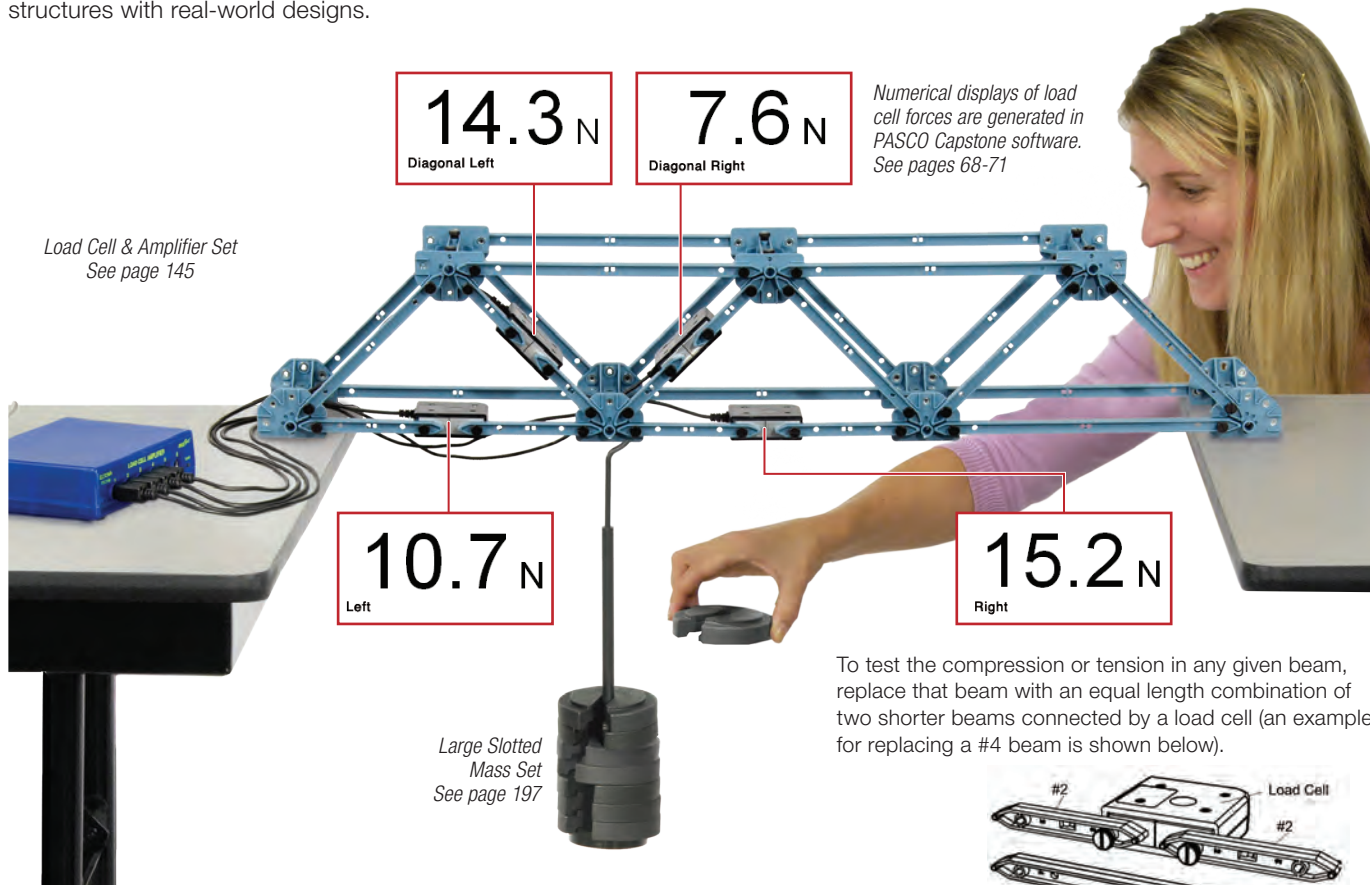
Developed in cooperation with Nancy Beverly, Assistant Professor of Physics at Mercy College, Dobbs Ferry, New York.

Order Information

PASPORT 2-Axis Force Platform	PS-2142	p. 30
PASPORT Force Platform	PS-2141	p. 30
Handle Set, Force Platform	PS-2548	p. 30

Build any structure you can imagine and add load cells wherever you want

With the PASCO Structures System, students can build and analyze trusses, bridges, roller coasters, cranes, booms, and human models. These versatile kits enable students to design their own structures, test them, and iterate their design. Far more advanced than toothpick models and much more hands-on than computer simulations, PASCO Structure Sets are ideal for developing structures with real-world designs.



A variety of structures sets are available and are detailed in the following pages:

<p>Truss Set See page 146</p>	<p>Bridge Set See page 147</p>	<p>Materials Tester See page 158</p> <p>Cast Beams Set See page 152</p>
<p>Advanced Set See pages 148-149</p>	<p>Large Structures Set See pages 150-151</p>	<p>Human Structures Set See page 155</p>

Choice of Wired Load Cells and Amplifiers

Load Cell 100 N PS-2200

Load Cell 5 N PS-2201

Load cells are available in two different ranges: ± 100 N and ± 5 N. These load cells are designed to be inserted into structures without changing the length of the member. A load cell attached to two shorter beams is equal in length to a longer beam.

These load cells require an amplifier (shown below). Load cells of different capacities can be used with the same amplifier in any combination.

These load cells are constructed to reject side-loading, giving a reading of pure compression or tension. The semi-transparent case lets students see the strain gauge and beam inside.

PS-2200 Specifications:

Range: ± 100 N

Accuracy: $\pm 1\%$ (± 1 N)

Resolution: 0.02 N

Safe Overload: ± 150 N

PS-2201 Specifications:

Range: ± 5 N

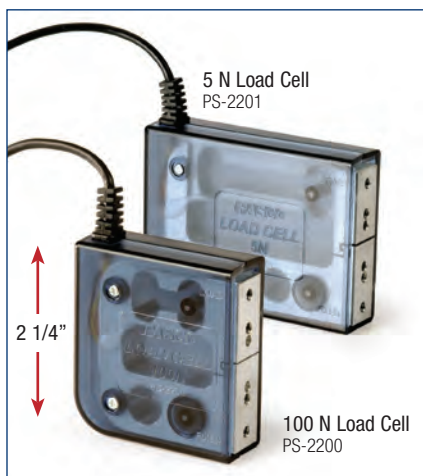
Accuracy: $\pm 1\%$ (± 0.05 N)

Resolution: 0.001 N

Safe Overload: ± 7.5 N

Order Information

100 N Load Cell PS-2200
5 N Load Cell PS-2201



Mix 5 N and 100 N load cells on the same amplifier.

PASPORT Dual Load Cell Amplifier

PS-2205



The Dual Load Cell

Amplifier is for applications where only one or two load cells are required, such as measuring the force acting on the top of a roller coaster loop. If you only want to examine the forces in a bridge one at a time, a single load cell can be moved around the bridge. The Amplifier accepts 100 N and 5 N load cells. Each port has a maximum data sample rate of 1000 Hz.

Order Information

PASPORT Dual Load Cell Amplifier PS-2205
Required for use:
PASPORT Interface p. 12
100 N Load Cell PS-2200
5 N Load Cell PS-2201

Also available at a discount:

PASPORT Load Cell and Dual Amplifier Set PS-2206

Set includes:

Dual Load Cell Amplifier (PS-2205)

Load Cell 100 N (PS-2200)

Requires PASPORT Interface (p. 12)



PASPORT Load Cell Amplifier

PS-2198



This Load Cell

Amplifier can accommodate up to six load cells and utilizes a single PASCO interface port to connect to a computer's USB port. Students can insert up to six load cells at various points of their structures to extensively analyze their bridges. The Amplifier is compatible with both 5 and 100 N Load Cells, and features a maximum data sampling rate of 500 Hz per port.

Order Information

PASPORT Load Cell Amplifier PS-2198
Required for use:
PASPORT Interface p. 12
100 N Load Cell PS-2200
5 N Load Cell PS-2201

Also available at a discount:

Load Cell and Amplifier Set PS-2199

Set includes:

Load Cell Amplifier (PS-2198)

Load Cell 100 N (PS-2200)

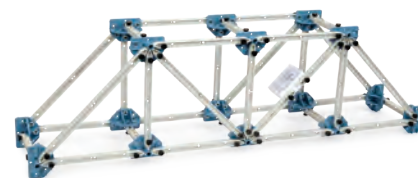
Requires PASPORT Interface (p. 12)



Wireless Load Cell and Accelerometer

PS-3216

- ▶ Measures loads in structures
- ▶ Built-in 3-axis accelerometer measures bridge vibrations
- ▶ No wires to interfere with motion



The Wireless Load Cell and Accelerometer is designed to measure loads in all PASCO Structures Systems. It is particularly useful for measuring vibrations because it includes an accelerometer and has no wires to impede movement.

Specifications:

Load Cell

Range: ± 50 N

Resolution: 0.03 N

Accuracy: 0.1 N

Maximum Sample Rate: 2 kHz

Acceleration

Range: ± 16 g (three axis)

Maximum Sample Rate: 500 Hz

Measurements: Force; Acceleration (3 axes and resultant)

Logging: Yes

Battery: Rechargeable Lithium-Polymer

Connectivity: Direct USB or via Bluetooth 4.0

Order Information

Wireless Load Cell and Accelerometer PS-3216
Shown in use with:
Building Better Bridges Kit (includes PS-3216) ME-3581

Truss Set

ME-6990

- ▶ Teach the basics of trusses
- ▶ Demonstrate the properties of I-Beams

Through Truss with Verticals

- Plastic I-Beams
- Plastic Connectors
- Steel Thumb Screws

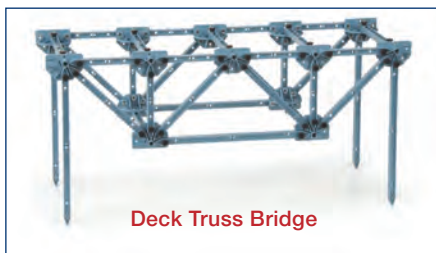
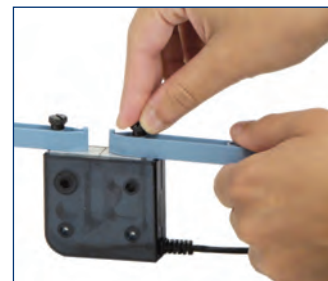
Use the Truss Set to build a variety of structures to investigate the principles of trusses. The ABS plastic I-Beams fasten securely together using the provided connectors and thumb screws. Load cells can be inserted anywhere into the design by replacing one beam at a time. Students can load the truss by hanging weights.



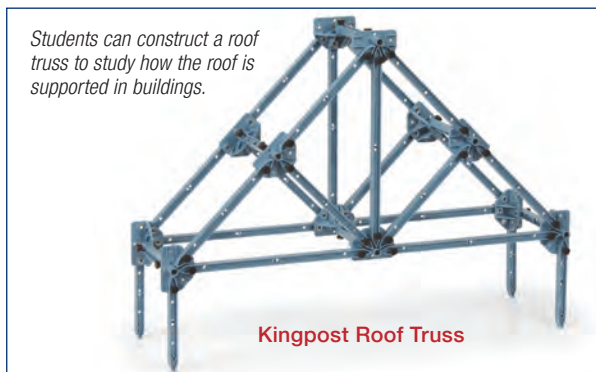
Measure the compression and tension in the I-Beam members by adding optional Load Cells.

Construction is easy: I-Beams fit into the connectors and are secured with thumb screws. Thumb screws are also slotted so a screwdriver can be used.

I-Beams key into the load cell and are fastened with thumb screws.



Deck Truss Bridge



Students can construct a roof truss to study how the roof is supported in buildings.

Kingpost Roof Truss

Includes:

- I-Beam #5 24 cm long (8)
- I-Beam #4 17 cm long (18)
- I-Beam #3 11.5 cm long (18)
- I-Beam #2 8 cm long (8)
- I-Beam #1 5.5 cm long (8)
- Connectors (14)
- Screws (75)
- Instruction Manual



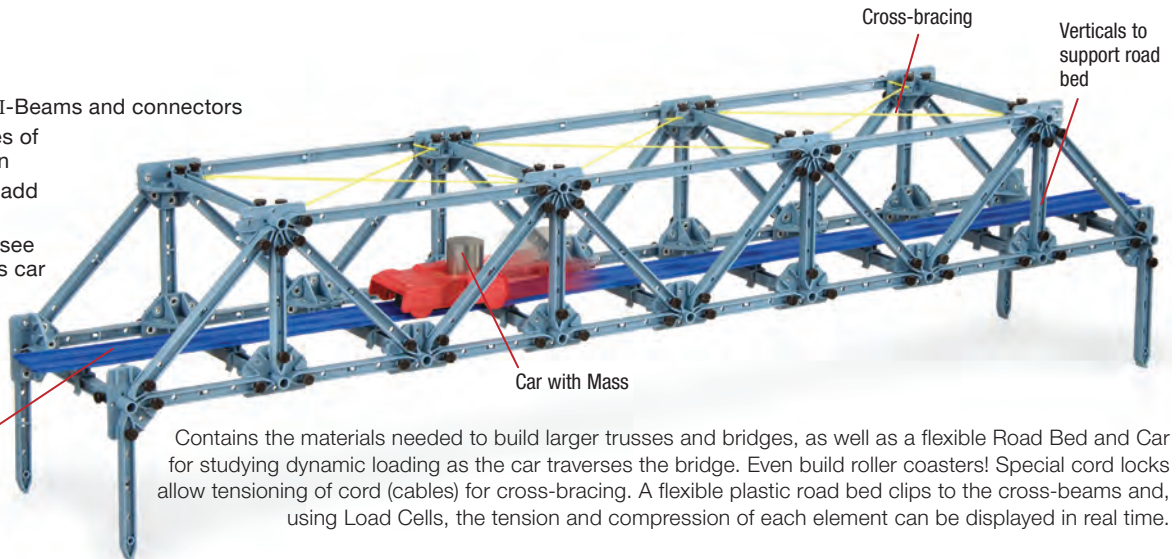
Order Information

Truss Set	ME-6990
Recommended:	
Load Cell and Amplifier Set	PS-2199

Bridge Set

ME-6991

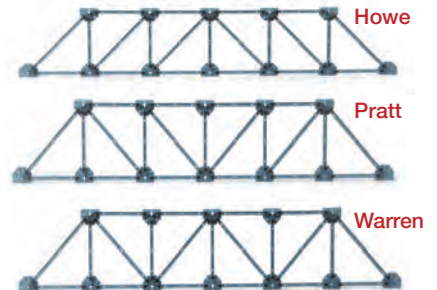
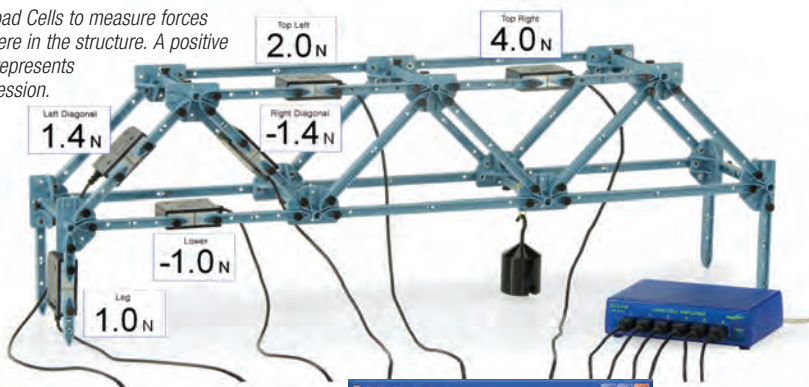
- ▶ Larger quantity of I-Beams and connectors
- ▶ Study the principles of bridge construction
- ▶ Road bed and car add realism to bridges
- ▶ Add Load Cells to see dynamic loading as car traverses bridge



Flexible Road Bed

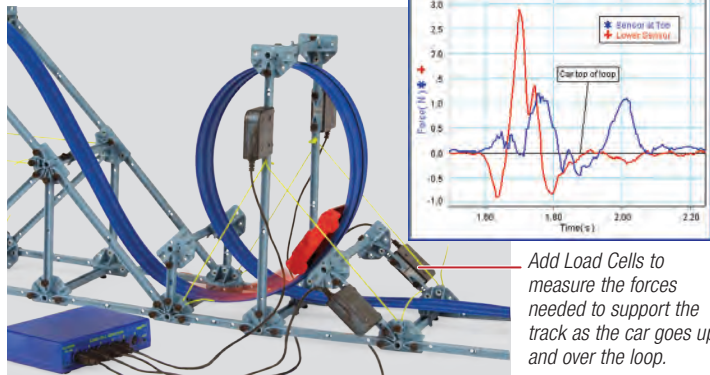
Contains the materials needed to build larger trusses and bridges, as well as a flexible Road Bed and Car for studying dynamic loading as the car traverses the bridge. Even build roller coasters! Special cord locks allow tensioning of cord (cables) for cross-bracing. A flexible plastic road bed clips to the cross-beams and, using Load Cells, the tension and compression of each element can be displayed in real time.

Add Load Cells to measure forces anywhere in the structure. A positive value represents compression.



Students can build several types of fundamental bridges including Howe, Pratt, and Warren bridges.

Design your own roller coaster!



Add Load Cells to measure the forces needed to support the track as the car goes up and over the loop.

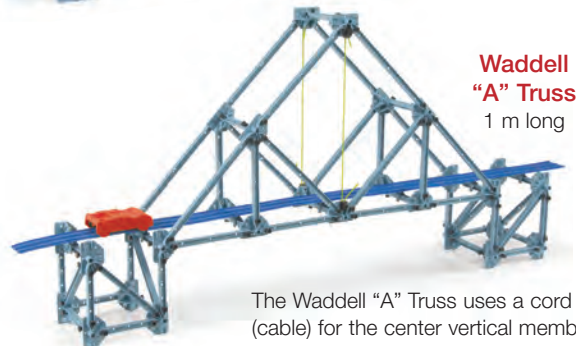
Deck Truss

80 cm long



Waddell "A" Truss

1 m long



The Waddell "A" Truss uses a cord (cable) for the center vertical member.

Includes:

- I-Beam #5 (16) 24 cm long (16)
- I-Beam #4 (36) 17 cm long (36)
- I-Beam #3 (36) 11.5 cm long (36)
- I-Beam #2 (16) 8 cm long (16)
- I-Beam #1 (16) 5.5 cm long (16)
- Connectors (28)
- Screws (150)
- Flexible road bed (3 m)
- Track coupler
- Road bed clips (24)
- Car with flag and mass
- Starter bracket
- Cord tensioning clips (32)
- Yellow cord (1 roll)
- Instruction manual



Order Information

Bridge Set.....	ME-6991	
Recommended:		
Load Cell and Amplifier Set.....	PS-2199	p. 31

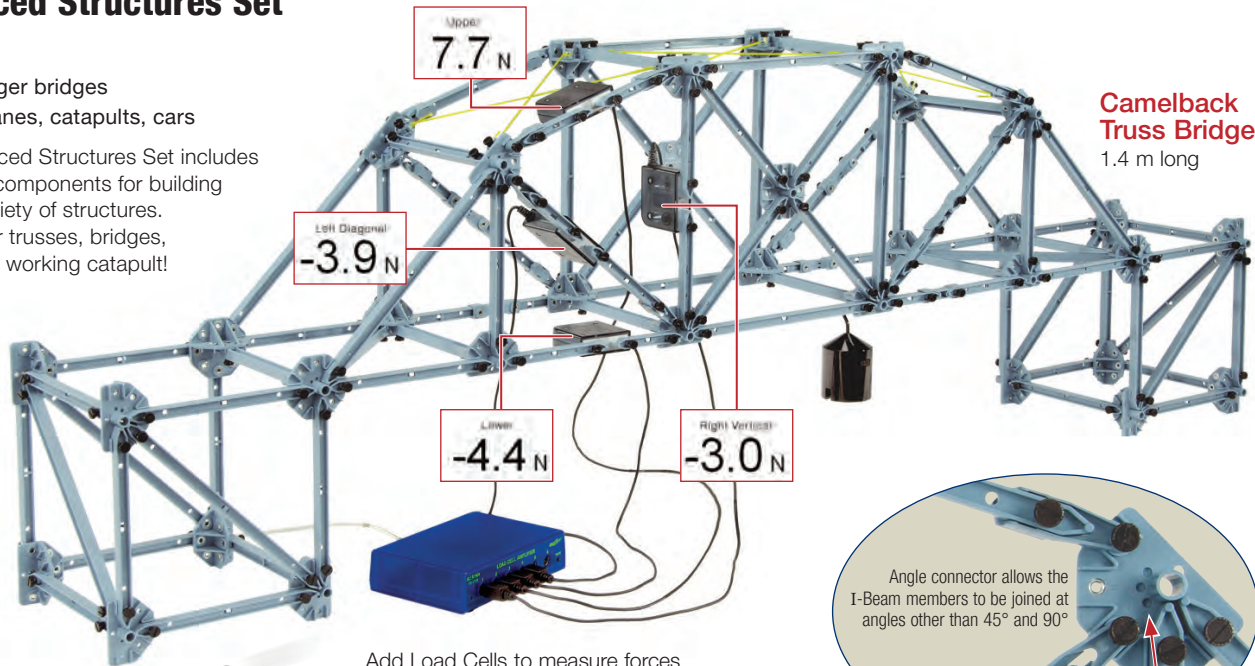
Structures Systems

Advanced Structures Set

ME-6992B

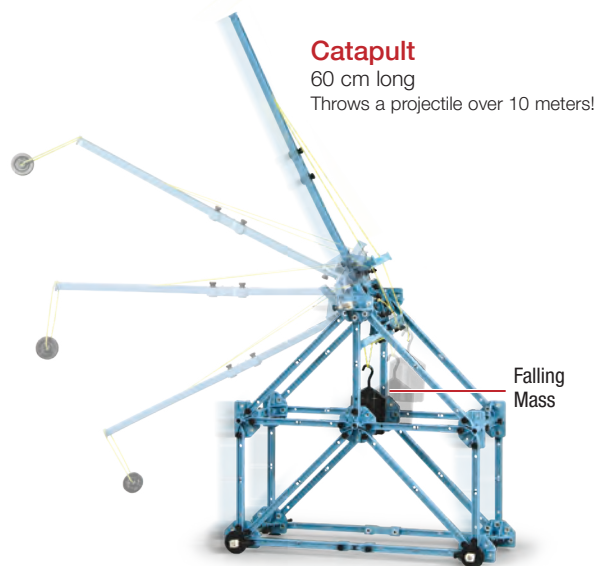
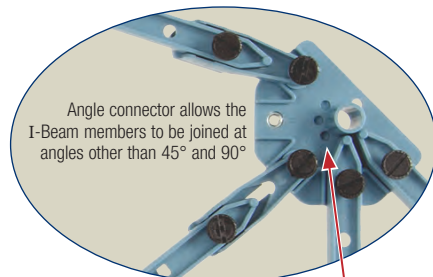
- ▶ Build larger bridges
- ▶ Build cranes, catapults, cars

The Advanced Structures Set includes additional components for building a wider variety of structures. Build larger trusses, bridges, and even a working catapult!

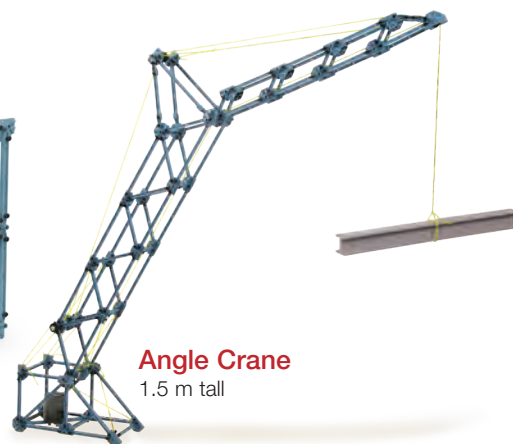
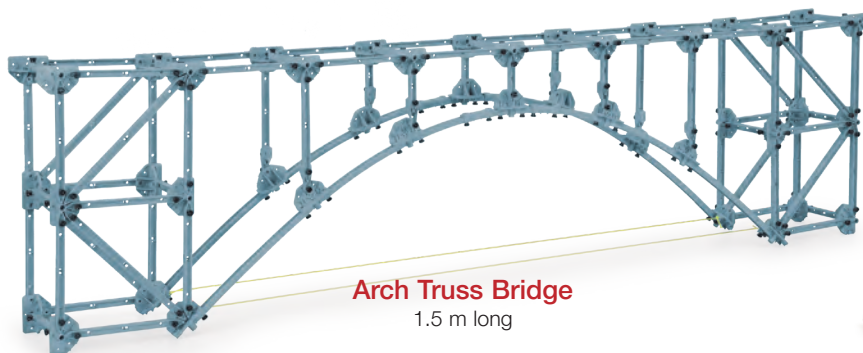
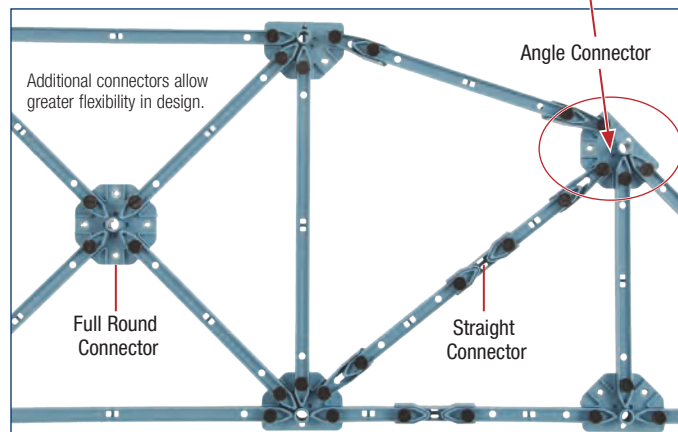


Camelback Truss Bridge
1.4 m long

Add Load Cells to measure forces anywhere in the structure.



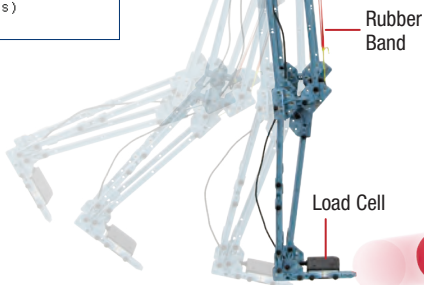
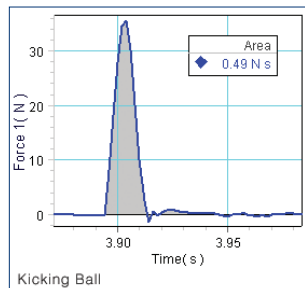
Wheels allow catapult to move.



Also see the Tower Crane on page 151.

Human Leg Model

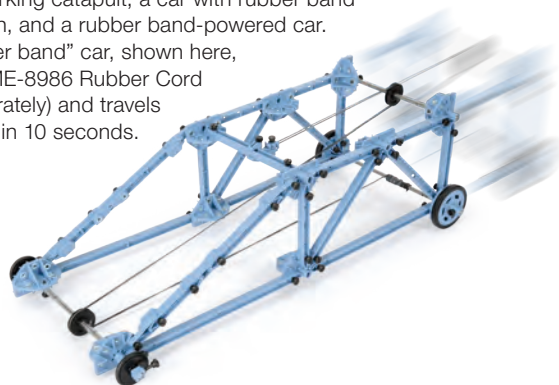
The articulated leg, shown below, uses a rubber band (not included) for the quadriceps and has a load cell on the foot to measure the force that the “toe” exerts on the ball. The impulse (area under the curve) is equal to the resulting momentum of the ball.



See page 155 for more Human Structures.

Rubber Band Car

Build a working catapult, a car with rubber band suspension, and a rubber band-powered car. The “rubber band” car, shown here, uses the ME-8986 Rubber Cord (sold separately) and travels over 50 ft. in 10 seconds.



Use these flexible I-Beams to make a bridge which dramatically demonstrates how a bridge fails and yet the beams will return to their original shape when the load is removed.

For more examples using the Advanced Structures Set go to pasco.com/structures



Includes:

- Force Platform Bracket (2)
- I-Beam #5 24 cm long (24)
- I-Beam #4 17 cm long (54)
- I-Beam #3 11.5 cm long (54)
- I-Beam #2 8 cm long (24)
- I-Beam #1 5.5 cm long (24)
- Flex I-Beam #5 24 cm long (10)
- Flex I-Beam #4 17 cm long (18)
- Flex I-Beam #3 11.5 cm long (18)
- Flat Beams (3 lengths) (16)
- Axles (3 lengths) (2)
- Connectors (42)
- Cord Tensioning Clips (32)
- Round and Flat Connectors (6)
- PASTrack Fasteners (6)
- Angle and Straight Connectors (24)
- Sliding Connector (12)
- Pulleys, O-rings, Spacers (12)
- Collets (24)
- Drive Wheel with Rubber Tire (4)
- Structures Rod Clamps (2)
- Screws (300)
- Yellow Cord (1 roll)
- Instruction Manual



Flexible I-Beams
Dramatically demonstrate structural failure.

Order Information

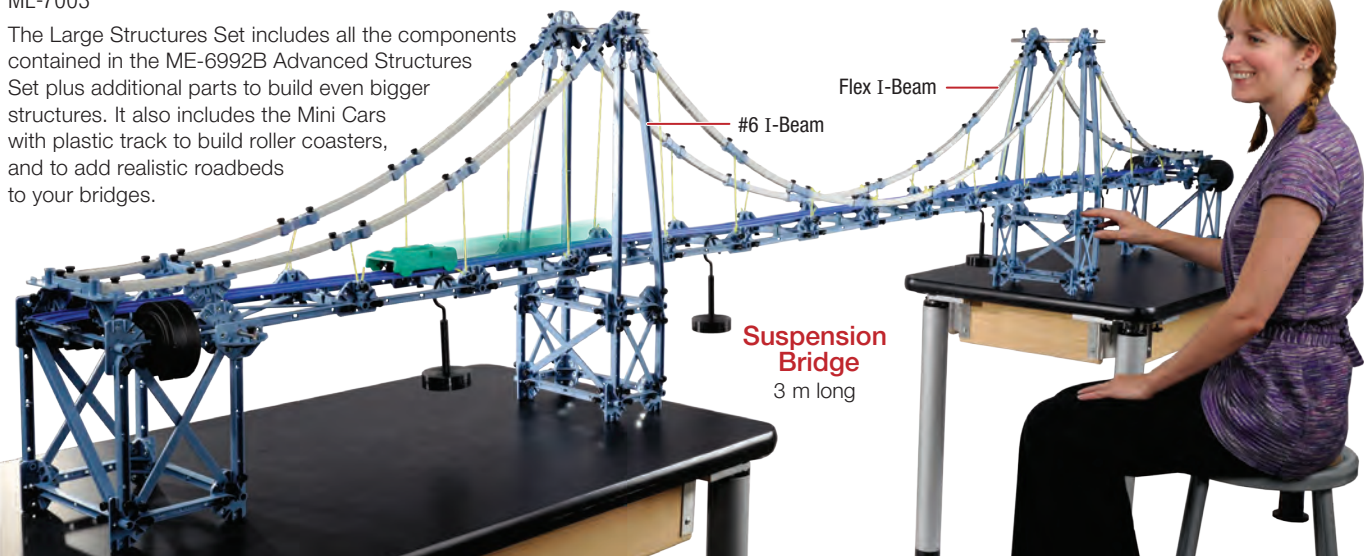
Advanced Structures Set.....	ME-6992B
Shown in use with:	
Load Cell and Amplifier Set.....	PS-2199
(includes four load cells)	
100 N Load Cell.....	PS-2200
Large Slotted Mass Set.....	ME-7566
Rubber Cord for IDS System (30m Spool).....	ME-8986

Structures Systems

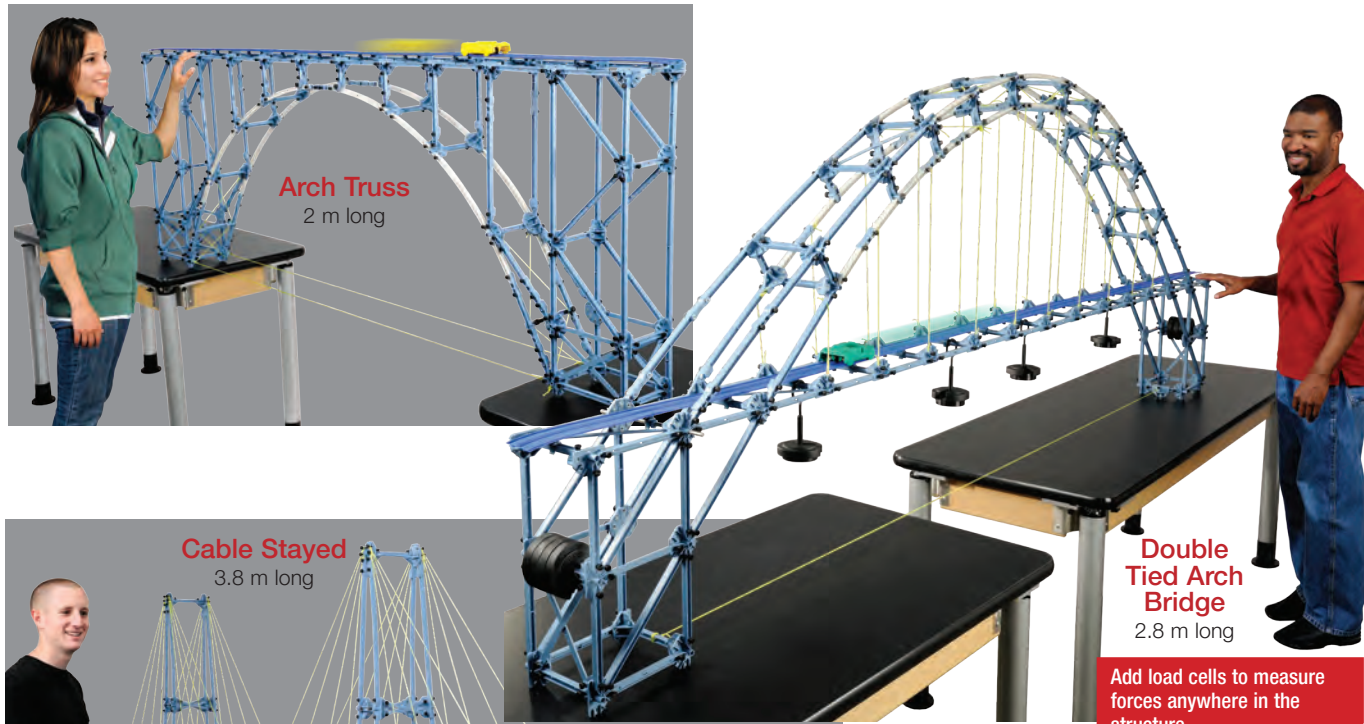
Large Structures Set

ME-7003

The Large Structures Set includes all the components contained in the ME-6992B Advanced Structures Set plus additional parts to build even bigger structures. It also includes the Mini Cars with plastic track to build roller coasters, and to add realistic roadbeds to your bridges.



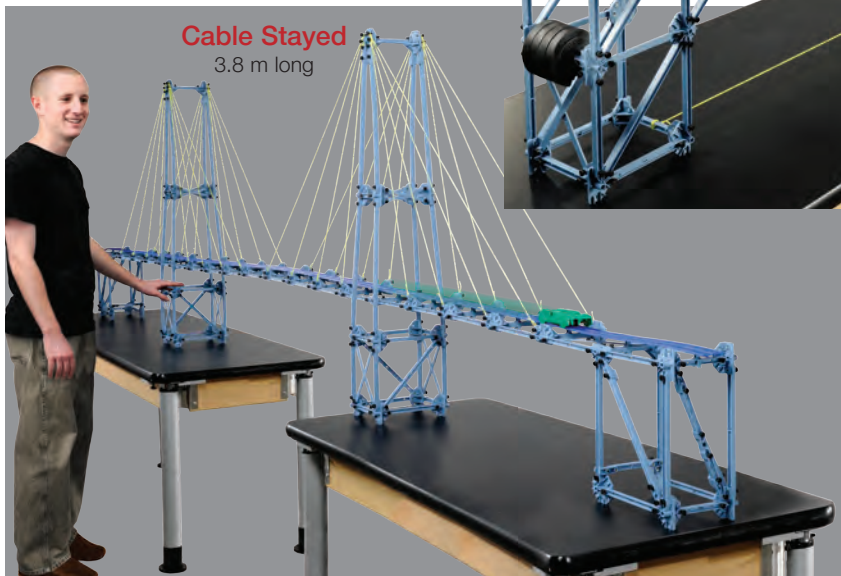
Suspension Bridge
3 m long



Arch Truss
2 m long

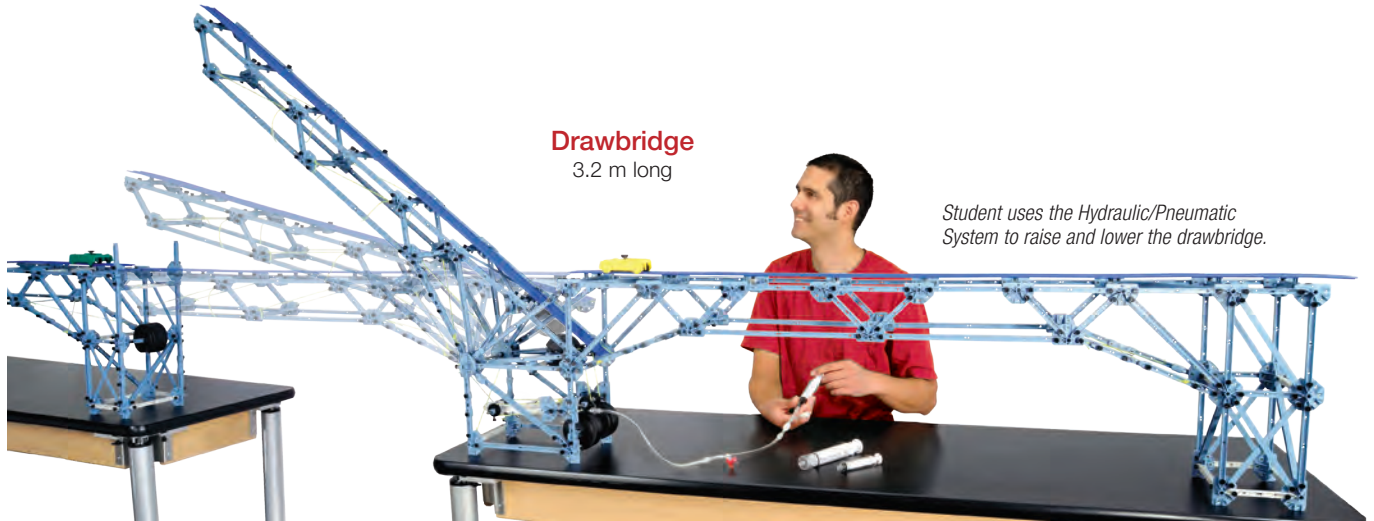
Double Tied Arch Bridge
2.8 m long

Add load cells to measure forces anywhere in the structure.



Cable Stayed
3.8 m long



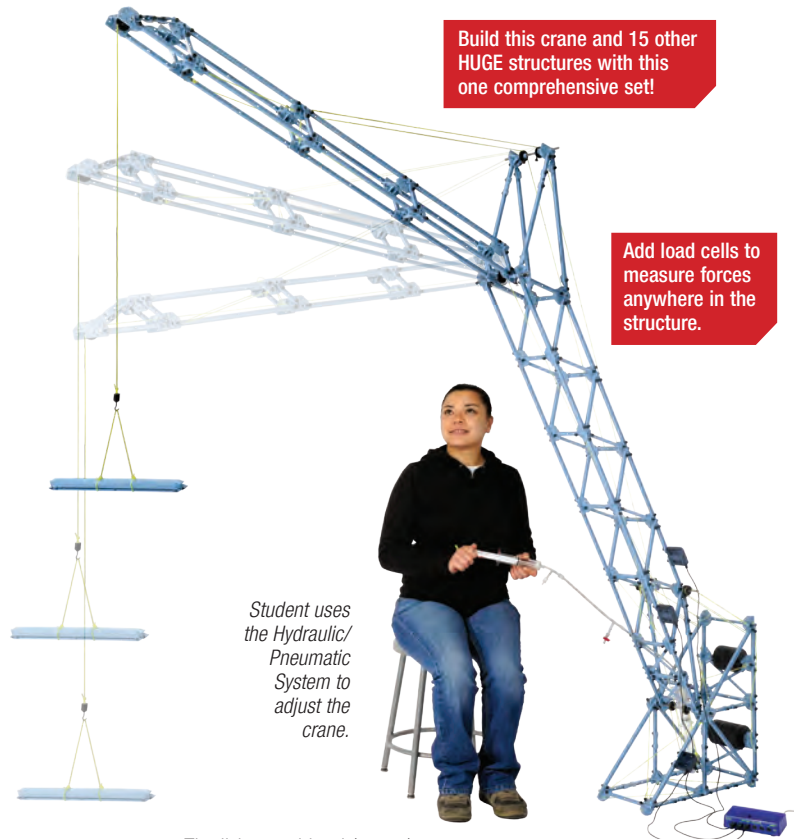


Drawbridge
3.2 m long

Student uses the Hydraulic/Pneumatic System to raise and lower the drawbridge.



Tower Crane
1.2 m tall



Build this crane and 15 other HUGE structures with this one comprehensive set!

Add load cells to measure forces anywhere in the structure.

Student uses the Hydraulic/Pneumatic System to adjust the crane.

Includes:

- I-Beam #6 35 cm long (24)
- I-Beam #5 24 cm long (24)
- I-Beam #4 17 cm long (54)
- I-Beam #3 11.5 cm long (54)
- I-Beam #2 8 cm long (24)
- I-Beam #1 5.5 cm long (24)
- Flex I-Beam #5 24 cm long (10)
- Flex I-Beam #4 17 cm long (18)
- Flex I-Beam #3 11.5 cm long (18)
- Flat Beams (3 lengths) (16)
- Axles (3 lengths) (2)
- Connectors (70)
- Cord Tensioning Clips (32)
- Yellow car and green car, each with flag
- Force Platform Bracket (2)
- Round and Flat Connectors (6)
- Angle and Straight Connectors (24)
- Drive Wheel with Rubber Tire (4)
- Pulleys, O-rings, Spacers (12)
- Structures Rod Clamps (2)
- Sliding Connector (12)
- PASTrack Fasteners (6)
- Collets (24)
- Screws (450)
- Yellow Cord (1 roll)
- Flexible road bed (9.1 m)
- Road bed clips (24)
- Starter bracket
- Track coupler (2)
- Instruction Manual

Order Information

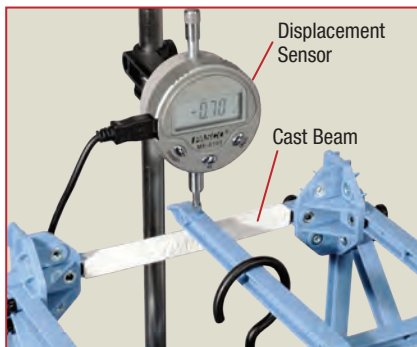
Large Structures Set.....	ME-7003
Shown in use with:	
Load Cell and Amplifier Set.....	PS-2199
(includes four load cells)	
Structures Hydraulic System.....	ME-6984
Large Slotted Mass Set (2 kg Set).....	ME-7589

Structures Systems

Structures Cast Beam Set

ME-7009

Make your own cast beams that look like pre-stressed concrete beams. Test them and you'll find they perform like them, too. These beams are cast with a mixture of sand and plaster of Paris (not included). The rebar is made of the same plastic used for the I-beams. Students can explore how the strength of the beam is affected by the amount of tension put on the rebar, the mixture of sand and plaster of Paris, or using one or two rebar.

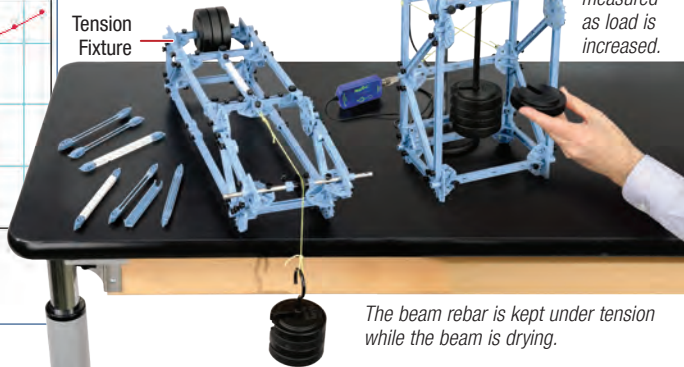
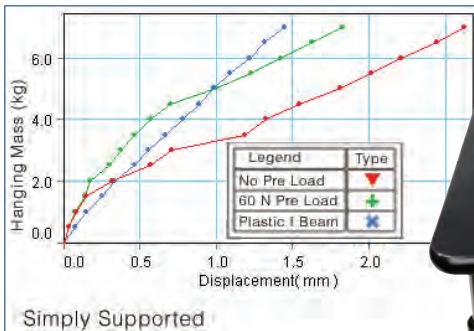


Both this tension fixture and the test fixture can be built concurrently with this set.

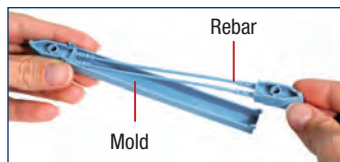


Displacement of beam is measured as load is increased.

The graph of hanging mass versus displacement shows the relative strengths of three beams: one cast beam made with no pre-load; one cast beam made with 60 N of pre-load; and one normal plastic I-beam. Notice that the traces for the cast beams show discontinuities when the beams cracked. Also notice that the pre-loaded cast beam is stronger than the plastic I-beam until the cast beam cracks.



The beam rebar is kept under tension while the beam is drying.



Step 1: The rebar with connecting ends snaps into the plastic mold. Pour a mixture of sand and plaster of Paris into the mold.

Step 2: After it dries, it is easy to remove the flexible plastic mold from the cast beam.

Includes:

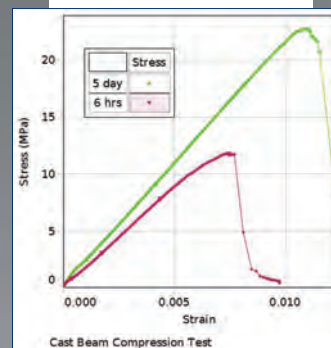
- I-Beam #5 24 cm long (8)
- I-Beam #4 17 cm long (18)
- I-Beam #3 11.5 cm long (18)
- I-Beam #2 8 cm long (8)
- I-Beam #1 5.5 cm long (8)
- Axles (3 lengths) (2)
- Connectors (14)
- Cord Tensioning Clips (32)
- Round and Flat Connectors (6)
- PASTrack Fasteners (6)
- Angle and Straight Connectors (24)
- Collets (24)
- Screws (150)
- Pulley, O-rings, Spacers (12)
- Sliding Connector (12)
- Reusable Plastic Molds (10)
- Rebar (30)
- Yellow Cord (1 roll)
- Instruction Manual
- Required but not included: Sand and Plaster of Paris



The cast beam shown here is tested to destruction under compression using the Materials Testing Machine on pages 158-159.



Close-up of beam after destruction showing plastic "rebar."



PASCO Capstone graph shows that strength of Plaster of Paris increases with cure time.

Cast Beam Spares Set

ME-6983

Consumable replacement parts for Cast Beams. These can also be used with the Advanced Structures Set.

Includes:

- Reusable Plastic Molds (10)
- Rebar with Connectors (30)



Order Information

Cast Beam Spares SetME-6983

Order Information

Structures Cast Beam Set.....ME-7009

Also shown:

PASPORT Displacement Sensor.....PS-2204

Large Slotted Mass Set.....ME-7566

Not shown, but required:

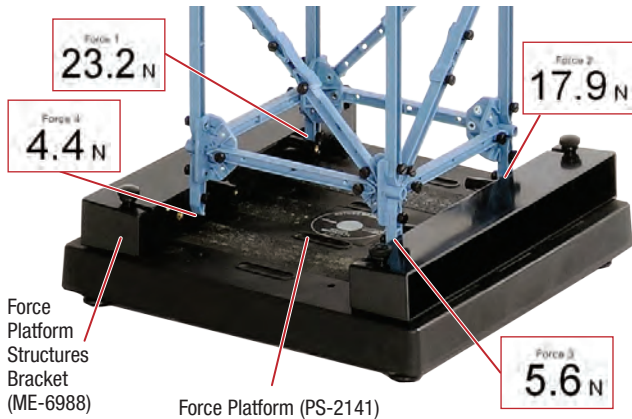
Interface and PASCO Capstone Software, see pages 68-71.

Measure support forces with a Force Platform

PASPORT Force Platform

PS-2141

Measure the support forces of a crane by connecting it to a Force Platform (PS-2141) using the special Force Platform Structures Bracket (ME-6988). The Force Platform is supported by four individual load cells which combine to measure the total vertical force on the platform. These four readings can also be viewed separately to measure the unequal forces on the crane supports.



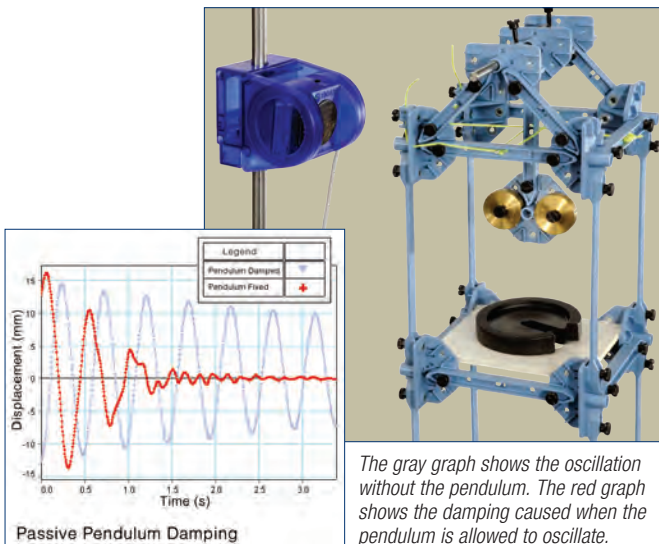
Crane is built using the Large Structures Set (ME-7003), shown on pages 150-151.

Order Information

PASPORT Force Platform.....PS-2141
Force Platform Structure Bracket.....ME-6988A

Measure passive damping with a Motion Sensor

This building frame is built with an Advanced Structures Set using the Flat Members. A pendulum with drag caused by strings is suspended from the top of the building. The Motion Sensor is positioned to record the oscillation of the building.



Order Information

Equipment shown:
Advanced Structures Set*ME-6992B
PASPORT Motion SensorPS-2103A
Large Slotted Mass SetME-7566

*Patents pending

Measure bridge deflection with a Displacement Sensor

PASPORT Displacement Sensor

PS-2204

The Displacement Sensor measures the travel of a spring-loaded indicator as a bridge is loaded with weight. The included PASPORT Sensor plugs into the included Digital Indicator, which includes its own digital LED readout and can be used as a standalone device. To record your data, simply plug the PASPORT sensor into an interface.

Specifications:

Maximum Travel: 10 mm

Maximum Sample Rate: 5 Hz

Resolution:
0.013 mm
(0.0005 in)



Order Information

PASPORT Displacement Sensor.....PS-2204
Shown in use with:
Hooked Mass Set.....SE-8759
Small "A" BaseME-8976
Stainless Steel Rod, 60 cm Threaded.....ME-8977
Required:
PASPORT Interface..... p. 12

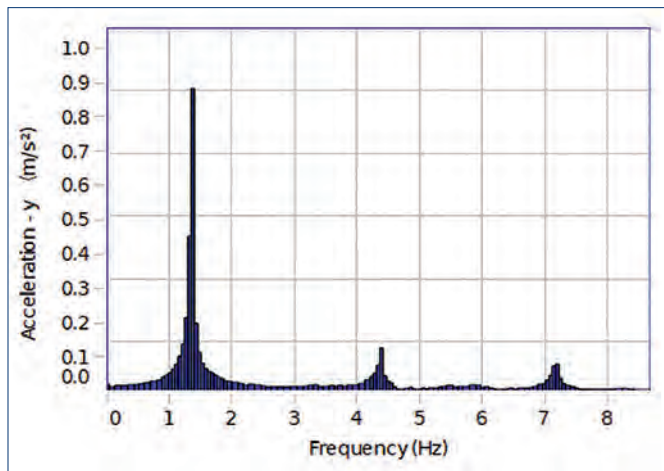
Structures Systems

Shaking Tower

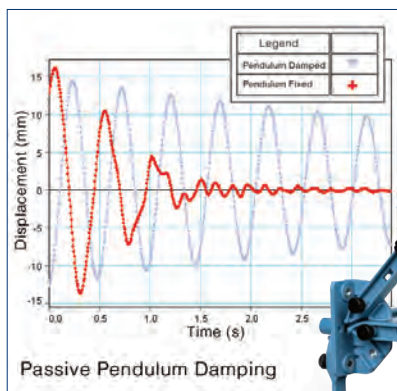
ME-7018

- ▶ Explore the resonance modes
- ▶ Measure accelerations with wireless sensors
- ▶ Demonstrate passive damping

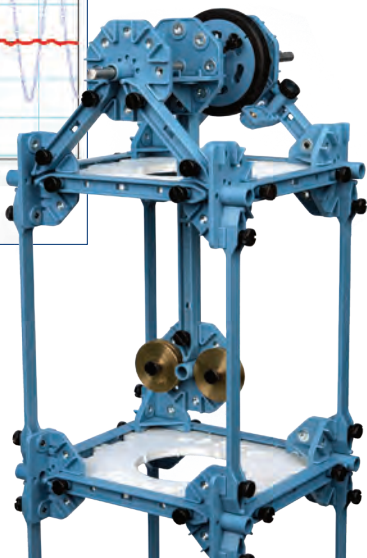
Built from PASCO Structures beams, this tower is made to oscillate in its various resonance modes by a driver attached by a rubber band to the first floor of the tower. Wireless Load Cells with Accelerometers are attached to each floor to record how much shaking each floor experiences.



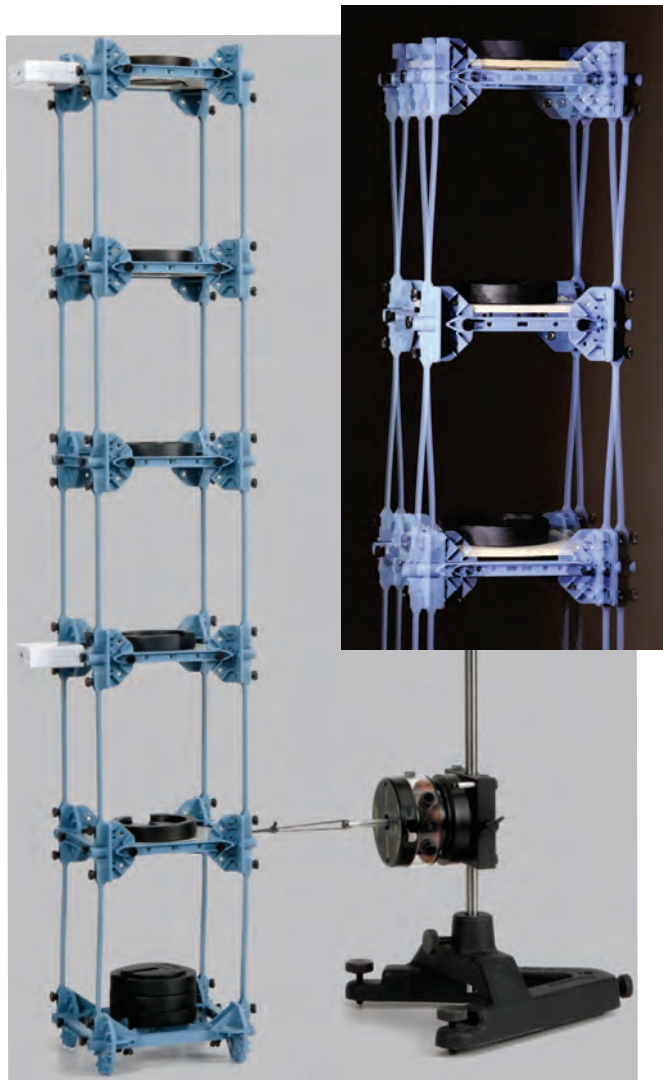
This FFT, generated in PASCO Capstone software, shows the frequency responses of the top Wireless Load Cell/Accelerometer.



The gray graph in PASCO Capstone software shows the oscillation without the pendulum. The red graph shows the damping caused when the pendulum is allowed to oscillate.



In modern buildings, passive damping mechanisms are installed to damp out oscillations during earthquakes. The damping pendulum in this tower quickly stops oscillations.



The tower is shaken by the Mechanical Wave Driver, which is powered by an 850 Universal Interface or Function Generator.

Includes:

- #1 I-Beams (10)
- #2 I-Beams (8)
- #3 I-Beams (24)
- #4 I-Beams (1)
- Nylon Spacers (2)
- Connectors (20)
- (F4) Flat Beam (20)
- Flat Round Connector (4)
- Full Round Connectors (5)
- Floors (5)
- Mass, 20 gram (2)
- Mass, 50 gram (2)
- Medium Shaft, Structures
- 2 sets Screws (150)
- Sliding Connector
- Tire, Structures
- Wheel, Structures

(Large Slotted Mass Set, shown in photo above, not included.)

Order Information

Shaking Tower	ME-7018
Required:	
Large Slotted Mass Set	ME-7566
Mechanical Wave Driver	SF-9324
2 Meter Patch Cord Set	SE-9415A
Large Rod Base	ME-8735
Stainless Steel Rod, 25 cm Threaded	ME-8988
Wireless Load Cell and Accelerometer	PS-3216
850 Universal Interface	UI-5000
PASCO Capstone Software	pp. 68-71

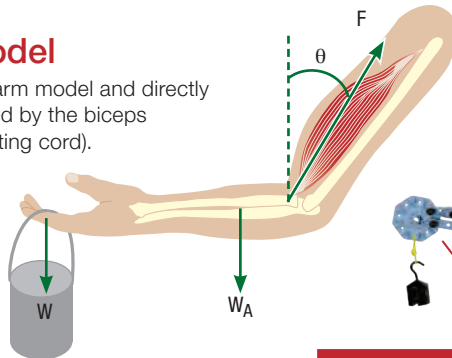
Human Structures Set

ME-7001

- ▶ Build models that represent real life examples.
- ▶ Construct all three models concurrently with this set.
- ▶ Bring homework problems to life!

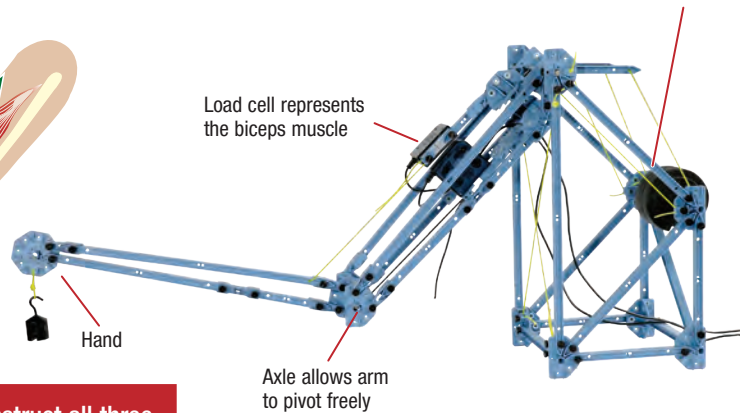
Human Arm Model

Students build a realistic arm model and directly measure the forces exerted by the biceps muscle (tension in supporting cord). Vary the length and angle of upper and lower arm, as well as the point of attachment of the muscle.



Load cell represents the biceps muscle

Support Structure allows the angle of the upper arm to be easily adjusted

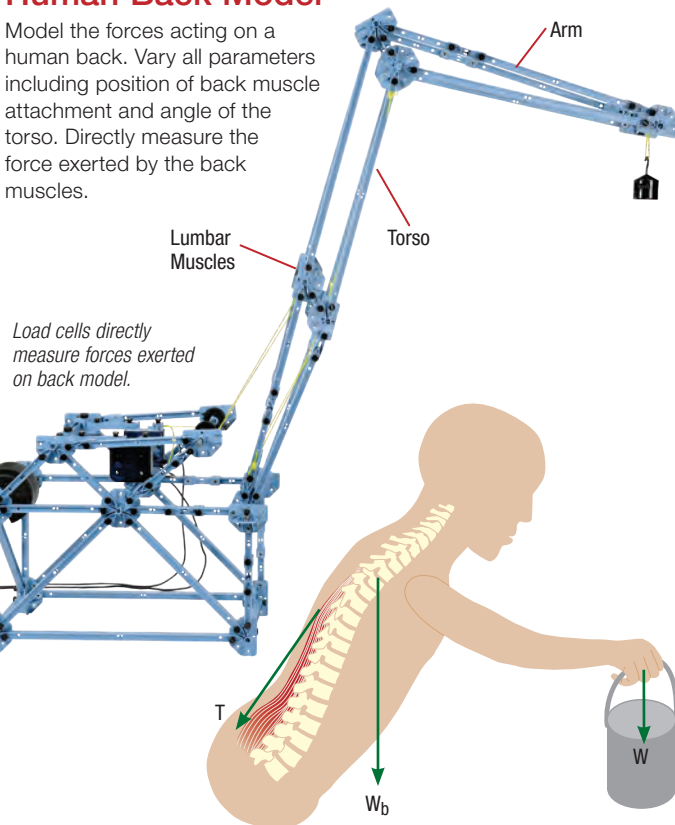


Axle allows arm to pivot freely

Construct all three models concurrently with this set.

Human Back Model

Model the forces acting on a human back. Vary all parameters including position of back muscle attachment and angle of the torso. Directly measure the force exerted by the back muscles.



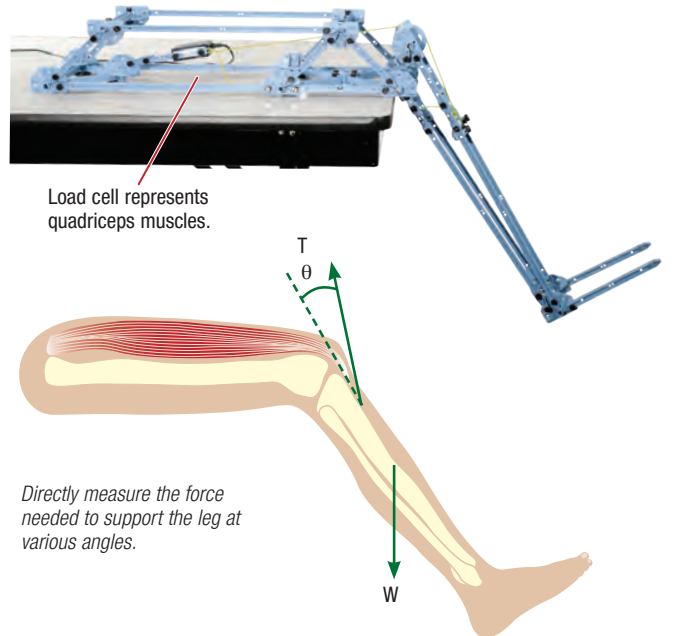
Load cells directly measure forces exerted on back model.

Includes:

- Truss Set Screws (5-pack)
- Truss Set Members (2-pack)
- Connector Spares (2-pack)
- #6 I-Beam Spares (1 pkg.)
- Cord Lock Spares (1 pkg.)
- Axle Spares (1 pkg.)
- Round Connector Spares (1 pkg.)
- Angle Connector Spares (1 pkg.)
- Roll of rubber cord

Human Leg Model

The leg model shown below uses a load cell for the quadriceps muscle to directly measure the force needed to support the leg at various angles.



Load cell represents quadriceps muscles.

Directly measure the force needed to support the leg at various angles.

Order Information

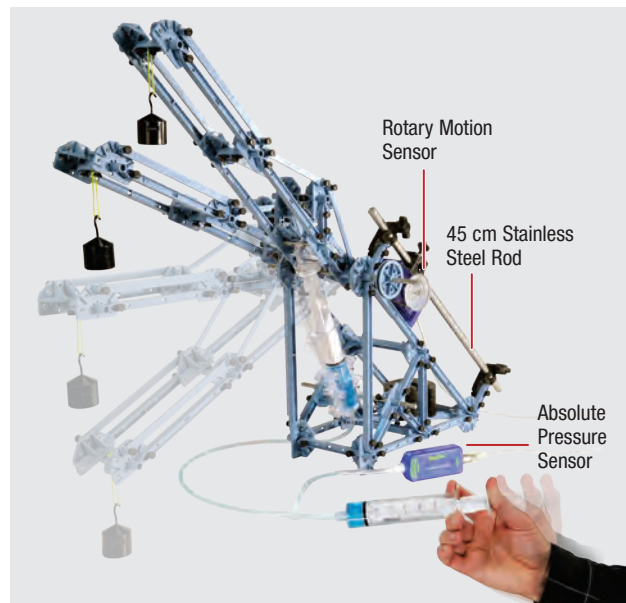
Human Structures Set.....	ME-7001
Shown in use with:	
Load Cell and Amplifier Set.....	PS-2199
(includes four load cells)	
Hooked Mass Set.....	SE-8759
Large Slotted Mass Set.....	ME-7566

Structures Systems

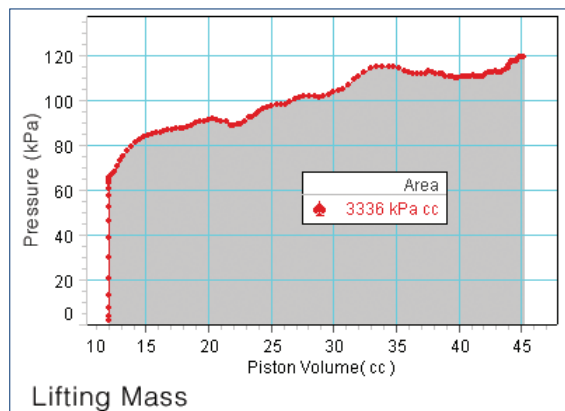
Structures Hydraulic System

ME-6984

Add a hydraulic/pneumatic ram to make your structures move and do work. Not only will students see the cranes and jacks in action, they can directly measure the pressure and volume to calculate how much work was done.



The weight is lifted using a syringe of water to fill the master cylinder. An Absolute Pressure Sensor measures the pressure and a Rotary Motion Sensor records the movement of the piston.



Pressure and volume are recorded as the weight is lifted, and the work done is the area under the curve.

Includes:

- Master Cylinder
- Pressure Sensor "T"
- Check Valves and Tubing
- Syringes (10, 20, 60 ml)
- Drive Belt for Rotary Motion Sensor (not shown)

**Order Information**

Structures Hydraulic System.....	ME-6984	
Advanced Structures Set.....	ME-6992B	p 148
45 cm Stainless Steel Rod.....	ME-8736	p. 186
PASPORT Absolute Pressure Sensor.....	PS-2107	p 32
PASPORT Rotary Motion Sensor.....	PS-2120A	p. 28

Building Better Bridges Kit

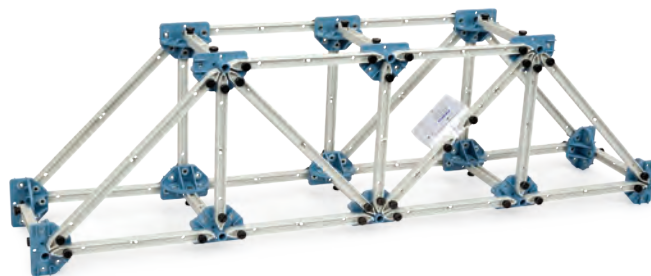
ME-3581

- ▶ A complete STEM kit to teach bridge-building
- ▶ Compatible with PASCO Structures System

Now is the perfect time for your students to learn about bridge-building and how bridges really work. This complete STEM kit allows students to learn and apply engineering design concepts. They can use the included I-Beams to build bridges and structures that behave like the real thing! And with the included Wireless Load Cell, students can measure forces under tension or compression anywhere in their structures.

Concepts:

- ▶ Forces in Equilibrium
- ▶ Internal Forces
- ▶ Moments in Equilibrium
- ▶ Strength of Members
- ▶ Truss Analysis



The kit has flexible I-Beams, and the Wireless Load Cell measures up to 50 N.

**Includes:**

- Lab Activities
- Wireless Load Cell and Accelerometer PS-3216
- Flexible I-Beams (various sizes)
- Connectors
- Truss Screws
- Weight Set
- Grattells® Storage Tray

Order Information

Building Better Bridges Kit.....	ME-3581	
Want an additional load cell?		
Wireless Load Cell and Accelerometer.....	PS-3216	p. 53

Flexible I-Beam Set

ME-6985

Use the flexible I-Beams to make a bridge that dramatically demonstrates how a bridge fails and yet the beams return to their original shape once the load is removed.



Dramatically demonstrate structural failure.



Includes:

- Flexible I-Beam #5, 24 cm long (10)
- Flexible I-Beam #4, 17 cm long (18)
- Flexible I-Beam #3, 11.5 cm long (18)

Order Information

Flexible I-Beam Set ME-6985
Shown in use with:
Truss Set ME-6990 p. 146

Mini Car Track Spares

ME-6974



Includes two gates, two track couplers and one bag (24) of roadbed clips.

Order Information

Mini Car Track Spares ME-6974

Axle Spares

ME-6998A



Includes drive wheel with rubber tire (4), pulleys with "O" rings (12 each), axles (two each of three lengths), spacers (12) and collets (24).

Order Information

Axle Spares ME-6998A

Cord Lock Spares

ME-6996

Includes 32 cord-tensioning clips and a spool of yellow cord.

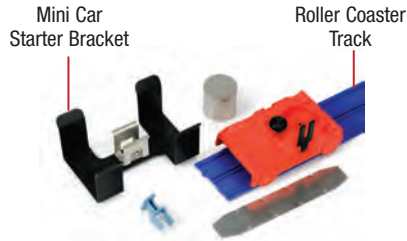


Order Information

Cord Lock Spares ME-6996
Yellow String (2 pack) ME-9876

Road Bed Spares

ME-6995



Includes flexible roadbed (3 m), roadbed clips (24), car with flag, extra mass, mini car starting bracket, and track couples (2).

Order Information

Road Bed Spares ME-6995
Sold separately:
Roller Coaster Track ME-9814

Force Platform Structure Bracket

ME-6988A

Includes:

- Brackets (2)
- Screws (4)



Order Information

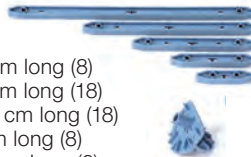
Force Platform
Structure Bracket ME-6988A

Truss Set Members

ME-6993

Includes:

- I-Beam #5 24 cm long (8)
- I-Beam #4 17 cm long (18)
- I-Beam #3 11.5 cm long (18)
- I-Beam #2 8 cm long (8)
- I-Beam #1 5.5 cm long (8)
- Connectors (14)



Order Information

Truss Set Members ME-6993

Truss Set Screws

ME-6994

Includes 80 screws. All components in the Structures System use this same 6-32 thumb screw.



Order Information

Truss Set Screws ME-6994

Structures Rod Clamp

ME-6986

Connects structure members to 1/2" rod. Includes a set of two.



Order Information

Structures Rod Clamp ME-6986

Beams & Connectors

Thin I-Beams

ME-7012

Set of 48 thin I-Beams, for use with structures systems. 24 each of #4 beams (17 cm length) and #3 beams (11.5 cm length).



Flexible I-Beam Set

ME-6985

Includes 18 each of:

Flexible I-Beam #4 (17 cm long)
Flexible I-Beam #3 (11.5 cm long)
and 10 Flexible I-Beam #5 (24 cm long)



Flat Structures Members

ME-6987

Includes 16 each of:
2x3 beams (12.5 cm long); F4 beams (17 cm long); 3x4 beams (19 cm long)



Structures #6 I-Beam Spares

ME-7008

Includes 24 #6 I-Beams (35 cm)



Structures #5 I-Beam Spares

ME-7017

Includes 24 #5 I-Beams (24 cm)



Photoelastic I-Beam Set

ME-7011

Clear plastic I-Beams that display stress lines.

Includes 24 each of:
#3 I-Beam (11.5 cm long)
#4 I-Beam (17 cm long)



Order Information

Thin I-Beams ME-7012
Flexible I-Beam Set ME-6985
Flat Structures Members ME-6987
Structures #6 I-Beam Spares ME-7008
Structures #5 I-Beam Spares ME-7017
Photoelastic I-Beam Set ME-7011

Connector Spares

ME-7002

Set of 14 connector spares used to join truss members.



Angle Connector Spares

ME-6999A

Includes 24 each of Angle Connectors, Straight Connectors and 12 Sliding Connectors.



Full Round and xyz Connector Spares

ME-6997

Includes 6 each of: full round connectors, xyz connectors, and bolts & nuts.



Order Information

Connector Spares ME-7002
Angle Connector Spares ME-6999A
Full Round and xyz
Connector Spares ME-6997

Materials Testing

Comprehensive Materials Testing System

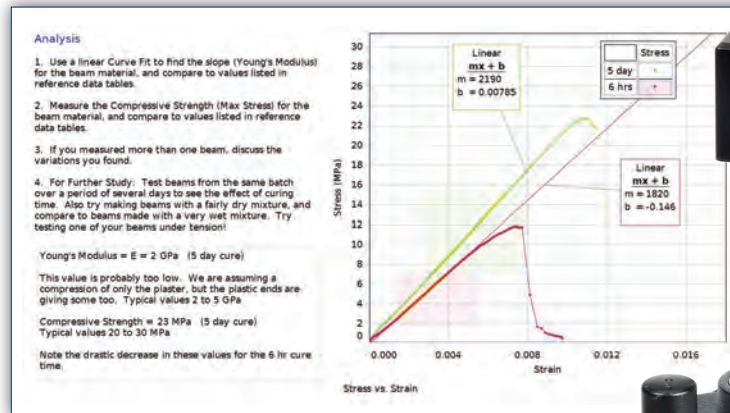
ME-8244

With this one system,
your students can investigate:

- ▶ Compression and tensile testing
- ▶ Column buckling
- ▶ Three and four-point bending
- ▶ Shear testing
- ▶ Stress lines with photoelasticity

The Comprehensive Materials Testing System includes everything needed to investigate compression and tensile testing, column buckling, three and four-point bending, shear testing, and stress lines with photoelasticity. In addition to everything the Materials Testing Machine provides, the Comprehensive System includes a sturdy, plastic base with convenient storage for all components and accessories.

Download experiments at pasco.com/MTS



Clear Safety Shields

Materials Testing Machine

Tensile Samples

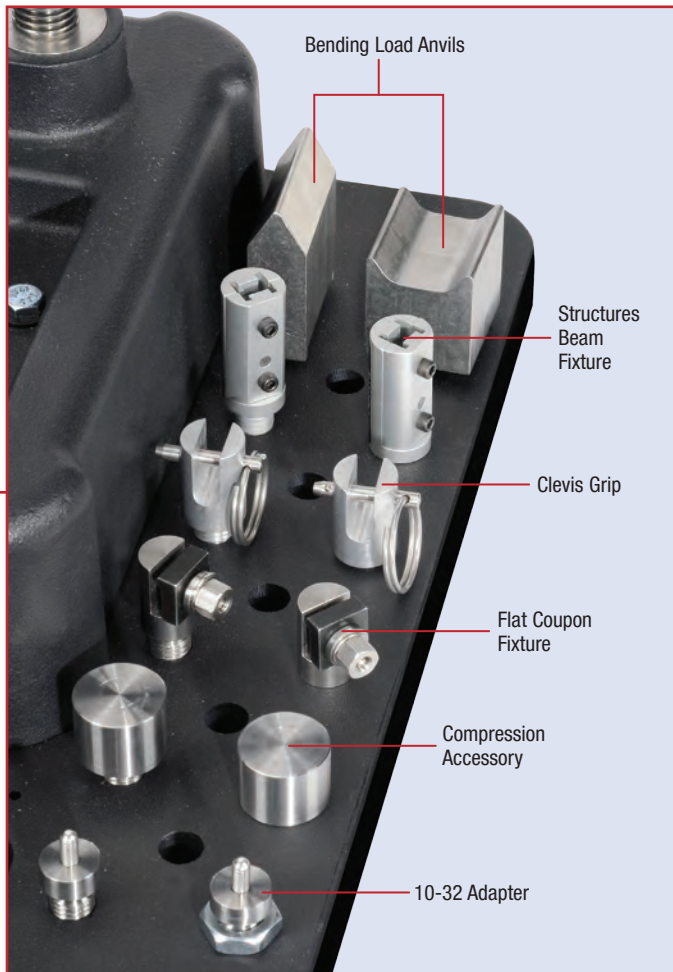
Calibration Rod

System Storage Base

Sturdy plastic base provides convenient storage for accessories. Use a C-clamp on the corner of the base to temporarily secure the Materials Testing Machine to the lab bench.

Bending Support Anvil

Shear Accessory



Includes:

- Materials Testing Machine ME-8236
- Tensile Samples:
Aluminum, Brass, Annealed Steel,
Steel, Acrylic, Polyethylene (10 of each)
- Bending Accessory ME-8237
- Four-point Load Anvil ME-8249
- Photoelasticity Accessory ME-8241
- Shear Accessory ME-8239
- Materials System Storage Base ME-8229
- Structures Beam Fixture ME-8242
- Thin I-Beams ME-7012
- Cast Beam Spares Set ME-6983
- Compression Accessory ME-8247
- Flat Coupon Fixture ME-8238
- Stress Strain Apparatus
Coupons – Plastic AP-8222
- Stress Strain Apparatus
Coupons – Metal AP-8223
- Clevis Grip ME-8245
- 10-32 Adapter ME-8246
- AirLink Interface PS-3200
- PASCO Capstone
Single User License UI-5401



See Complete Experiments:
 Tensile Testing of Metalspage 351
 Column Bucklingpage 352
 Bending: 3-Point and 4-Pointpage 353

Order Information

- Comprehensive Materials Testing SystemME-8244
- Materials Testing MachineME-8236

Materials Testing

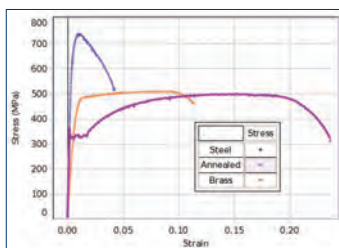
Materials Testing Machine

ME-8236

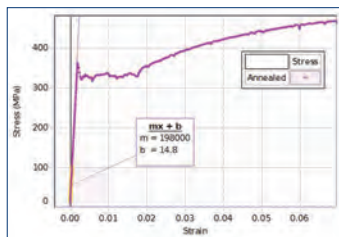
- ▶ 7100 N max load
- ▶ Hand-cranked so students can feel samples break
- ▶ Inexpensive samples make it possible for each student to experience it firsthand

Measure force and displacement for various materials as they are stretched, compressed, sheared, or bent. Investigate material properties including Young's Modulus, Tensile Strength, Yield Strength, Ductility and Modulus of Resilience.

The Materials Testing Machine measures force with a 7100 N load cell and displacement with an optical encoder. It runs on PASCO Capstone software, which has a built-in compliance calibration wizard and has all the tools to record and display stress vs. strain, apply linear fits to find Young's Modulus, and to record and play back webcam movies of the breaking samples, synced to the data.



Tensile Stress vs. Strain is plotted in PASCO Capstone software for steel, annealed steel, and brass.



For annealed steel, a linear fit is applied to find Young's Modulus.

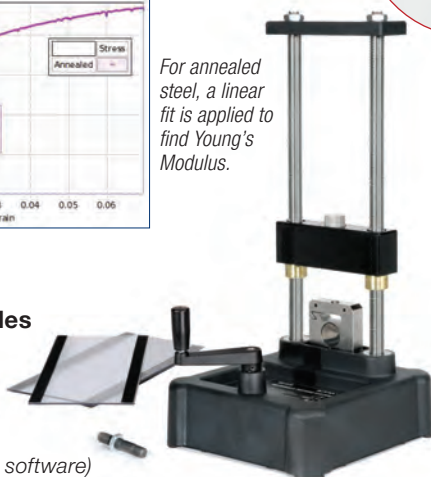
See the PS-2343 USB Camera Microscope on page 161.



ME-8236 Includes

- Machine
- Compliance calibration rod
- Safety shields

(requires Capstone software)

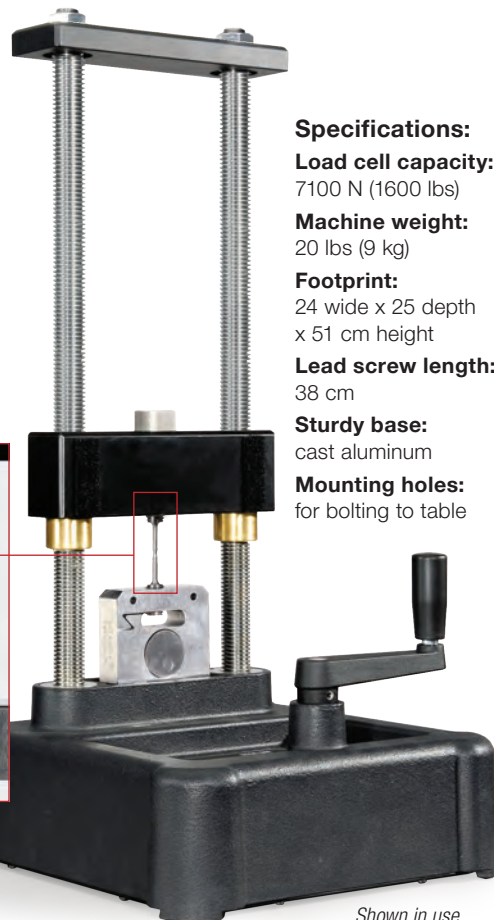


Tensile Samples

Set of 10 each

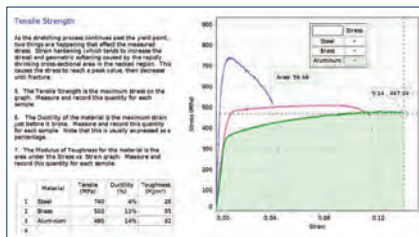
Order Information

Aluminum Tensile Sample.....	ME-8231
Brass Tensile Sample.....	ME-8232
Annealed Steel Tensile Sample.....	ME-8233
Steel Tensile Sample.....	ME-8243
Acrylic Tensile Sample.....	ME-8234
Polyethylene Tensile Sample.....	ME-8235



- Specifications:**
- Load cell capacity:** 7100 N (1600 lbs)
 - Machine weight:** 20 lbs (9 kg)
 - Footprint:** 24 wide x 25 depth x 51 cm height
 - Lead screw length:** 38 cm
 - Sturdy base:** cast aluminum
 - Mounting holes:** for bolting to table

Shown in use without the included safety shields.



Speed Control

- Click on Record and then turn the crank. Note that the Motor display at right shows you the rate that you are turning (in revolutions) (1) the cross-head beam, in millimeters/minute.
- Practice turning the crank to give you the experience of a smooth, constant rate between 15 and 25 mm/min.

Tensile Samples

- Use calipers (or a micrometer) to measure the diameter of the narrow portion of the tensile sample. Record the value for diameter in Figure 4.
- Note that the calculator also has a value for the length of the sample. If you measure the complete measured portion, this should be about 20 mm. However, since it is a gauge length, the length of the narrow portion is actually smaller. It will be a good average length for the length of 15 to 20 mm.
- Install the test sample as shown in Figure 3. The end of the bar with the larger diameter should be attached directly into the inverted step.
- Loosen the screws through the hole in the cross-head, and screw the other end of the sample into the top of the lead set, as shown in Figure 4. You will need to use the lead screw to adjust the height of the cross-head.
- When you are setting the sample, it is important that you use the safety shields as shown in Figure 5. They attach with Velcro straps to the cross-head, and are easily released and removed. Tensile breaks the test sample when it is under load.

FREE Download
www.pasco.com/MaterialsTester

Workbooks include all instructions needed to perform the experiment:

- ▶ Introduction and theory
- ▶ Setup instructions
- ▶ Detailed analysis and summary questions

Order Information

Materials Testing Machine.....	ME-8236
Required:	
PASCO Capstone Software.....	pp. 68-71
AirLink Interface.....	PS-3200 p. 48
Tensile Samples (at left)	

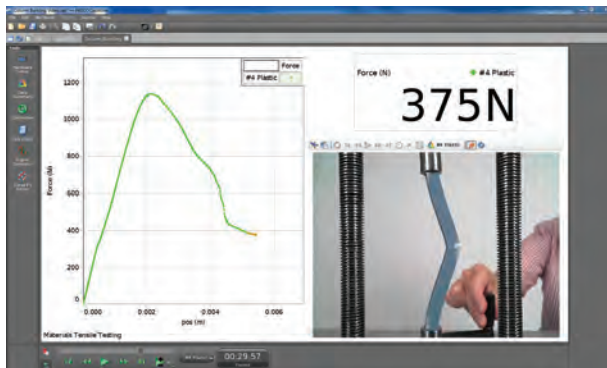


PASCO capstone™ Software

Combining video with simultaneous data graphs is a very powerful tool.

- ▶ PASCO Capstone is data collection and analysis software that has a special built-in compliance calibration routine for the Materials Tester.
- ▶ It is shown here plotting a graph and recording a video that are synced together in real time. Data analysis tools such as curve fits and area under the curve are available.
- ▶ With any of PASCO's interfaces, you can take advantage of the power of PASCO Capstone by using some of the 80+ sensors from PASCO.

Download a **FREE PASCO Capstone trial** at www.pasco.com/capstone



Enhance student understanding of the behavior of materials. PASCO Capstone software has the ability to embed live video from a webcam and sync the Materials Tester data to the recorded video. Then you can playback the video along with the data on the graph, stepping through one frame at a time to see the exact breaking point.

Order Information

PASCO Capstone	
Single User License	UI-5401
PASCO Capstone Site License	UI-5400 or UI-5400-DIG

USB Camera Microscope

PS-2343



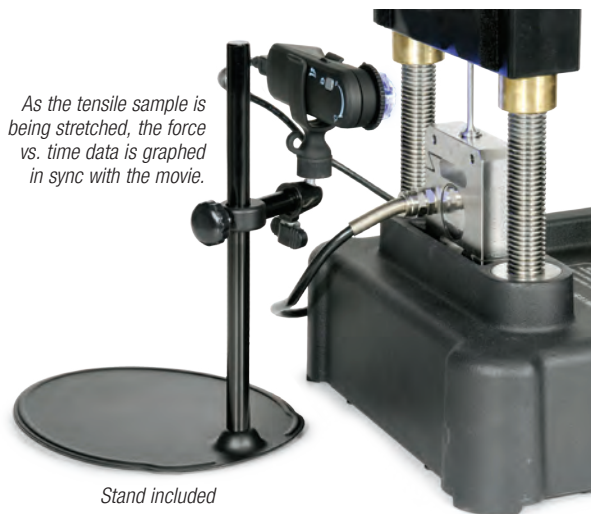
- ▶ Use as a web camera
- ▶ Optical zoom from 1x to 60x
- ▶ Built-in LED lighting

The versatile USB Camera Microscope can take pictures and video just like a digital camera, but it can also magnify like a microscope when it's up close to a specimen. And you can use it to take pictures showing lab setups, and document the appearance of materials before and after an experiment.

Use with the video and image capture features in PASCO Capstone. Magnification of specimens can be changed by adjusting the dial located on the front of the camera.

Specifications:

- Magnification:** 1x to 80x, 320x on 22" monitor
- Lens & CMOS sensor:** 2M pixels
- Still Image Resolution:** 1600x1200 pixels
- Formats:** JPEG, BMP
- Video Resolution:** 1600x1200 pixels
- Formats:** AVI
- Frame rate:** 30 FPS on 640x480 pixels; AVI
- PC Interface:** USB 2.0; works on Windows, MacBooks, and Android phones with OTG functions
- Light Source:** 4 white LED lights



Stand included

Includes:

- Camera
- Microscope
- Stand



Image of broken steel tensile sample taken with the microscope.

Order Information

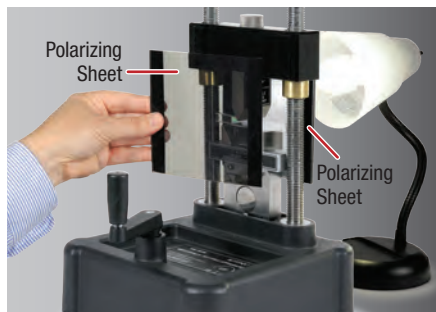
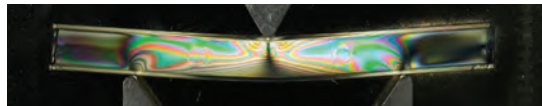
USB Camera Microscope	PS-2343
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Materials Testing Accessories

Photoelasticity Accessory

ME-8241

See stress lines by bending a clear, colorless photoelastic I-Beam between two polarizing sheets. As the beam is bent, areas of greater stress show up as patterns of colored lines.



Photoelasticity Accessory consists of two crossed polarizing sheets that are placed in front of and behind the clear beam. When illuminated from behind by a bright white light, fringes due to the stress lines become visible.

Lamp not included.



Includes:

- One Photoelastic I-Beam Set: ME-7011
- Two polarizing sheets, 5 3/8" x 5 3/8" x 1/8"

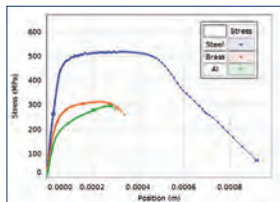
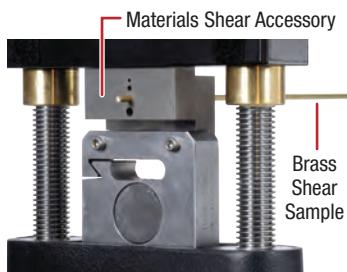
Order Information

Photoelasticity Accessory	ME-8241
Photoelastic I-Beam Set	ME-7011
Shown in use with:	
Bending Accessory	ME-8237

Shear Accessory

ME-8239

Perform shear tests for a variety of wires. Accessory accepts diameters of 1/16", 3/32", 1/8," and 5/32". The Shear Accessory includes the ME-8240 Shear Samples, three each of 1/8" diameter, 12" long, aluminum, brass and mild steel.



The graph shows shearing of steel, brass, and aluminum rods, all having an 1/8" diameter. The shear strength of each material is measured.

Includes:

- Shearing Block and Shear Samples (ME-8240)
- 3 Each of three types of wire



Order Information

Shear Accessory	ME-8239
Replacement Supplies:	
Shear Samples	ME-8240

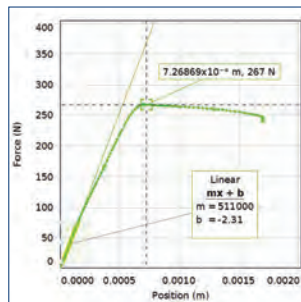
Structures Beam Fixture

ME-8242

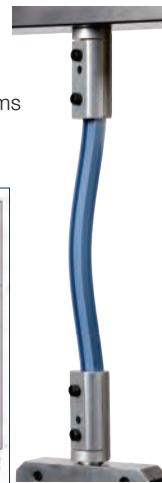
The Structures Beam Fixture allows any of the I-Beams from PASCO's Structures System to be stretched or compressed in the Materials Testing Machine.

Includes:

- Clamps (2)



Find the critical load that causes the beam to buckle.



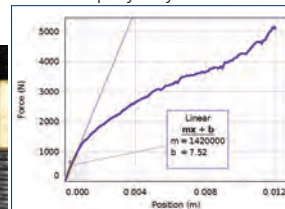
Order Information

Structures Beam Fixture	ME-8242
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Compression Accessory

ME-8247

This one-inch diameter platform provides a sturdy base to investigate compression of a variety of materials. It is shown here in a compression test on one of the included polyethylene test samples.



Before and after photo of compression sample



Includes:

- Platform
- 20 Polyethylene cylinders (ME-8284), 1.3 cm dia. x 2 cm long



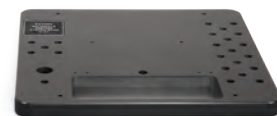
Order Information

Compression Accessory	ME-8247
Replacement Supplies:	
Compression Samples	ME-8248

Materials System Storage Base

ME-8229

The plastic base is made of High Density Polyethylene (HDPE). Includes base and mounting hardware.



Order Information

Materials System Storage Base	ME-8229
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Bending Accessory

ME-8237

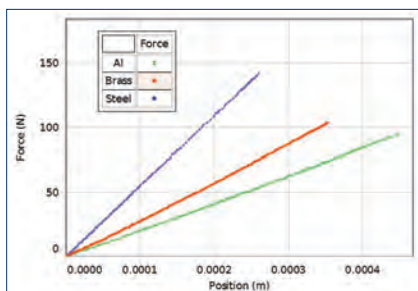
Perform three-point bending tests of various materials, including beams from the PASCO Structures System. Support anvils have adjustable separation up to 10 cm.



See EX-5559 Bending Experiment on p. 353

A Three-Point Bend Test is performed on a brass rod from the ME-8240 Shear Samples. The support anvils have adjustable separation up to 10 cm.

This Force vs. Position graph shows three-point bending for aluminum, brass, and steel samples, all with the same anvil spacing. From this graph, the flexural elastic modulus for each material is measured.



Four-Point Bending Accessory

ME-8249

Add the optional Four-Point Bending Accessory to the ME-8237 to perform both three-point and four-point bending.

Perform a Four-Point Bend Test on the Cast Beams from the PASCO Structures System. Quantities measured include the Flexural Elastic Modulus and the Modulus of Rupture for the material.



ME-8249 Includes:

- A two-point fixture that, when added to the Bending Accessory, allows four-point bending.



ME-8237 Includes:

- Base
- Adjustable support anvil
- Load anvil



Order Information

Bending Accessory	ME-8237
Four-Point Load Anvil	ME-8249

Shown in use with:

Shear Samples	ME-8240
Thin I-Beams	ME-7012
Cast Beam Spares Set	ME-6983
(includes 30 rebar members)	

Flat Coupon Fixture

ME-8238

Test any flat material, such as paper, foil, or plastic. Shown using the Flat Plastic Test Coupons (AP-8222).



Includes:

- Clamps (2)
- Wrench



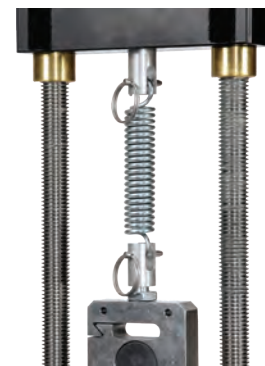
Order Information

Flat Coupon Fixture	ME-8238
Stress Strain Apparatus Coupons (40) - Plastic	AP-8222
Stress Strain Apparatus Coupons (40) - Metal	AP-8223

Clevis Grip

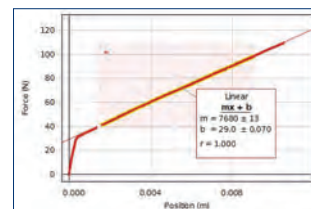
ME-8245

This generic pin and clevis adapter allows the user to tensile test a wide variety of samples with hooked ends or through-holes. It is shown here testing an extension spring (not included).



Includes:

- Clevis adapter and pin. Pin diameter is 0.187 in. Max width of sample is 0.300 in.



Order Information

Clevis Grip	ME-8245
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10-32 Adapter

ME-8246

Allows use of grips and attachments from other vendors that require a 10-32 male thread.



Includes:

- Upper and lower adapters



Order Information

10-32 Adapter	ME-8246
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Rotational Inertia

Looking for Tensile Samples for the legacy Stress/Strain Apparatus?



Although the AP-8214A Stress/Strain Apparatus is obsolete, we will continue to supply the test coupons indefinitely to accommodate current users. These coupons are also useful in PASCO's new Materials Testing Machine (ME-8236). Please see pages 158-159 for this new Materials Testing Machine. There is an adapter, the Flat Coupon Fixture (ME-8238), which allows these coupons to be tested in the new machine.

Plastic Test Coupons

AP-8222

Comprised of a set of plastic coupons for use with PASCO's Stress/Strain Apparatus. Four types of color-coded samples, 10 pieces per sample:

- High impact polystyrene (HIPS)
- Nylon 6 (15% glass fiber reinforced)
- Acrylonitrile butadiene styrene (ABS)
- Polypropylene (PP)

Metal Test Coupons

AP-8223

Set of metal test coupons of varying strengths, designed for use with PASCO's Stress Strain Apparatus. Five types of samples, 10 pieces per sample (sample containers labeled with thickness in inches)

- Brass (thin) 0.003"
- Brass (thick) 0.005"
- Cold-rolled steel 0.003"
- Aluminum 0.003"
- Annealed steel 0.003"

Order Information

Stress Strain Apparatus
Coupons – Plastic AP-8222
Stress Strain Apparatus
Coupons – Metal AP-8223

Super-Flex I-Beam

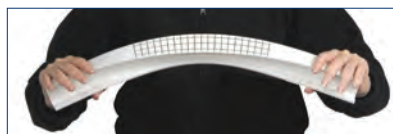
ME-8987

- ▶ Demonstrate the difference in stiffness between the two directions of bending
- ▶ Show that I-beams twist easily
- ▶ Show torsion and buckling
- ▶ Grid shows deformation

This Super-Flex I-Beam is made of plastic, so it can be visibly bent by hand. It shows the basic reasons for using this cross-section in construction. It is four times as stiff in the upright orientation as it is sideways.



Column buckling



Demonstrate lack of torsional strength.

Includes:

- Super-Flex I-Beam (24 inches long, 2 inches high)
- Instructions



Order Information

Super-Flex I-Beam ME-8987

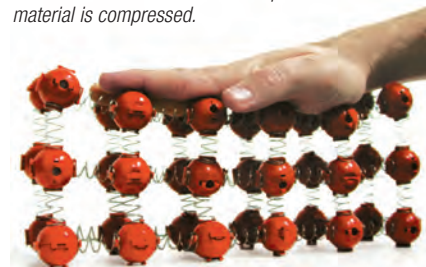
Matter Model

ME-9825A

The atoms of the Matter Model are brightly colored spheres with the bonds between the atoms modeled by springs, so that when forces are applied, the atoms can move in response.



Demonstrate the normal force response as a material is compressed.



Includes:

- Atoms (4.5 g each) (40)
- Heavy, light and long springs (60)
- Nuts (to increase the atom mass) (30)
- 90 cm brass rod (for longitudinal waves)



The Matter Model is shipped in component pieces, ready for assembly.

Order Information

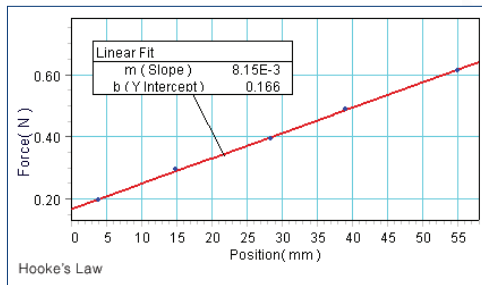
Matter Model ME-9825A

Hooke's Law Set

ME-9827

- ▶ Brightly colored stretch indicator
- ▶ Transparent measuring scale
- ▶ Compatible with PASCO mass sets

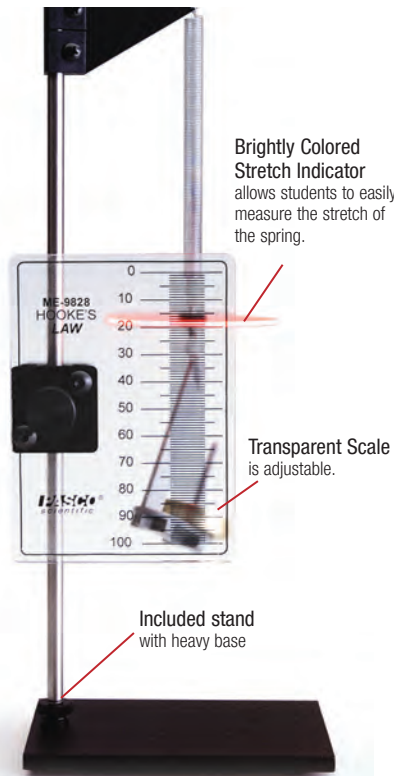
The Hooke's Law Set allows students to investigate the relationship between the force applied to a spring and the amount of stretch on the spring. This rugged set features a heavy base, so you can stretch the springs without toppling the unit. The transparent scale can be moved vertically to align zero with the brightly colored stretch indicator.



As a force is applied to the spring by placing mass on the hanger, the spring stretches. Students can graph the Applied Force vs. Spring Stretch. The slope of this graph is the spring constant of the spring. The vertical intercept shows the initial force required to begin stretching the spring.

Includes:

- Stand with heavy base
- Transparent scale with mm resolution
- Horizontal support for spring
- Brightly colored stretch indicator
- Three springs with identical diameter and length, but different spring constants
- Three of each spring included, for a total of nine springs: spring constants are 5 N/m, 8 N/m, 70 N/m



Order Information

Hooke's Law Set..... ME-9827
 Recommended:
 Mass and Hanger Set..... ME-8979 p. 197

Hooke's Law Spring Set

SE-8749

Includes three springs with the same diameter and length, but different spring constants. Three of each type of spring are included, and the springs fit nicely on PASCO mass hangers. All springs are 55 mm long and 7 mm in diameter. Spring constants are 5 N/m, 8 N/m and 70 N/m.



Order Information

Hooke's Law Spring Set..... SE-8749

Dropper Popper

SE-7304

Invert this half rubber ball and drop it. It will bounce up higher than the release point. Discuss conservation of energy with your students.



There is a minimum height required to trigger the popper that can be related to barrier potentials.



Order Information

Dropper Popper SE-7304

Springs & Oscillations

Series/Parallel Springs

ME-6842

The set of six springs consists of two each of three different spring constants. These springs are 15 cm long, half the length of the Equal-Length Spring Set, making it possible to combine two series short springs in parallel with one long spring.



Shown in use with the Parallel Spring Bracket and the Hooked Mass Set.

Specifications:

The six color-coded springs, two of each color, have different spring constants: 10 N/m, 20 N/m, 40 N/m ($\pm 5\%$)

Includes:

- White storage box
- Six (color-coded) springs 15 cm long



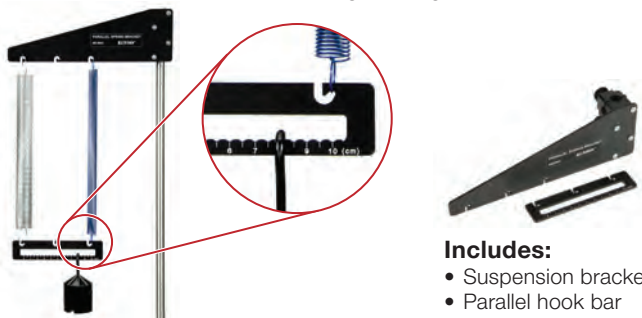
Order Information

Series/Parallel Springs.....	ME-6842	
Recommended:		
Hooked Mass Set.....	SE-8759	p. 197

Parallel Spring Bracket

ME-6844

This unique bracket allows springs of different spring constants to be hung in series and parallel. The masses can be hung in an offset position to compensate for the stronger spring.



Includes:

- Suspension bracket
- Parallel hook bar

Order Information

Parallel Spring Bracket.....	ME-6844
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Equal Length Spring Set

ME-8970

The five color-coded equal-length springs in this set have different spring constants: 25 N/m, 30 N/m, 35 N/m, 40 N/m, 50 N/m ($\pm 5\%$).



The five color-coded springs stretch different amounts when a 1 kg mass is hung from each spring.

These springs appear to be the same except for their colors. But, when equal masses are hung on them, each stretches a different amount. These extension springs are made of steel and are closed, requiring a slight initial force to separate the coils. The unstretched length of each spring is 30 cm and the approximate diameter is 1.4 cm. These springs are supplied with a white storage box with cardboard separators to keep the springs from touching each other.



Includes:

- White storage box
- Five (color-coded) springs 30 cm long

Order Information

Equal Length Spring Set.....	ME-8970	
Recommended:		
Pendulum Clamp.....	ME-9506	p. 188
Hooked Mass Set.....	SE-8759	p. 197

Demonstration Spring Set

ME-9866



This set includes four large springs for the demonstration of Hooke's Law or Conservation of Energy. Each spring is constructed of rugged spring steel with large loops that hang from a pendulum clamp or stretch with hanging masses. Spring constants range from 4 N/m to 14 N/m. Spring lengths vary between 11 cm and 22 cm.

Order Information

Demonstration Spring Set.....	ME-9866	
Recommended:		
Pendulum Clamp.....	ME-9506	p. 188
Hooked Mass Set.....	SE-8759	p. 197

Double-Length Slinky

SE-8760



The Slinky is an excellent tool for demonstrating transverse and longitudinal wave phenomena. This Double-Length Slinky is twice as long as a traditional Slinky, allowing students to create well-defined wave pulses and standing wave patterns. The tension in the Slinky is very low, causing wave pulses to travel slowly throughout its length.

Order Information

Double-Length Slinky..... SE-8760

Snakey

SE-7331



This extra-long metal spring is ideal for studying mechanical waves. The Snakey has an unstretched length of 2 meters. Pull the convenient end loops more than 10 meters apart to demonstrate transverse, longitudinal, and standing waves.

Order Information

Snakey SE-7331

Longitudinal Wave Spring

WA-9401



Using the Longitudinal Wave Spring accessory, it is easy to demonstrate and visualize the nodes and antinodes of longitudinal waves. Unstretched length is 13 cm.

Order Information

Longitudinal Wave Spring.....WA-9401

Photogate Pendulum Set

ME-8752

- ▶ Great for classic pendulum experiments

Cylindrical shape allows easy calculation of the speed of the pendulum using the time it blocks the photogate. Photogate not included.



The Photogate Pendulum Set is a unique set of four pendulums that have the same shape and size, but different masses. Due to their cylindrical shape, these pendulums are ideal for use in timing experiments with the photogate. One pendulum each of brass, plastic, wood, and aluminum is included.

Applications:

- ▶ Determine relationship between period and mass
- ▶ Determine relationship between period and amplitude
- ▶ Determine relationship between period and length



Includes:

- Brass pendulum
- Aluminum pendulum
- Plastic pendulum
- Wood pendulum

Order Information

Photogate Pendulum Set..... ME-8752

IDS Spring Kit

ME-8999



Includes 12 springs (1.6 cm diameter) with approximate spring constants of:
 3.4 N/m (3 short and 3 long springs)
 6.8 N/m (3 short and 3 long springs)

Order Information

IDS Spring Kit..... ME-8999

Pendulum Clamp

ME-9506



Hang up to three springs or pendulums. Easily adjust the lengths of the pendulum strings.



See page 136 for more information.



Easily adjust length of pendulum.

Order Information

Pendulum ClampME-9506
 Shown in use with:
 Photogate
 Pendulum SetME-8752
 Small "A" BaseME-8976 p. 186
 45 cm Stainless
 Steel RodME-8736 p. 186

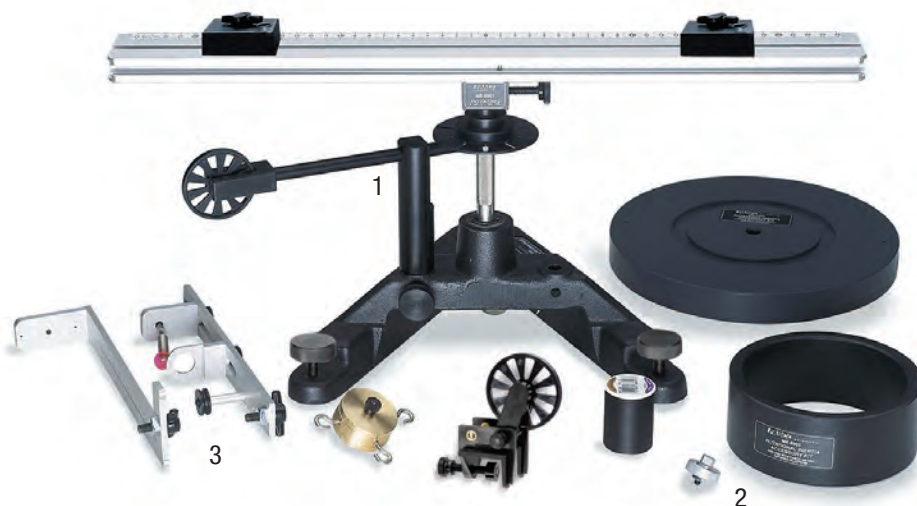
Rotation

Complete Rotational System

ME-8950A

- ▶ Most versatile rotational system available
- ▶ Stable, 4 kg cast iron base
- ▶ Dual, low-friction ball bearings

The Complete Rotational System features a cast iron base, dual ball bearings, and stainless steel shaft. It generates moments of inertia large enough to be sensed by anyone rotating the system by hand. This system is ideal for experiments pertaining to centripetal force, angular momentum, and rotational motion. Additional accessories can be added for experiments concerning torques, friction, magnetic levitation, and Faraday's Law. Angular velocity and motorized drive can be monitored using a computer.



Components of this system

1. Rotating aluminum platform with 4 kg cast iron base, dual ball bearings, stainless steel shaft, three-step pulley, two rectangular sliding 300 g masses, and 50 cm track where a number of accessories may be mounted.
2. The Rotational Inertia Accessory with a 22.9 cm diameter, 1.50 kg disk (which may be rotated on two axes), a 12.7 cm diameter, 1.42 kg ring and Super Pulley with support rod and adapter.
3. The Centripetal Force Accessory with spring support and radius indicator, mass support, three masses, and Super Pulley with Clamp.



Included Experiments

- ▶ Centripetal Force
- ▶ Rotational Inertia of a Point Mass
- ▶ Rotational Inertia of a Disk Off-Axis (fixed and rotating)
- ▶ Rotational Inertia of Disk and Ring – Two Axes
- ▶ Conservation of Angular Momentum, Using a Point Mass
- ▶ Conservation of Angular Momentum, Using a Disk and Ring
- ▶ Conservation of Angular Momentum (Projectile Version)



To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Includes:

- Rotating Platform ME-8951
- Rotational Inertia Accessory ME-8953
- Centripetal Force Accessory ME-8952
- Instruction Manual

Order Information

Complete Rotational System	ME-8950A	
Required:		
Mass and Hanger Set.....	ME-8979	p. 197

Interfacing Options

It is easy to use a computer to monitor rotational motion with the PASCO Rotational System. Here are two methods:

1. The **ME-9498A Photogate Head** mounts directly to the rotating platform base and measures angular speed. This works with the 850 and 550 Universal Interfaces.

NOTE: PASPORT interfaces require a Digital Adapter (PS-2109).



Order Information

Recommended:		
Photogate Head	ME-9498A	p. 21

2. The **CI-6538 or PS-2120 Rotary Motion Sensor** mounts to the base with an "A" Adapter and measures both angular speed and direction.



Order Information

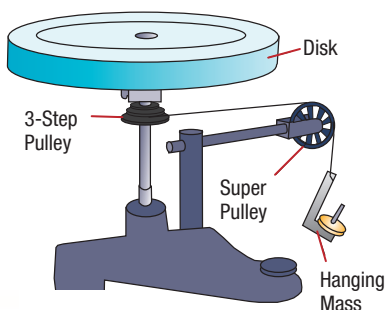
Required for use with ScienceWorkshop:		
Rotary Motion Sensor	CI-6538	
Required for use with PASPORT:		
PASPORT Rotary Motion Sensor	PS-2120A	
A-Base Rotational Adapter	CI-6690	p. 171

Experiments you can do with this rotational system:

Rotational Inertia of a Disk and Ring, 2 Axes

Center axis

With the disk mounted on the top of the vertical shaft, a torque is applied by a hanging mass. From the mass, radius, angular acceleration, and the rotational inertia of the disk can be determined.



Radial axis

The disk can also be mounted on edge to decrease the rotational inertia by half.

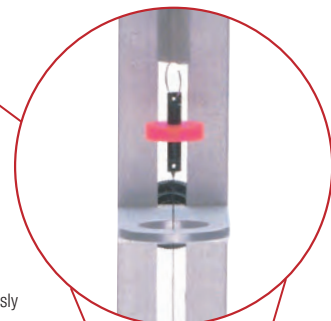


Centripetal Force

Centripetal force may be thoroughly investigated by varying both the mass and radius. The unique radius indicator allows students to continuously monitor the equilibrium position.

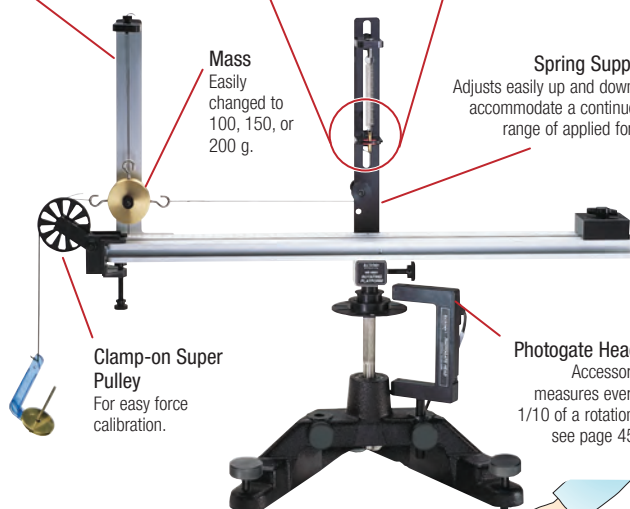
Accurate Radius Indicator
Can be monitored throughout the cycle of rotation.

Mass Support
Can be easily moved to change radius continuously from 2 to 20 cm.



Mass
Easily changed to 100, 150, or 200 g.

Spring Support
Adjusts easily up and down to accommodate a continuous range of applied force.



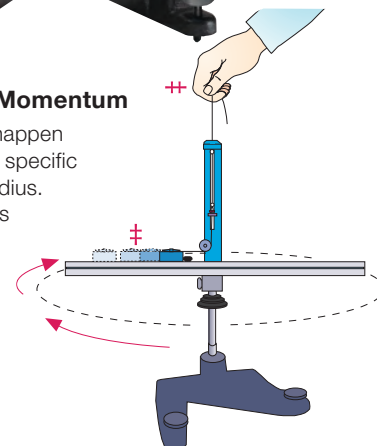
Rotational Inertia of Off-axis Disk

The Rotational Inertia Adapter allows students to mount the disk anywhere along the platform. A bearing mounted on one side of the disk allows it to act either as a rigid mass or as a mass free to rotate around its point of attachment as the platform turns on the vertical shaft.



Conservation of Angular Momentum

Students can predict what will happen when a point mass rotating at a specific radius is pulled into a smaller radius. The rotational inertia of the mass at the inner and outer radii can be calculated and the results verified.



Rotational System Components and Accessories see pages 170-171

Rotating Platform and Rotational Inertia Accessory
p. 170



Centripetal Force Accessory
p. 170



Rotational Motor Drive
p. 171



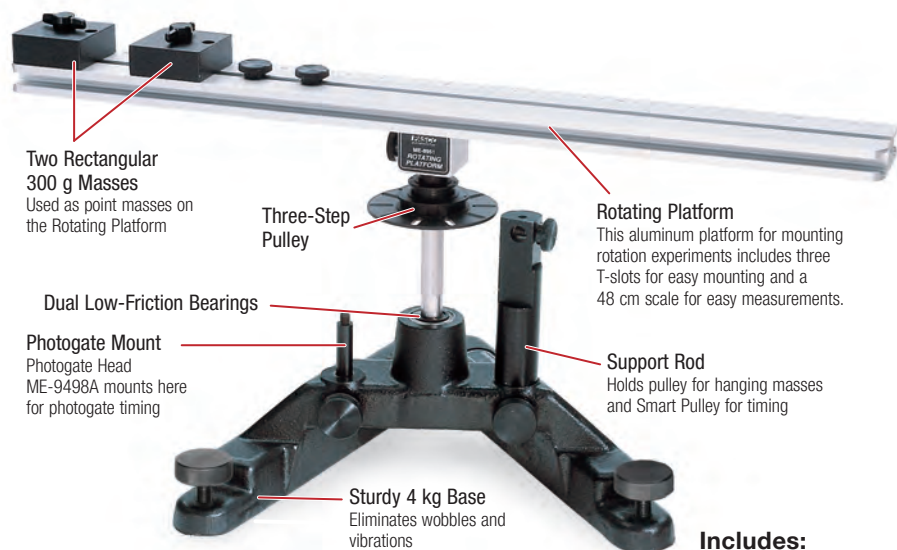
"A"-base Rotational Adapter
p. 171



Rotational System Components

Rotating Platform

ME-8951



The stable base and precision bearings of the Rotating Platform are the foundation of PASCO's Rotational System. It serves as an excellent base for general rotation experiments.

Order Information

Rotating Platform.....	ME-8951
Recommended:	
Rotational Inertia Accessory.....	ME-8953
Centripetal Force Accessory.....	ME-8952
Rotational Motor Drive.....	ME-8955

p. 171

Includes:

- Aluminum Platform for mounting rotation experiments
- 2 Rectangular 300 g Masses
- Sturdy 4 kg Cast Iron Base
- 3-step Pulley
- Support Rod

Centripetal Force Accessory

ME-8952

With traditional centripetal units, the ability to change the variables is either impossible or limited. The PASCO Centripetal Force Accessory is designed to make changing the mass, radius, or force quick and easy.



Features:

- ▶ **Vary Parameters Independently:** Change the centripetal force, mass and radius independently of each other.
- ▶ **Change Variables over a Wide Range:** Radius can be varied continuously from 2 to 20 cm, and the rotating mass can be 100, 150 or 200 g.
- ▶ **Observe the Radius Indicator throughout the Cycle:** PASCO's design has the indicator at the center of rotation, allowing continuous observation throughout the rotation cycle, resulting in more accurate measurements.

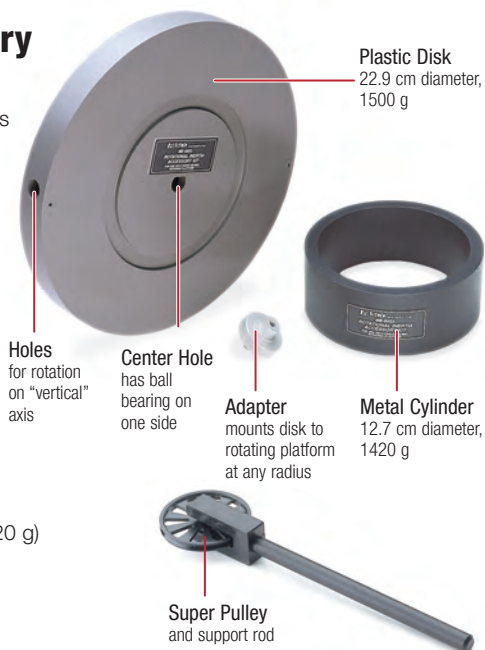
Rotational Inertia Accessory

ME-8953

A disk and a ring permit several experiments in rotational inertia. The disk may be rotated about several axes. When used in conjunction with the adapter, experiments using the parallel-axis theorem may be performed by moving the disk off from the center of rotation. The ball bearing on one side of the disk permits it to rotate freely for some experiments, while a "D" hole on the other side prevents rotation about the disk axis.

Includes:

- Heavy-Grade Plastic Disk (22.9 cm diameter, 1500 g)
- Metal Ring (12.7 cm outside diameter, 1420 g)
- Disk Adapter
- Super Pulley and Support Rod



Includes:

- Spring Support and Radius Indicator Assembly
- Mass Support
- Masses (100 g and two 50 g)
- Super Pulley with Clamp

Order Information

Centripetal Force Accessory.....	ME-8952
----------------------------------	---------

Rotational Motor Drive

ME-8955

The Motor Drive is used with the Rotational Platform to power continuous rotational motion demonstrations. Use this motor to drive the Rotational Acceleration Tank at a constant speed. Power the Motor Drive with a ramp function using the DC Power Supply to smoothly increase the angular speed of the Centripetal Force Accessory. The motor requires a 12 V DC power supply or a function generator.



Easily change the gear ratio of the motor drive by moving the drive belt to one of the three possible pulley steps.

Specifications:

Motor: 12 V maximum, 0.2 A minimum

Base Spindle Speed Range: 10 to 600 rpm

Includes:

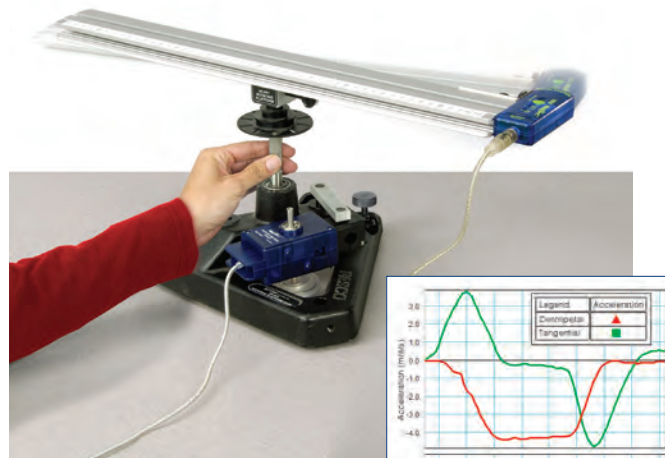
- Motor
- Three-Step Pulley
- Drive Belt



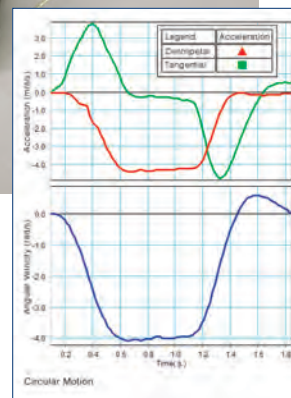
A-Base Rotational Adapter

CI-6690

The A-Base Adapter allows students to mount a Rotary Motion Sensor for high resolution data collection. One revolution of the vertical shaft corresponds to one revolution of the Rotary Motion Sensor, generating up to 4000 data points per revolution.



The platform is quickly rotated (from rest) and then brought to a stop. Both the tangential and centripetal acceleration is measured (using the 2-Axis Acceleration Sensor), while the platform's angular velocity is measured by the Rotary Motion Sensor.



Close-up of Rotary Motion Sensor mounted on "A"-Base



Includes:

- Rotary Motion Sensor Mounting Post
- O-Ring Drive Belt
- Three-Step Pulley
- Pulley Mounting Screw



Order Information

A-Base Rotational Adapter CI-6690

Required:

Rotating Platform ME-8951 p. 170

Rotary Motion Sensor CI-6538

OR

PASPORT Rotary Motion Sensor PS-2120A

Order Information

Rotational Motor Drive ME-8955

Required:

Rotating Platform ME-8951 p. 170

850 Universal Interface UI-5000 p. 14

OR

Function Generator PI-8127 p. 256

OR

DC Programmable Power Supply PI-9880 p. 251

Rotational System Components

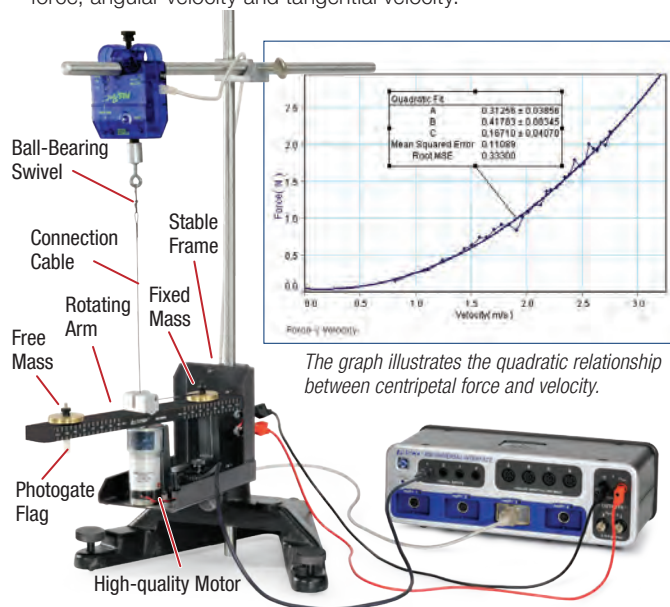
Centripetal Force Apparatus

ME-8088

- ▶ Empirically determine centripetal force
- ▶ Easy to set up
- ▶ Repeatable results

Features:

- ▶ **Stable Frame:** The metal frame can be easily attached to a ring stand using the included clamp. The frame may also be attached to a tabletop with a large table clamp.
- ▶ **High Quality Motor:** Will withstand years of student use.
- ▶ **Computer-based Measurements:** The Force Sensor and photogate facilitate accurate and repeatable measurements of force, angular velocity and tangential velocity.



The graph illustrates the quadratic relationship between centripetal force and velocity.

How It Works:

The rotating arm features a groove with two captured masses along its length. One of the masses is free to move along the length of the groove. The free mass is connected to a small cable that runs under a pulley in the center of the arm and up to a Force Sensor. A ball-bearing swivel is used to ensure the cable does not tangle as the arm rotates. The other mass is placed the same distance from the center as the free mass, thereby balancing the arm. A flag attached to the bottom of the fixed mass passes through the photogate once per revolution, allowing a calculation to be made of the angular and tangential velocity of the mass.

Includes:

- Frame with Mounted 12 VDC Electric Motor
- Connecting Cable
- Ball-Bearing Swivel
- Connecting Hardware for Photogate
- Mass Holder for Free Mass
- Mass Holder for Fixed Mass
- 5 g Mass (2)
- 10 g Mass (2)
- 20 g Mass (2)



Order Information

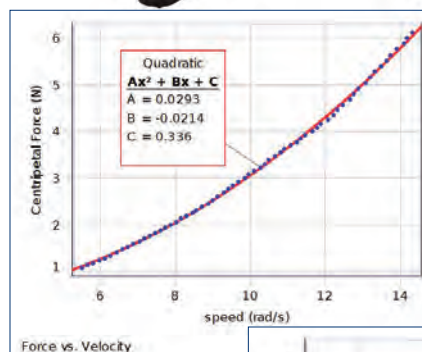
Centripetal Force Apparatus.....	ME-8088
Required:	
Force Sensor	p. 20, 29, 53
Photogate Head	p. 21
Triple Output Power Supply	SE-8587 p. 252
Large Rod Base	ME-8735 p. 186
45 cm Stainless Steel Rod	ME-8736 p. 186
120 cm Stainless Steel Rod	ME-8741 p. 186
Multi-Clamp	ME-9507 p. 188

Wireless Centripetal Force Accessory

ME-8094

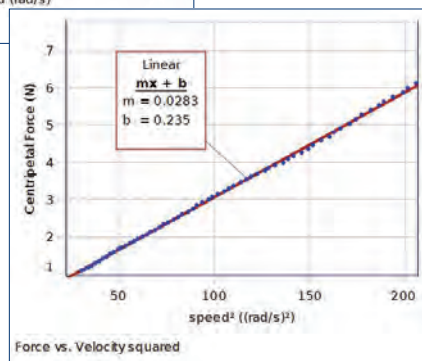
- ▶ Transmitting data wirelessly eliminates friction
- ▶ Uses Wireless Force Acceleration Sensor
- ▶ Vary speed, radius, and mass

The Wireless Centripetal Force Accessory is a low-friction, sliding mass holder that connects to a Wireless Force Acceleration Sensor (PS-3202). When installed on a Rotating Platform (ME-8951), it provides a simple and direct measurement of centripetal force and acceleration. Vary the mass using the holed masses in the Mass and Hanger Set (ME-8979). The string length is easily adjusted to vary the radius.



This PASCO Capstone graph shows the Centripetal Force (measured directly by the Wireless Force Acceleration Sensor) versus Angular Speed as the platform slows down.

In this PASCO Capstone graph, a "QuickCalc" of speed squared has been chosen on the horizontal axis, resulting in a straight line.



Includes:

- Low-friction sliding mass holder
- Mounting post for force sensor

Order Information

Wireless Centripetal Force Accessory	ME-8094
Recommended:	
Wireless Force Acceleration Sensor.....	PS-3202
Mass and Hanger Set.....	ME-8979
Rotating Platform.....	ME-8951
PASCO Capstone.....	pp. 68-71

Handheld Centripetal Force Discover Centripetal Force Kit

ME-9837A



As the stopper is swung around in a circle by hand, the Force Sensor directly measures the centripetal force. This handheld method allows students to feel the centripetal force.

The Motion Sensor detects the stopper on each rotation and is used to calculate its speed.

Use the traditional method with hanging masses, or use with a Force Sensor to continuously measure the centripetal force. Adding sensors to this classic experiment creates a dynamic, quantitative lab that your students will never forget.

Includes:

- Rubber Stoppers (sizes 6, 8, 10)
- Plastic Ties (10)
- Yellow String (73 meters)
- Hollow Tube



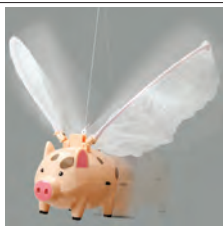
Order Information

Discover Centripetal Force Kit	ME-9837A	
Shown in use with:		
PASPORT High Resolution Force Sensor	PS-2189	p. 29
PASPORT Motion Sensor	PS-2103A	p. 28
Required for Classic Approach:		
Hooked Mass Set.....	SE-8759	p. 197
PASCO Stopwatch.....	ME-1234	p. 119

Flying Pig

SE-6655

This classic centripetal force experiment is used in high school AP Physics 1 curriculum. Hang from the ceiling, give it a push, and it flaps its wings as it "flies" in a circle.



Order Information

Flying Pig.....	SE-6655
-----------------	---------

Flying Plane

SE-6673

An alternative to the Flying Pig, the Flying Plane is a great way to do experiments in uniform circular motion. The Flying Plane sweeps a conic section allowing students to measure the angle from the point of attachment and analyze the motion using force vector diagrams.



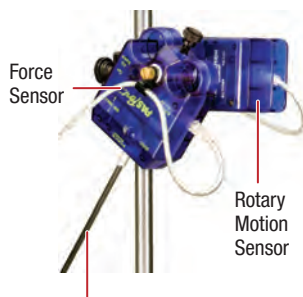
Order Information

Flying Plane.....	SE-6673
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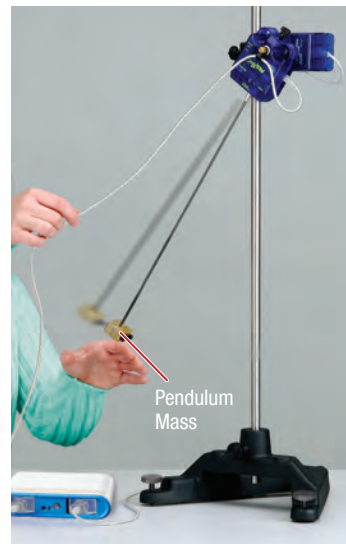
Centripetal Force Pendulum

ME-9821

- ▶ Quantitative force vs. velocity data
- ▶ Repeatable results
- ▶ Vary pendulum length and mass

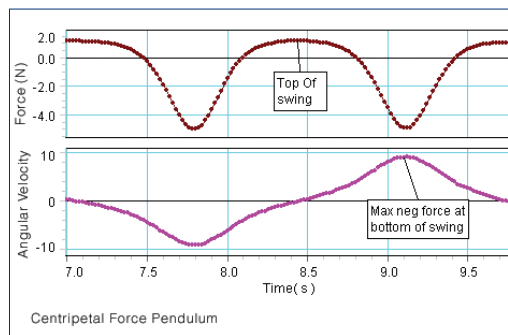


Very Low Mass Rigid Graphite Tube



When used with Force and Rotary Motion Sensors, the Centripetal Force Pendulum allows students to collect accurate circular motion data.

The Centripetal Force Pendulum attaches to a Force Sensor and allows students to directly measure the forces involved in circular motion. By attaching the Force Sensor/pendulum combination to the Rotary Motion Sensor, the relationship between force, mass, and velocity in a circular path can be investigated.



The Centripetal Force Pendulum is used to produce graphs of force and angular velocity vs. time. Note that the force changes direction at the top of the swing for large amplitudes.

Includes:

- Graphite Pendulum Rod with Threaded Connector
- Sliding Mass (100 g)
- Mount with Cord Clip



Order Information

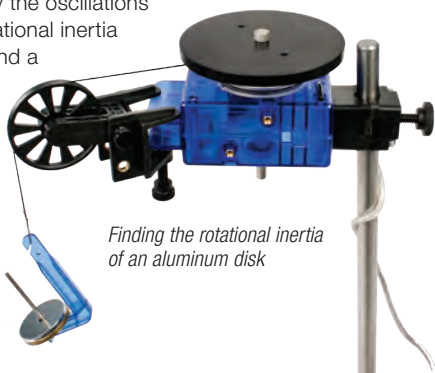
Centripetal Force Pendulum	ME-9821	
Required:		
Large Rod Base	ME-8735	p. 187
45 cm Stainless Steel Rod.....	ME-8736	p. 187
90 cm Stainless Steel Rod	ME-8738	p. 187
Multi-Clamp.....	ME-9507	p. 188
PASPORT Rotary Motion Sensor	PS-2120A	p. 28
PASPORT Force Sensor	PS-2104	p. 29

Rotational Motion Accessories

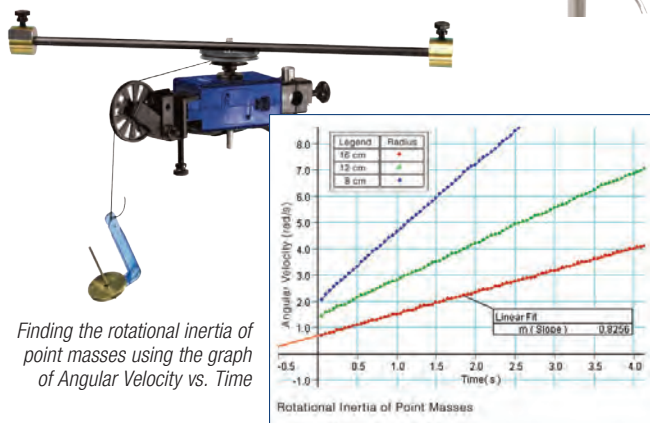
Rotational Inertia Accessory

ME-3420

Add the Rotational Inertia Accessory to any PASCO Rotary Motion Sensor to study the oscillations of a pendulum, the rotational inertia of a disk, a steel ring and a metal rod, as well as the conservation of momentum during a rotational collision. The clamp-on Super Pulley allows students to apply a torque by hanging a mass over the pulley.



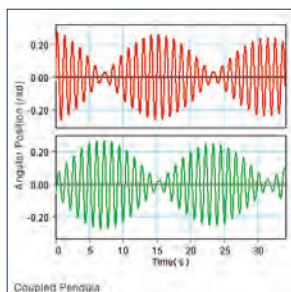
Finding the rotational inertia of an aluminum disk



Finding the rotational inertia of point masses using the graph of Angular Velocity vs. Time

Coupled Pendulums

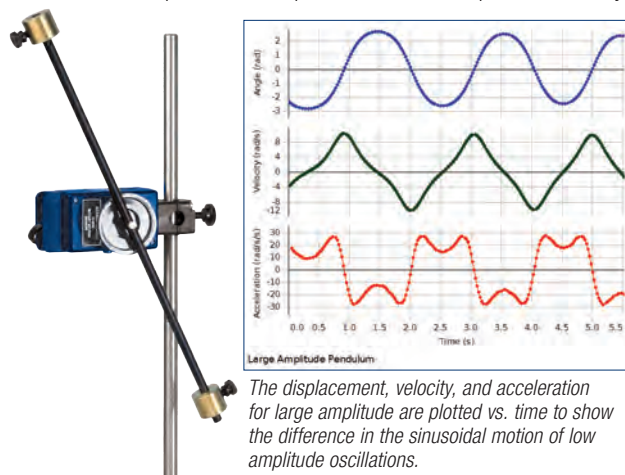
Couple two pendulums with a rubber band and plot the Position vs. Time for each pendulum. The result is a vivid example of energy transfer between the pendulums.



Large Amplitude Pendulum

See page 341 for complete experiment.

By placing one mass on each end of the tube, the pendulum will oscillate slowly. Students will have time to view the motion of the pendulum, while also watching the real-time graph of displacement, velocity, and acceleration vs. time. The period can be measured as a function of the amplitude of the pendulum and compared to theory.

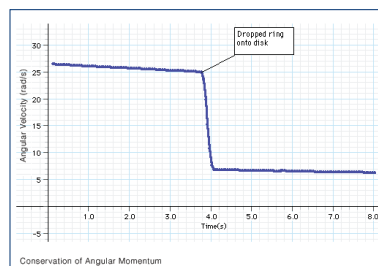


The displacement, velocity, and acceleration for large amplitude are plotted vs. time to show the difference in the sinusoidal motion of low amplitude oscillations.

Conservation of Angular Momentum

See page 344 for complete experiment.

To demonstrate conservation of angular momentum, a non-rotating ring is dropped onto a rotating disk. The angular velocity of the disk is recorded in real time, and students can easily determine the angular velocities of the disk just before and after the ring is dropped. Combining these velocities with the rotational inertia of the disk and ring, students can confirm that angular momentum is conserved.



The angular speed of the disk decreases when the ring is dropped onto the spinning disk.



Includes:

- Disks: 8.9 cm diameter, 100 g
- Thin Ring: 8.9 cm o.d., 7.9 cm i.d., 100 g
- 38 cm Pendulum Rod (27 g)
- 75 g Mass (2)
- Clamp-on Super Pulley
- Alignment Guides: 3.9 cm radius, 1.7 g



Order Information

Rotational Inertia Accessory ME-3420
 Also available:
 Ring And Disk Set ME-3419
 (Includes ring, 2 disks, and 3 alignment guides)

Pendulum Accessory

ME-8969

The pendulum rod and masses can be purchased separately.

Includes:

- 38 cm Pendulum Rod (27 g)
- 75 g Mass (2)



Order Information

Pendulum Accessory ME-8969

Rotational Inertia Set

ME-9774



Release two different sized objects simultaneously.

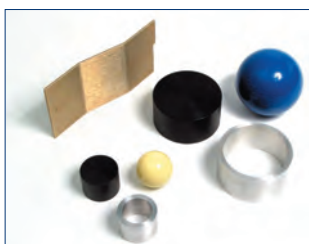


How It Works:

Compare rotational inertias of objects with different shapes and sizes. Students learn that the speed of an object rolling down the ramp is not affected by its mass or radius. The shape or distribution of the mass determines the outcome. The sphere will reach the bottom first, followed by the ring. The ring will be last.

Includes:

- 10 cm outer diameter set
 - Solid Sphere (810 g)
 - Ring (Aluminum, 230 g)
 - Disk (Plastic, 370 g)
- 5 cm outer diameter set
 - Solid Sphere (110 g)
 - Ring (Aluminum, 90 g)
 - Disk (Plastic, 70 g)
- Release Mechanism



Order Information

Rotational Inertia Set.....ME-9774

Spherical Mass Set

ME-8968



Hollow Steel Ball

This set includes four balls with a diameter of 2.5 cm each, but features various masses, including a hollow steel ball, solid steel ball, plastic ball and aluminum ball.

Applications:

- ▶ Race the hollow steel ball and solid aluminum ball down an incline. They have about the same mass, but the solid aluminum ball has a much larger acceleration down the ramp.
- ▶ Fire the yellow plastic, solid steel, and hollow steel balls from a PASCO Projectile Launcher.

Includes:

- Solid Yellow Nylon Ball (10 grams)
- Solid Steel Ball (66 grams)
- Hollow Steel Ball (21 grams)
- Solid Aluminum Ball (24 grams)
(release mechanism not included)



Order Information

Spherical Mass Set.....ME-8968

Rotational Inertia Wands

ME-9847

The red and blue wands have the same mass, but the red wand is easier to rotate because the red wand has less rotational inertia.

These two wands have the same mass and the same dimensions and yet the red wand is easier to rotate. This is because the red wand has two metal slugs near its center, while the blue wand has two similar metal slugs at its ends. This demonstrates that rotational inertia depends on the distribution of the mass.

These sturdy plastic wands have small holes near the center and at the ends to enable students to see where the metal is located in each wand. What initially seems a mystery can be explained to the students by allowing them to examine the wands more closely.



To demonstrate the difference in rotational inertia of the two rods, ask two students to grab the center of a wand and instruct them to rotate the wand back and forth as rapidly as they can. No matter how strong the student with the blue wand is, he or she is not able to rotate it as fast as the student with the red wand.

Specifications:

Length: 1 m

Diameter: 4 cm

Ratio of Blue Rotational Inertia to Red: Approx. 6

Includes:

- Red Wand (1)
- Blue Wand (1)



Order Information

Rotational Inertia WandsME-9847

Oscillation

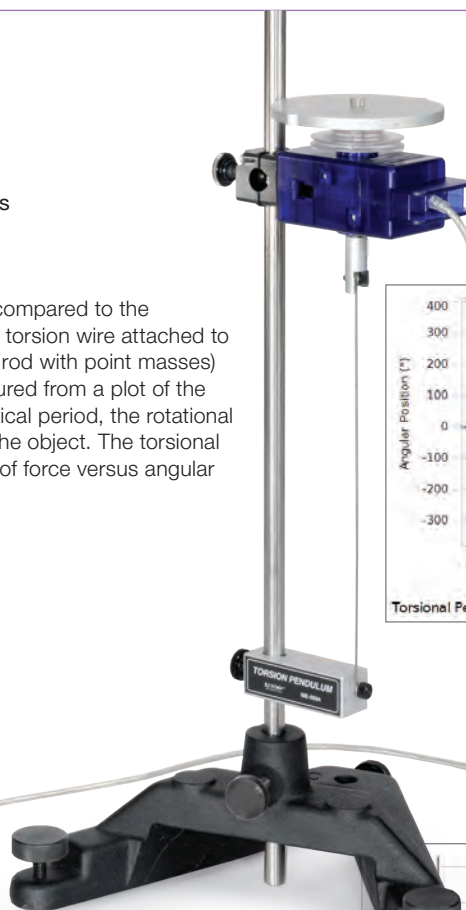
Torsional Pendulum

ME-6694

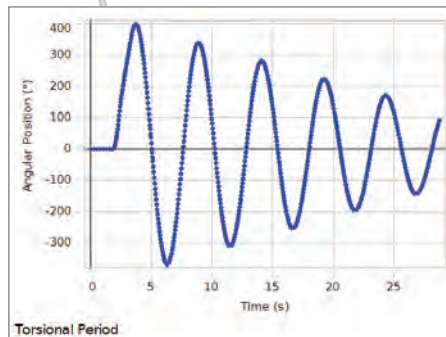
Concepts:

- ▶ Period of a torsional pendulum
- ▶ Rotational inertias of a disk, ring, and point masses
- ▶ Torque
- ▶ Torsional spring constant

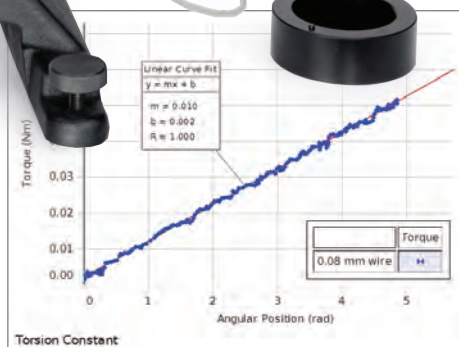
The period of a Torsional Pendulum is measured and compared to the theoretical value. The torsional pendulum consists of a torsion wire attached to a Rotary Motion Sensor with an object (a disk, ring, or rod with point masses) mounted on top of it. The period of oscillation is measured from a plot of the angular displacement versus time. To calculate theoretical period, the rotational inertia is determined by measuring the dimensions of the object. The torsional spring constant is determined from the slope of a plot of force versus angular displacement.



The Torsional Pendulum uses a Rotary Motion Sensor to record the oscillations.

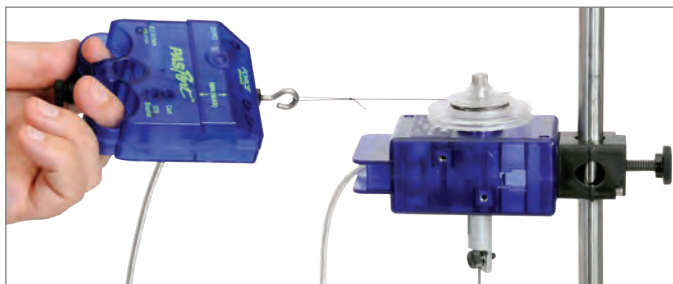


The period of the Torsional Pendulum is determined from a plot of angular displacement versus time.



The torsional spring constant is determined from a plot of torque versus angular displacement.

To determine the torsional spring constant, a torque is applied by pulling with a Force Sensor.



Includes:

- Torsional Wires (3 each of 3 different spring constants)
- Wire Clamps (2)



PASCO Advantage

To determine the torsional spring constant, the Force versus Angular Displacement graph is quickly and easily obtained by pulling with a Force Sensor on a string wrapped around the Rotary Motion Sensor pulley.

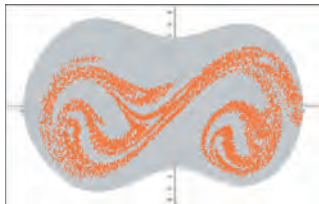
Order Information

Torsional Pendulum	ME-6694
Required:	
Large Rod Base	ME-8735
Stainless Steel Rod, 60 cm Threaded	ME-8977
Rotational Inertia Accessory	ME-3420
PASPORT Rotary Motion Sensor	PS-2120A
PASPORT Force Sensor	PS-2104
550 or 850 Universal Interface*	pp. 14-17
PASCO Capstone Software	pp. 68-71
* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.	

Chaos/Driven Harmonic Accessory

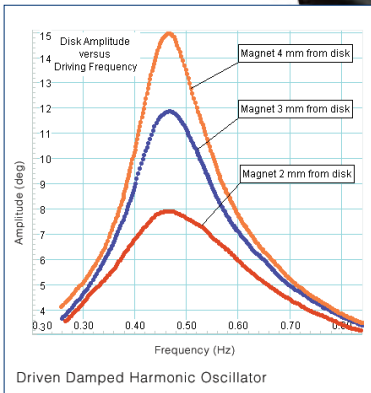
CI-6689A

The Chaos/Driven Harmonic Accessory allows students to study the behavior of a physical pendulum in either harmonic or chaotic motion. The disk mounts to a Rotary Motion Sensor, allowing PASCO Capstone™ to monitor and plot the pendulum's angular position and velocity.



Mechanical Oscillator/Driver ME-8750

See full experiments: EX-5522A Driven Damped Harmonic Oscillator on page 347 and EX-5523A Chaos Experiment on page 345.



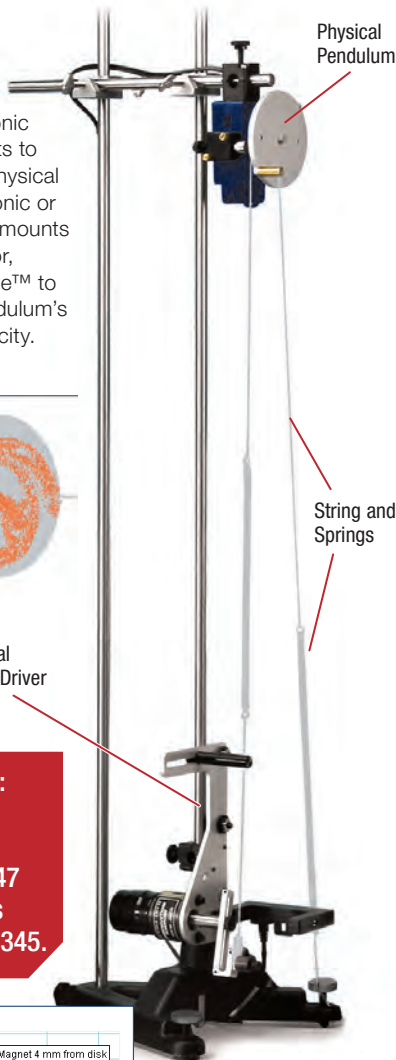
Angular Velocity vs. Frequency graph shows effects of magnetic damping on amplitude of resonance peak.

Includes:

- Rotating Disk (9.5 cm diameter, 120 g)
- Eccentric Mass (15 g)
- Springs
- Adjustable Magnet for Damping

Order Information

Chaos/Driven Harmonic Accessory..... CI-6689A

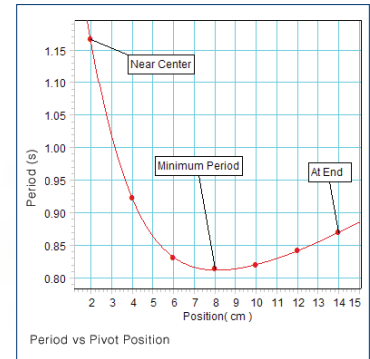


Physical Pendulum Set

ME-9833

This set of six objects is perfect for studying Physical Pendulums, Moments of Inertia, and the Parallel Axis Theorem. Each piece fastens directly to a Rotary Motion Sensor to measure the object's acceleration due to an applied torque, or the period when the pendulum freely oscillates.

Each piece is made from 1/4 inch-thick aluminum plate.



The Pendulum Bar has holes spaced at 2 cm intervals. A graph of Oscillation Period vs. Pivot Hole Position shows that there is a unique placement that gives a minimum period. This location can be verified using calculus.

Unique design allows pivot exactly at the edge. Measure the period of the thick ring oscillating at either the inner or outer radius.

Includes:

- Solid Disk
- Thick Ring
- Thin Ring
- Offset Hole
- Pendulum Bar
- Irregular Shape
- Mounting Screws (6)

Order Information

Physical Pendulum Set..... ME-9833

Gyroscope

Gyroscopic Motion

Demonstration Gyroscope (3-Axis)

ME-8960

- ▶ All components accessible
- ▶ Excellent demonstration tool
- ▶ Precision angle indicator

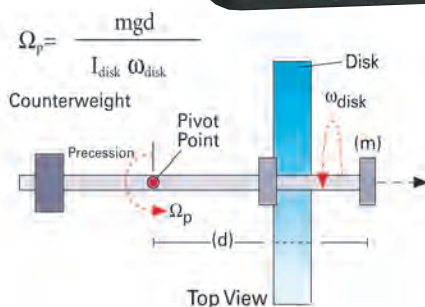
The low friction, open design of PASCO's Gyroscope enables rotational motion studies that were previously impossible with commercial units. The completely open design lets students stop precession by grabbing the vertical shaft, causing the Gyroscope to dip. Rotational mathematics can predict the dipping motion, but with PASCO's Gyroscope it can finally be confirmed.

How It Works:

The disk is spun by wrapping a string around the pulley and pulling. Or the disks can be spun by hand. Add mass to either end of the gyroscope and it responds with a predictable precession. Many features make this an exceptional demonstration tool for rotational motion concepts.

Features:

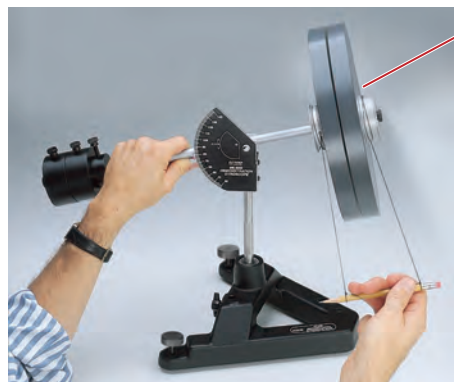
- ▶ **Low Friction:** The disk takes almost 6 minutes to slow to half of its original speed due to low-friction bearings in the gyroscope axle and vertical shaft.
- ▶ **Accurate Angle Indicator:** Measures from 30° to 140° and is easily read to the nearest degree. A retractable stop acts as a marker during experiments.
- ▶ **Easy Timing:** Low rotation speeds allow measurement of angular speed by counting revolutions and using a stopwatch.
- ▶ **Easy Balancing:** Two counterweights allow coarse and fine balance adjustment.
- ▶ **Large Inertia Disk:** With the large rotational inertia of the disk, PASCO's gyroscope generates precession rates similar to smaller, enclosed gyroscopes. The slow rotation speed of PASCO's disk lets students study fast as well as slow precession and use a stopwatch to make measurements.



Students can determine the rotational inertia of the rotating disk. They can then check the measured precession rate when a mass (m) is added a distance (d) from the pivot point.

Order Information

Demonstration Gyroscope (3-Axis)..... ME-8960
Recommended:
Gyroscope Disk and Mass..... ME-8961



Accessory Disk
Add a second disk spinning in same or opposite directions.

A Unique Experiment: Rotate two disks in opposite directions at the same speed. The angular momenta cancel and the total angular momentum of the gyroscope is zero. The result is no precession.

Gyroscope Disk and Mass

ME-8961

Includes:

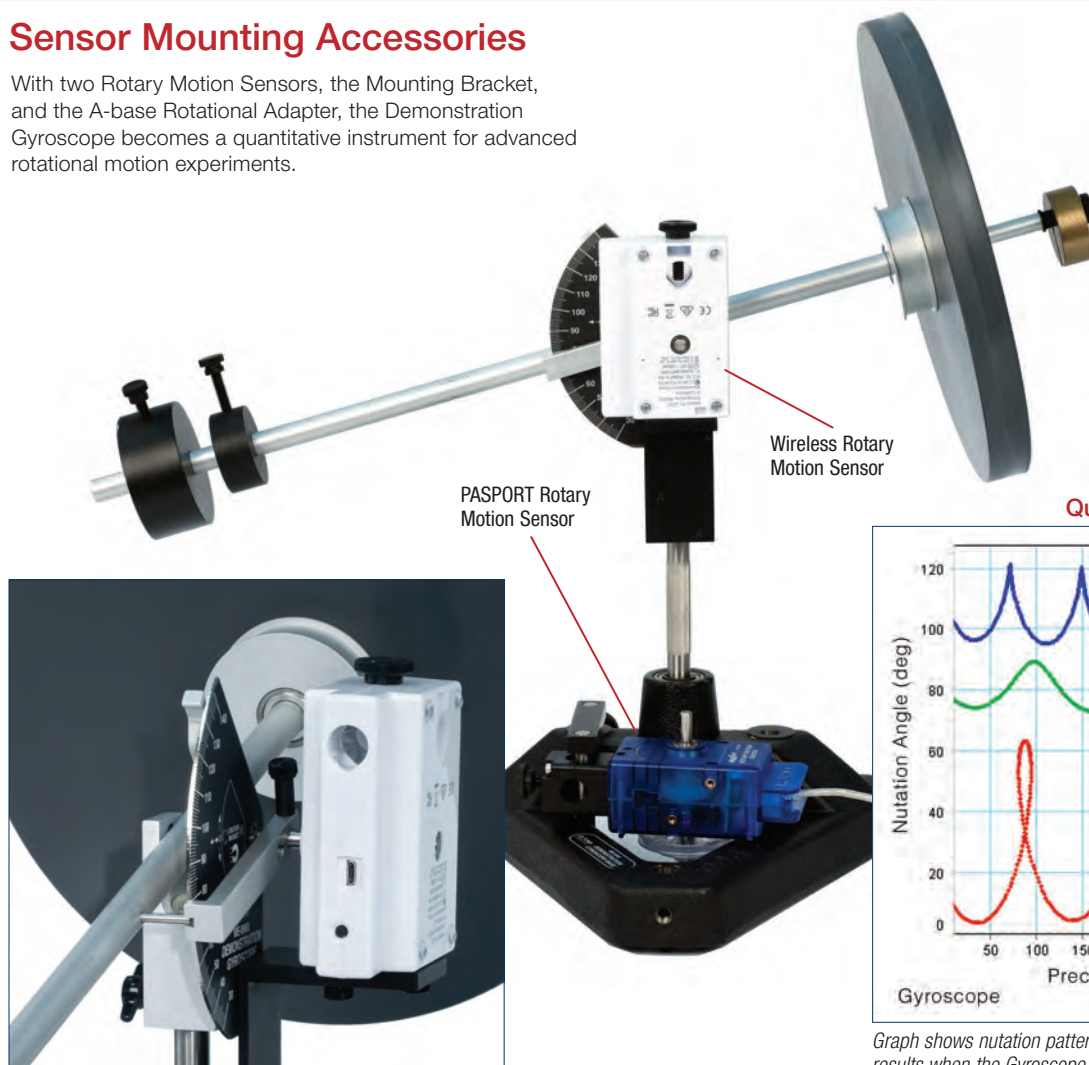
- Accessory Disk
- Extra Counter Mass

Order Information

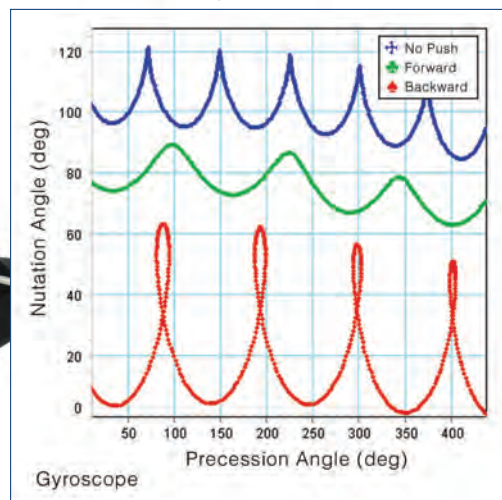
Gyroscope Disk and Mass.....ME-8961

Sensor Mounting Accessories

With two Rotary Motion Sensors, the Mounting Bracket, and the A-base Rotational Adapter, the Demonstration Gyroscope becomes a quantitative instrument for advanced rotational motion experiments.



Quantitative Measurements



Graph shows nutation pattern for three cases: The blue trace results when the Gyroscope is released from rest, with no initial push forward or backward.

Gyroscope Mounting Bracket for Rotary Motion Sensor

ME-8963

With the Mounting Bracket and the A-base Rotational Adapter (CI-6690), the Demonstration Gyroscope becomes a quantitative instrument for advanced rotational motion experiments. With two Rotary Motion Sensors, students obtain a graphical picture of the Gyroscope's nutation and precession motions.



A-Base Rotational Adapter

CI-6690

The A-base Adapter allows students to mount a Rotary Motion Sensor for high resolution data collection. One revolution of the vertical shaft corresponds to one revolution of the Rotary Motion Sensor, generating up to 4000 data points per revolution.

Includes:

- Rotary Motion Sensor Mounting Post
- O-Ring Drive Belt
- Three-Step Pulley
- Pulley Mounting Screw



This accessory is not compatible with PS-3220 Wireless Rotary Motion Sensor.

Order Information

For Recording Nutation Data:	
Gyroscope Mounting Bracket for Rotary Motion Sensor	ME-8963
Required:	
PASPORT Rotary Motion Sensor	PS-2120A p. 28
Interface	pp. 12-13
OR	
Wireless Rotary Motion Sensor	PS-3220 p. 51

Order Information

For Recording Precession Data:	
A-Base Rotational Adapter	CI-6690
Required:	
PASPORT Rotary Motion Sensor	PS-2120A p. 28
Interface	pp. 12-13

Gyroscope

Bicycle Gyroscope

ME-6837

- ▶ Solid 1/2" steel shaft
- ▶ Cushioned hand-grips
- ▶ Precision ball bearings for low friction
- ▶ Non-marking rubber tire

The newly redesigned Bicycle Gyroscope is perfect for getting your students engaged in understanding rotational motion. Unlike other bicycle gyroscopes, the PASCO model is extremely rugged for years of use, but also lightweight at just 6 lbs. Cushioned hand-grips, a pull-cord with handle, and an included suspension cord (to demonstrate precession) make it simple and easy to use.

Precision ball bearings result in extremely low friction for both the Bicycle Gyroscope and the Rotating Chair.



The Bicycle Gyroscope with the Rotating Chair gives you a perfect demonstration of the conservation of angular momentum.



Use the included pull-cord with handle to spin up the wheel.

This 2.8 kg (6 lb.) Bicycle Gyroscope has a solid 2.7 mm (1/2") steel shaft with cushioned hand-grips.

Attach cord (included) to hole in handle to demonstrate precession.



- Includes:**
- Bicycle Gyroscope
 - Cords with Handles (2)



Order Information

Bicycle Gyroscope..... ME-6837
 Shown in use with:
 Rotating Chair..... ME-6856

Bicycle Wheel Mass Set

ME-6972

Adding all four of the masses adds 1.6 kg to the wheel's approximate 2.8 kg mass and increases its rotational inertia by over 60%.

Mass securely clamps to the wheel rim using included screws.



Includes:

- Four 400 g masses

Order Information

Bicycle Wheel Mass Set..... ME-6972
 Shown in use with:
 Bicycle Gyroscope..... ME-6837

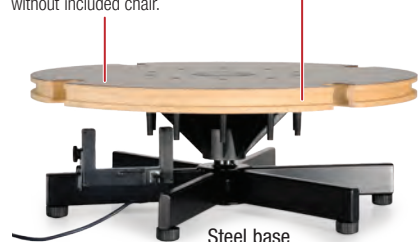
Rotating Chair

ME-6856

Rugged design and incredibly low friction make this far superior to any office chair.

Sturdy 45 cm diameter rotating platform can be used with or without included chair.

Wrap rope around groove to apply torque.



Includes:

- Chair
- Rotating Platform with Leveling Feet



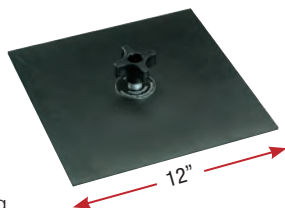
Order Information

Rotating Chair..... ME-6856
 Shown in use with:
 Photogate Head..... ME-9498A

Atmospheric Pressure Demonstrator

ME-8966A

Demonstrate the effect of a pressure differential. Easily lift a box or stool by simply placing the rubber sheet on a smooth surface of the object and lifting up on the handle.



As you pull up on the handle, a low-pressure region is created.



Order Information	
Atmospheric Pressure Demonstrator.....	ME-8966A

Air Cannon

SE-7370

The Air Cannon uses a vortex of air for ammunition. Its unique shape creates a stable toroidal vortex. Pull back the flexible membrane, release, and the invisible wave front of air can hit a target 20 feet away. Here is a great demonstration of the energy that can be stored in waves.



Order Information	
Air Cannon.....	SE-7370

Student Bell Jar

SE-9790



This bell jar provides a vacuum chamber for students to perform many experiments including:

- ▶ Watching a balloon expand or warm water boiling as air is pumped from the chamber
- ▶ Observing that a suction cup no longer sticks when the jar is evacuated



Water boils as air is evacuated from the Bell Jar.

Includes:

- 8 cm x 6 cm dia. clear plastic bell jar with base
- Plastic vial, balloons and suction cup
- 60 cc syringe and valves for evacuating the jar



Order Information	
Student Bell Jar.....	SE-9790

Phi Top

SE-7594

The PhiTOP is an egg-shaped top (a prolate ellipsoid) that can be spun by hand to stand up on end. This is a fascinating demonstration used by Nikoli Tesla in 1893.

When spun with a magnetic stirrer, the PhiTOP replicates Tesla's famous Egg of Columbus demonstration. An alternating magnetic field will spin the PhiTOP from rest along its minor axis due to Lenz's law of electromagnetic induction. As the angular speed increases, the center of mass will rise, and the PhiTOP will spin along its major axis.



Includes:

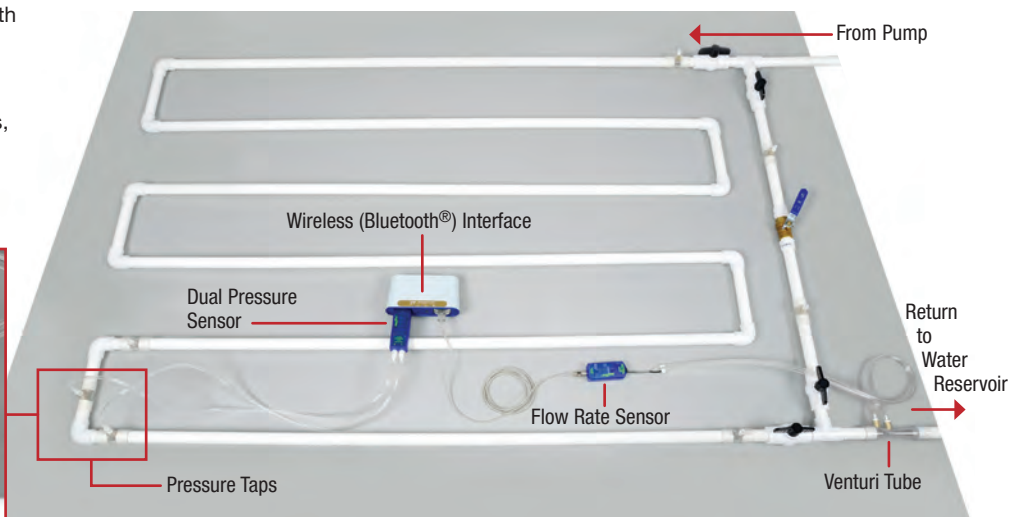
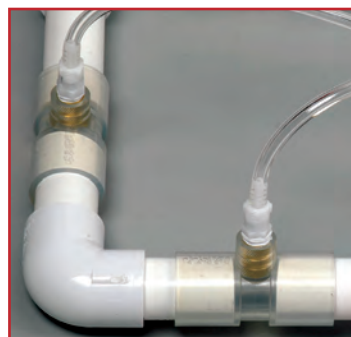
- PhiTOP
- Mirror Stand

Order Information	
Phi Top.....	SE-7594
Recommended:	
Magnetic Stirrer.....	SE-7700

Pipe Network

Pipe Network: Build it your way and instrument it inexpensively.

- ▶ Instrument your pipe network with pressure and flow sensors
- ▶ Transparent Venturi Tube and pressure taps
- ▶ Study head loss in pipes, fittings, and valves
- ▶ Find the relationship between pump head and flow rate



Measure Pressure

When constructing a pipe network, it is useful to know the pressure in the fluid at numerous places along the pipe. The transparent Pressure Taps can be glued into a 3/4" PVC pipe network at any place, using a slip joint. Each Pressure Tap has a quick-connect for a Dual Pressure Sensor (PS-2181). Since the quick-connect closes when disconnected, it is possible to move the pressure sensor around the network to determine the pressures at different positions, rather than having a separate pressure sensor for each position.

Measure Flow Rate

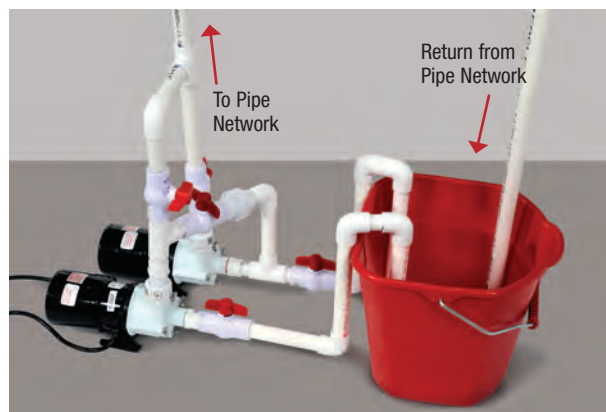
The General Flow Sensor measures the difference in fluid pressure between the two different cross-sectional areas, and the software does a calculation to convert this pressure difference into a velocity or volumetric flow rate. The Venturi Tube slip joints are designed to be glued into any 3/4" PVC pipe network. The Venturi Tube is made of clear PVC so the water can be seen flowing through it. It has a constriction and two pressure ports with tubing attached. The Venturi Tube is connected to the General Flow Sensor (PS-2225) by the matching couplers.

Create Pump Curves

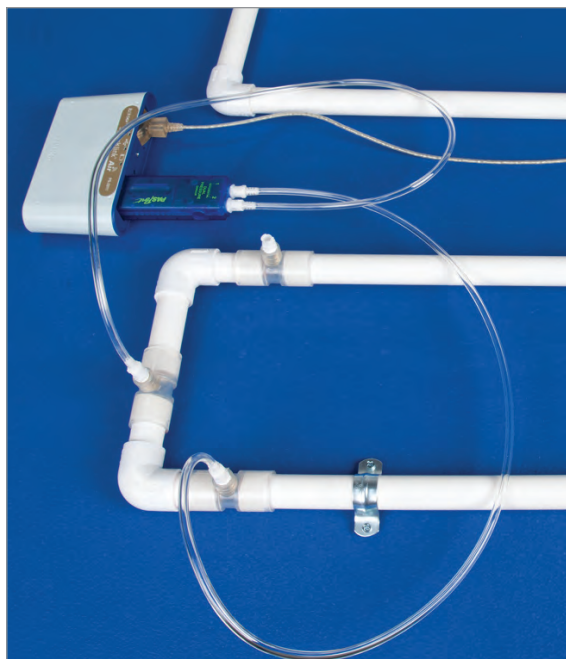
Create a plot of pressure vs. flow rate for a pump and determine the maximum head and flow rate. Study how these change when two pumps are connected in series or parallel.

Portable Interface

Use the SPARKlink Air (PS-2011) with a Dual Pressure Sensor (PS-2181) as a great portable pressure measurement system. The SPARKlink Air has two PASPORT sensor ports and can accommodate a General Flow Sensor to measure the volume flow rate and a Dual Pressure Sensor to measure the pressures along the pipe.



Study one pump or two pumps in series and parallel.



See our experiments:
Piping Systems on p. 336
Pumping Systems on p. 337

*Pressure Taps are installed before and after elbow joints to measure the pressure loss.
The Venturi Tube measures the velocity.*

General Flow Sensor

PS-2222

The General Flow Sensor determines the fluid velocity of air or water by measuring the difference in pressure between the two input tubes. The Venturi Tube or Pitot Tube must be connected to the General Flow Sensor to collect data. The type of fluid (air or water) being used is selected using PASCO software.



Venturi Tube

ME-2220

The Venturi Tube is made of clear PVC, so the water can be seen flowing through it. It has a constriction and two pressure ports with tubing attached. The Venturi Tube is connected to the General Flow Sensor by the matching couplers. The General Flow Sensor measures the difference in fluid pressure between the two different cross-sectional areas and the software does a calculation to convert this pressure difference into a velocity or volumetric flow rate. The Venturi Tube slip joints are designed to be glued into any 3/4" PVC pipe network.



Order Information

General Flow Sensor.....PS-2222

Order Information

Venturi Tube.....ME-2220

PASPORT Dual Pressure Sensor

PS-2181

- ▶ Measure pressure at two pipe pressure taps at once

The Dual Pressure Sensor is capable of reading two absolute pressures, one gauge pressure, or one differential pressure. Dynamic variable over-sampling automatically reduces the measurement noise at low sampling rates. Sample rates up to 1000 Hz make studies of both transient and steady-state pressure possible. Includes quick-connect tubing.



Pressure Taps (set of 5)

ME-2224A

The transparent Pressure Taps can be glued into a 3/4" PVC pipe network at any place, using a slip joint. Each Pressure Tap has a quick-connect for a Dual Pressure Sensor (PS-2181). Since the quick-connect closes when disconnected, it is possible to move the pressure sensor around the network to determine the pressures at different positions, rather than having a separate pressure sensor for each position.



Includes:

- Pressure Taps (5)
- 1/8" ID Tubing (4.5 m)
- Couplings (10)

Order Information

Pressure Taps (set of 5).....ME-2224A

Specifications:

Maximum Sample Rate: 1000 Hz

Absolute Pressure: 0 to 200 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m², and psi)

Differential Pressure: ±100 kPa, 0.01 kPa resolution at 10 Hz and 1 kPa repeatability (displays pressure in kPa, N/m², and psi)

Order Information

PASPORT Dual Pressure Sensor.....PS-2181

Order Information

Required for all above:
 PASPORT Interface.....p. 12-13
 PASCO Capstone Software.....pp. 68-71
 PVC Pipe and Fittings (supplied by user)
 Pumps (2) (supplied by user)

Wireless Interface

The SPARKlink Air (PS-2011) is a Bluetooth® interface that allows the computer to be away from water spills. See page 48 for more information.



Order Information

Shown in use with:
 SPARKlink Air InterfacePS-2011 p. 48
 Pitot Tube.....ME-2221 p. 43

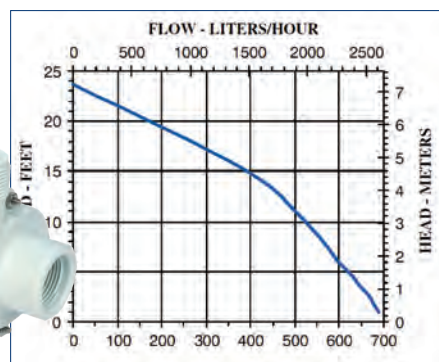
Water Pump

SE-7727 (US Only)

- ▶ Ideal for pipe network experiments

Features:

- ▶ Little Giant Pump 4-MD Non-Submersible, In-line Use
- ▶ 1/12 hp open FC motor
- ▶ Glass-filled polypropylene magnet housing
- ▶ Glass-filled polypropylene volute
- ▶ Magnetic drive
- ▶ Nitrile O-ring
- ▶ Titanium thrust washers and shaft



Picture shows 12-inch (30 cm) ruler (not included) to indicate size.

Order Information

Water Pump.....SE-7727

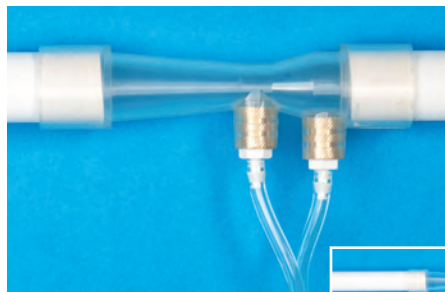
Fluids

Explore the Equations for Fluid Flow Using Sensors

General Flow Sensor with Venturi Tube

PS-2225

- ▶ Measure fluid velocities and confirm the Continuity Equation
- ▶ Use Bernoulli's Equation to determine pressure difference
- ▶ Show faster moving fluids have lower pressures



The Venturi Tube has pressure taps at the narrow diameter and the larger diameter.

The General Flow Sensor connects to the Venturi Tube to measure the pressures.



In this apparatus, the Venturi Tube has pressure taps at the narrow diameter and the larger diameter. The General Flow Sensor connects to the Venturi Tube to measure the different pressures due to different fluid velocities. You supply the 3/4 inch PVC pipe and the water. It is suggested that you connect the pipe to a faucet with flexible tubing and, at the other end, let the water flow into a bucket resting on a Force Platform (PS-2141). As the water flows, the velocity can be determined by the changing weight of the bucket as measured by the Force Platform.

The recommended interface is the SPARKlink Air because two ports are required and it is convenient to have a wireless interface so your laptop can be away from the water. However, two AirLinks (PS-3200) or a 550 or 850 Universal Interface will do as well.

Continuity Equation: $A_1 v_1 = A_2 v_2$

Bernoulli's Equation: $P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$
(at constant height)

Order Information

General Flow Sensor with Venturi Tube.....	PS-2225
PASPORT Force Platform.....	PS-2141
SPARKlink Air Interface	PS-2011
PASCO Capstone Software.....	See pages 68-71
Supplied by User:	
PVC Pipe (3/4 inch), water, bucket	
Recommended (for velocity verification):	
Pitot Tube.....	ME-2221

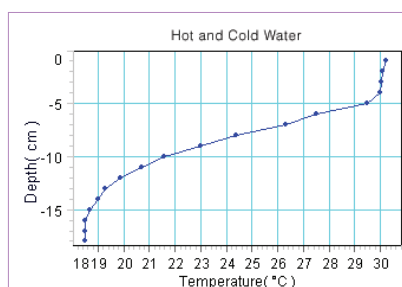
Density Circulation Model

ME-6816

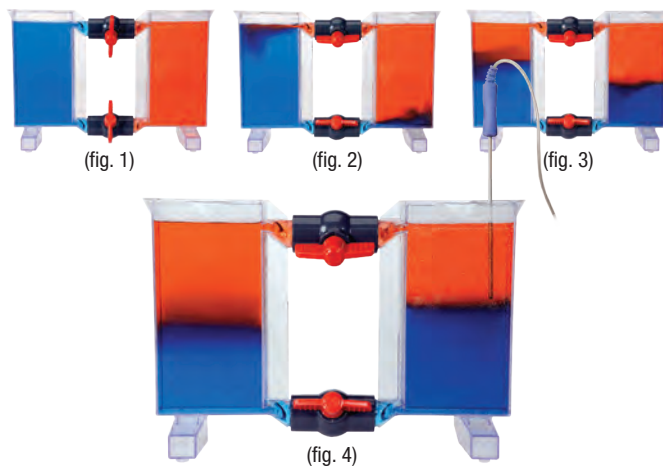
- ▶ Model density-driven circulation based on temperature, dissolved substances, or different liquids
- ▶ Demonstrate the driving forces of vertical ocean currents
- ▶ Measure temperature inversions based on density difference



The PASCO Density Circulation Model allows students to model, measure and understand the complex density-driven circulation associated with heat transfer through convection. Students can recreate vertical ocean currents driven by water bodies with density differences. They can extend this learning by using sensors to collect data and create graphs showing the thermocline, halocline and pycnocline using a Salinity Sensor PS-2195 (page 44).



Here is data showing Temperature vs. Depth. Rapid temperature change occurs in the region where the two water bodies mix.



With the valves closed (fig. 1), two bodies of liquid can be created that differ in temperature, dissolved materials, or other properties. When the valves are opened, a smooth flow of liquid occurs between the chambers (fig. 2 and fig. 3). Minimal mixing occurs and results in clearly defined layers of liquid based on density (fig. 4).

Order Information

Density Circulation Model	ME-6816
Show in use with:	
PASPORT Stainless Steel Temperature Probe	PS-2153 p. 33, 55

Density Set

ME-8569A

Use this versatile set of materials with the Overflow Can to investigate Archimedes' Principle of displacement, specific heats, and basic length/volume relationships. Includes pieces that have the same shape, volume, density, and mass, so the variable of interest can readily be isolated. Each piece has a hole, so it can be suspended from a string.



Includes:

- Three cylinders: aluminum, brass, plastic; 2.2 cm dia. x 6.4 cm long (plastic is less dense than water)
- Two blocks: aluminum (1.9 x 3.2 x 4.1 cm) and brass (1.6 x 1.9 x 2.8 cm); The mass of each block equals that of the aluminum cylinder.
- One irregular shape: aluminum
- Instruction manual

Order Information

Density Set ME-8569A

Archimedes' Principle Experiment

EX-9909

Concepts:

- ▶ Archimedes' Principle
- ▶ Density
- ▶ Buoyant force

See page 338
for complete
experiment.

Archimedes' Principle states that the buoyant force on a submerged object is equal to the weight of the fluid that is displaced by the object.

The buoyant force on several objects is measured by weighing the water displaced by a submerged object. The buoyant force is also determined by measuring the difference between the object's weight in air and its apparent weight in water.

Some of the objects have the same density, some have the same volume, and some have the same mass. The density of each object is measured and the dependence of the buoyant force on density, mass, and volume is explored.



Order Information

Archimedes' Principle Experiment EX-9909

Mole Set

SE-7586A

The Mole Set contains four element specimens: Copper, Iron, Zinc and Aluminum. Each sample contains approximately one mole, 6.02×10^{23} atoms of the element.

Includes:

- Mole samples: Zinc, Aluminum, Iron, Copper
- Teaching Suggestions



Order Information

Mole Set SE-7586

Overflow Can

SE-8568

This aluminum Overflow Can provides direct volume measurements for the materials supplied in the Density Set, as well as displacement measurements for buoyancy experiments. It has a 76 mm diameter, a usable volume of 477 cm³, and an angled downspout. Requires a graduated cylinder or a gram balance to measure the displaced volume.



Includes:

- Can only

Order Information

Overflow Can SE-8568

Glassware

Rugged borosilicate glassware for use in the physics lab.



Order Information

Beaker, 100 ml (12 Pack) SE-7287

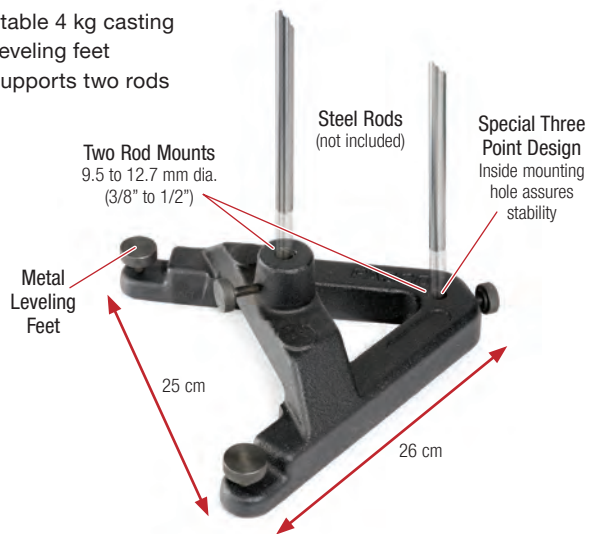
Beaker, 1000 ml (6 Pack) SE-7288

50 ml Graduated
Cylinder (12 Pack) SE-7289

Large Rod Base

ME-8735

- ▶ Stable 4 kg casting
- ▶ Leveling feet
- ▶ Supports two rods



This sturdy 4 kg cast-iron wide base supports one or two rods. Rods from 9.5 to 12.7 mm (3/8 to 1/2 inches) diameter can be supported. Two adjustable feet provide the necessary leveling capabilities.

Order Information

Large Rod BaseME-8735

Metal Knobs and Feet (4 pack)

ME-8954

These replacement knobs and feet for the ME-8735 Large Rod Base are made of solid steel with knurled knobs and 5/16"-24 thread.



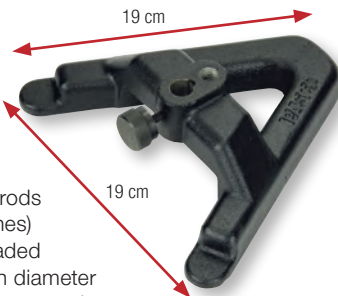
Order Information

Metal Knobs and Feet ME-8954

Small "A" Base

ME-8976

This 1.7 kg cast iron base is smaller than the Large Rod Base (above) and does not have leveling feet. This base can be used with both threaded and nonthreaded rods. Non-threaded rods from 9.5 to 13 mm (3/8 to 1/2 inches) diameter can be supported. Threaded rods must be 12.7 mm (1/2 inch) in diameter with 1/2"-13 thread, such as the 60 cm rod shown at right.



Order Information

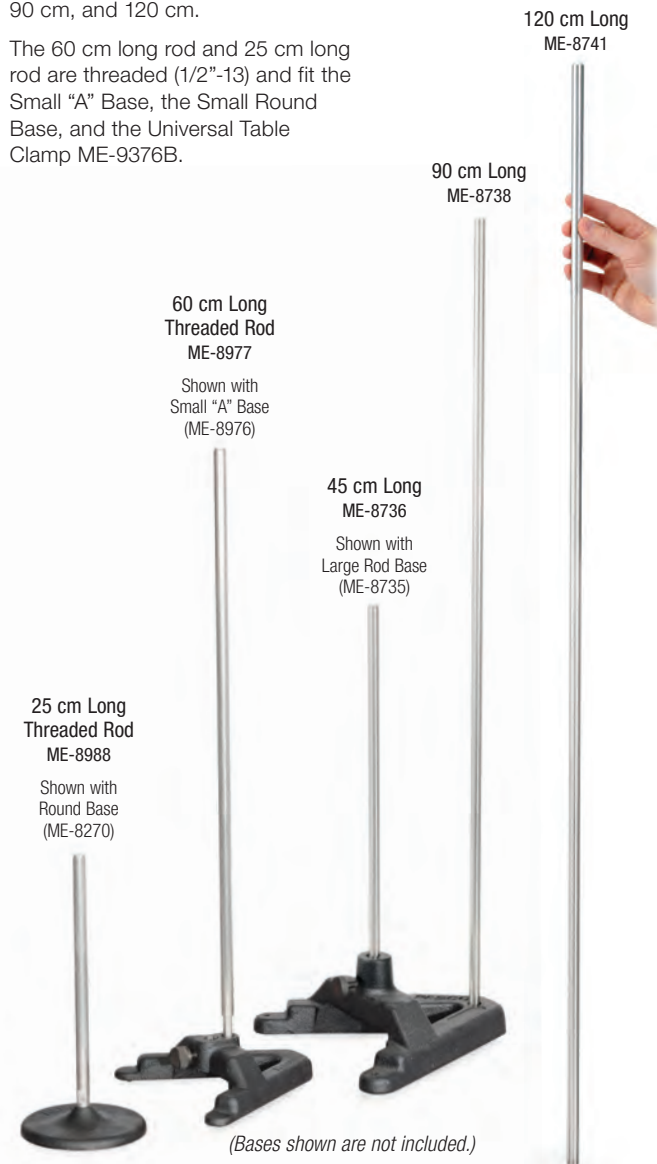
Small "A" BaseME-8976

Stainless Steel Rods

These 12.7 mm (1/2 in.) diameter stainless steel rods do not mar like aluminum rods. They are non-magnetic, very rigid, and durable.

Three different lengths are available in the non-threaded version: 45 cm, 90 cm, and 120 cm.

The 60 cm long rod and 25 cm long rod are threaded (1/2"-13) and fit the Small "A" Base, the Small Round Base, and the Universal Table Clamp ME-9376B.



Order Information

Stainless Steel Rods 12.7 mm (1/2 in.) in diameter:
 45 cm Stainless Steel RodME-8736
 90 cm Stainless Steel RodME-8738
 120 cm Stainless Steel RodME-8741
 Stainless Steel Rod, 25 cm ThreadedME-8988
 Stainless Steel Rod, 60 cm ThreadedME-8977

Flex Rod

ME-8978A

- ▶ Flexible rod for holding objects in any orientation

The Flex Rod provides the freedom to place equipment where it's needed. Simply connect the object to the end of the 46 cm long flexible tubing and move it to the desired location. The tubing has enough rigidity to hold many common items in any orientation. In addition, two convenient clamps are included.



The Flex Rod holds a green laser pointer. Shown with Small "A" Base (not included).



Flex Rod holds photogate for Acceleration Due to Gravity experiment using a picket fence (shown with T able Clamp, not included).



The Flex Rod with rod clamp attachment fits sensor handles.



Includes:

- Flex Rod attached to rigid section
- 2 Rod Clamp attachments
- 3-Finger Clamp attachment (Base support not included.)

Order Information

Flex Rod	ME-8978A
Suggested Base Supports:	
Small "A" Base	ME-8976
Aluminum Table Clamp	ME-8995

Base and Support Rod



Large
ME-9355

Round
ME-8270

Large

Large Base and Support Rod with built-in leveling screws and a threaded aluminum rod that is 12.7 mm (1/2 in.) in diameter and 45 cm long.

Round

Round base with rod. The threaded steel rod is 12.7 mm (1/2 in.) in diameter and 25 cm long.

Order Information

Base and Support Rod	ME-9355
Round Base with Rod.....	ME-8270

How to choose the best mounting rod

Both of these rods are useful for mounting sensors, particularly photogates. They also work well with Smart Pulleys.

The SA-9242 stainless steel rod is the same length as the ME-9483 plastic rod. However, the steel rod has a smaller diameter that may not work with all clamps that require a standard 12.7 mm (1/2 in) diameter. The ME-9483 is made of a hard plastic that clamp screws do not dent and it has a threaded brass stud. The lighter weight of the plastic rod will not damage pulleys when thrown into a bin.



Mounting Rods (10 pack)

ME-9483

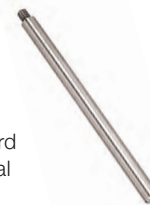
These rigid plastic pulley handles (14 cm long, 1.27 mm diameter) have a 1/4" metal stud that screws into a Super Pulley.



Pulley Mounting Rod

SA-9242

This 14 cm long stainless steel mounting rod is 9.5 mm (3/8 in.) in diameter and fits most standard laboratory clamps, including the PASCO Universal Clamp. It has a standard 1/4"-20 thread.



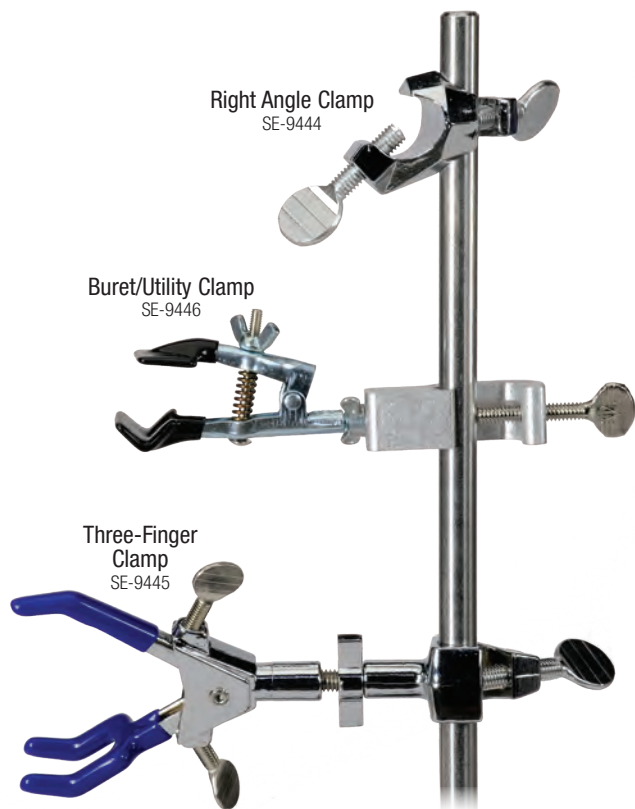
Order Information

Mounting Rods (10 pack)	ME-9483
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Order Information

Pulley Mounting Rod	SA-9242
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Clamps



Right Angle Clamp
SE-9444

Buret/Utility Clamp
SE-9446

Three-Finger Clamp
SE-9445

Right Angle Clamp

SE-9444

This standard right angle clamp fits rods up to 18 mm (11/16 inch) in diameter.

Buret/Utility Clamp

SE-9446

The V-shaped, plastic-coated jaws of this Buret Clamp open from 5 to 35 mm, rotate 360°, and lock in position at any angle. Fits rods up to 16 mm (5/8 inch) in diameter.

Three-Finger Clamp

SE-9445

Clamp tubes, rods, and irregularly shaped objects. The jaws extend 19 mm, open to 57 mm, rotate 360°, and lock securely at any angle. Fits rods up to 19 mm (3/4 inch) in diameter.

Order Information

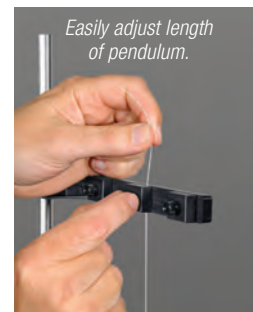
Right Angle Clamp	SE-9444
Buret/Utility Clamp	SE-9446
Three-Finger Clamp	SE-9445

Pendulum Clamp

ME-9506



Hang up to three springs or pendulums. Easily adjust the lengths of the pendulum strings.



Easily adjust length of pendulum.

Order Information

Pendulum Clamp	ME-9506	
Shown in use with:		
Photogate Pendulum Set.....	ME-8752	p. 167
Small "A" Base	ME-8976	p. 186
45 cm Stainless Steel Rod	ME-8736	p. 186

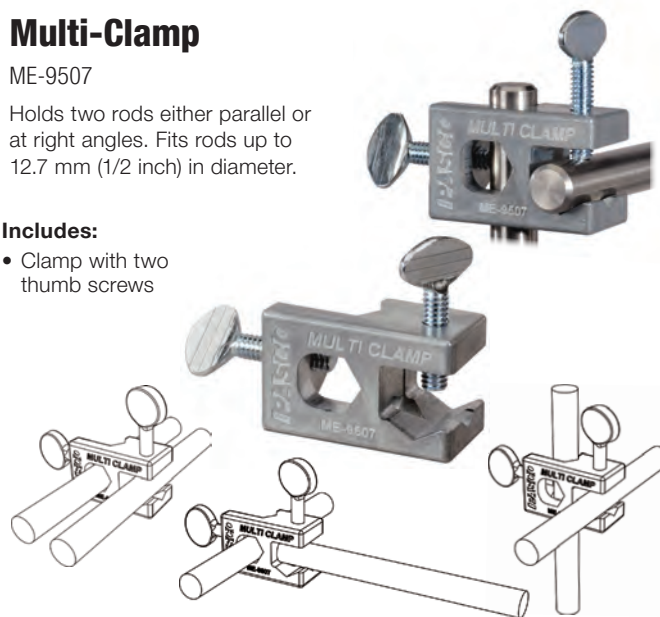
Multi-Clamp

ME-9507

Holds two rods either parallel or at right angles. Fits rods up to 12.7 mm (1/2 inch) in diameter.

Includes:

- Clamp with two thumb screws



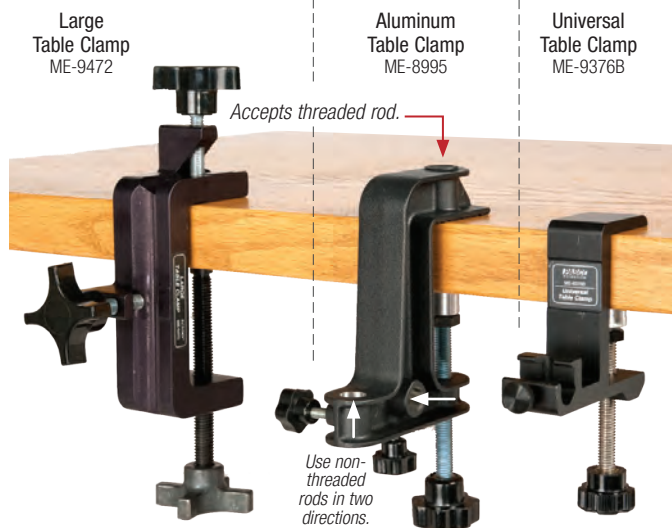
Order Information

Multi-Clamp.....	ME-9507
------------------	---------

Large Table Clamp

ME-9472

These clamps hold up to 12.7 mm (1/2 inch) diameter rods that can be mounted either horizontally or vertically.



Order Information

Large Table Clamp	ME-9472
(10 cm grip range)	
Aluminum Table Clamp	ME-8995
(6 1/2 cm grip range)	
Universal Table Clamp	ME-9376B
(6 cm grip range)	

“C” Clamps

SE-7285

This rugged clamp is perfect for attaching a variety of objects to a table. Available in 10 cm (4 inch) size.



Order Information

Large “C” Clamp (6 Pack)	SE-7285
--------------------------------	---------

Laboratory Jacks

Raise, support and align equipment with these Lab Jacks. They're rugged, stable and ensure precise height adjustment. Two sizes are available.

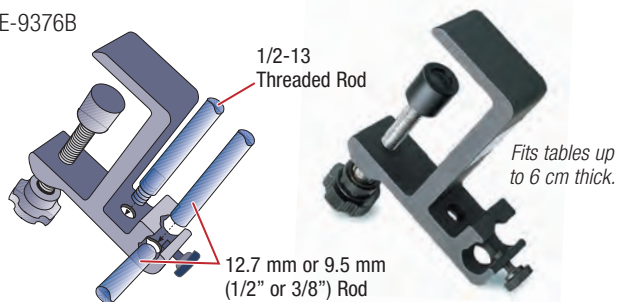


Order Information

Lab Jack	Model	Platform (cm)	Height (cm)	Load (kg)
Medium	SE-9373	15 x 15	7-25	25
Large	SE-9372	20 x 20	7-25	25

Universal Table Clamp

ME-9376B



Attach this Universal Table Clamp to tables or shelves up to 6.0 cm (2 3/8 inch) thick. Can also be mounted on a ring stand.

Mount rods in the clamp either vertically or horizontally. The rods are held securely by stable three-point contacts. Use standard unthreaded lab rods — 9.5 mm (3/8 inch) to 12.7 mm (1/2 inch) — vertically or horizontally. Use 1/2-13 threaded lab rod vertically.

Order Information

Universal Table Clamp	ME-9376B
-----------------------------	----------

Double Rod Clamp (3 pack)

ME-9873

Holds any two rods up to 12.7 mm (1/2 inch) in diameter, either parallel or perpendicular to one another.



Order Information

Double Rod Clamp (3 pack)	ME-9873
---------------------------------	---------

Swivel Clamp (2 pack)

ME-8743

Clamp two rods at any angle or clamp the two rods parallel to each other. Accepts 12.7 mm (1/2 inch) rods.

- Includes Two Clamps



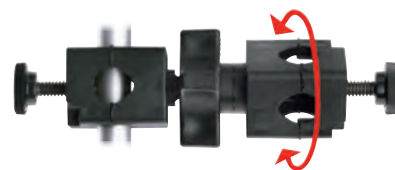
Order Information

Swivel Clamp	ME-8743
--------------------	---------

Adjustable Angle Clamp

ME-8744

This unique clamp fits any rod up to 12.7 mm (1/2 inch) in diameter and can lock the rod in place at any angle.



Order Information

Adjustable Angle Clamp	ME-8744
------------------------------	---------

Pulleys

Super Pulley

ME-9450A

- ▶ 20 N max load
- ▶ Nearly frictionless
- ▶ Durable
- ▶ Precision dimensions



The PASCO Super Pulley is the standard in physics labs. Its low-friction design produces excellent results. The precision spacing of the 10 spokes makes it ideal for photogate monitoring with PASCO's computer interfaces and photogate systems.

Order Information

Super Pulley ME-9450A

Pulley Mounting Rod

SA-9242

This 14 cm long stainless steel mounting rod is 9.5 mm (3/8 in.) in diameter and fits most standard laboratory clamps, including the PASCO Universal Clamp. It has a standard 1/4"-20 thread.



Order Information

Pulley Mounting Rod (rod only) SA-9242

Smart Gate Pulley System

PS-3702

The Super Pulley attaches directly to the Smart Gate, providing a simple, low-friction system to measure position, velocity and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments.



Includes:

- Smart Gate (1) PS-2180
- Super Pulley (1) ME-9450A
- Super Pulley Rod (1)

Order Information

Smart Gate Pulley System PS-3702

Super Pulley With Mounting Rod

ME-9499

This Super Pulley mounted on a rigid plastic mounting rod (12.7 mm diameter, 14 cm long) fits most standard laboratory clamps.



Order Information

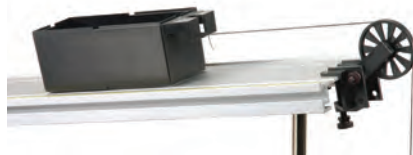
Super Pulley With Mounting Rod ME-9499

Super Pulley with Clamp

ME-9448B



Upgrade your force table and inclined plane experiments. The Super Pulley with its integral clamp makes setup and alignment easy. The pulley height is fully adjustable, so you can skim the top of a force table for parallax-free readings. Yet you can keep the force parallel to the track on an inclined plane, as shown in the photo below. Fits tables up to 2.0 cm (13/16 in.) thick.



Order Information

Super Pulley with Clamp ME-9448B

Mounting Rods (10 pack)

ME-9483

These rigid plastic pulley handles (14 cm long, 1.27 mm diameter) screw into a Super Pulley.



Order Information

Mounting Rods (10 pack) ME-9483

Photogate/Pulley System

ME-6838A

The Super Pulley attaches directly to a Photogate Head, providing a simple, low-friction system to measure position, velocity and acceleration. Additionally, with the pulley removed, the photogate can be used to perform standard photogate experiments.



Order Information

Photogate & Pulley System ME-6838A

Atwood's Machine

SA-9241



Two Super Pulleys mounted on a 6.4 cm long rod produce a classic, low-friction introduction to Newton's Second Law. The instruction sheet fully describes both the experiment and the theory.

Includes:

- Two Pulleys
- Connecting Rod



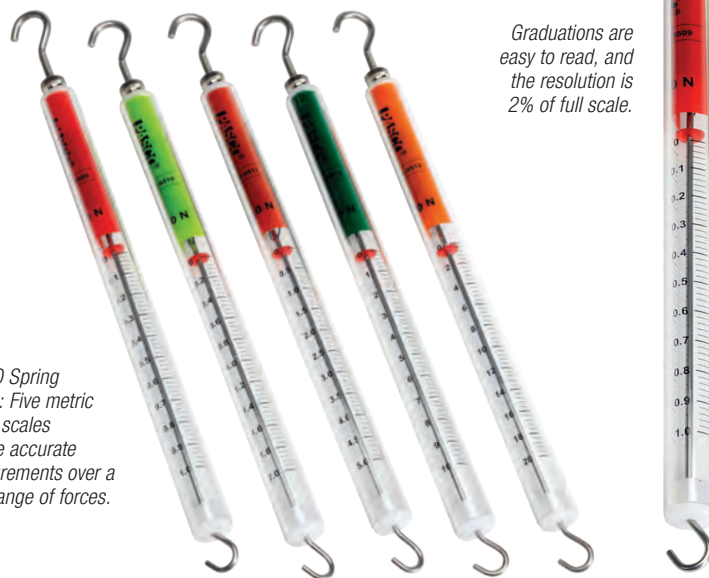
Atwood's Machine SA-9241

Metric Spring Scales

These high-quality metric spring scales are precise, durable, and calibrated in Newtons. Five different scales are available. Students can measure forces from a fraction of a Newton to 20 Newtons with excellent accuracy.

Features:

- ▶ **Accurate:** The precision springs provide excellent linearity, and the 10 cm long scales are sharp and clear for superior resolution.
- ▶ **Sealed Spring:** Can't get tangled, over-stretched, or lost.
- ▶ **Zero Adjust:** Turn the knob to zero the balance.
- ▶ **Scales on Inside:** They won't wear off.
- ▶ **Five Color-coded Ranges:** Measure almost any force from 0.1 N to 20 N.



Graduations are easy to read, and the resolution is 2% of full scale.

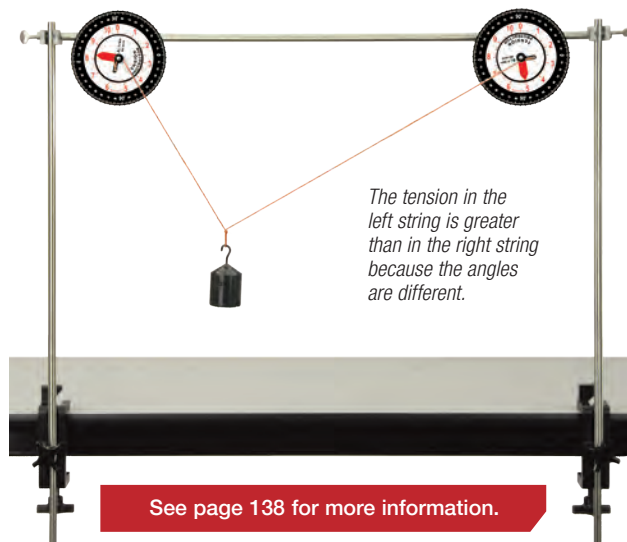
PASCO Spring Scales: Five metric spring scales provide accurate measurements over a wide range of forces.

Order Information			
Metric Spring Scales			
Model	Range	Resolution	Color
ME-9509	1.0 N	0.02 N	Red
ME-9510	2.0 N	0.04 N	Lt. Green
ME-9511	5.0 N	0.1 N	Brown
ME-9512	10 N	0.2 N	Dk. Green
ME-9513	20 N	0.4 N	Orange

Tension Protractor

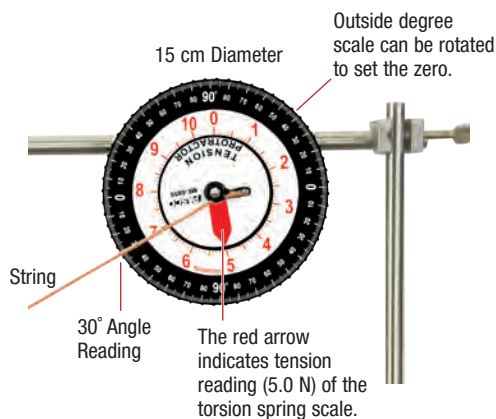
ME-6855

The Tension Protractor is a spring scale and a protractor integrated into one device. Perfect for static equilibrium experiments, the rotary dial indicates the tension in the string and the angle is read where the string passes over the degree scale on the outer ring. Since the Tension Protractor is supported on a rod, it has an advantage over other spring scales that tend to weigh down the string, changing the angle.



The tension in the left string is greater than in the right string because the angles are different.

See page 138 for more information.



- ▶ Measure tension and angle with one device
- ▶ Large scale for viewing demonstrations
- ▶ Zero-adjust for torsion spring scale
- ▶ Built-in rod clamp

Order Information	
Tension Protractor.....	ME-6855
Recommended:	
Large Table Clamp	ME-9472 p. 189
90 cm Stainless Steel Rod	ME-8738 p. 186
Multi-Clamp.....	ME-9507 p. 188
Hooked Mass Set.....	SE-8759 p. 197

Lab Supplies

30 Meter Measuring Tape

SE-8712A

This 30-meter woven fiberglass measuring tape reads metric on one side and imperial on the other.



Order Information

30 Meter Measuring TapeSE-8712A

Digital Calipers

SE-8710



This metric/English (15 cm/6 in.) digital caliper measures to 0.01 mm (0.0005 in.). It has auto power-off and includes a sturdy plastic storage case.

Order Information

Digital CalipersSE-8710

Stainless Steel Calipers

SF-8711



These metric/English (18 cm/6 in.) calipers have an expanded Vernier scale of 20 divisions (instead of the usual 10), so it's easier to read and more accurate. The sliding mechanism is smooth and durable. A case is included for added protection.

Order Information

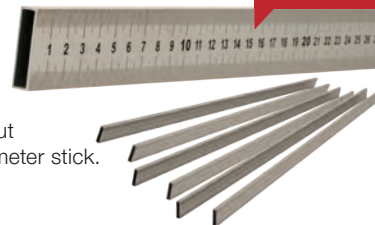
Stainless Steel Calipers.....SF-8711

Aluminum Meter Sticks (6 Pack)

NEW

ME-7032

These aluminum meter sticks are rigid and straight. Because they are hollow, the aluminum meter stick has about the same mass as a wooden meter stick.



Includes:

- Aluminum Meter Sticks (6)

Order Information

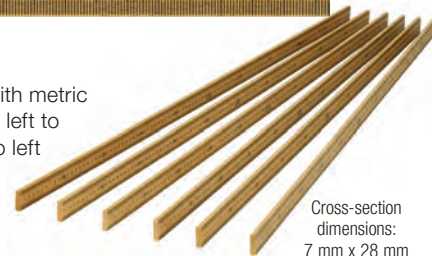
Aluminum Meter Sticks (6 Pack)ME-7032

High Quality Meter Sticks (6 Pack)

SE-8827



Hardwood meter stick with metric graduations; scale reads left to right on one side, right to left on the other.



Cross-section dimensions:
7 mm x 28 mm

Order Information

Meter Sticks (6 Pack).....SE-8827

Four Scale Meter Stick

SE-8695



The Four-Scale Meter Stick is constructed of plastic square channel. One side has millimeter markings, one has centimeter markings, one has decimeter markings, and the last side has only a one-meter mark.

Order Information

Four Scale Meter Stick.....SE-8695

Micrometer

SE-7337

This low-cost micrometer provides measurements from 0 to 25 mm with 0.1 mm resolution. The wooden box is form-fitted to protect the micrometer during storage.



Order Information

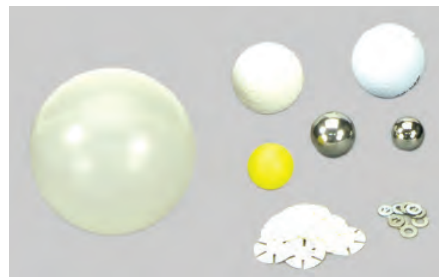
Micrometer.....SE-7337

Freefall Balls Accessory

ME-9890

This set of balls is used with the Discover Freefall system. The special stickers are used to attach the metal washers to the plastic balls, allowing them to be suspended from a magnet.

WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.



Includes:

- Small Nylon Ball (2.5 cm)
- Large Plastic Ball (10 cm)
- Golf Ball (4.4 cm)
- Hollow Golf Ball (4.2 cm)
- Steel Ball (2.5 cm)
- Steel Ball (1.6 cm)
- Release Washers (10)
- Release Stickers (50)



Order Information

Freefall Balls Accessory ME-9890

Steel Balls

ME-9864

Four pack of 2.5 cm diameter balls for use with PASCO Short or Long-Range Projectile Launchers (ME-6800 or ME-6801).



WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Order Information

Steel Balls (4 pack) ME-9864

Spherical Mass Set

ME-8968

This set includes four balls with a diameter of 2.5 cm each, but features various masses, including a hollow steel ball, solid steel ball, plastic ball and aluminum ball.



WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Includes:

- Solid Yellow Nylon Ball (10 grams)
- Solid Steel Ball (66 grams)
- Hollow Steel Ball (21 grams)
- Solid Aluminum Ball (24 grams)

Applications:

- ▶ Race the hollow steel ball and solid aluminum ball down an incline. They have about the same mass, but the solid aluminum ball has a much larger acceleration down the ramp.
- ▶ Fire the yellow plastic, solid steel, and hollow steel balls from a PASCO Projectile Launcher.

Order Information

Spherical Mass Set ME-8968

Bounce/No Bounce Ball Set (3 sets)

SE-7571

WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

These two black balls look and feel identical, but drop them side by side and students will notice a big difference in their elasticity. One bounces close to the original drop height, while the other doesn't bounce at all. Includes three sets of the Bounce/No Bounce Balls. Each ball has a diameter of 2.5 cm.



Order Information

Bounce/No Bounce Ball Set (3 pack) SE-7571

Small Steel Balls

ME-9872

These 1.6 cm diameter steel balls are used with the Mini Launcher (ME-6825).

WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.



Order Information

Small Steel Balls (10 pack) ME-9872

Plastic Balls

ME-6822

WARNING
CHOKING HAZARD
Contains small balls. Not for children under 3 years.

Extra brightly colored balls for the Projectile Launcher. Diameter is 2.5 cm (1 in.).



Order Information

Plastic Balls (10 Pack) ME-6822

Lab Supplies

Braided Physics String

SE-8050

▶ 30-lb. Test

This braided Dacron string is tough, resists stretching, and won't unravel. Withstands up to 133 Newtons of force (equivalent to 13.6 kg). Each roll provides 320 meters of string.



Order Information

Braided Physics String SE-8050

Elastic Wave Cord

SE-9409

Unlike a Slinky®, the tension can be varied. In addition to the Slinky, this Elastic Wave Cord is great for wave demonstrations. The cord is 3 mm in diameter. Each roll provides 90 meters of cord.



Order Information

Elastic Wave Cord SE-9409

Yellow Cord

ME-9876

Two rolls of highly visible braided yellow cord. Total length of 140 meters.



Order Information

Yellow String (2 pack) ME-9876

Rubber Cord (30 meters)

ME-8986

This rubber cord is used with PASCO's Elastic Bumper, and also fits the Air Track Bumper Set With Holder.



Order Information

Rubber Cord
(Spool of 30 meters) ME-8986

Glow String (2 Pack)

SE-8690



This stretchy "string" glows in the dark after being exposed to light. Use it to demonstrate wave motion, including resonance and standing wave patterns. Two rolls are included, totaling over 15 meters of string.

WARNING
CHOKING HAZARD
Small parts. Not for
children under
3 years.

Order Information

Glow String (2 Pack) SE-8690

Black Thread (3 Pack)

ME-9875



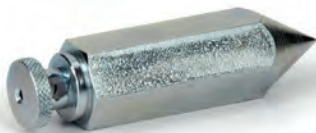
Includes three spools of black Nylon thread

Order Information

Black Thread (3 Pack) ME-9875

Plumb Bobs (10 Pack)

SE-8728



These finished steel plumb bobs are precision-machined to a fine point. Just slide a string through the hole in the top and tie a knot. The plumb bob hangs precisely centered.

Order Information

Plumb Bobs (10 Pack) SE-8728

No-Bounce Pad

SE-7347



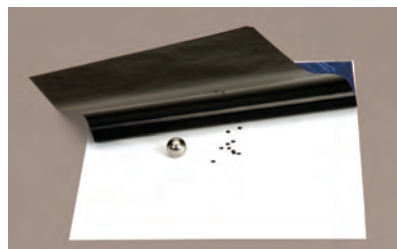
Stop falling objects from bouncing with PASCO's No-Bounce Pad. The 30 cm x 30 cm x 2.5 cm dimensions of the pad provide an ample target for gravity demonstrations. Prevents heavy objects from damaging the floor and prevents falling objects from being damaged on impact.

Order Information

No-Bounce Pad SE-7347

Carbon Paper (100 Pack)

SE-8693



Carbon paper is ideal for marking the position of an object as it strikes the floor or other surface.

Order Information

Carbon Paper (100 Sheets) SE-8693

Spirit Levels (10 Pack)

SE-8729



These 23 cm long Spirit Levels have three vials with striped gradations to indicate vertical, horizontal, and 45° alignment. The frame is a durable plastic with tough acrylic vials. A magnetic tape allows hands-free leveling.

Order Information

Spirit Levels (10 Pack) SE-8729

Gratnells® Rolling Carts

EP-3574 (2-column) EP-3575 (3-column)

Gratnells Rolling Carts are the best way to store and transport PASCO sensors and equipment. They can be configured for trays of any size and include large castors with brakes for added stability.

Designed for Gratnells trays, these movable storage rack carts can store up to 8 (2 column) or 12 (3 column) Gratnells F2 trays (sold separately). Each cart comes with either 16 or 24 pairs of runners.

They can be used to store the equipment kits from the Essential Physics or Essential Chemistry curriculum, the storage trays we offer for wireless sensors, or any of the four sizes of empty trays that we offer for everything else you'd like to store.

*Assembly is required.
Trays not included.*



EP-3575

Stores up to 12 Gratnells F2 trays
24 pairs of runners
107 cm high, 102 cm wide, 43.5 cm deep



EP-3574

Stores up to 8 Gratnells F2 trays
16 pairs of runners
107 cm high, 70 cm wide, 43.5 cm deep

Order Information

Gratnells Rolling Cart (2-column) EP-3574
Gratnells Rolling Cart (3-column) EP-3575

Gratnells® Storage Trays with Lids



F1

F2

F25

F3

Order Information

Storage Tray (F1) Shallow PS-3326
Storage Tray (F2) Deep PS-3327
Storage Tray (F25) X-Deep PS-3328
Storage Tray (F3) Jumbo PS-3329

These empty Gratnells storage trays with lids have a length of 427 mm and width of 312 mm.

Depths:

F1: 75 mm
F2: 150 mm
F25: 225 mm
F3: 300 mm

Storage Bins

SE-7560



Stackable plastic bins with lids are useful for storing sensors. 14" L x 9.5" W x 6.9" D

Order Information

Storage Bins (Set of 5) SE-7560

3.8 Liter Plastic Container Set

ME-7559

These containers are great for experiments needing ice water baths. See the Heat Engine Experiment on page 358 for an example.



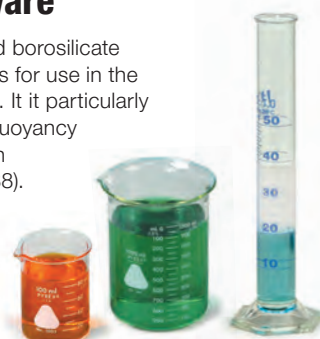
14 cm x 14 cm x 19.5 cm tall

Order Information

3.8 Liter Plastic Container Set (set of 2) ME-7559

Glassware

This rugged borosilicate glassware is for use in the physics lab. It is particularly useful for buoyancy labs (shown on page 338).



Order Information

Beaker, 100 ml (12 Pack) SE-7287
Beaker, 1000 ml (6 Pack) SE-7288
50 ml Graduated Cylinder (12 Pack) SE-7289

Discover Pi Set (10 Pack)

ME-6819A

The Discover Pi Set allows students to derive the meaning of π directly from their measurements. This activity transforms π from a constant with unknown origin to a fundamental characteristic of all circular objects.

Includes:

- 4 Pi Circles: 5.2, 6.4, 8.9, 10.0 cm diameter
- Transparent Measuring Tape



Order Information

Discover Pi Set (10 Pack) ME-6819A

Water Reservoir

ME-8594

This calibrated 1000 ml cylinder is useful for experiments (as shown on page 344), requiring either a specific amount of water, a constant flow of water, or water at a constant pressure. The cylinder has three hose connections: one for connection to a source of water, one for overflow, and an outlet near the bottom. Comes with six meters of tubing and two restriction clips.



Order Information

Water Reservoir ME-8594

Balances

OHAUS Electronic Balances

SE-8823A (220 g) SE-8756B (420 g)
SE-8757B (2200 g) SE-8758B (8200 g)



The Ohaus Scout SKX digital electronic balances combine range, resolution, and low cost, making them ideal for the student physics lab.

Simple two-button operation and visual menu prompts allow students to begin weighing with minimal instruction. The large, crisp display is easily viewed from any angle, so teachers can quickly check student results. A sealed front panel, molded spill ring, and removable stainless steel platforms provide protection from spills and make these balances easy to keep clean.

Specifications:**SE-8823A:**

Capacity: 0-220 g
Resolution: 0.01 g
Pan Size: 12 cm dia.

SE-8757B:

Capacity: 0-2200 g
Resolution: 0.1 g
Pan Size: 16.5 x 4.2 cm

SE-8758B:

Capacity: 0-8200 g
Resolution: 1.0 g
Pan Size: 16.5 x 14.2 cm

SE-8756B:

Capacity: 0-420 g
Resolution: 0.01 g
Pan Size: 12 cm dia.

Make these balances work with PASCO Capstone and SPARKvue on your computer via Bluetooth® or USB with:



Ohaus Bluetooth Adapter SE-8822

Ohaus USB Adapter..... SE-8821

Order Information

OHAUS Scout SKX Balances
220g..... SE-8823A
420g..... SE-8756B
2200g..... SE-8757B
8200g..... SE-8758B

Ohaus Triple-Beam Balance

SE-8723 (without tare) / SE-8707 (with tare)



Ohaus Cent-O-Gram Balance

SE-8725



Ohaus mechanical balances have been the standard weighing instruments in student laboratories for decades. They're accurate, easy to use, durable, and inexpensive.

- ▶ **Precision-Ground Steel Knives:** for exact measurements and a long balance life
- ▶ **Stainless Steel Weighing Pan:** easy to clean, lasts indefinitely
- ▶ **Magnetic Damping:** for quick, true measurements
- ▶ **Simple Zero-Adjustment:** just zero the masses, then rotate the knob
- ▶ **Capacities:** see table below

Specifications:**SE-8723:**

Ohaus #: 750-S0
Type: Triple-Beam
Capacity: 610 g
with additional mass set: 2610 g
Readability: 0.1 g
Tare: None

SE-8725:

Ohaus #: 311-00
Type: Cent-o-Gram
Capacity: 311 g
Readability: 0.01 g
Tare: None

SE-8707:

Ohaus #: 760-00
Type: Triple-Beam
Capacity: 610 g
with additional mass set: 2610 g
Readability: 0.1 g
Tare: 225 g

Order Information

Ohaus Triple-Beam Balance (without Tare)..... SE-8723
Ohaus Triple-Beam Balance (with Tare)..... SE-8707
Ohaus Cent-O-Gram Balance..... SE-8725
Recommended:
Ohaus Additional Mass Set..... SE-8708

Ohaus Additional Mass Set

SE-8708



For Triple-Beam Balances

These additional masses can increase the range of the Ohaus Triple-Beam Balances (SE-8723 and SE-8707) by an additional 2 kg. Included are a 0.5 kg and two 1 kg masses.

Order Information

Ohaus Additional Mass Set SE-8708

Slotted Masses

SE-8726A Set (10 g resolution)

SE-8704A Set (1 g resolution)

SE-8703A Hanger (50 g)



This 50 gram mass hanger is the standard hanger for the slotted masses shown.

These slotted masses provide medium to heavy mass (up to 1.110 kg) with 1 g or 10 g resolution.

The SE-8726A Set Includes:

Masses: 1 x 500 g 2 x 200 g 1 x 100 g
 1 x 50 g 2 x 20 g 1 x 10 g

The SE-8704A Set Includes:

The above masses plus a 5 g, 1 g, and two 2 g masses. Mass hangers available separately.

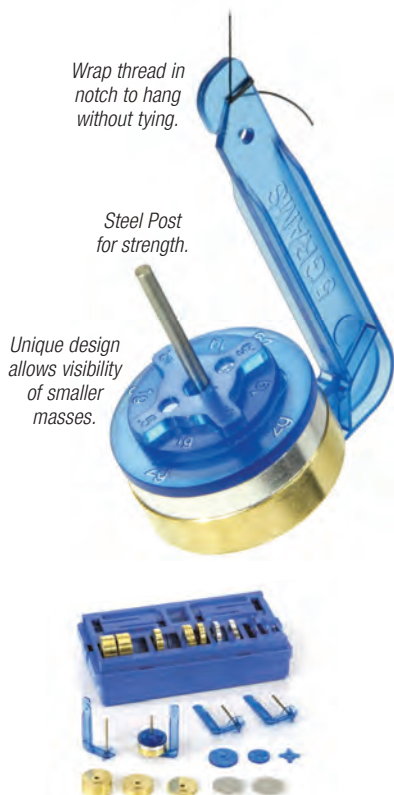
Order Information

10 g Slotted Mass Set..... SE-8726A
1 g Slotted Mass Set..... SE-8704A
Slotted Mass Hanger..... SE-8703A

Mass and Hanger Set

ME-8979

PASCO's Mass and Hanger Set includes varying units of mass that attach to the 5.0 g mass hangers' steel posts. This set includes 4 hangers and 27 masses ranging from 0.5 g to 100 g. The masses are marked on each unit, and each hanger can hold up to 250 g.



Includes:

- Four Mass hangers (5.0 g each) $\pm 2\%$
- Brass masses: $\pm 1\%$
3 x 100 g 3 x 50 g 6 x 20 g
- Aluminum masses: $\pm 1\%$
3 x 10 g 3 x 5 g
- Plastic masses: $\pm 2\%$
3 x 2 g 3 x 1 g 3 x 0.5 g
- Molded storage case

Order Information

Mass and Hanger Set..... ME-8979

Recommended:

Mass and Hanger Spares Kit..... ME-8980
(Contains four mass hangers and 10 each of 2 g, 1 g, and 0.5 g plastic masses)

Replacement Mass Sets for ME-8979:

5-gram Mass Set (set of 6) ME-8981

10-gram Mass Set (set of 6) ME-8982

20-gram Mass Set (set of 6) ME-8983

50-gram Mass Set (set of 6) ME-8984

100-gram Mass Set (set of 6) ME-8985

Large Slotted Mass Set

ME-7566

Includes:

- One 0.5 kg mass hanger
- Nine 0.5 kg slotted masses
- Diameter of masses: 8 cm
- Height of hanger: 36 cm



Order Information

Large Slotted Mass Set (5 kg Set)..... ME-7566

Short Slotted Mass Set

ME-7589 (2 kg Set)

Includes:

- One 0.5 kg mass hanger
- Three 0.5 kg slotted masses
- Diameter of masses: 8 cm
- Height of hanger: 15 cm



Order Information

Large Slotted Mass Set (2 kg Set)..... ME-7589
Short Mass Hanger ME-7590

Hooked Mass Set

SE-8759

Includes:

- Masses:
1 x 1000 g 1 x 500 g 2 x 200 g
1 x 100 g 1 x 50 g 2 x 20 g
1 x 10 g
- Molded mass holder



Order Information

Hooked Mass Set..... SE-8759

1 kg Mass and Hanger Set

ME-9337 (1 kg set)

Set features a 200 g cast aluminum mass hanger with a steel post, and four "holed" 200 g brass masses that will not fall off the hanger. Multiple mass hangers can be used by hooking the top of one into the bottom of another.



The flat bottom on the mass hanger makes it perfect for use with a Motion Sensor when performing Hooke's Law and spring oscillation experiments.



Can be used in conjunction with the entire set of smaller brass and plastic masses in the ME-8978 Mass and Hanger Set.



Includes:

- Mass Hanger ME-9350, Hanger height: 16 cm
- Set of four masses ME-9351, Diameter of masses: 5 cm
- Steel pin, 8 cm height, 3.6 mm diameter

Order Information

1 kg Mass and Hanger Set..... ME-9337
200 g Mass Hanger ME-9350
200 g Masses (Set of Four)..... ME-9351

Shown in use with:

Bases and Rods pp. 186-187

Equal Length Spring Set..... ME-8970

Pendulum Clamp ME-9506

PASPORT Motion Sensor PS-2103A

Stopwatches

PASCO Stopwatch

ME-1234

- ▶ No alarm or clock
- ▶ Memory for stored event times
- ▶ Uses one AA battery
- ▶ Durable buttons

Are you tired of annoying stopwatch alarms going off all day? Are your students stuck in the clock mode and can't get their stopwatch back into the timing mode? Does your stopwatch stop working after changing that little watch battery? The PASCO Stopwatch solves all these problems.

This stopwatch was designed specifically for science timing. The modes of operation are intuitive and complete instructions are included. The buttons are built to last and it uses a single long-lasting AA battery, which is less expensive than a watch battery (and easier to install).



The PASCO Stopwatch fits comfortably in your hand.

Specifications:

LED Display: Visible indoors and outdoors

Two Display Modes: MM:SS.SS (01:25.34) or Decimal Sec (85.34 s)

Precision: 0.01 sec up to 59:59.99 (MM:SS.SS) or 3599.99 s Then 1 sec to 99:59:59 (HH:MM:SS) or 359999 s

Max Number of Event Times: Nine

Auto-off: After one hour idle

Includes: One AA battery and instruction sheet



The EVENT/RECALL button allows you to view the last time, in case you forget to write it down. The EVENT/RECALL button is also used to store and recall up to 9 event times: For example, record a series of events, such as times at which sandbags were dropped along the gym floor.



Two display modes:
MM:SS.SS (00:25.18) or
Decimal Seconds (25.18s)

Order Information

PASCO Stopwatch..... ME-1234

PASCO Stopwatch, 10-pack

ME-1235

- ▶ Includes fitted foam storage box



Order Information

PASCO Stopwatch, 10-pack.....ME-1235

Student Timer

SE-8768

- ▶ Inexpensive
- ▶ 0.01 Second Resolution
- ▶ Easy Operation – start/stop, reset and lap

Appearance may vary



Order Information

Student Timer.....SE-8768

Strobe System

ME-6978

- ▶ 1 Hz to 500 Hz
- ▶ Variable intensity
- ▶ Low cost
- ▶ External trigger

This unique modular design makes it easy to light any geometry. The Strobe includes the Strobe Control Box and one Strobe Module. Additional Strobe Modules can be purchased separately (see below) for up to a total of four lamp modules per controller, and multiple control boxes can be connected together using the External Trigger. The Strobe Modules have a tilting lamp head on a sturdy base that sits on the table or fastens to a rod stand.



Specifications:

Accuracy: 0.1%

Frequency Range: 1 Hz to 500 Hz

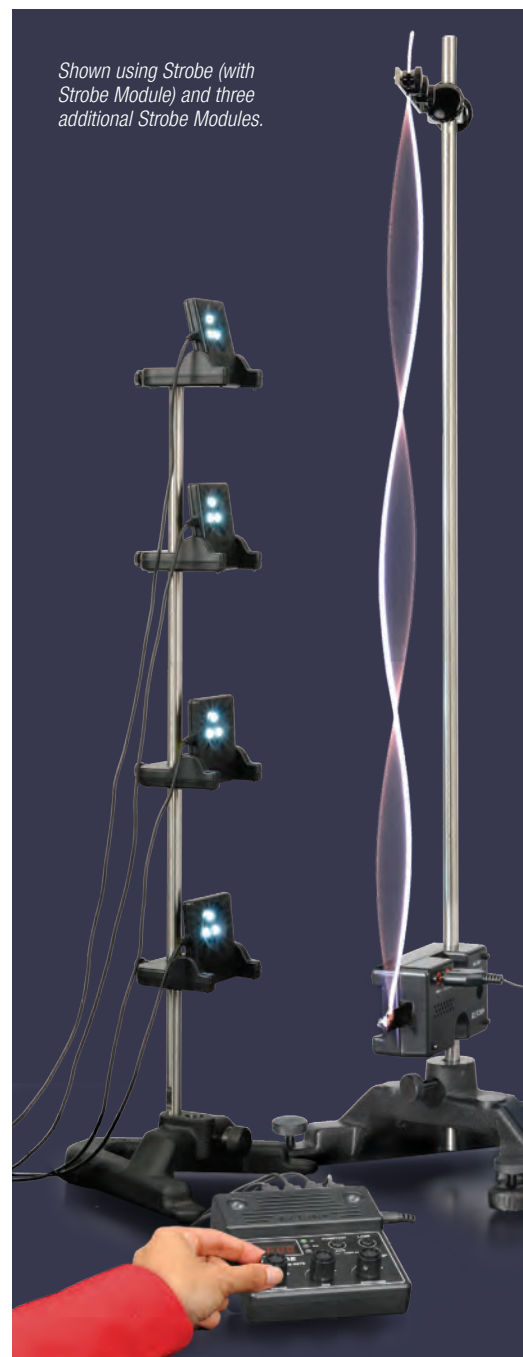
Resolution: 0.1 Hz

Lamp Life: 50,000 hours

Brightness: 230 lumens (peak) per module

Features:

- ▶ Display frequency in Hz or RPM
- ▶ Adjustable light intensity
- ▶ Add additional strobe lamps (ME-6982), up to four modules per controller
- ▶ External Trigger to daisy-chain multiple controllers together
- ▶ Trigger strobe using external input such as the ME-9498A photogate.



Order Information

Strobe System ME-6978
(Includes Control Box and one Strobe Module)
Strobe Lamp Module..... ME-6982

Shown in use with:

String Vibrator..... WA-9857A p. 260
Sine Wave Generator WA-9867 p. 261

Learn more at pasco.com/strobe

Thermal Expansion

Thermal Expansion Apparatus

TD-8856

- ▶ Use with Multimeter or Temperature Sensor
- ▶ Brass, copper, and aluminum tubes included

With PASCO's Thermal Expansion Apparatus, students can accurately and easily investigate the expansion of metals with increasing temperature.



Base
Provides storage for all three tubes

Steam Generator
(sold separately)



Built-in Digital Gauge
Simple and very accurate measurements with 0.01 mm resolution



Built-in 10 k Ω Thermistor
Together with a digital ohmmeter, or Temperature Sensor directly measures the temperature of the tube

Digital Multimeter
Measures thermistor resistance (sold separately)

Features:

- ▶ **Built-in Digital Gauge:** Measure the rod expansion with 0.01 mm resolution
- ▶ **Built-in Thermistor:** A 10 k Ω thermistor is connected directly to each tube and the temperature can be determined using a digital ohmmeter or Temperature Sensor.
- ▶ **Heat with Steam or Water:** The fluid used may be steam or water at any temperature.
- ▶ **Three Drop-in Metal Tubes:** Each tube connects securely onto the rigid base. The other two can be simultaneously mounted on the base for convenient storage.

Includes:

- Base with built-in dial gauge and thermistor
- Expansion tubes brass, copper and aluminum; 16 mm dia. (80 cm length)



Thermistor cable connects directly to the Temperature Sensor.

Order Information

Thermal Expansion Apparatus.....	TD-8856	
Required:		
Steam Generator.....	TD-8556A	p. 201
Recommended:		
Basic Digital Multimeter.....	SE-9786A	p. 230
OR		
PASPORT Quad Temperature Sensor.....	PS-2143	p. 33

Steam Generator

TD-8556A

- ▶ Variable steam output
- ▶ Rapid heating
- ▶ Automatic safety shut-off

The Steam Generator is an inexpensive heat reservoir with constant temperature. It can boil 3/4 of a liter of water in ten minutes and provides continuous steam at up to 10 g/min. The included baster can be used to remove hot water during experiments. This product also includes additional features for safety and convenience.



See page 202-203 for additional Steam Generator applications.

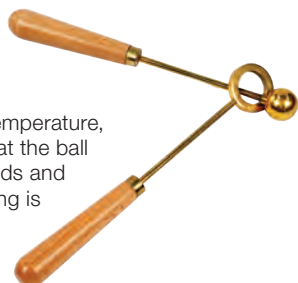
Order Information	
Steam Generator.....	TD-8556A

Ball and Ring

SE-7597

- ▶ Demonstrates thermal expansion

When the Ball and Ring are at room temperature, the ball easily fits through the ring. Heat the ball in a Bunsen burner flame and it expands and no longer fits through the ring. If the ring is also heated, the ball will fit through it once again.



Specifications:

Length: 23 cm

Ball Diameter at Room Temperature: 2.36 cm

Ring Inner Diameter at Room Temperature: 2.39 cm

Order Information	
Ball and Ring	SE-7597

Heater Stirrer

PS-3401

- ▶ The Heater-Stirrer is a great lab essential!



This compact hot plate and stirrer has a white ceramic top that is ideal for heating and for seeing color changes when mixing solutions. It has been designed to withstand spills. Its safety features include warning labels and indicator LEDs. And the included rod makes it easy to support sensors.

When used as a heater:

This compact new Heater-Stirrer can boil water in minutes. The ceramic top provides an even heating surface and the indicator LEDs let you know when the top is hot.

When used as a stirrer:

This new apparatus is great for mixing solutions. The white top makes color changes during titrations easy to see.

Specifications:

Speed Range: 50-1500 rpm

Plate Diameter: 135 mm

Max Temperature: 310°C

Includes:

- Support Rod

Order Information	
Heater Stirrer.....	PS-3401

Bimetallic Strip

SE-7598

- ▶ Demonstrates differential thermal expansion
- ▶ Demonstrates how thermostats work

When heated in a Bunsen burner flame, this bi-metallic strip bends. The strip is steel on one side and brass on the other side. Since brass expands more than steel, the strip becomes longer on the brass side. As it cools, it becomes straight again.

Specifications:

Blade Length: 12.5 cm



Order Information	
Bimetallic Strip	SE-7598

Thermal Conductivity

Thermal Conductivity Apparatus

TD-8561

- ▶ Measure heat flow through five different materials
- ▶ Constant temperature differential makes calculations easy
- ▶ Easy to use, no mess



One of the most important considerations for buildings in the modern world is their ability to provide good thermal insulation. This apparatus gives students a way to observe and quantify heat flow across a constant temperature differential. Students use five common materials as test samples: glass, wood, polycarbonate, Masonite and sheetrock.

Features:

- ▶ **No Mess:** The water from the melting ice runs off into the measuring cup — not on the lab table.
- ▶ **Durable Test Materials:** The wood, Masonite and sheetrock are covered with a thin aluminum sheet for waterproofing and to ensure good thermal contact.
- ▶ **Elevated Steam Reservoir:** The hot reservoir is well above the lab table to eliminate heat damage.

Order Information

Thermal Conductivity Apparatus..... TD-8561
 Required:
 Steam Generator..... TD-8556A p. 201
 Graduated Cylinder

How It Works:

A block of ice is placed against one side of the test material. The other side is clamped against a steam chamber, establishing a constant 100°C temperature differential. The rate at which the ice is converted to water is a measure of the rate at which heat passes from the steam, through the test material, and into the ice.

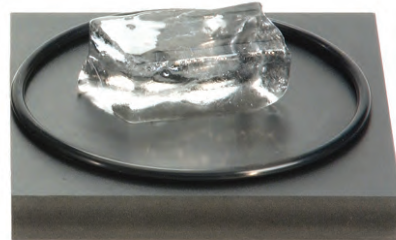
Includes:

- Stand with insulating pads
- Ice molds (2)
- Materials: 12.7 cm squares of glass, wood, polycarbonate, Masonite, and sheetrock
- Plastic tubing to connect steam generator
- Instruction manual and experiment guide

Ice Melting Blocks

SE-7317

- ▶ Great thermal conductivity and heat capacity demonstration



The two Ice Melting Blocks look similar but are composed of different materials. One block feels cold to the touch, while the other block feels slightly warm. Both blocks are at room temperature but have very different thermal conductivities and heat capacities.

After allowing students to hold the blocks, ask them which block would melt ice more quickly. Place an ice cube on each block and watch their amazement as the "cold" block melts the ice cube within two minutes. Melting the ice cube is barely noticeable on the "warm" block. The "cold" block is aluminum and has a much greater ability to transfer heat to the ice cube or the hand.

The "warm" block is plastic, which does not conduct heat as well.

Includes:

- Aluminum Block
- Plastic Block
- O-rings (2)



Order Information

Ice Melting Blocks SE-7317

Basic Calorimetry Set

TD-8557B

- ▶ An affordable introduction to thermodynamics

Styrofoam™ calorimeter cup (7.5 cm inside diameter, 10 cm deep) has 1.3 cm thick walls for excellent thermal properties. Set includes five different metal samples, a thermometer, plastic tubing, and a water trap that prevents unwanted condensation of steam.

Applications:

- ▶ Define the calorie
- ▶ Determine thermal capacity and specific heat of aluminum, copper, brass, stainless steel, and zinc
- ▶ Latent heat of vaporization
- ▶ Latent heat of fusion

Includes:

- Calorimeter cup with lid
- Alcohol thermometer 20°C to 110°C in 1° increments
- Samples of aluminum, copper, brass, zinc, and stainless steel (80 g each)
- Water trap and plastic tubing
- Instruction manual and experiment guide



Order Information

Basic Calorimetry Set	TD-8557B	
Required:		
Steam Generator.....	TD-8556A	p. 201
Ohaus Triple-Beam Balance (without Tare)	SE-8723	p. 196
Replacement Supplies:		
Calorimetry Cups (6)	TD-8825A	

Specific Heat Set

SE-6849

This specific heat set has five different materials, all with the same mass (80 g). Each has a hole to tie a loop of string to hang the samples in water.



Includes:

- Aluminum 1.25" d x 1.5" h
- Brass 3/4" d x 1.5" h
- Stainless Steel 3/4" d x 1.44" h
- Zinc 3/4" d x 1.58" h
- Copper 0.625" d x 1.8" h

Order Information

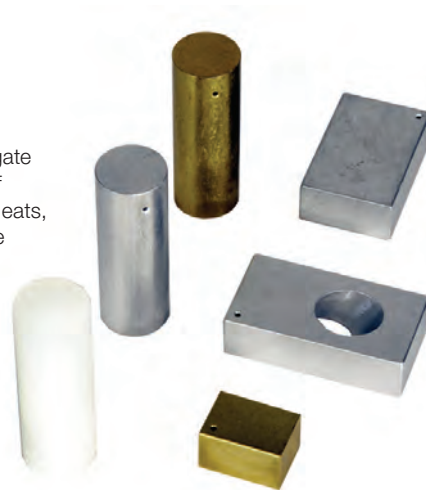
Specific Heat Set	SE-6849
Recommended:	
Calorimetry Cups (6)	TD-8825A

Density Set

ME-8569A

Use this versatile set of materials with the Overflow Can to investigate Archimedes' Principle of displacement, specific heats, and basic length/volume relationships.

Includes pieces that have the same shape, volume, density, and mass, so the variable of interest can readily be isolated. Each piece has a hole, so it can be suspended from a string.



Includes:

- Three cylinders: aluminum, brass, plastic; 2.2 cm dia. x 6.4 cm long (plastic is less dense than water)
- Two blocks: aluminum (1.9 x 3.2 x 4.1 cm) and brass (1.6 x 1.9 x 2.8 cm). The mass of each block equals that of the aluminum cylinder.
- Irregular shape: aluminum
- Instruction manual

Order Information

Density Set	ME-8569A
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Equivalent of Heat

Mechanical Equivalent of Heat Apparatus

TD-8551A

- ▶ Accurate to 5%
- ▶ Rugged ball-bearing construction
- ▶ Thermistor—no thermometer to break

This Mechanical Equivalent of Heat Apparatus provides an updated version of one of Joule's most important experiments: converting mechanical work to thermal energy.

Crank Counter
Counts the number of turns on the handle.

Thermistor
Embedded in the cylinder, it has lower thermal mass than a thermometer and is less breakable.

Double Ball Bearings
Minimize the wear on moving parts.

Durable Construction
Made primarily of steel and aluminum, there's virtually nothing to break. The thermistor is protected in the cylinder.

How It Works:

Turn the crank to perform a measurable amount of work. The crank turns an aluminum cylinder. A flat nylon rope is wrapped several times around the cylinder. The friction between the rope and the cylinder is just enough to support a mass hanging from the other end of the rope. This ensures that the torque acting on the cylinder is constant and measurable. A counter keeps track of the number of turns of the crank. The thermal energy is measured by monitoring the temperature of the cylinder using the embedded thermistor.

With this apparatus, the equivalence of work and heat is easily established to within 5%.

Includes:

- Base, cylinder, crank, and counter with a built-in table clamp
- 1-gallon can that can be filled with a measured mass of sand or water (if 10 kg of laboratory masses are not available)
- 3.7 m of flat nylon rope
- Laboratory manual including theory, step-by-step instructions, and data tables

Order Information

Mechanical Equivalent of Heat Apparatus..... TD-8551A

Required:

Basic Digital Multimeter..... SE-9786A p. 230
Ohaus Triple-Beam Balance (with Tare)..... SE-8707 p. 196

A refrigerator (or ice) for cooling the cylinder below room temperature; calipers and a thermometer for measuring room temperature are helpful, but not necessary.

Replacement Supplies:

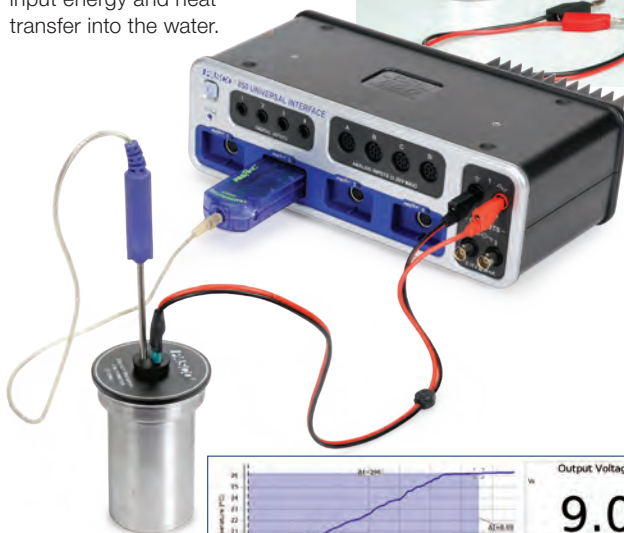
Replacement Brush..... TD-8583
Replacement Cylinder..... TD-8582

Energy Transfer - Calorimeter

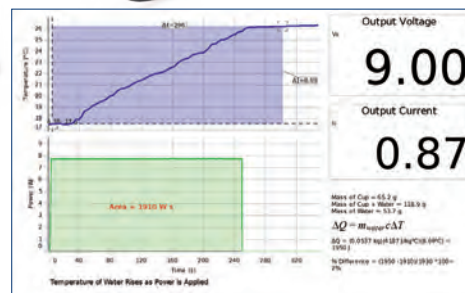
ET-8499

- ▶ Compare electrical energy input to changes in internal energy

The Energy Transfer - Calorimeter includes two nested aluminum cups with an air space in between for insulation. While most calorimeters use a coil to heat the water, PASCO's design features a 10 Ω heating resistor mounted to a circuit board. Using temperature, voltage, and current sensors, students can investigate the relationship between the input energy and heat transfer into the water.



The bottom graph displays the power output from the generator, and the top graph shows the increase in temperature. The amount of electrical energy used to heat the water is determined by finding the area under the Power vs. Time curve.



Includes:

- Outer Aluminum Cup (8.9 cm tall, 4.7 cm dia)
- Inner Aluminum Cup (7.5 cm tall, 3.8 cm dia)
- Plastic Lid
- Two-Hole Rubber Stopper
- Heating Resistor with Input Cables



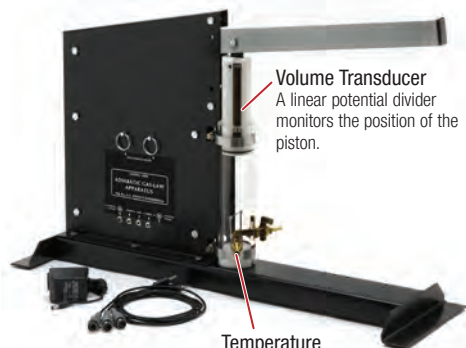
Order Information

Energy Transfer - Calorimeter ET-8499
Recommended for use with ScienceWorkshop:
Temperature Sensor CI-6605A
Voltage Sensor (unshrouded) UI-5100
Current Sensor CI-6556
Recommended for use with PASPORT:
PASPORT Temperature Sensor PS-2125
PASPORT Voltage/Current Sensor PS-2115

Adiabatic Gas Law Apparatus

TD-8565

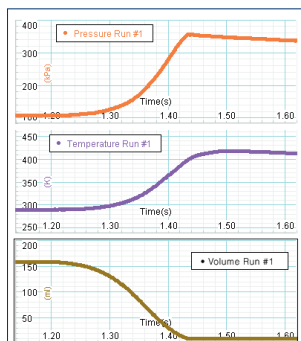
- ▶ Investigate the compression of gases
- ▶ Computer monitors temperature, pressure, and volume



Volume Transducer
A linear potential divider monitors the position of the piston.

Three Signal Cables
Carry the volume, pressure, and temperature signals to the computer.

Temperature Sensor
Measures rapid changes in temperature as the resistance of a fine nickel wire changes.



Students monitor pressure, temperature, and volume as a gas is compressed rapidly.

Adiabatic Gas Law Apparatus

Experiments

PASCO's Adiabatic Gas Law Apparatus can be used with our 850 Universal Interface. The computer functions as a 3-channel storage oscilloscope, generating graphs for pressure, temperature, and volume, as well as integrating the area under a Pressure vs. Volume curve to determine the work done on the gas.

Includes:

- Adiabatic Gas Law Apparatus
- Instruction Manual, Experiment Guide
- Signal Cables 3.5 mm plug to 5-pin DIN
- Power Adapter 9 V DC @ 1 A

Order Information

Adiabatic Gas Law Apparatus TD-8565

Required:
PASCO Capstone Software pp. 68-71
A computer with an interface that will accept three analog signals simultaneously via 5 or 8-pin DIN connectors such as PASCO's 550 and 850 Interfaces.

Compression Igniter

TD-8577

- ▶ Adiabatic compression ignites paper!
- ▶ Works every time
- ▶ Durable and cleanable

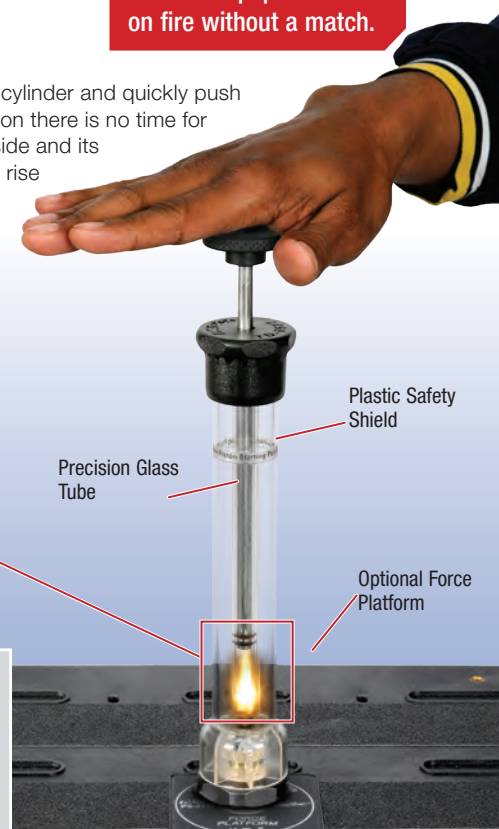
Put a small piece of tissue paper into the cylinder and quickly push down on the piston. In a quick compression there is no time for heat to be exchanged between the air inside and its surroundings, causing the temperature to rise well above the combustion temperature of paper.

Students will be amazed to see the paper catch on fire without a match.



Bottom

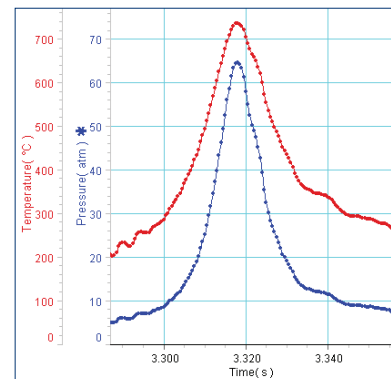
Easy Cleanout



Plastic Safety Shield

Precision Glass Tube

Optional Force Platform



Pressure data is calculated using the force measured by the Force Platform. Assuming Adiabatic, the data shown gives a compression ratio of nearly 20:1 and a peak temperature of over 700°C.

Includes:

- Compression Igniter
- Spare Glass Tube with O-rings
- Cleaning Wire
- Complete Instructions with Theory



Order Information

Compression Igniter TD-8577
Replacement Glass Tubes TD-8498A
Shown in use with:
PASPORT Force Platform PS-2141 p. 30

Gas Laws

Ideal Gas Law Apparatus

TD-8596A

- ▶ Experimentally determine the Ideal Gas Law
- ▶ Large syringe for accurate volume measurements
- ▶ Built-in fast response thermistor

Investigating the Ideal Gas Law is simple using PASCO's Ideal Gas Law Apparatus. By connecting a Pressure Sensor and a Temperature Sensor to the syringe, students can quantitatively look at the relationships between pressure, temperature, and volume.

Measure temperature and pressure.

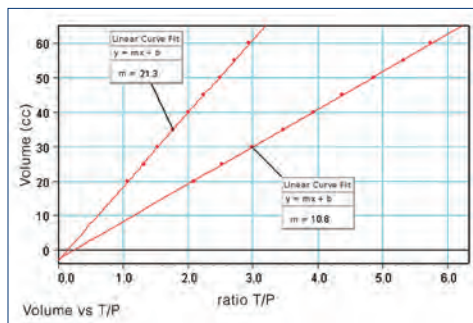


How It Works:

A low thermal mass thermistor is mounted within the syringe for real-time measurement of temperature changes inside the syringe. Tubing and a quick-connect port allow a Pressure Sensor to be directly connected to the syringe. As the plunger of the syringe is depressed, the volume decreases while pressure and temperature increase. The data will help students better understand the Ideal Gas Law.

$$PV = nRT$$

A mechanical stop is included on the syringe plunger to prevent damaging of the thermistor within the syringe and to allow quick (adiabatic) volume changes.



Slope of the Volume vs. $\frac{T}{P}$ graph equals nR .



Includes:

- Ideal Gas Law Syringe
- Built-in Fast Response Thermistor
- Quick-Connect Pressure Port
- Male Luer connectors to attach Wireless Pressure Sensor

Order Information

Ideal Gas Law Apparatus	TD-8596A	
Shown in use with:		
PASPORT Absolute Pressure/ Temperature Sensor	PS-2146	p. 32
AirLink Interface	PS-3200	p. 12
PASCO Capstone Software	pp. 68-71	

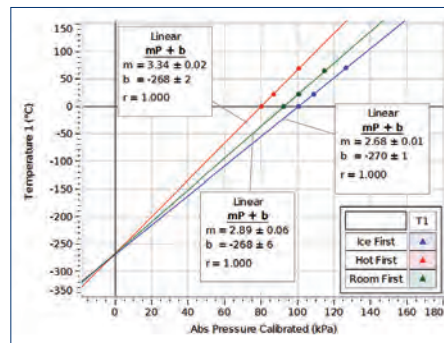
Absolute Zero Sphere

TD-8595

- ▶ Constant volume sphere
- ▶ Measure pressure and temperature directly using PASCO sensors
- ▶ Empirically determine the absolute zero temperature

The Absolute Zero Sphere is an effective tool for determining absolute zero temperature. Students connect Pressure and Temperature Sensors before immersing the sphere in water baths of varying temperatures. As the pressure and temperature change, a live graph is generated in PASCO Capstone™. Once the data is collected, students can use a linear fit to extrapolate the value of absolute zero.

Absolute Zero Apparatus being used with PASPORT Absolute Pressure Sensor



Temperature and pressure data is taken for three temperature water baths. The experiment is repeated with a different amount of gas initially in the sphere. The slopes of the two graphs reflect the change in the number of moles of gas, and both graphs extrapolate to about the same value for absolute zero.

Includes:

- Absolute Zero Sphere
- Built-in Fast Response
- Thermistor Probe
- Quick Connect Pressure Port
- Male Luer connector to attach wireless pressure sensor



Order Information

Absolute Zero Sphere.....	TD-8595	
Shown in use with:		
PASPORT Absolute Pressure/ Temperature Sensor	PS-2146	p. 32
AirLink Interface	PS-3200	p. 12
PASCO Capstone Software	pp. 68-71	

Heat Engine and Gas Law Apparatus

TD-8572A

- ▶ Measure the actual efficiency of a real heat engine.
- ▶ Bring P-V diagrams to life.
- ▶ Low-friction graphite piston in glass cylinder
- ▶ See the complete experiment (EX-5530B) on page 358.

The Heat Engine and Gas Law Apparatus enables students to perform quantitative Ideal Gas Law experiments, while exploring a functional heat engine. A Rotary Motion Sensor and Pressure Sensor can be added to graph heat engine cycles, determine actual efficiency, and more!

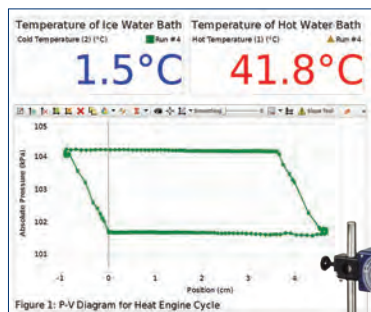
How It Works:

When the air chamber is moved from the cold water bath to the hot bath, the piston rises, lifting the 200 g mass to demonstrate work. The mass is removed, and the air chamber is returned to the cold bath, closing the isobaric/isothermal cycle.

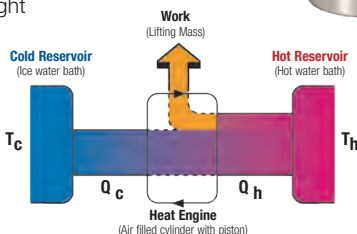
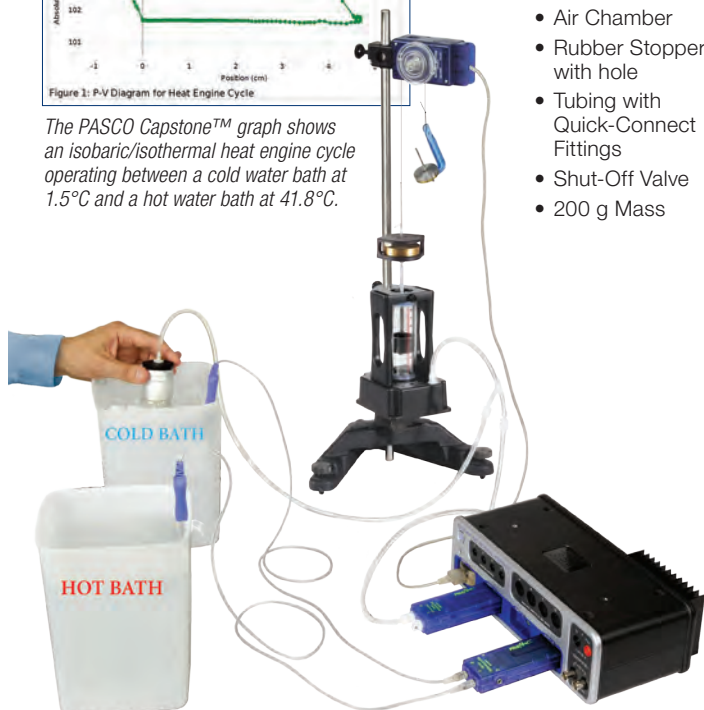
The heat engine cycle is plotted in real time using a Pressure vs. Volume graph.

Pressure in the cylinder is measured by a pressure sensor. Volume is measured by tracking the piston's position with a rotary motion or motion sensor. Temperatures of the hot and cold baths are recorded using temperature sensors.

Students compare the area inside the P-V cycle to the actual work done while lifting the weight to determine how the efficiency of their heat engine compares to the theoretical maximum.



The PASCO Capstone™ graph shows an isobaric/isothermal heat engine cycle operating between a cold water bath at 1.5°C and a hot water bath at 41.8°C.



Includes:

- Heat Engine
- Air Chamber
- Rubber Stopper with hole
- Tubing with Quick-Connect Fittings
- Shut-Off Valve
- 200 g Mass

Specifications:

Piston diameter: 32.5 mm

Maximum piston displacement: ≈10 cm

Order Information

Heat Engine and Gas Law Apparatus.....	TD-8572A	
Shown in use with:		
850 Universal Interface	UI-5000	p. 14
PASPORT Quad Temperature Sensor	PS-2143	p. 33
PASPORT Dual Pressure Sensor	PS-2181	p. 32
PASPORT Rotary Motion Sensor	PS-2120A	p. 28
3-Liter Plastic Tub (2-Pack).....	ME-7559	p. 195
Small "A" Base	ME-8976	p. 195
Stainless Steel Rod, 60 cm Threaded	ME-8977	p. 186

Heat Engine Accessory Included in TD-8572A

TD-8581A

This replacement kit includes a set of parts for the Heat Engine (suitable for both versions TD-8572 and TD-8572A) that are most likely to need replacement after extensive use. These parts connect the air chamber and the Pressure Sensor to the Heat Engine.

Includes:

- Air Chamber
- Rubber Stopper #10 with hole
- Male Luer Lock Barbs (2)
- Female Luer Lock Barbs (2)
- Tube Connector 3/16 x 1/8"
- Plastic Tee for 1/8" Tubing
- One-way Stopcock
- Female In-line 1/8" CPLG (2)
- Polyurethane Tubing 1/8" ID 80 cm

Order Information

Heat Engine Accessory.....	TD-8581A
----------------------------	----------

Heat Engine

Glass Stirling Engine

SE-8636A



This functional Stirling Engine provides a close-up look at the Stirling Cycle Principle with its active pistons and glass cylinders. This highly engaging apparatus connects to a generator which lights LEDs and includes a burner for denatured alcohol, as well as a platform for solid fuel.

**Features:**

- ▶ Completely assembled and ready to run
- ▶ Solid hardwood platform
- ▶ Replaceable Pyrex® power cylinder
- ▶ Replaceable, adjustable Pyrex® heat cap
- ▶ Generator with LEDs
- ▶ Clear cylinders for viewing pistons

Specifications:

Dimensions: 18 cm length x 9 cm width x 8 cm height

Order Information

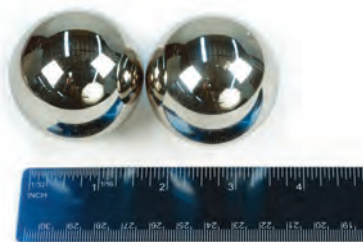
Glass Stirling EngineSE-8636A

Colliding Spheres

SE-7303

- ▶ Demonstrates transformation of kinetic energy into heat
- ▶ Colliding spheres leave burn mark on paper

Hit these two steel balls together with a piece of paper in between. The kinetic energy is converted to heat and leaves a burn mark on the paper.

**Specifications:**

Diameter: 2 in (5 cm)

Order Information

Colliding SpheresSE-7303

Thermoelectric Converter

TD-8550A

- ▶ Demonstrate the First Law of Thermodynamics
- ▶ Reversible

Features:

- ▶ Demonstrates that a temperature differential is essential for extracting usable energy
- ▶ Produces electrical energy from a temperature differential
- ▶ Produces a temperature differential with electrical energy
- ▶ 15 cm tall with 6 cm diameter fan

**How It Works:**

The Thermoelectric Converter uses a series of semiconductor thermoelectric cells to convert thermal energy into electrical energy. The output from the cells drives a small electric motor.

Heat to Electrical Energy

Place one leg of the Thermoelectric Converter into cold water, the other into hot. The fan turns as the converter draws energy from the hot source (typically a 50°C temperature differential is required).

Electrical Energy to Heat

Pass a current (3 A DC at 5 V) through the Thermoelectric Converter. It acts as a heat pump. One leg becomes warmer while the other becomes cooler.



When a temperature differential is established between the two legs, the fan turns.

Order Information

Thermoelectric Converter TD-8550A

Required:

Containers for holding hot water, cold water, etc.

Triple Output Power Supply SE-8587

Partial Immersion Thermometer SE-9084B

p. 252

PASPORT Non-Contact Temperature Sensor

PS-2197

- ▶ Non-contact
- ▶ -70°C to 380°C



The Non-Contact Temperature Sensor measures surface temperature by detecting the emitted infrared light. Record the temperature of objects without touching them!

Applications:

- ▶ Compare temperature of hands, skin, face, and clothes
- ▶ Measure the temperature of different outdoor ground surfaces
- ▶ Map the temperature profile of an exterior wall

Specifications:

Range: -70°C to 380°C

Accuracy: ±0.5°C

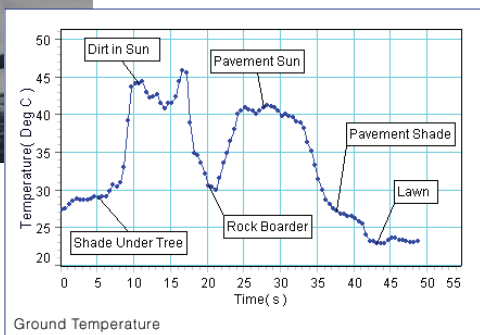
Response Time: Less than 0.1 s

Maximum Sample Rate: 200 Hz

Field of View: ±35°



The student measures the late-morning ground temperature over four distinct surfaces. Starting in the shade under the distant tree, she then crosses bare dirt (in sun), a rock border, pavement, and lawn.



PASPORT Temperature Type K Sensor

PS-2134

- ▶ Extra-long probe

The PS-2134 is a single channel sensor that uses the same Type K thermocouple probe as the PS-2127 shown on this page. Includes one Type K Thermocouple.



Applications:

- ▶ Measure temperatures down to -200°C
- ▶ Measure temperatures in hard-to-reach places
- ▶ Use in high temperature applications where the narrow tip of the probe can be applied without burning the insulation cover (such as a candle flame)

Specifications:

Temperature Range: -200°C to +1000°C

Maximum Sample Rate: 10 Hz

Accuracy: ±3°C or 3%, whichever is greater



The Type K Temperature Sensor can be used to measure the temperature of a flame. Works with any industry standard Type K thermocouple.

Order Information

PASPORT Temperature Type K Sensor	PS-2134
Recommended:	
Type K Thermocouple	PS-2155

Partial Immersion Thermometer

SE-9084B

Features 1°C accuracy or better. Filled with environmentally safe non-toxic, non-hazardous, biodegradable Enviro-Safe liquid. Measure from -20° to 110°C with this 30 cm long thermometer. It is clearly marked at 1 degree intervals, and a ring on top allows students to suspend it from a string.



-20° to 110°C Range

Order Information

Partial Immersion Thermometer	SE-9084B
-------------------------------------	----------

Order Information

PASPORT Non-Contact Temperature Sensor	PS-2197
Shown in use with:	
PASCO Capstone Software	pp. 72-75

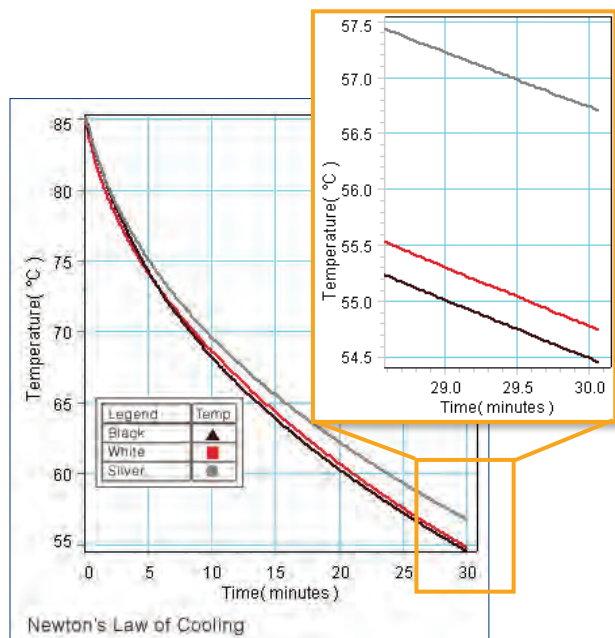
Radiation

Radiation Cans

TD-8570A



These three aluminum cans have different surface finishes: silver (unpainted), white, and flat black. They are 15 cm high and hold about 350 ml of water. Their large thermal mass ensures good results with both temperature probes and standard glass thermometers. Fill them with cool water and place them outside in the sunlight to investigate the effect of the surface finish on solar heating. Or place them inside filled with hot water to discover Newton's Law of Cooling.



The black, white, and silver Radiation Cans are filled with hot water and allowed to cool. Graphs made in PASCO Capstone.

Order Information

Radiation Cans..... TD-8570A
 Required to measure temperature:
 Wireless Temperature Sensor..... PS-3201
 OR
 Partial Immersion Thermometer SE-9084B p. 209

Thermal Radiation Cube (Leslie's Cube)

TD-8554A

► Low-temperature radiation source

Features:

- **Electrically Heated:** The 100-watt bulb inside eliminates the danger of an open flame and the inconvenience of water-heated cubes. Temperature is conveniently controlled with the power control knob.
- **Thick Aluminum Walls**
- **Thermistor:** A 100 k Ω thermistor embedded in one wall of the cube provides accurate temperature measurement with no thermometer to break.



Order Information

Thermal Radiation Cube (Leslie's Cube) TD-8554A
 Required:
 Radiation Sensor..... TD-8553
 Basic Digital Multimeter SE-9786A p. 230

Radiation Sensor

TD-8553

- Radiation detector
- Thermopile

Point the Radiation Sensor toward any object – open the shutter and read the digital voltmeter to measure the relative intensity of the thermal radiation emitted.



Flat Spectral Response:

0.6 to 30 μm

Order Information

Radiation Sensor..... TD-8553
 Required:
 Basic Digital Multimeter SE-9786A p. 230

Stefan-Boltzmann Lamp

TD-8555

- High-temperature radiation source

The temperature of this 12 V incandescent lamp filament can be accurately determined by measuring the voltage and current that students supply to the lamp (a graph of Temperature vs. Resistivity is provided).



Order Information

Stefan-Boltzmann Lamp TD-8555
 Required:
 12 V DC Power Supply – see page 251

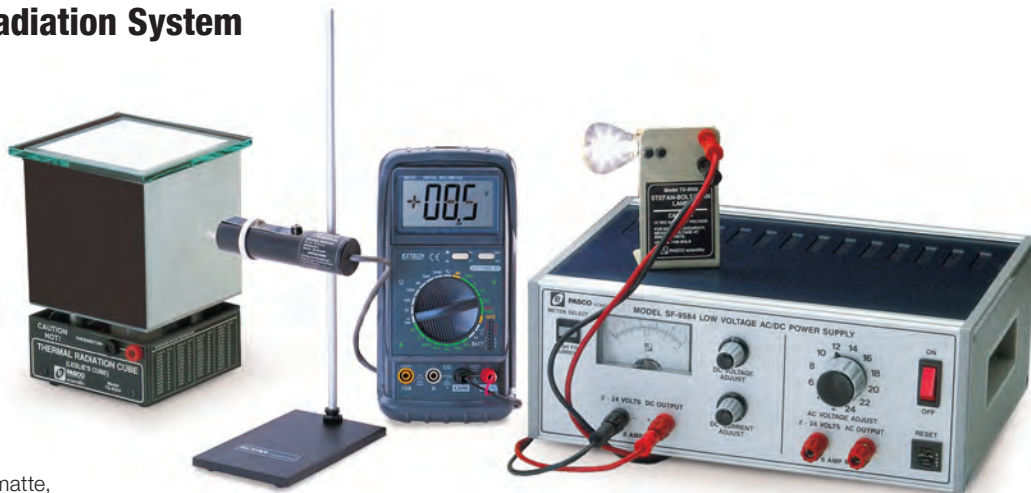
Complete Thermal Radiation System

TD-8855

With the Radiation Sensor, a versatile Radiation Cube, and the Stefan-Boltzmann Lamp, four key experiments in thermal radiation can be performed.

Students begin with a study of thermal radiation from different types of surfaces at the same temperature.

The Thermal Radiation Cube has four different surfaces that can be monitored (black matte, white matte, polished aluminum, and dull aluminum). The cube is heated electrically with a 100-watt bulb (its output can be varied). The thick aluminum walls assure the same temperature on all four walls to within a fraction of a degree. The Radiation Sensor provides an accurate measure of thermal radiation throughout the infrared region. Its output is a voltage that is proportional to the intensity of radiation.



Another important introductory experiment is the Inverse Square Law. The Stefan-Boltzmann Lamp uses a special bulb to provide a near-perfect point source, providing accurate results.

Finally, students can verify the Stefan-Boltzmann Law for both low and high temperatures by using the Radiation Cube for the low temperatures and the Stefan-Boltzmann Lamp for the high temperatures.



Includes:

- Thermal Radiation Cube
- Stefan-Boltzmann Lamp
- Radiation Sensor

See opposite page for component details.



Typical Experiments

With Teacher's Guide and Sample Data

- ▶ Introduction to Thermal Radiation
- ▶ Stefan-Boltzmann Law at Low Temperatures ($R_{\text{rad}} = \sigma T^4$)
- ▶ Inverse Square Law
- ▶ Stefan-Boltzmann Law at High Temperatures



To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Crooke's Radiometer

SE-7283

- ▶ Demonstrates that black surfaces are better radiators

This product consists of a set of vanes, each with one shiny side and one black side, mounted on a spindle in a partially evacuated glass bulb. When exposed to the sun or other intense light, the vanes begin to rotate with the black side trailing. The black side heats the air next to it more than the shiny side, so the air pushes harder on the black side.



Specifications:

Dimensions: Diameter 8 cm; height 13 cm

Order Information

Crooke's RadiometerSE-7283

Order Information

Complete Thermal Radiation System.....	TD-8855	
Required:		
Basic Digital Multimeter.....	SE-9786A	p. 230
Low Voltage AC/DC Power Supply.....	SF-9584B	p. 254
Shown in use with:		
2 Meter Patch Cord Set.....	SE-9415A	p. 228

Van de Graaff Generator

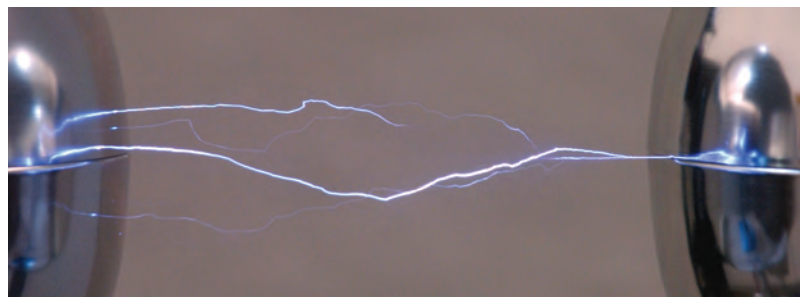
Van de Graaff Generator, High Voltage

SE-8691

- ▶ Large sphere creates higher voltage
- ▶ Sparks up to 35 cm in length
- ▶ Large size ideal for demonstrations

The High Voltage Van de Graaff Generator features a 25 cm diameter sphere that can generate approximately 400,000 volts. The size of the sphere, its rounded edges, and its height from the demonstration table contribute to the high voltages generated.

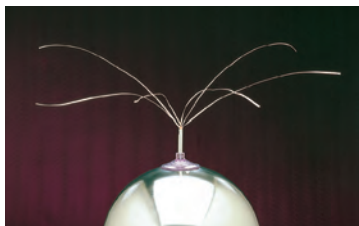
Its large size, long sparks, and high voltages make it ideal for use in larger rooms or lecture halls. An extra belt is included.



Electrostatic Plume

SE-7232

The lightweight ribbons are connected to a stand that rests on top of the Van de Graaff Generator. As the generator operates, the ribbons stand on end, due to the repulsive force between their like charges.

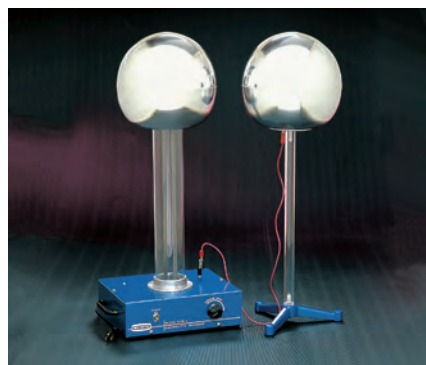


Order Information

Electrostatic Plume SE-7232

Discharge Sphere

SE-7231



This 25 cm sphere is supported on a Lucite column with a cast iron base. Includes cabling for connection to the Van de Graaff Generator or to a ground.

Order Information

Discharge Sphere SE-7231

Electrostatic Whirl

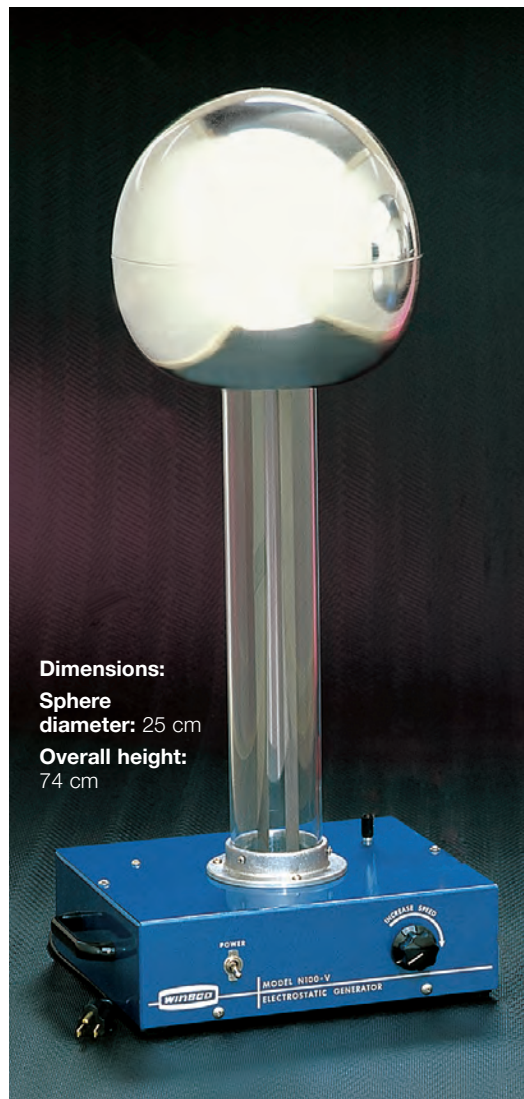
SE-7233



When held near the sphere of the generator, the spokes are propelled by charge leaving the points.

Order Information

Electrostatic Whirl SE-7233



Dimensions:

Sphere diameter: 25 cm
Overall height: 74 cm

Order Information

Van de Graaff Generator,
High Voltage SE-8691
Replacement Supplies:
Replacement Belt SE-7355

Replacement Belt, Van de Graaff Generator

SE-7355



Order Information

Replacement Belt,
Van de Graaff Generator SE-7355

Classic Electrostatics Materials Kit

SF-9068

Providing the classic introduction to electrostatics, this kit allows students to rub any of the three rods with rubbing cloths to produce a positive or negative charge. Place the rods on the insulated pivot stands to investigate electrostatic forces.



Includes:

- Three rods (acrylic, glass, PVC)
- Two insulated pivot stands
- Three rubbing cloths (wool, silk, fur)

Order Information

Classic Electrostatics Materials Kit.....SF-9068

Electroscope

SE-7247

Show the amount of charge and the sign of the charge relative to a standard. Includes charging ball plus a set of condenser plates with insulated rod.

Ring diameter: 150 mm



Order Information

Electroscope.....SE-7247

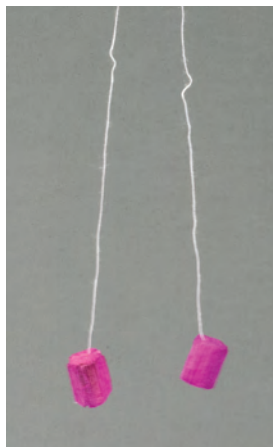
Coated Pith Balls (Set of 10)

SE-7719

These threaded pith balls are coated with a conductive material. Suspend two pith balls from a rod and charge with the Electrostatic Materials SE-6658.

Includes:

- Threaded Coated Pith Balls (10)



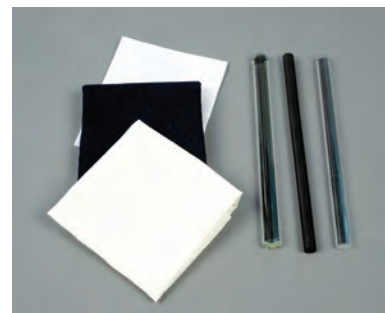
Order Information

Coated Pith Balls (Set of 10).....SE-7719

Electrostatics Materials

SE-6658

This electrostatics kit provides the necessary tools to separate positive and negative charges. Students can experiment with different combinations of cloth and rod materials to explore how each becomes charged.



Includes:

- 3 fabric cloths (wool, cotton, silk)
- 3 rods (glass, ebonite, acrylic)

Order Information

Electrostatics Materials.....SE-6658

Dissectible Leyden Jar

SE-7718

► Acts as a capacitor

This Leyden Jar is designed for classroom demonstrations and comes with a durable inner and outer plate, a plastic dielectric, and instructions. The inner plate has a hook and ball attached, which makes it easy to charge with a Van de Graaff Generator or a charged rod.

Leyden Jar is 3" in diameter and 8" tall.



Order Information

Dissectible Leyden Jar.....SE-7718

Coulomb's Law Apparatus

ES-9070

See page 313.



Electrostatics Systems

Basic Electrostatics System

ES-9080B

- ▶ Quantitative electrostatics
- ▶ Comprehensive experiment manual included
- ▶ Individual or demonstration use

The PASCO Basic Electrostatics System includes all the components necessary for a quantitative investigation into the basics of electrostatics.

Topics Covered:

- ▶ Production of charges, equal and opposite
- ▶ Charge by induction
- ▶ Principle of the Faraday Ice Pail
- ▶ Charge transfer
- ▶ Charge distribution in electric fields
- ▶ Capacitors and the $Q=CV$ relationship
- ▶ Moving charges and current



Includes:

- Basic Electrometer: ES-9078A
- Charge Producers and Proof Plane: ES-9057C
- Faraday Ice Pail: ES-9042A
- Conductive Spheres: ES-9059C
- Conductive Shapes: ES-9061
- Basic Variable Capacitor: ES-9079
- Electrostatics Voltage Source: ES-9077
- Experiment Manual

Order Information

Basic Electrostatics System ES-9080B

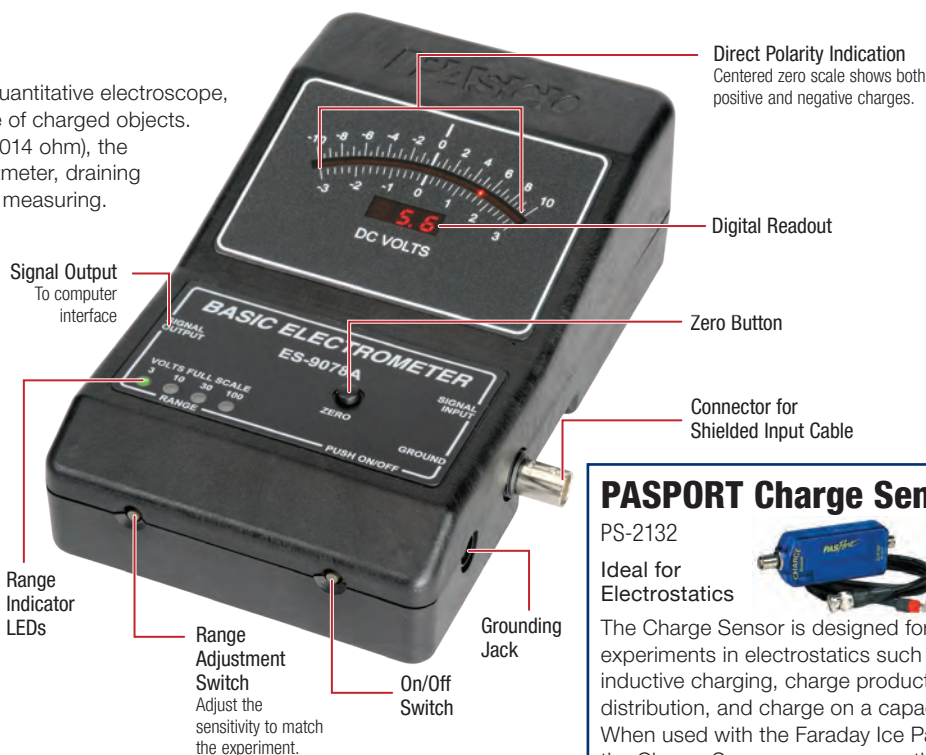
Basic Electrometer

ES-9078A

The PASCO Basic Electrometer is a quantitative electroscopes, measuring the polarity and magnitude of charged objects. With almost infinite input resistance (10^{14} ohm), the Electrometer is a high-impedance voltmeter, draining almost no charge from the object it is measuring.

Features:

- ▶ **Center-Zero Meter:** Polarity is indicated directly.
- ▶ **Switch-Selectable Ranges:** 3, 10, 30 and 100 VDC. LED lights indicate the range in use.
- ▶ **Zeroing Switch:** Removes all charge from the input and brings the meter to zero.
- ▶ **Automatic Shutoff:** Turns off about 3 hours after turned on (or used in any way).
- ▶ **Output Compatible with PASCO Interfaces:** The interface cable included with the electrometer connects directly to an analog channel on a ScienceWorkshop interface, and connects to a PASPORT interface through an Analog Adapter. This enables the output signal from the electrometer to be recorded, displayed, and analyzed by the data acquisition software.
- ▶ **Battery Operation:** 4 "AA" cells included. Range indicator lights flash when batteries need to be replaced.



Includes:

- Shielded input cable to connect the Electrometer to the Faraday Ice Pail or other source of charge
- Grounding cable with clip
- Interface cable
- Instruction and experiment manual

Order Information

Basic Electrometer ES-9078A

PASPORT Charge Sensor

PS-2132

Ideal for Electrostatics



The Charge Sensor is designed for experiments in electrostatics such as inductive charging, charge production/distribution, and charge on a capacitor. When used with the Faraday Ice Pail, the Charge Sensor can measure the total charge on an object by the induction method.

The Charge Sensor can also be used as a high impedance voltmeter (10^{12} Ω). It includes a 0.9 m shielded cable with alligator clips to eliminate stray fields.

Order Information

PASPORT Charge Sensor PS-2132

Electrostatics Voltage Source

ES-9077



This compact unit is ideal for performing experiments in electrostatics. It may be used as a source of charge or to maintain an object at a constant potential.

Output voltages are 1000, 2000, and 3000 VDC for charging spheres, capacitor plates, etc. A 30 VDC source is also provided for experiments with capacitors.

Specifications:

Output: 30, 1000, 2000, 3000 VDC
±3%, line regulated

Resistance in Series with Output:
120 MΩ/kV

Operating Voltage: 115/220, 50/60 Hz

AC Adapter: 9 VDC

Order Information

Electrostatics
Voltage Source..... ES-9077

Basic Variable Capacitor

ES-9079



Two 18 cm diameter plates allow the capacitance to be varied from 225 pF to zero by sliding the movable plate in its 28 cm long track. The sliding plate has adjustment screws to make the plates parallel to each other. Electrical connection studs are located on each plate.

A BNC connector cable is provided for connection to an Electrometer.

Order Information

Basic Variable
Capacitor..... ES-9079

Conductive Spheres

ES-9059C

30 cm
high

These Conductive Spheres (two per set) can be used to store charge or to investigate the charge distribution on one or two spherical conductors. A terminal on one or two spherical conductors. A terminal on the bottom of each sphere provides a connection point for the power supply. Each sphere is attached to a heavy base (for stability) with an insulating rod. The spheres are 13 cm in diameter and 30 cm high.

Order Information

Conductive Spheres..... ES-9059C

Charge Producers and Proof Plane

ES-9057C



The Charge Producers create equal positive and negative charges when rubbed together. The Proof Plane samples the charge density from a charged object. The charge can then be measured using the Electrometer and Faraday Ice Pail.



Use the ball end to sample inside the hollow sphere.

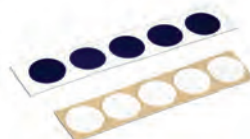
Order Information

Charge Producers and
Proof Plane..... ES-9057C

Replacement Pad Set

ES-9056

(for ES-9057C)



Includes:

- Artificial leather pads (5)
- Blue vinyl pads (5)

Order Information

Replacement Pad Set..... ES-9056

Conductive Shapes

ES-9061

30 cm
high

This set includes a conductive sphere with a hole in it. Demonstrate that static charge resides outside the surface of a conductive sphere by sampling the inside surface with the ball end of the proof plane. Also included is an oblong shape for demonstrating the difference in charge densities on a large-radius surface vs. a small-radius surface. The whole surface is at the same potential, and students seem surprised to find that the charge density is greater on the smaller end.

Order Information

Conductive Shapes..... ES-9061

Faraday Ice Pail

ES-9042A



With the Faraday Ice Pail, students can use the Electrometer to measure charge as well as potential.

Touch the Proof Plane to the point of interest on the charged body, then place the Proof Plane inside the Ice Pail. The Electrometer reading will be directly proportional to the charge on the Proof Plane.

The Faraday Ice Pail is 10 cm in diameter and 15 cm deep. It is made of wire mesh, so it is easy to see what is going on inside. The outside shield has a diameter of 15 cm.

Order Information

Faraday Ice Pail..... ES-9042A

Electric Field Mapping

Charge, Equipotential and Field Mapper

ES-9060



The Charge, Equipotential, and Field Mapper is an excellent addition to the Basic Electrostatics System.

Draw any set of two-dimensional conductors with the conductive ink. Investigate the electric field and the equipotential field lines between and around the conductive paper. Charge it and investigate the distribution of charge on its surface.

Similar to the Field Mapper Kit, except it includes electrometer probes, a "point charge" holder, and larger sheets of conductive paper for investigating charge distributions on conductive surfaces.

Includes:

- Conductive paper for mapping charge distributions: 30 x 45 cm (50 sheets)
- Conductive paper with cm grid for mapping equipotentials and field gradients: 23 x 30 cm (100 sheets)
- Pushpins, connecting wire and electrometer probes
- Conductive ink pen and a circular template for drawing conductors
- "Point charge" holder
- Plastic tray with corkboard top: 32 x 48 cm
- Manual with 13 experiments

Order Information

Charge, Equipotential and Field Mapper.....ES-9060

Replacement Supplies:

Special Conductive Ink PenPK-9031B
(limited shelf life of six months; not refillable)

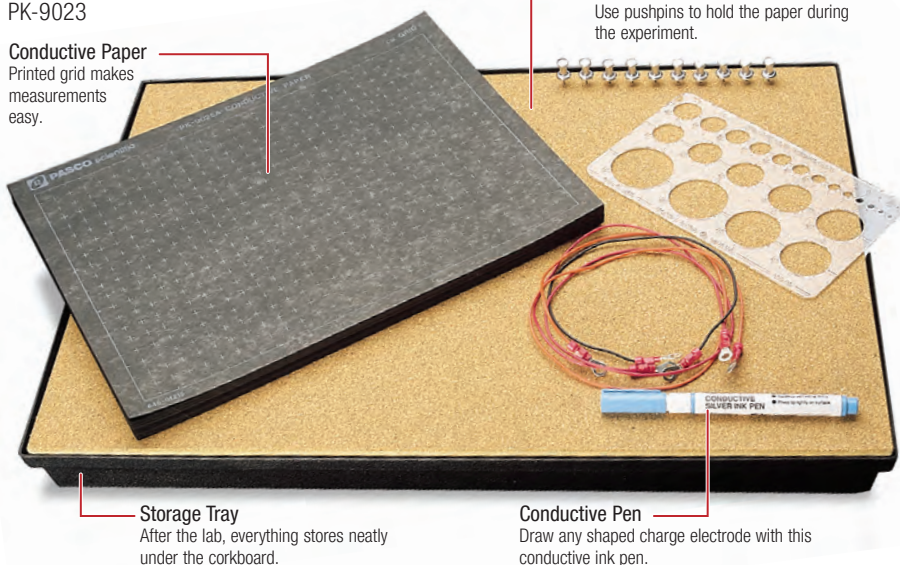
Conductive Paper with Grid.....PK-9025B

Conductive Paper (no Grid).....PK-9026

Field Mapper Kit

PK-9023

Conductive Paper
Printed grid makes measurements easy.



Cork Surface
Use pushpins to hold the paper during the experiment.

Storage Tray
After the lab, everything stores neatly under the corkboard.

Conductive Pen
Draw any shaped charge electrode with this conductive ink pen.

Start by investigating standard electrostatic configurations, such as point sources, dipoles, and capacitors. Then go further. You might, for example, investigate whether a person is safe in a car, under a tree, or on top of a flag pole in a thunder storm. Or you might create an electrostatic model of fluid flow to show that water flows fastest in the narrowest portion of a hose.

How It Works

With this kit students can map both the potentials and the electric fields around any conceivable system of two-dimensional charged conductors.

The procedure is simple:

1. Draw any electrode
2. Plot the equipotentials
3. Plot the electric field

Features:

- ▶ Complete kit
- ▶ Complete manual
- ▶ Measure electric fields directly
- ▶ Measure potentials directly
- ▶ No mess
- ▶ Inexpensive
- ▶ Easy storage

Special Conductive Ink Pen

PK-9031B

The PASCO Conductive Silver Ink Pen makes it easy to study field patterns. Draw over 60 meters of patterns with a single pen. Pen shelf life is six months. Not refillable.

Order Information

Special Conductive Ink Pen PK-9031B



Typical Experiments

- ▶ Dipoles of Like Charges
- ▶ Dipoles of Opposite Charges
- ▶ Parallel Plate Capacitor
- ▶ Point Source and Guard Ring (cylindrical capacitor)
- ▶ Floating Electrode



To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Includes:

- Conductive paper with cm grid: 23 x 30 cm (50 sheets)
- Pushpins (10) and Wires (3)
- Conductive Ink Pen and circular template
- Plastic tray with corkboard top: 32 x 48 cm
- Instruction manual with 10 experiments

Order Information

Field Mapper Kit.....PK-9023

Required:

Basic Digital Multimeter.....SE-9786A p. 230
(or any voltmeter with at least a 10 M Ω input impedance)

Triple Output Power Supply.....SE-8587 p. 252
(or another low voltage DC power supply or battery)

Replacement Supplies:

Special Conductive Ink Pen PK-9031B
(limited shelf life of six months; not refillable)

Conductive Paper with Grid.....PK-9025B

Conductive Paper (no Grid).....PK-9026

Resistivity Apparatus

EM-8812

- ▶ Slide-wire potentiometer
- ▶ Measure resistance and resistivity
- ▶ Four wire diameters, five wire materials

A current is established in a wire of known diameter, and the voltage drop across a section of the wire is measured. Students can calculate the resistance of the wire and the resistivity of the material.

$$R = \frac{\rho L}{A}$$

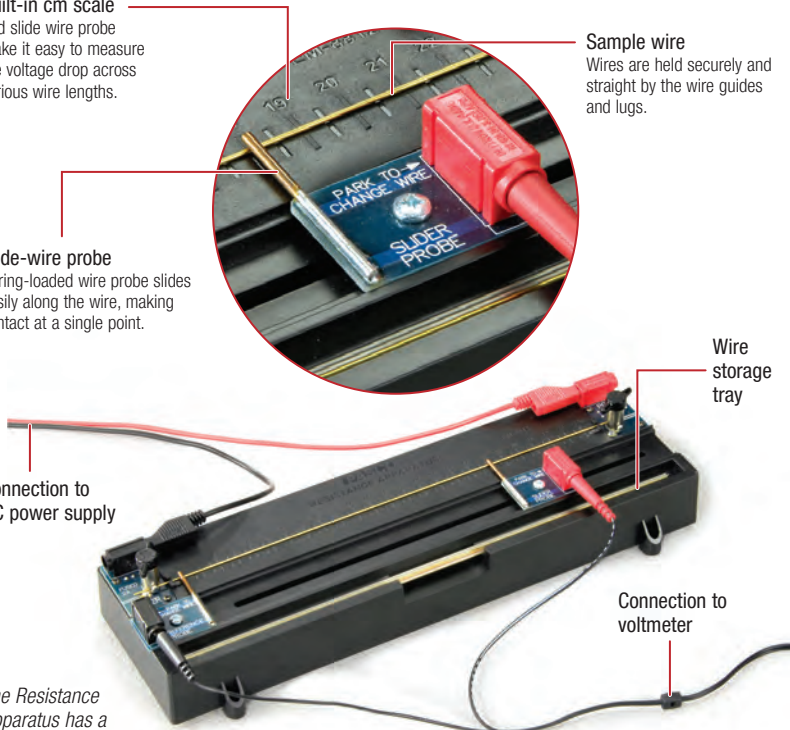
Features:

- ▶ **Vary wire length:** Slide-wire potentiometer pick-up makes it easy. Use the built-in scale to measure the length of the wire.
- ▶ **Vary wire diameter:** Four different diameters of brass wire are included. Investigate the difference between resistance and resistivity. Interchange wires quickly and easily.
- ▶ **Vary wire material:** Five different material wires are included. Investigate how resistivity depends on the wire material.
- ▶ **Storage:** Built-in storage tray to hold wires.
- ▶ **Sample Wire:** Wires are held securely and straight by the wire guides and lugs.
- ▶ **Slide Wire Probe:** Spring-loaded wire probe slides easily along the wire, making contact at a single point.
- ▶ **Built-in cm Scale** and slide wire probe make it easy to measure the voltage drop across various wire lengths.

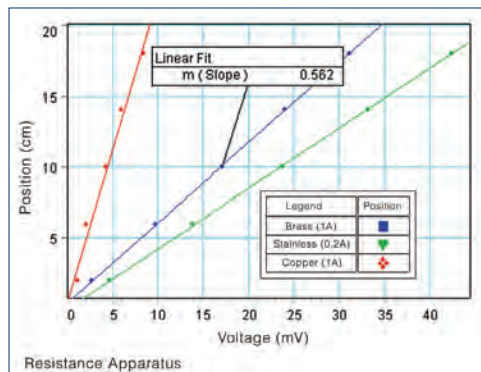
Built-in cm scale and slide wire probe make it easy to measure the voltage drop across various wire lengths.

Sample wire Wires are held securely and straight by the wire guides and lugs.

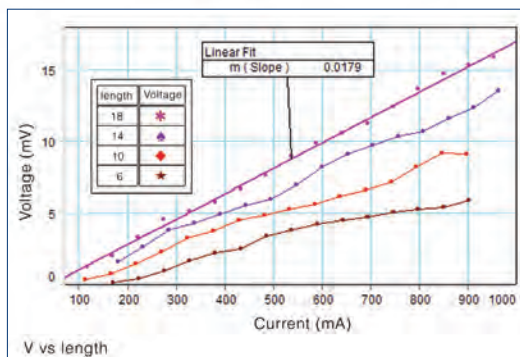
Slide-wire probe Spring-loaded wire probe slides easily along the wire, making contact at a single point.



The Resistance Apparatus has a slide-wire probe to easily change the measured length of the wire and utilizes a four wire hook-up to accurately measure the voltage drop. It comes with four different brass wire diameters and four other wire materials.



Graph shows voltage drop across various lengths for three different material wires. The slope of the line (along with wire diameter and current) is used to calculate the resistivity of the material.



For this experiment, the 850 Universal Interface produces a 10 sec voltage ramp to apply a varying current through a brass wire. A graph of Voltage Drop vs. Current is created, and the slope of this line is the resistance of that length of wire.

Includes:

- 30 cm long wires (2 of each):
 - Copper (1.0 mm diameter)
 - Aluminum (1.0 mm diameter)
 - Stainless Steel (1.0 mm diameter)
 - Nichrome (1.0 mm diameter)
 - Brass (0.5 mm, 0.8 mm, 1.0 mm, 1.3 mm diameter)



Order Information

Resistivity Apparatus.....	EM-8812	
Shown in use with:		
850 Universal Interface.....	UI-5000	p. 14
Voltage Sensor (unshrouded)	UI-5100	p. 23
2 Meter Patch Cord Set.....	SE-9415A	p. 228
Recommended:		
PASPORT Galvanometer.....	PS-2160	p. 37
Replacement Wires, Resistivity Apparatus	EM-8813	

Circuits

PASCO Modular Circuits

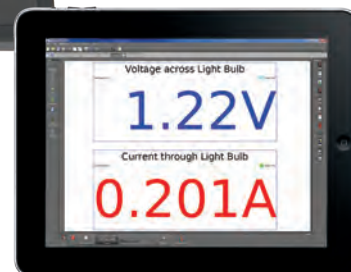
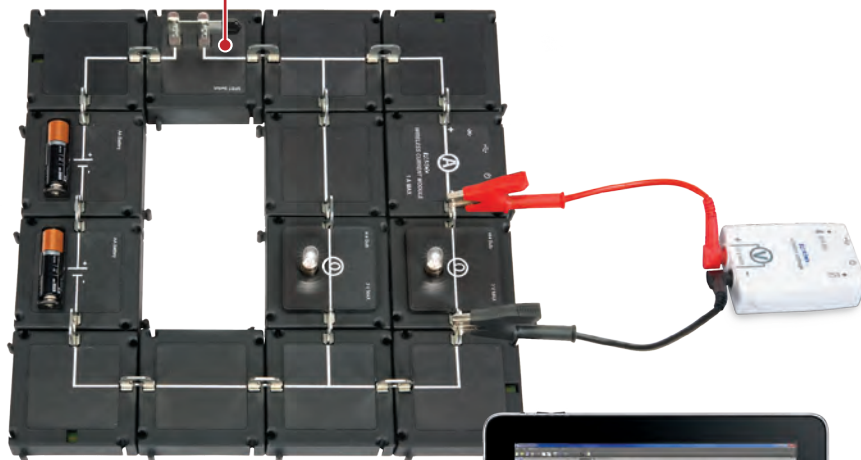
- ▶ Puts learning first
- ▶ Eliminates confusing wires
- ▶ Easy-to-connect modules

These circuit modules are designed specifically for introductory circuits classes. For students who have never wired a circuit, this modular system makes it easy for them to see the layout because it ends up looking like a circuit diagram.

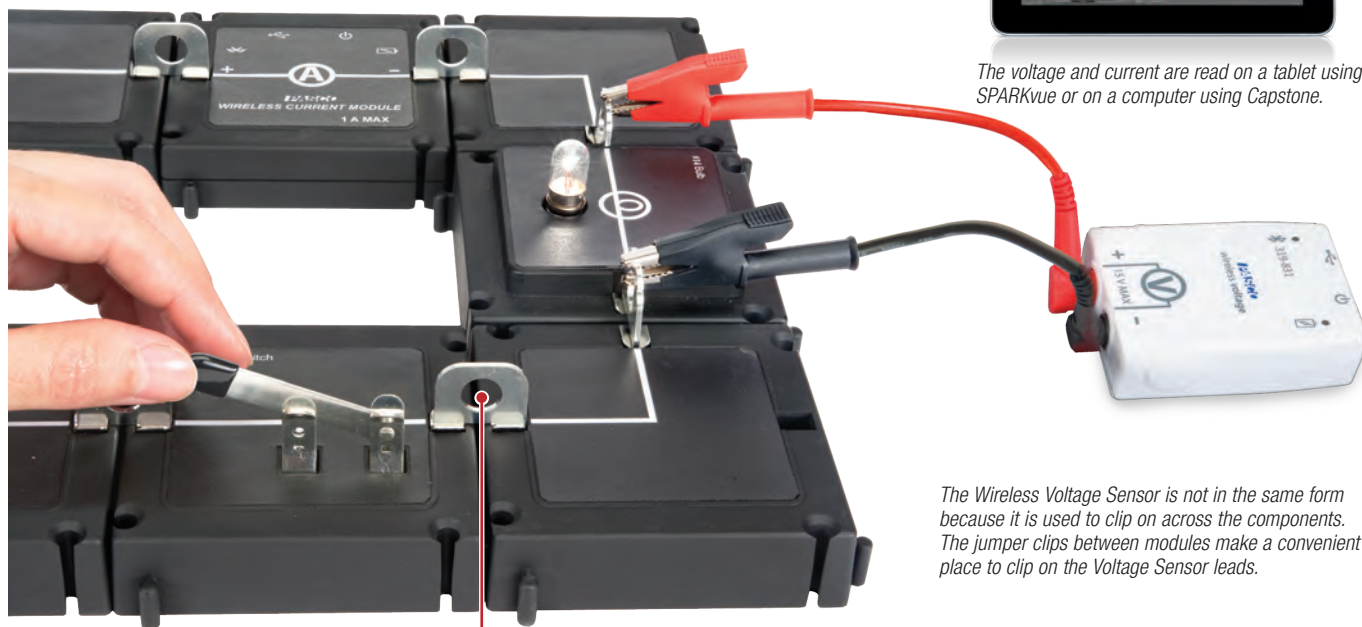
Each module connects mechanically to another by sliding the tabs into each other. It works on any tabletop. No special surface is required. To electrically connect two modules, students insert a jumper clip, which emphasizes that an electrical connection has been made. The large size of the modules (8 cm x 8 cm) enables all the students around the table to see and understand the completed circuit.

Students learn the correct way to insert an ammeter into a circuit: First they remove one of the straight wire modules from their circuit and then they replace it with the Wireless Current Sensor Module. Since the Current Sensor Module is in the same form factor as the other modules, it naturally fits in series with the circuit components. The fact that the Current Sensor is wireless helps the pedagogy: There is only one way in and one way out of the Current Sensor. There are no extra wires coming out of it to confuse students.

Believe it or not, these two circuits are the same. Which would be easier for your students to understand?



The voltage and current are read on a tablet using SPARKvue or on a computer using Capstone.



The Wireless Voltage Sensor is not in the same form because it is used to clip on across the components. The jumper clips between modules make a convenient place to clip on the Voltage Sensor leads.

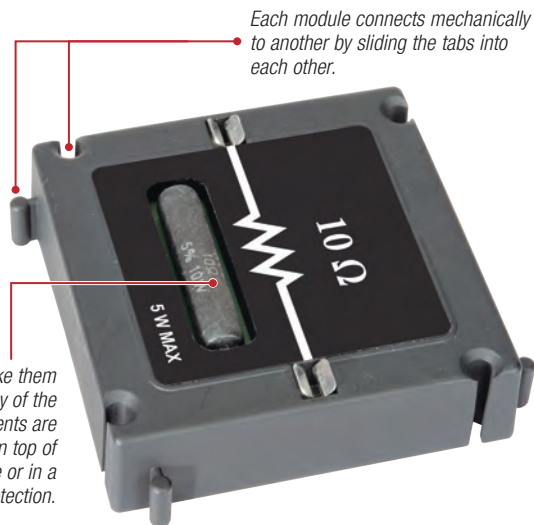
To electrically connect two modules, students insert a jumper clip, which emphasizes that an electrical connection has been made.



Since the Current Sensor Module is in the same form factor as the other modules, it naturally fits in series with the circuit components.

Wireless Current Sensor Module EM-3534 (included in EM-3536) Specifications:

- ▶ **Two ranges:** ±1A, ±0.1A
- ▶ **Resolution:** 0.2mA (±1A range); 0.02mA (±0.1A range)
- ▶ **Bluetooth® sampling rate of 1 kHz**
- ▶ **Higher speed sampling via USB**
- ▶ **Includes remote logging**



To make them visible, many of the components are mounted on top of the module or in a well for protection.

See more Modular Circuits Kits and the AC/DC Module on pages 220-221.

Basic Modular Circuits Kit

EM-3535

The Basic Kit has enough modules to do the five basic experiments listed below.

- Ohm's Law
- Series/Parallel Circuits
- Batteries and Bulbs Circuits
- Switches/Open/Closed Circuits
- Electric Power and Energy

Essential Physics Modular Circuits Kit

EM-3536

The Essential Kit has more modules, includes the Wireless Current Sensor Module and Wireless Voltage Sensor, and has 12 experiments.

- Ohm's Law
- Series/Parallel Circuits
- Kirchhoff's Laws
- Batteries and Bulbs Circuits
- Switches/Open/Closed Circuits
- Electric Power and Energy
- Electromagnets
- Electromagnetic Induction
- RC and RL Circuits
- Variable Resistance
- LED Circuits
- Electric Motors

Includes Module	Basic EM-3535	Essential EM-3536
Straight	4	5
Corner	4	4
Resistor	2	3
Light Bulb	2	3
Tee	2	2
Battery Holder (batteries not included)	2	2
SPST	1	1
Capacitor	1	1
Spring Clips	1	1
Inductor	0	1
Motor	0	1
LED	0	1
Potentiometer	0	1
SPDT Switch	0	1
Bar Magnet	0	1
Wireless Voltage Sensor	0	1
Wireless Current Sensor Module	0	1
Extra Jumpers	15	15
Loose Components for Spring Clips	5	5
Gratnells® Case	1	1
Experiments (download)	5	12



Each kit comes in a Gratnells® case with trays that organize the modules.

Order Information

- Basic Modular Circuits Kit EM-3535
- Essential Physics Modular Circuits Kit EM-3536
- Required:
- 2 AA Batteries
- Required for EM-3536:
- PASCO Capstone Software see pages 68-71
- OR SPARKvue Software see pages 72-73
- Also available separately:
- Wireless Current Sensor Module EM-3534
- Wireless Voltage Sensor PS-3211

Circuits

Modular Circuits Expansion Kit

EM-3540

This expansion pack supplies extra modules found in both the Basic and Essential Physics Modular Circuits Kits (EM-3535 and EM-3536). It also includes a Banana Jack Terminals module for powering your circuits with an external power supply or signal generator. It also includes a storage case with custom foam insert.

Includes:

- Spring Clips
- Straight (2)
- Tee (2)
- Corner (2)
- Light Bulb
- Battery Holder (battery not included)
- Jumper Clips (15)
- Banana Jack Terminals
- Gratnells® Storage Case

**Order Information**

Modular Circuits Expansion Kit.....	EM-3540	
Recommended:		
Basic Modular Circuits Kit.....	EM-3535	p. 219
Essential Physics Modular Circuits Kit.....	EM-3536	p. 219
Replacements		
Replacement Bulbs for Modular Circuits.....	EM-3541	
Replacement Jumper Clips.....	EM-3542	

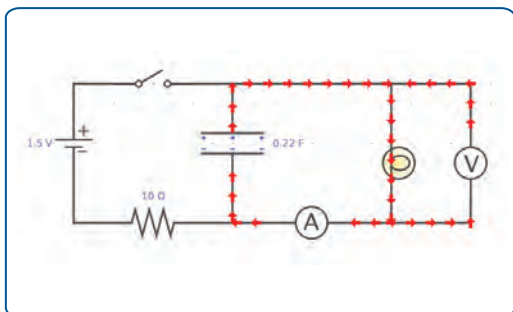
Perform Circuits Emulations with Modular Circuits and PASCO Capstone 2

Reinforce DC circuit concepts and tackle student misconceptions using circuit visualization.

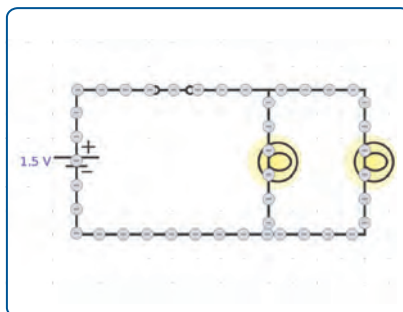
When you use Modular Circuits and PASCO Capstone 2 with its Circuits Emulation tool, you can:

- ▶ Construct and modify circuits
- ▶ Show conventional current or electron flow animation
- ▶ Animate circuits with live sensor data

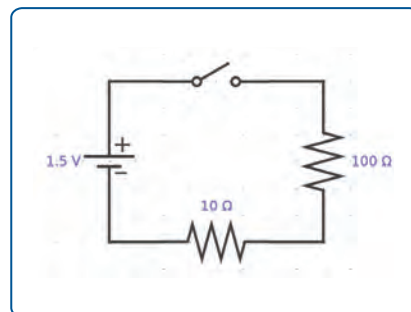
**Learn more about
Capstone 2
on pages 68-71.**



- ▶ Animate conventional current flow
- ▶ Animate capacitor—charge or discharge
- ▶ Edit capacitor values



- ▶ Animate electron flow
- ▶ Connect components in parallel or series



- ▶ Operate switches
- ▶ Edit voltage and resistor values

Wireless AC/DC Module

EM-3533



The Wireless AC/DC Module is a Bluetooth Low Energy wireless signal generator designed for use with PASCO's Modular Circuits. The AC/DC Module can act as a DC power supply, as well as generate Sine, Triangle, and Square AC signals. A built-in rechargeable battery provides long-lasting power for your basic circuits, and is rechargeable using the included USB cable. An internal voltage sensor monitors the output voltage at all times. The Wireless AC/DC Module is controllable in either PASCO Capstone or SPARKvue software. This latest circuit module expands the number and type of experiments you can perform with Modular Circuits including Ohm's Law, RC Circuit Time Constant, and LRC labs. Programmable using Blockly programming in PASCO Capstone 2 software.

The Wireless AC/DC Module is the perfect power supply for these experiments:

- Series and Parallel Circuits
- Capacitor Charge and Discharge
- RC and LRC Circuits
- Ohm's Law

Features:

- ▶ Compatible with Modular Circuits
- ▶ $\pm 3V$ Output; 0.3 A Max
- ▶ DC, Sine, Triangle, Square
- ▶ Bluetooth Low Energy
- ▶ Rechargeable Battery
- ▶ Controllable with PASCO Capstone or SPARKvue Software

Waveforms:

- ▶ DC
- ▶ Sine
- ▶ Triangle
- ▶ Square

Includes:

- Micro USB Cable (PS-3584)

Order Information

Wireless AC/DC Module EM-3533
 Requires:
 PASCO Capstone Single User License UI-5401
 OR
 SPARKvue Single User License..... PS-2401

Modular Circuits Advanced Expansion Kit

EM-3556



This expansion pack supplies additional modules for constructing more complex and advanced circuits. The modules in the Modular Circuits Advanced Expansion Kit are intended to be used with (and as an addition to) the circuit modules found in either the Basic or Essential Physics Modular Circuits Kits (EM-3535 and EM-3536). This kit includes a storage case with custom foam insert.

Includes:

- Speaker Module
- DC Buzzer Module
- Diode Module
- Solar Cell Module
- MOSFET Module
- Bipolar Junction Transistor Module
- Two-Terminal Module
- Jumper Clips (15)
- N-Channel MOSFET Transistor (2)
- P-Channel MOSFET Transistor (2)
- NPN Bipolar Junction Transistor (2)
- PNP Bipolar Junction Transistor (2)
- Grattells case with foam, tray, and lid

Order Information

Modular Circuits Advanced Expansion Kit..... EM-3556

AC/DC Expansion Kit

EM-3555

This kit includes the AC/DC Module (EM-3533) and the Modular Circuits Advanced Expansion Kit (EM-3556). This expansion pack supplies additional modules for constructing more complex and advanced circuits. The modules in the Modular Circuits Advanced Expansion Kit are intended to be used with (and as an addition to) the circuit modules found in either the Basic or *Essential Physics* Modular Circuits Kits (EM-3535 and EM-3536). This kit includes a storage case with custom foam insert.

Includes:

- Modular Circuits Advanced Expansion Kit (EM-3556) (shown above)
- Wireless AC/DC Module (EM-3533)

Order Information

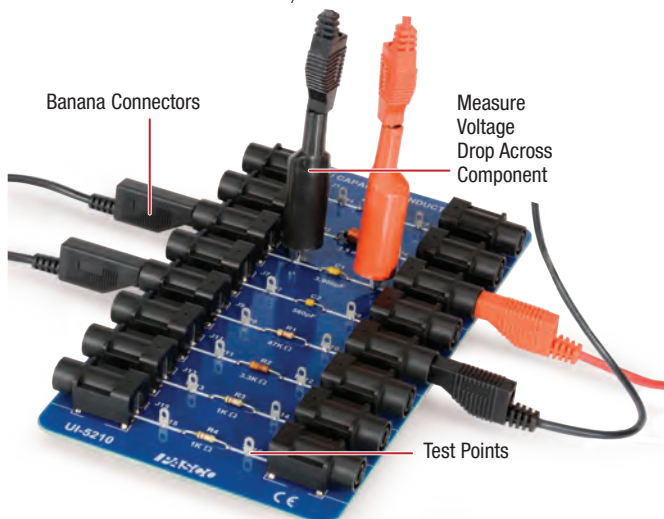
AC/DC Expansion Kit..... EM-3555
 (The AC/DC Expansion Kit includes everything in the Advanced Expansion Kit, plus the AC/DC Module.)

Circuits

Resistor Capacitor Inductor Network

UI-5210

Circuit board designed to study and test RC circuits, circuit laws and theories using PASCO's 850 Universal Interface. Board components can be used to investigate Kirchhoff's Circuit Laws, Ohms' Law, RC Circuits, and A.C. LRC circuit theory with resonant frequencies between 55 kHz and 135 kHz, depending on values used. (Designed for the 850 Universal Interface)



The circuit board accepts patch cords with shrouded banana terminals.

Shown in use with the 850 Universal Interface power amplifier. Both the applied voltage and the resulting current are measured directly by the 850.

**Includes:**

- Inductor: 6.8 mH, 2.5 mH (2)
- Capacitor: 3900 pF, 560 pF (2)
- Resistor: 47 k Ω , 3.3 k Ω , and two 1.0 k Ω (4)

Order Information

Resistor Capacitor Inductor Network..... UI-5210

RLC Circuit

CI-6512

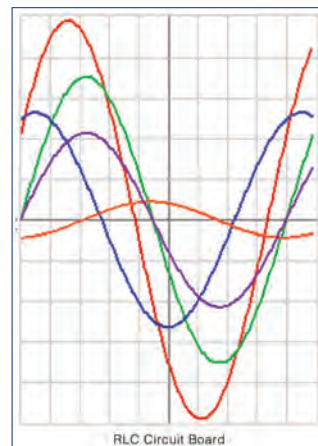
Designed to be used with an 850 Universal Interface to study the behavior of resistors, inductors, and capacitors in an AC circuit.

This board offers a unique set of components for demonstrating:

- ▶ Voltage/Current Phase Relationships
- ▶ RLC Resonance
- ▶ Non-Ohmic Characteristics; components include resistors, capacitors, and an inductor coil.



Phase relationships can be studied between voltage across the capacitor, resistor, and inductor.



The 550 or 850 Interface can measure current and voltage as well as provide power to the RLC Circuit.

**Specifications:**

Resistors: 100 Ω , 1 W; 33 Ω , 5 W; 10 Ω , 10 W

Capacitors: 100 μF , 16 V and 330 μF , 16 V
(capacitance values may vary by $\pm 20\%$)

Lamp: 7.5 V, 0.22 A, # 50 miniature screw style

Red LED: 655 nm

Green LED: 565 nm

LED: Typical forward voltage = 1.7 V to 2.1 V

LED: Average brightness at 20 mA = 1.5 mcd

Inductor: 8.2 mH @ 1 kHz

Inductor: 6.5 Ω maximum DC resistance

Inductor: 0.8 A current rating RMS

Inductor: 3/4" I.D. x 1-3/4"

Order Information

RLC Circuit CI-6512

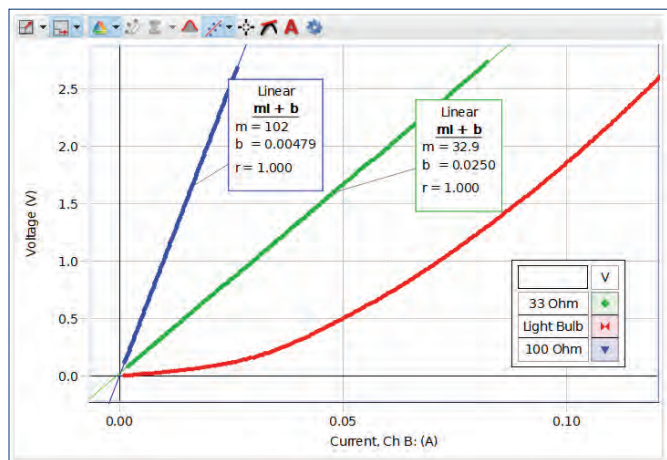
Charge/Discharge Circuit

EM-8678A

The Charge/Discharge Circuit offers a unique way to observe and measure the behavior of DC circuits including batteries, capacitors, light bulbs, and resistors. It also includes an open slot that allows a component to be inserted for further experimentation.

Works Like a Variable DC Power Supply

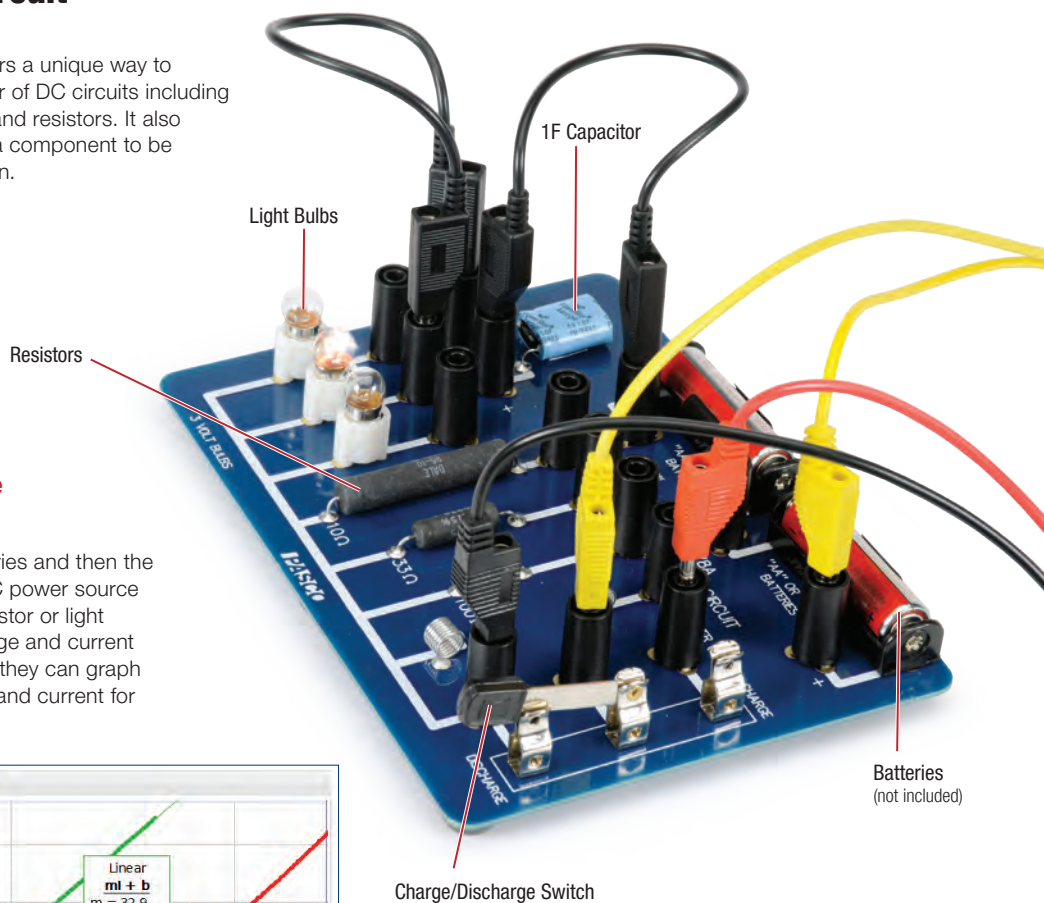
Charge the capacitor using batteries and then the capacitor will act as a variable DC power source as you discharge it through a resistor or light bulb. Students measure the voltage and current as the capacitor discharges, and they can graph the relationship between voltage and current for various components.



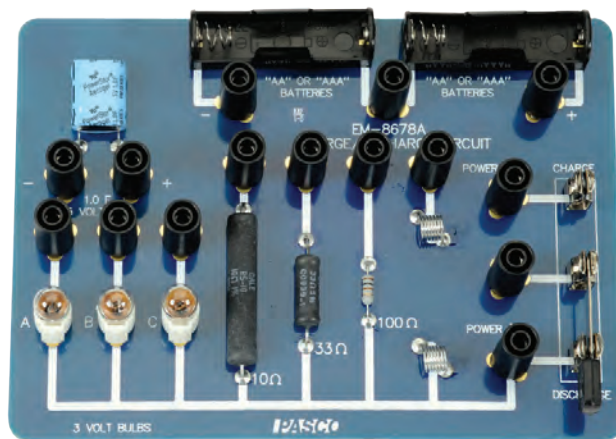
Voltage vs. Current for a 33 Ω resistor, a 10 Ω resistor, and a light bulb. Note the non-linearity for the bulb. Data was recorded in PASCO Capstone using a 550 Universal Interface, Voltage Sensor (UI-5100) and a Wireless Current Sensor (PS-3212).

Includes:

- Farad Capacitor
- #14 Light Bulbs (3)
- 10 Ω Resistor
- 33 Ω Resistor
- 100 Ω Resistor
- Battery Holders (uses AA or AAA; batteries not included)
- Double-Throw Knife Switch
- Instruction Manual



Charge/Discharge Switch



Order Information

Charge/Discharge Circuit	EM-8678A	
Recommended:		
Light Bulbs (#14, 25 Pack)	EM-8627	p. 227
4-pack "AA" Batteries (not included)		
Wireless Current Sensor	PS-3212	p. 57
Wireless Voltage Sensor	PS-3211	p. 57
PASCO Capstone Software		pp. 68-71

Circuits

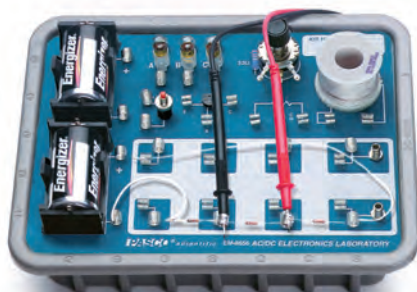
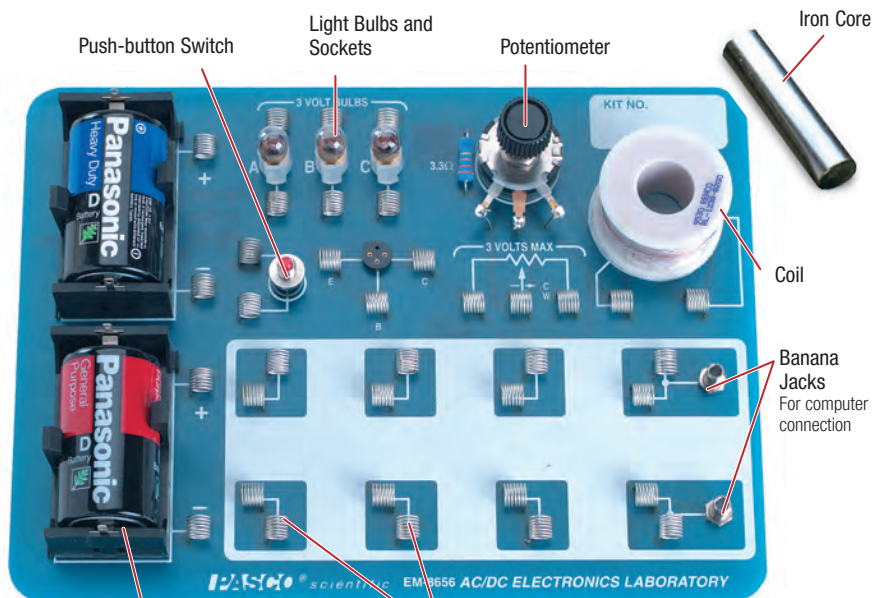
AC/DC Electronics Laboratory

EM-8656

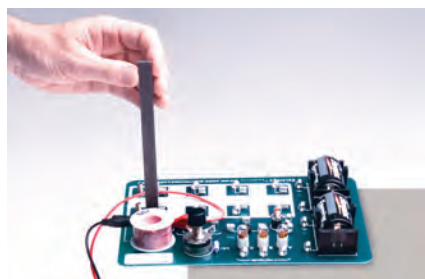
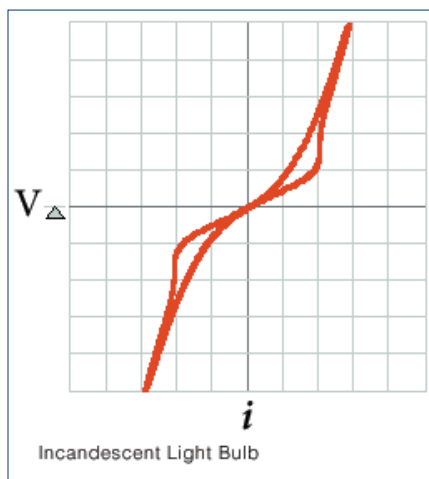
- ▶ Stand-alone operation
- ▶ Computer compatible
- ▶ Includes coil and iron core

The AC/DC Electronics Laboratory dynamically teaches the basics of AC/DC circuits. It features banana jacks for computer connection, component springs that secure circuit components, a push button switch, light bulbs and sockets, potentiometer, coil, battery holder, storage tray, and an iron core.

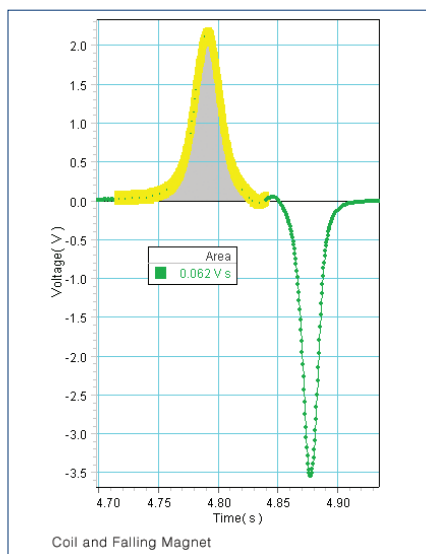
The AC/DC Electronics Laboratory can be used with an 850 or 550 Interface or as a stand-alone unit with D batteries.



Students study how the resistance of a light bulb filament changes as it heats up. The graph below displays Voltage vs. Current for an incandescent light bulb. It is clear that the resistance is not linear but changes as the bulb begins to glow.



With PASCO Capstone and a Voltage Sensor, students can measure the electromotive force (EMF) created when a magnet is dropped through a coil, as well as the changes in magnetic flux caused by the magnet.

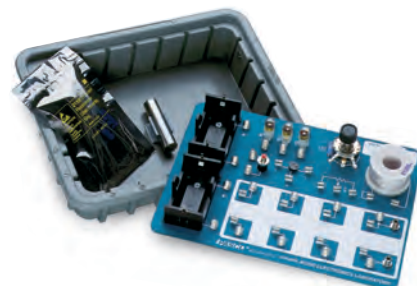


Battery Holder
Hold circuit components securely.

Component Springs

Includes:

- 18 cm x 25 cm circuit board
- Resistors (24)
(4.7 Ω – 220 k Ω , 5%, 0.25 - 5 W)
- Capacitors (7) (1 μF – 330 μF)
- Diodes, Transistors, and LEDs
- Wire leads (22 gauge)
- Push-button switch
- Storage tray and laboratory manual
- Battery holders (2)
- Light sockets and lamps (3)
- 25 Ω , 2 W potentiometer
- Component connectors (36)
- Transistor socket
- 8.2 to 19 mH coil and iron core

**Order Information**

AC/DC Electronics Laboratory EM-8656
Electronic Components – AC/DC Lab EM-8668



To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Basic Electricity Lab

EM-8622

- ▶ Durable, easy-to-use kits
- ▶ Explore basic electronics
- ▶ Complete lab manual

These simple kits provide a strong foundation for future studies in electronics. They take students from the basics of Ohm's Law through simple series and parallel circuit analysis and into some elementary aspects of electronics, where they will build circuits using capacitors, transistors, and diodes. One kit per two students is recommended, giving each student his or her own circuit board.

Includes:

Two Circuit Boards with the following features:

- Battery holders (2)
- Resistor: 3.3 Ω , 2 W
- Light sockets with 3 bulbs (#14)
- Potentiometer: 25 Ω , 2 W
- Spring connectors (32)
- Transistor socket
- Storage tube for holding components (components stay with the kit longer)

Components Package containing:

- Resistors (23) (10 Ω - 220 k Ω , 5%, 1/2 W)
- Capacitors (4) (100 μF , 330 μF)
- Diodes (2)
- Transistors (2)
- Wire leads: 22 gauge

Components Set

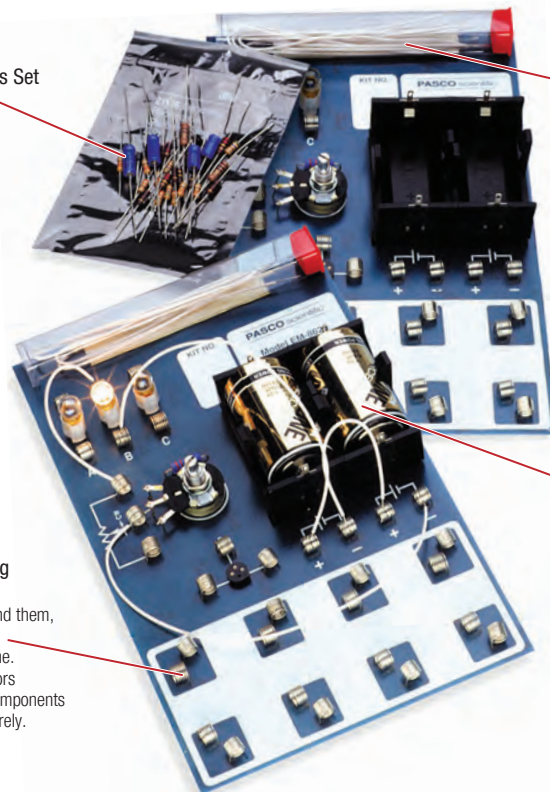
Circuit Experiment Board

With this board and the included components, students can build a variety of basic circuits, from resistors in series and parallel to a simple amplifier.

Low Voltage
Two D batteries provide all the power needed (batteries not included).

Unique Spring Connectors

Twist them, bend them, push on them: no damage done. These connectors will still hold components and wires securely.



Typical Experiments

- ▶ Getting Acquainted
- ▶ Series vs. Parallel Circuits
- ▶ Ohm's Law
- ▶ Resistances in Circuits
- ▶ Voltages in Circuits
- ▶ Currents in Circuits
- ▶ Kirchhoff's Rules (nodes and loops)
- ▶ Capacitors in Circuits
- ▶ Diodes
- ▶ Transistors



To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Order Information

Basic Electricity Lab
(2 boards)EM-8622

Required:

"D" Cell Batteries

Basic Digital
MultimeterSE-9786A p. 230

Replacement Supplies:

Light Bulbs
(#14, 25 Pack)EM-8627

Electronic Components –
Basic Electricity LabEM-8663

Innovative physics textbooks and PASCO physics products

Matter & Interactions is a two-volume textbook and curriculum by Ruth Chabay and Bruce Sherwood, published by Wiley & Sons. It is intended for science and engineering students taking calculus-based introductory university physics. For more information on purchasing these textbooks, visit www.wiley.com.

Electric and Magnetic Interactions

Electric and Magnetic Interactions (Vol. 2 of 2) continues the emphasis on atomic-level descriptions and analysis and modeling physical systems. Electrostatics and circuit phenomena are treated as one integrated subject. The Desktop Electricity Kit allows students to carry out just-in-time desktop experiments on electrostatics, magnetism, and circuits.



Desktop Electricity Kit

EM-8675



When used in tandem with the *Electric and Magnetic Interactions* textbook, this kit gives students the conceptual tools to further their understanding of electric and magnetic interactions. While its components look simple, they provide hands-on opportunities for students to build powerful conceptual models.

Includes:

- Capacitor 1F, 2.5 V
- Resistor 47 Ω , 0.5 W
- Resistor 100 Ω , 0.5 W
- Lamp Holder T3-1/4 (2)
- #48 Miniature Lamp 2.0 V, 0.6 A (2)
- Incandescent Lamp 2.5 V, 0.3 A (2)
- Battery Holder
- Alkaline Battery D-cell (2)
- Bar Magnet (0.375" x 1")
- Compass, Liquid Filled
- Wire-Red 22AWG (6 ft)
- Alligator Clip Leads (12") (7)
- Nichrome Wire #26 (18")
- Nichrome Wire #30 (18")

Order Information

Desktop
Electricity KitEM-8675

Circuits

CASTLE “2005” Curriculum

Capacitor-aided system for teaching and learning electricity

- ▶ Complete electricity curriculum
- ▶ Redesigned sections to facilitate beginning CASTLE curriculum in grade 8 or 9

CASTLE Kit

EM-8624A

Economy CASTLE Kit

(for 8 students) EM-8654

The CASTLE™ Approach

CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) is a high school electricity curriculum that leads students from initial naive ideas to an increasingly expert understanding of electrical phenomena. A sequence of self-guided experiments uses large capacitors and transient bulb lighting to help students confront their misconceptions, grasp the physics of current propulsion and build intuitive explanatory models.



Typical Experiments

Core Curriculum investigates:

- ▶ What is happening in the wires?
- ▶ What do the bulbs do to moving charge?
- ▶ Where does the moving charge originate?
- ▶ What makes charge move in a circuit?
- ▶ How do wires distribute electric pressure in a circuit?
- ▶ How are values of circuit variables measured?

Advanced Curriculum investigates:

- ▶ Does all matter contain charge?
- ▶ What is the cause of distant action effects?
- ▶ What pushes on tiny charge carriers like electrons?
- ▶ How do semiconductors work?
- ▶ What is AC?
- ▶ How do motors and generators work?
- ▶ How are magnetic and electromagnetic fields produced?



To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

The Curriculum Guide

Download the Manuals FREE.

Download the CASTLE Curriculum Guide for FREE. At www.pasco.com just type CASTLE in the search box and click GO!

The teacher's manual helps teachers put the CASTLE Kits to the best possible use. The student manual has investigations for each stated experiment, plus commentaries to prepare students for labs, as well as summary exercises to reinforce the lab experience.

Carbon Resistors

These impede flow similar to low resistance bulbs, but don't glow and divert attention to role as energy sinks.

Battery Holder

Securely holds batteries and yet makes them visible so their function within the circuit is evident.

High-Quality Compass

Non-invasive monitoring of movement in wires enables students to visualize the direction of charge flow.

Miniature Light Bulbs

Different shaped bulbs have different resistance values.

Screw Sockets and Stands

Stands provide a sturdy support for bulbs and are easy to quickly connect into a circuit.

25,000 μ F Capacitor

Provides the foundation for this intuitive introduction to current electricity.

Auxiliary Equipment for Core Curriculum



The Mini Generator (1) enables students to distinguish charge circulation from energy transfer. The 100,000 μ F Capacitor (2) lengthens the time scale of transient bulb lighting.

The Kits

Each CASTLE Kit includes all the materials needed (except for three D batteries) for two students to work through a complete introduction to basic electricity. Each Economy CASTLE Kit includes all the materials needed (except batteries) for eight students.

Materials Included in Each Kit

Component	CASTLE Kit	Economy Kit
25,000 μ F capacitor (20 V, nonpolar)	1	4
#14 light bulbs (round)	4	25
#48 light bulbs (oblong)	6	25
10 Ohm resistor	4	16
Miniature light bulb sockets and stands	4	16
Wires with alligator clips	10	40
Battery holder (spring-loaded)	1	4
High-quality compass	1	4
Storage box	1	0

Auxiliary Equipment for Advanced Curriculum



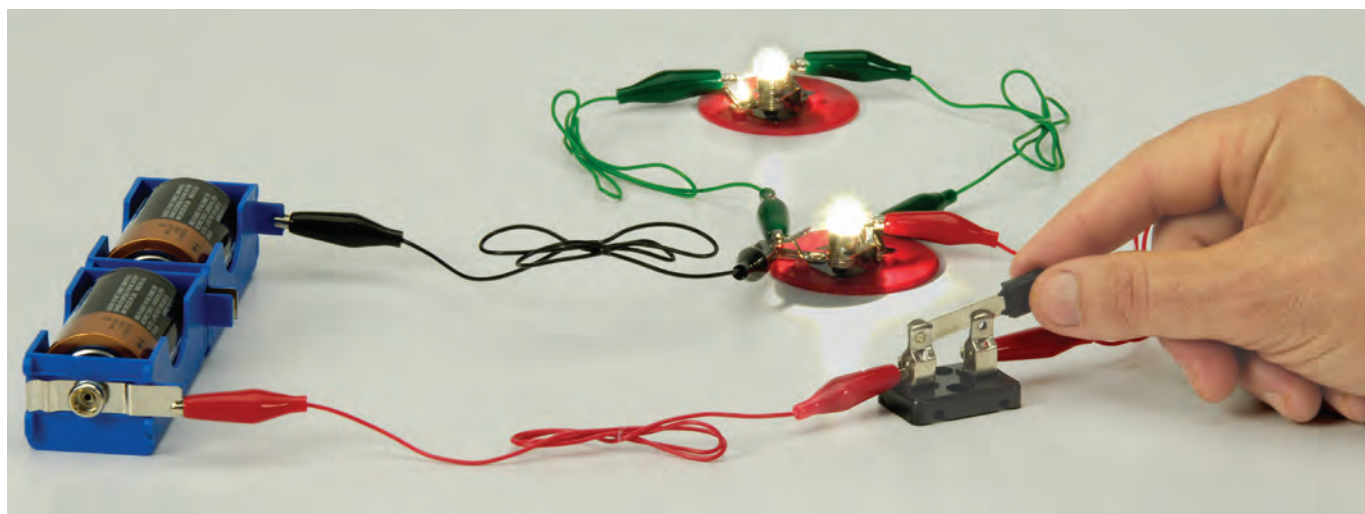
Bi-color LEDs detect electric vectors in electromagnetic fields produced in these coils (3) by accelerating charge when current is turned on and turned off.

Order Information

CASTLE Kit.....	EM-8624A	
Three "D" batteries are required per kit, (not included).		
Economy CASTLE Kit	EM-8654	
12 "D" batteries are required per kit, (not included).		
Recommended:		
Mini Generator.....	SE-8645	p. 231
Capacitor (0.1 F)	EM-8655	
(Minimum of two each per class)		
Primary and Secondary Coils.....	SE-8653A	p. 236
(Minimum of two each per class)		
Replacement Supplies:		
We recommend the purchase of one EM-8627 and one EM-8628 spare bulb set for every five CASTLE Kits, or for every Economy CASTLE Kit.		
Light Bulbs (#14, 25 Pack)	EM-8627	
Light Bulbs (#48, 25 Pack)	EM-8628	
Light Bulb Sockets (10 Pack)	EM-8630	
Liquid-Filled Compasses (5 Pack)	EM-8631A	
Capacitor (0.025 F, 2 Pack)	EM-8632	

Circuit Components

Use these stand-alone components to build your own circuits.



Series/Parallel Battery Holder (10 Pack)

SE-8799

This unique battery holder allows “D” cell batteries to be easily connected in both series and parallel. Metal extensions on both sides of the holder are also convenient for use with alligator clips.

Features:

► **Series:** Use the snaps to connect the batteries end to end.



► **Parallel:** Use the metal slides to use the batteries side by side.



Order Information

Series/Parallel Battery Holder (10 Pack)	SE-8799
Recommended:	
Light Bulbs (#14, 25 Pack)	EM-8627
Light Bulb Sockets (10 Pack)	EM-8630
Alligator Clip Leads (Set of 10).....	EM-8634

Light Bulb Sockets (10 Pack)

EM-8630

Miniature socket has a plastic base with spring-loaded metal clips to hold wire leads. Accepts screw-type miniature bulbs. Includes ten sockets.



Order Information

Light Bulb Sockets (10 Pack)	EM-8630
------------------------------------	---------

Light Bulbs

EM-8627: 2.5 V, 0.3 A bulbs (25 bulbs)

EM-8628: 2.0 V, 0.06 A bulbs (25 bulbs)

EM-8814: 7.5 V, 0.22 A bulbs (25 bulbs)

Screw-type base, suitable for use with EM-8630 Sockets



Order Information

Light Bulbs (#14, 25 Pack)	EM-8627
Light Bulbs (#48, 25 Pack)	EM-8628
Light Bulbs (#50, 25 Pack)	EM-8814

Knife Switches

EM-8815

This single-pole single-throw knife switch has screw terminals and a Bakelite™ base. Through-holes allow for mounting base to another surface.



Order Information

Knife Switches.....	EM-8815
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Alligator Clip Leads (Set of 10)

EM-8634

Use these 30 cm long Alligator Clip Leads for almost any application — from hooking up instruments to bread boarding circuits. They come in sets of 10: two each of yellow, white, red, green and black.



Order Information

Alligator Clip Leads (Set of 10).....	EM-8634
---------------------------------------	---------

Replacement Bulbs (5 Pack)

EM-8679

The Replacement Bulbs (5 pack) is a replacement part for the:

- Series/Parallel Circuit (EM-8677)
- Introductory Optics System (OS-8500)



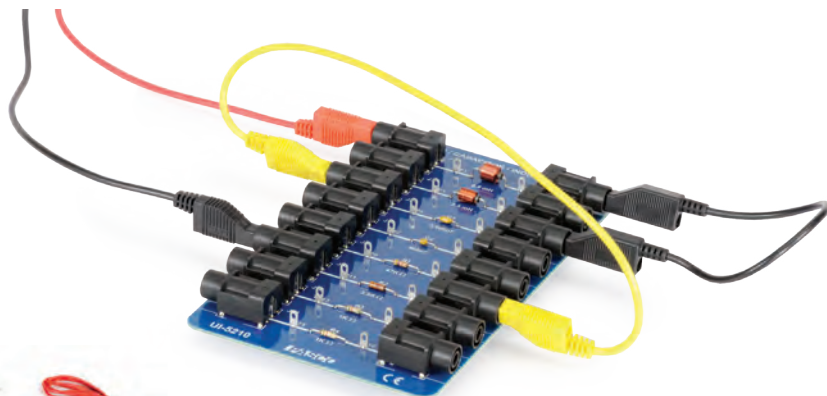
Order Information

Replacement Bulbs (5 Pack) Series/Parallel Circuit.....	EM-8679
---	---------

Patch Cords

These stackable patch cords come in four convenient lengths. The grips are made of soft plastic for flexible strain relief. Spring connectors rotate in the grips, reducing wear due to friction.

*Shown in use with UI-5210 circuit board.
See page 222 for more information.*



2 Meter Patch Cord Set

SE-9415A

These heavy insulation patch cords are convenient and durable. The grips are stackable and made of soft plastic for flexible strain relief. The spring connectors rotate in the grips, reducing the wear due to friction. The wire itself is 18 AWG. Set includes 2 red and 2 black patch cords.



Order Information

2 Meter Patch Cord Set.....SE-9415A

Patch Cord, Jumper Set

EM-9737

This banana plug cord and jumper set includes 5 cords with length of 15 cm. Available in black only.



Order Information

Patch Cord, Jumper Set.....EM-9737

Banana Plug Cord Sets, 30 cm Length

SE-7123

These insulated 30 cm patch cords are convenient, durable, and inexpensive. The stackable grips are made of soft plastic for flexible strain relief and the spring connectors rotate, reducing wear due to friction. This set of 8 includes 2 red, 2 yellow, 2 blue, and 2 black.



Order Information

Banana Plug Cord Sets, 30 cm Length.....SE-7123

Alligator Clip Leads (Set of 10)

EM-8634

Use these 30 cm long Alligator Clip Leads for almost any application — from hooking up instruments to bread boarding circuits. They come in sets of 10: two each of yellow, white, red, green and black.



Order Information

Alligator Clip Leads (Set of 10).....EM-8634

Banana Plug Cords (5 Pack)

SE-9750 (red) SE-9751 (black)

These heavy, insulated patch cords are convenient, durable and inexpensive. The grips are stackable and made of soft plastic for flexible strain relief. The spring connectors rotate in the grips, reducing wear due to friction.



The 75 cm long cords are available in red or black.

Order Information

Banana Plug Cord-Red (5 Pack) SE-9750
Banana Plug Cord-Black (5 Pack)..... SE-9751

Shrouded Long Patch Cords

EM-9740 (red) EM-9745 (black)

Set of five 75 cm long shrouded patch cords in red or black. Terminals are shrouded banana plugs. Maximum rating: 30 Vrms or 60 VDC, 10 Amps.



Order Information

Shrouded Red Patch Cords EM-9740
Shrouded Black Patch Cords..... EM-9745

High Voltage Patch Cord Set

SE-9269

Shrouded (4 mm) male banana plug to right-angle shrouded male banana plug 120 cm long (one red and one black).



Order Information

High Voltage Patch Cord Set.....SE-9269

Alligator Clip Adapters

SE-9756

Convert banana plugs into alligator clips with this set of 10 adapters. The 4 mm banana plug clips are tin-plated steel. These adapters just slide over the end of your 4 mm banana plug. Set includes 5 red and 5 black insulated adapters.



Order Information

Alligator Clip Adapters.....SE-9756

Shrouded Alligator Clip Adapters

SE-9758

Designed for use with both regular and shrouded banana plugs, this set of adapters comes with 5 red and 5 black shrouded alligator clip adapters.



Order Information

Shrouded Alligator Clip AdaptersSE-9758

Spade to Banana Adapter

EM-8629

For use with both regular and shrouded banana plugs. Includes five red and five black adapters.



Order Information

Spade to Banana Adapter.....EM-8629

Shrouded Alligator Test Leads

PS-3544

These test leads are included with the Wireless Voltage Sensor (PS-3211). They can also be used with the Wireless Current Sensor (PS-3212). Includes one red and one black lead.



Order Information

Shrouded Alligator Test Leads.....PS-3544

Resistor Pack

EM-8784

Assortment of electrical resistors including 10 each of the following: 10 Ω , 100 Ω , 330 Ω , 560 Ω , 1000 Ω , 3300 Ω , 10 k Ω , 22 k Ω , 100 k Ω , 220 k Ω , 330 k Ω .



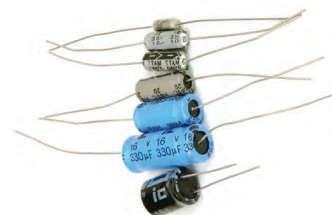
Order Information

Resistor Pack.....EM-8784

Capacitor Pack

EM-8785

Assortment of electrical capacitors ranging from 1 microfarad to 470 microfarads.



Order Information

Capacitor Pack.....EM-8785

Capacitor (0.1 F)

EM-8655

(0.1 F) Electrolytic, bipolar, 10 V capacitor with screw terminals, 4.5 cm diameter, 14 cm long.



Order Information

Capacitor (0.1 F).....EM-8655

Capacitor (0.025 F, 2 Pack)

EM-8632

Electrolytic, bi-polar, 25 Volt capacitor with screw terminals, 5 cm diameter, 8 cm long. Contains 2 capacitors



Order Information

Capacitor (0.025 F, 2 Pack)EM-8632

Capacitor (1 Farad)

SE-8626

Electrolytic, bipolar, 5 V 1.0 F capacitor. Charge up this capacitor with the Mini Generator and then let go of the crank. The handle will continue to rotate in the same direction as the capacitor discharges.



Order Information

Capacitor (1 Farad)SE-8626

Voltage

Voltaic Cell

SE-7249

- ▶ Learn how batteries work
- ▶ Includes different types of electrodes

Voltaic cell sets are ideal for demonstrating the characteristics of battery cells. This set includes one plastic cell, complete with a screw-on plastic ring, two adjustable electrode holders, a porous ceramic cup, and ten electrodes (aluminum (1), nickel (1), tin (1), graphite (1), iron (1), copper (1), lead (2), and zinc (2)).

Electrolyte is not included.

Order Information

Voltaic Cell.....SE-7249
 Recommended:
 Basic Digital Multimeter.....SE-9786A



Basic Digital Multimeter

SE-9786A

This basic meter includes all of the functions and ranges needed for most introductory lab work.



Features:

- ▶ 10 amp range
- ▶ Backlit display with 25 mm digits
- ▶ Soft rubber boot for drop protection
- ▶ Built-in tilt stand
- ▶ Type K thermometer built in for surface or air measurements
- ▶ Auto power off saves battery life

Specifications:

DC Voltage: 0.1 mV to 600 V with $\pm 0.5\%$ accuracy

AC Voltage: 1 mV to 600 V with $\pm 0.3\%$ accuracy

DC Current: 0.1 μ A to 10 A

AC Current: 0.1 mA to 10 A

Resistance: 0.1 Ω to 20 M Ω

Additional Functions: Input fuse protection, audible and visible misconnection signals, data hold freezes display reading

Display: 3-1/2 digit display with 25 mm digits, polarity indication, low battery indication

Power: 9 V battery (included)

Order Information

Basic Digital Multimeter..... SE-9786A

Precision Digital Multimeter, Component Tester and Thermometer

SB-9631B

This is an excellent general purpose multimeter that features high-accuracy overload protection on all ranges and a built-in digital thermometer. It can measure capacitance and transistor gain (hFE).

Includes test leads, temperature probe and battery.



Specifications:

DC Current: 200 μ A, 2 mA, 20 mA, 200 mA; $\pm (1\% + 1 \text{ digit})$

AC Current: 200 μ A, 2 mA, 20 mA, 200 mA; $\pm (1.2\% + 4 \text{ digits})$

Capacitance: 20 nF, 200 nF, 2 μ F, 20 μ F, 200 μ F; $\pm (3\% + 10 \text{ digits})$

Temperature: 4° to 1400°F; 4°F to 900°F; $\pm 2.0\%$ reading + 4°F; 900°F to 1,400°F; $\pm 3.0\%$ reading + 4°F

Power: 200-hour life on 9 V alkaline (battery included)

DC Voltage: 200 mV, 2 V, 20 V, 200 V, 1000 V; $\pm (0.5\% + 1 \text{ digit})$ 10 M Ω input impedance

AC Voltage: 200 mV, 2 V, 20 V, 200 V; $\pm (1\% + 4 \text{ digits})$ 750 V; $\pm (1.5\% + 4 \text{ digits})$ 10 M Ω input impedance

Resistance: 200 Ω ; $\pm (1\% + 3 \text{ digits})$ 2 k Ω , 20 k Ω , 200 k Ω , 2 M Ω ; $\pm (0.8\% + 1 \text{ digit})$ 20 M Ω ; $\pm (3\% + 3 \text{ digit})$

Additional Functions: Diode test, transistor hFE, audible continuity test, fold-out stand

Display: 3-1/2 digit LCD display, 17 mm high digits, polarity indication, low battery indication

Drop Resistant

Order Information

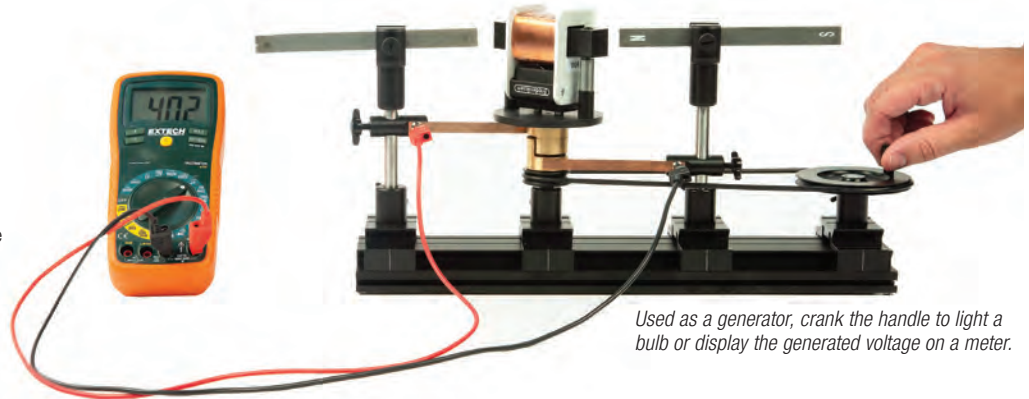
Precision Digital Multimeter,
 Component Tester and ThermometerSB-9631B
 Replacement Supplies:
 Thermocouple Probe.....SB-9632

Motor/Generator Demonstration

SF-7216

- ▶ Hand-crank generator
- ▶ AC and DC generators
- ▶ DC motor

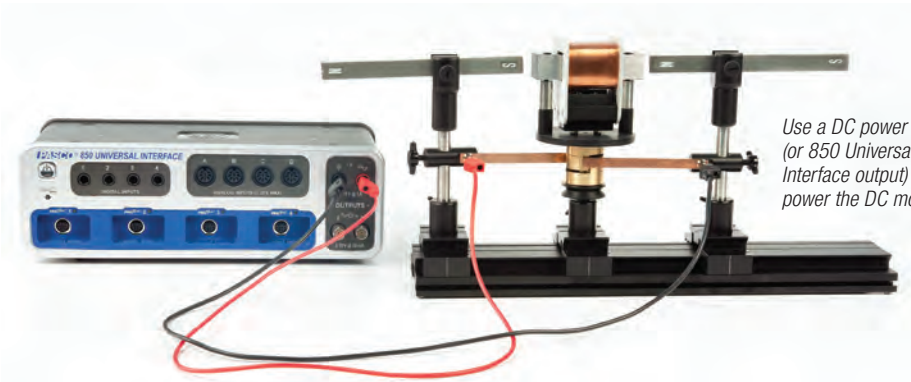
This sturdy kit clearly demonstrates single-phase AC and DC generators and DC motors. The brushes can be adjusted on the commutator to convert the generator from AC to DC.



Used as a generator, crank the handle to light a bulb or display the generated voltage on a meter.

Includes:

- Coil holder with commutator
- Coil, 800 windings
- Laminated core
- Commutator contact spring (2)
- Base rail: 37 cm long
- Carrier with 10 mm diameter hole (4)
- Magnet mount (2)
- Bar magnets: 100 x 10 x 10 mm
- Manual drive pulley
- Drive belts, set of 4 different
- Instructions



Use a DC power supply (or 850 Universal Interface output) to power the DC motor.



Order Information

Motor/Generator Demonstration.....	SF-7216	
Required:		
Power Supply (18 VDC, 5 A).....	SE-9720A	p. 250
OR		
850 Universal Interface	UI-5000	p. 14
Banana Plug Cord-Red (5 Pack)	SE-9750	p. 228
Basic Digital Multimeter.....	SE-9786A	p. 230

Mini Generator

SE-8645

The Mini Generator is a hand-cranked generator that produces up to 6 volts DC for basic experiments in electricity, electromagnetism, and electrolysis. It replaces the usual power supply with a device that students can see, operate, and understand.



Order Information

Mini Generator.....	SE-8645
Recommended:	
Capacitor (1 Farad)	SE-8626
Light Bulb Sockets (10 Pack)	EM-8630
Light Bulbs (#50) 25 Pack.....	EM-8814

Capacitor (1 Farad)

SE-8626



Electrolytic, bipolar, 5 V 1.0 F capacitor. Charge up this capacitor with the Mini Generator and then let go of the crank. The handle will continue to rotate in the same direction as the capacitor discharges.

Order Information

Capacitor (1 Farad)	SE-8626
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Generators

Energy Transfer – Generator

ET-8771B

- ▶ Transfers gravitational potential energy to electrical energy
- ▶ Open design: 19 mm neodymium magnet can be seen spinning between the two coils
- ▶ Real-time computer measurement of output power

PASCO's Energy Transfer Generator demonstrates the conversion of gravitational potential energy into electrical energy as a falling weight turns a magnet between two coils. The open design permits easy identification of the essential parts of the generator. The supplied lamp or load resistor can be plugged into the output banana jacks. A Voltage Sensor can measure the generated voltage across the load resistor, which can then be used to calculate power generated.

By wrapping the string around different-sized steps on the three-step pulley, the generator will spin at different speeds. The smaller the pulley radius, the slower the weight falls and the greater percentage of the potential energy is converted to electrical energy.

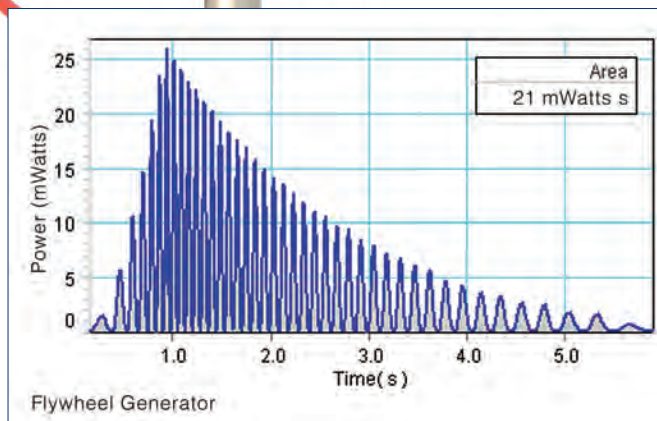
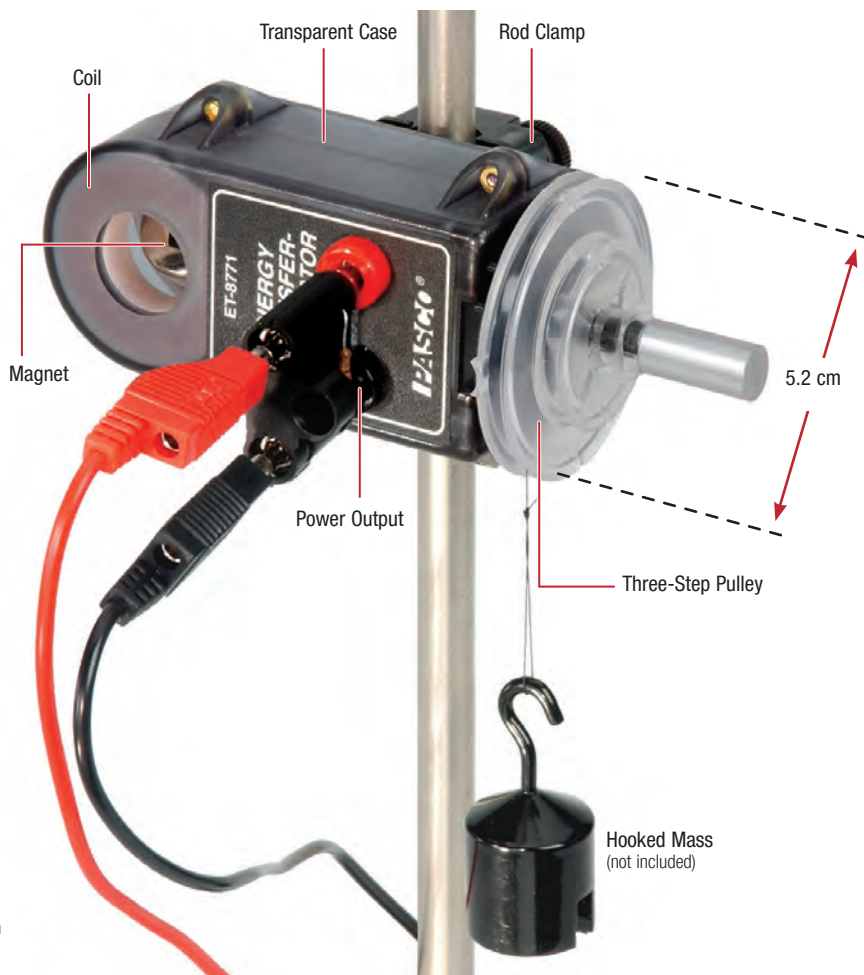
The AC power generated by spinning the shaft by hand easily lights the included red-green LED. The LED goes from red to green, indicating the direction of the current.

The built-in rod clamp is used to mount the generator on a rod stand.

Case Dimensions: 8.7 x 4.4 x 3.6 cm

**Includes:**

- Generator with three-step pulley
- Red-green LED mounted on plug
- 100-ohm load resistor mounted on plug
- Spool of thread

**Order Information**

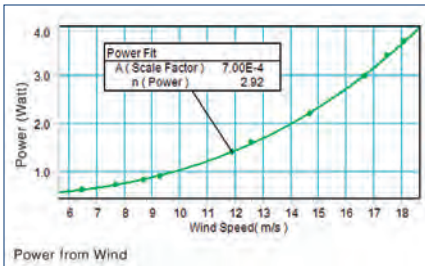
Energy Transfer - Generator	ET-8771B	
Recommended:		
2 Meter Patch Cord Set.....	SE-9415A	p. 228
Energy Transfer - Hydro Accessory.....	ET-8772	p. 233
Hooked Mass Set.....	SE-8759	p. 197
Large Rod Base	ME-8735	p. 187
90 cm Stainless Steel Rod	ME-8738	p. 187
No-Bounce Pad.....	SE-7347	p. 194
Required for use with PASPORT:		
PASPORT Voltage-Current Sensor.....	PS-2115	p. 36

Energy Transfer – Wind Turbine

ET-8783



Attach this clear propeller to the Energy Transfer Generator for a complete wind energy turbine. Students will better understand the process of electrical energy production from wind after using the turbine.



Includes:

- Fan
- Mounting hardware

Order Information

Energy Transfer – Wind Turbine..... ET-8783
 Required:
 Energy Transfer – Generator ET-8771B

Energy Transfer – Hydro Accessory

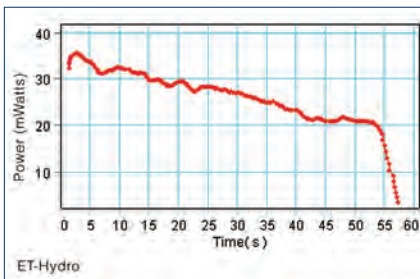
ET-8772

- ▶ Demonstrates hydroelectric power generation
- ▶ Open design gives view of spinning turbine and water stream
- ▶ Falling water lights an LED



The Hydro Accessory is used with the Energy Transfer Generator to demonstrate how falling water generates electricity. The gravitational potential energy of the water is converted into electrical energy as the falling water turns the turbine. The water can be supplied using the optional Water Reservoir. The water that has passed through the turbine is caught in a beaker and measured to determine the total mass that has fallen.

The water nozzle size and angle can be adjusted to optimize performance. By changing the height of the Water Reservoir, different efficiencies are achieved.



Includes:

- Turbine housing
- Plastic turbine (4 cm diameter)
- Water nozzles (5)
- Tubing (2 m long)
- Plastic hose clamp
- Screwdriver for attaching Hydro Accessory to Generator



Order Information

Energy Transfer - Hydro Accessory..... ET-8772
 Required:
 Energy Transfer - Generator ET-8771B
 Recommended:
 Water Reservoir ME-8594 p. 195
 Large Rod Base ME-8735 p. 186
 90 cm Stainless Steel Rod ME-8738 p. 186
 Three-Finger Clamp SE-9445 p. 188
 Beaker, 1000 ml (6 Pack) SE-7288 p. 195

Generators

Magnetic Demonstration System

EM-8644B

Demonstrate:

- ▶ Magnetic damping
- ▶ Diamagnetism and paramagnetism
- ▶ Magnetic force on a current-carrying wire swing

This all-in-one demonstration system includes the Variable Gap Magnet (EM-8618) and the Magnetic Force Accessory (EM-8642A).



Demonstrate Magnetic Damping

Swing the solid aluminum paddle through the gap and it stops dead, the motion is damped due to eddy currents. Now try the slotted paddles. One swings freely, while the other is immediately damped.



Demonstrate Force on a Current-Carrying Wire

Pass a current through the wire swing (power supply not included) to investigate the right-hand rule for magnetic forces.

Includes:

- Variable Gap Magnet
- Pole pieces
- Aluminum paddles (solid, slotted, closed slotted) (3)
- Glass rod
- Aluminum rod
- Wire swing
- Special mounting rod

Demonstrate Diamagnetism and Paramagnetism

The diamagnetic glass rod (Figure a) aligns transverse to the field; the paramagnetic aluminum rod (Figure b) aligns with the field.



Order Information

Magnetic Demonstration System	EM-8644B	
(Includes EM-8618 and EM-8642A)		
Required:		
Power Supply (18 VDC, 5 A).....	SE-9720A	p. 252
OR		
Mini Generator.....	SE-8645	p. 231
Base and Support Rod	ME-9355	p. 187
Shown in use with:		
2 Meter Patch Cord Set.....	SE-9415A	p. 228

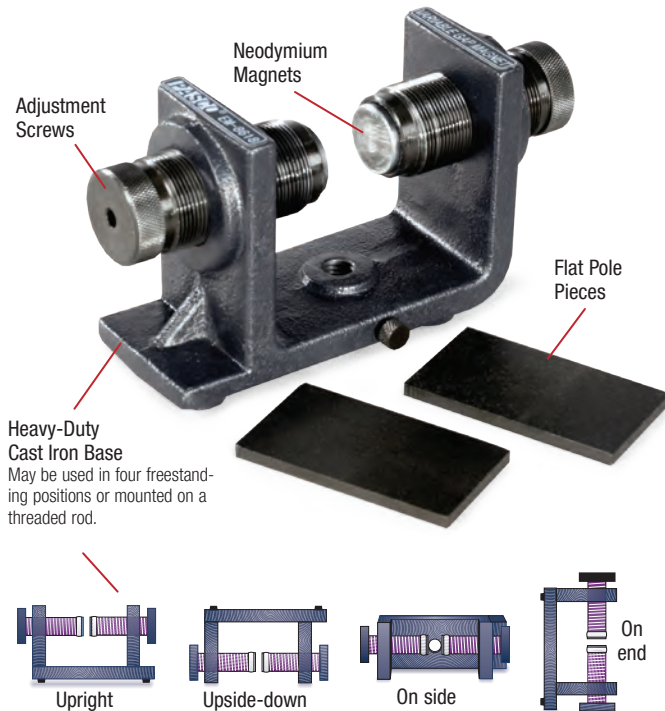
Variable Gap Magnet

EM-8618

- ▶ Lower cost
- ▶ Larger magnets (1 inch diameter)
- ▶ Greater field (1 Tesla maximum)
- ▶ Great for induction experiments

The redesigned Variable Gap Magnet is rugged and durable, while providing excellent results as a demonstration tool. The two one inch (2.54 cm) diameter neodymium magnets are mounted on a heavy-duty cast iron base that has a threaded hole to mount on a support rod, which provides even more versatility.

The gap may be varied from 0.5 cm to 8.9 cm using the adjustment screws. Two flat pole pieces are also included to provide a uniform magnetic field when needed.



Order Information

Variable Gap Magnet.....EM-8618
(Includes Variable Gap Magnet with Pole Pieces)

Magnetic Force Accessory

EM-8642A

Includes:

- Three aluminum paddles (solid, slotted, closed slotted)
- Glass rod
- Aluminum rod
- Wire swing
- Special mounting rod



Order Information

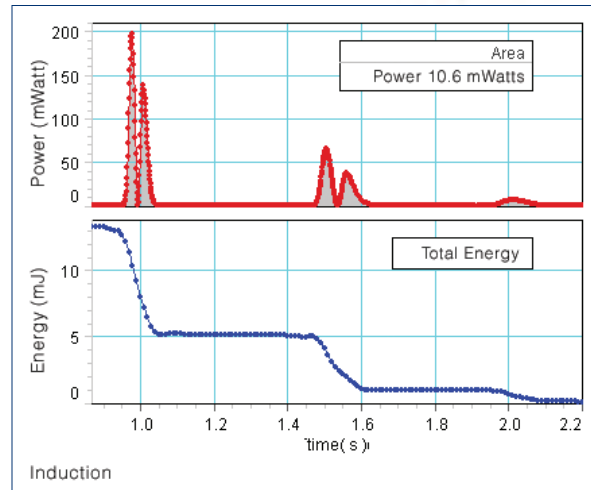
Magnetic Force AccessoryEM-8642A

Induction Wand

EM-8099

See EX-5541A
Faraday's Law of Induction
Experiment on
page 373.

The Induction Wand is a rigid pendulum with a coil at the bottom end connected to the banana terminals at the other end. A through-hole allows the pendulum to be connected to a Rotary Motion Sensor, for detailed investigations of induction as the coil is swung through a magnetic field.



The energy of the pendulum decreases with each pass of the coil through the magnet. The energy dissipated in the resistor is obtained from the area under a Power vs. Time plot.

Includes:

- Wand with screw
- Resistive load



Order Information

Induction WandEM-8099

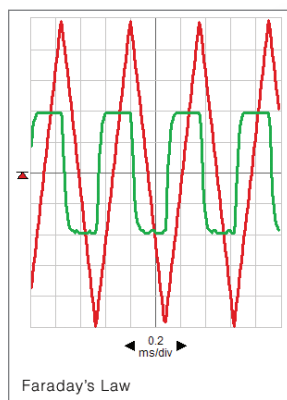
See our
Superconductors
on pages 244-245



Coils and Cores

Field and Detector Coils

1. EM-6711A Field Coil
200 turns of #22 copper wire,
18.6 cm ID, 22.1 cm OD. Max.
current 2 A.
2. EM-6723A Field Coil
500 turns of #22 copper wire.
Max current 2 A.
3. EM-6712 Detector Coil
400 turns of #28 copper wire.
4. EM-6713 Detector Coil
2000 turns of #36 copper wire.
5. EM-6714 Bi-Color
LED Indicator.



A 5 V triangle wave (red trace) is applied to the Field Coil, and the induced voltage in the 2000-turn Detector Coil is a square wave (green trace).

Features:

- **Verify Faraday's Law:** Verify all aspects of Faraday's Law.
- **Qualitative Demonstration:** With the Bi-Color LED Indicator and the Variable Gap Magnet, students can see when a current is induced in the detector coil. With the LED indicator plugged into a detector coil, the LED flashes red or green as the detector coil passes through the magnet.
- **Quantitative Demonstration:** PASCO's coils can be used with a function generator and an oscilloscope, or connected to the 850 Universal Interface.

Developed for Workshop Physics® activities.



For details of experiments using these coils, see Christopher C. Jones, "Faraday's Law Apparatus for the Freshman Laboratory," *Am. J. Phys.* 1987; 55(12):1148-1150.

Order Information

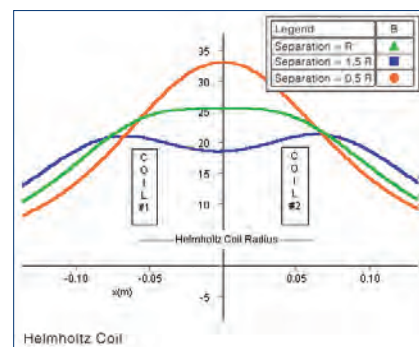
Field Coil (200 Turn).....	EM-6711A	
500-Turn Field Coil.....	EM-6723A	
Detector Coil (400 turn).....	EM-6712	
Detector Coil (2000 Turn).....	EM-6713	
LED Indicator.....	EM-6714	
Recommended:		
Variable Gap Magnet.....	EM-8618	p. 235
850 Universal Interface.....		pp. 14-15
OR		
Low Voltage AC/DC Power Supply.....	SF-9584B	p. 254
AND		
Function Generator.....	PI-8127	p. 256

Helmholtz Coils

EM-6722 with 200-turn Coils
EM-6724 with 500-turn Coils



The Helmholtz Coils consist of two coils mounted on a base to provide a uniform magnetic field between the coils. The base has a slot that allows the coils to be spaced apart at any distance from 3 cm to 20 cm (center-to-center distance). The proper separation for Helmholtz coils (i.e., the radius of the coils) is marked on the base. Two 0.635 cm (0.25 inch) diameter holes between the coils accommodate mounting devices in the uniform magnetic field.



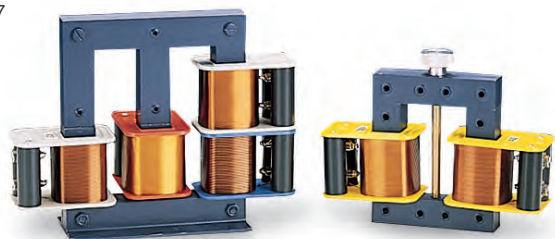
This plot shows the magnetic field strength along the axis of Helmholtz coils for three different coil separations: the green data is the magnetic field with the coils separated at the proper distance (the radius of the coils).

Order Information

Helmholtz Coil Set, 200 Turn.....	EM-6722
Helmholtz Coil Set, 500 Turn.....	EM-6724
Helmholtz Coil Base.....	EM-6715

Complete Coil Set

SF-8617



Includes:

- Coil (200 turn) SF-8609
- Coil (400 turn) SF-8610
- Coil (800 turn) SF-8611
- Coil (1600 turn) SF-8612
- Coil (3200 turn) SF-8613
- U-shaped Core
- E-shaped Core

Basic Coil Set

SF-8616



Includes:

- Coil (200 turn) SF-8609
- Coil (400 turn) SF-8610 (2)
- Coil (800 turn) SF-8611
- U-shaped iron core

These high-quality coils and laminated iron cores provide an effective introduction to electromagnetic theory. Purchase them individually or as a complete set. The coils are color-coded and each coil is labeled with the number of turns and the direction of the winding. Use them to investigate:

Electromagnetism: Show how the magnetic field can be increased by increasing the current, by adding an iron core, or by using a coil with more turns.

Induction: Pass a magnet through a coil and detect the resulting electromotive force (EMF) with a galvanometer. Show how the EMF depends on the number of turns in the coil and on the relative velocity of the magnet and coil.

Transformers: Mount coils onto the U- or E-shaped iron cores to demonstrate mutual inductance and transformer theory. Then connect a load to investigate power transfer. Investigate basic transformer theory with an AC power supply and a voltmeter. Advanced principles require a high power output function generator (Model PI-9587C or PI-9598) and an oscilloscope. For more in-depth experiments and demonstrations, use a computer with PASCO's 850 Universal Interface.

Using the signal generator capability of the 850 Universal Interface and oscilloscope display of PASCO Capstone™ software, students can investigate transformer theory.

Order Information

Basic Coil Set	SF-8616
Complete Coil Set	SF-8617
Individual parts sold separately:	
Coil (200 turn).....	SF-8609
Coil (400 turn).....	SF-8610
Coil (800 turn).....	SF-8611
Coil (1600 turn).....	SF-8612
Coil (3200 turn).....	SF-8613

Primary and Secondary Coils

SE-8653A

- ▶ Study transformer theory with this set of nested coils.
- ▶ Drop a magnet through the outer coil to demonstrate induction.



The secondary coil slides over the primary coil, and the soft iron core slides into either or both, providing a look at magnetic induction and transformer theory. This rugged device is sensitive enough to be used with voltmeters instead of galvanometers. The coils are wound around hollow wooden cores, with a turns ratio of approximately 12 to 1. The primary coil is mounted on a wooden stand.

Specifications:

Outer Coil: 2920 turns; length 11 cm; 2 cm ID

Inner Coil: 235 turns; length 12 cm; 1 cm ID

Soft Iron Core: 0.96 cm diameter

Order Information

Primary and Secondary Coils	SE-8653A
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Economy Coils, Primary and Secondary

SE-8722

Specifications:

Outer Coil: 1100 Turns;

Length 11.4 cm;

Inner Diameter 4.7 cm

Inner Coil: 210 Turns;

Length 10.9 cm;

Inner Diameter 1.7 cm

Iron Core: 1.6 cm diameter

Connections:

Shielded Banana Jacks



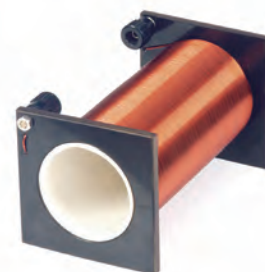
Order Information

Economy Coils, Primary and Secondary	SE-8722
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Air Core Solenoid

SE-7585

This Air Core Solenoid has an inner diameter of 5.5 cm and a length of 14.5 cm, allowing ample room to insert an experimental apparatus into its uniform magnetic field. The maximum current of 5 A produces a 125 Gauss magnetic field.



Order Information

Air Core Solenoid	SE-7585
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Electromagnets

Electromagnet

SE-9655

► Zeeman Effect

This electromagnet has a magnetic field strength up to 1.2 T at a maximum current of 5 A. The sturdy base can be rotated and locked into place for viewing perpendicular and parallel to the magnetic field lines. There is a removable iron core that opens a hole through the pole, allowing for viewing parallel to the magnetic field lines. This electromagnet is suitable for the Zeeman Experiment.

Features:

- 1.2 T magnetic field strength at 5 A
- Approximately 7.4 mm pole gap
- Swivel Base
- Hole in pole allows viewing parallel to the axis of the magnetic field

Specifications:

Maximum Magnetic Field Strength: 1.2 T

Maximum Current: 5 A

Pole Gap: Approximately 7.4 mm

NEW



This electromagnet provides a magnetic field strength up to 1.2 T for the Zeeman Experiment.



Removing the core allows viewing parallel to the magnetic field axis.

Order Information

Electromagnet	SE-9655	
Recommended:		
Tunable DC Power Supply 6A	SE-9656	p. 251
Tesla Meter	SF-7579A	p. 246

Ring Launcher with Accessories

EM-8817

- ▶ Electromagnetic induction
- ▶ Shoots ring 2 meters high
- ▶ Improved design with thermal shutoff

This Ring Launcher has been optimized to maximize safety by enclosing all wiring inside the case. A thermal shutoff switch protects the coil by preventing overheating.

Includes a coil with a bulb that lights by induction when the coil is placed over the launcher core. Also includes five rings: one split aluminum ring that will not launch, one copper ring, one shorter aluminum ring, and two regular length aluminum rings.

A classic demonstration

In this demo, an aluminum ring is propelled straight up by the Lorentz force that arises from the interaction between the alternating magnetic field of the coil and the current induced in the ring.

For great demo ideas using the PASCO Ring Launcher, check out James Lincoln's AAPT video. James explains how the Ring Launcher works and walks you through all the classic demonstrations.

<https://www.youtube.com/watch?v=G0sTOcyhcFM>



Ring Launcher design ideas contributed by Carl Schneider and John Ertel from the U.S. Naval Academy.



Includes:

- Launcher
- Coil with Light Bulb
- Split Aluminum Ring
- Aluminum Ring (2)
- Short Aluminum Ring
- Copper Ring



Lighting a bulb connected to a coil by induction; coil and bulb are included in Ring Launcher Accessories.

Order Information

Ring Launcher with Accessories.....	EM-8817
Also available:	
Ring Launcher	EM-8661
Replacement:	
Ring Launcher Accessories	EM-8662

Electron Charge

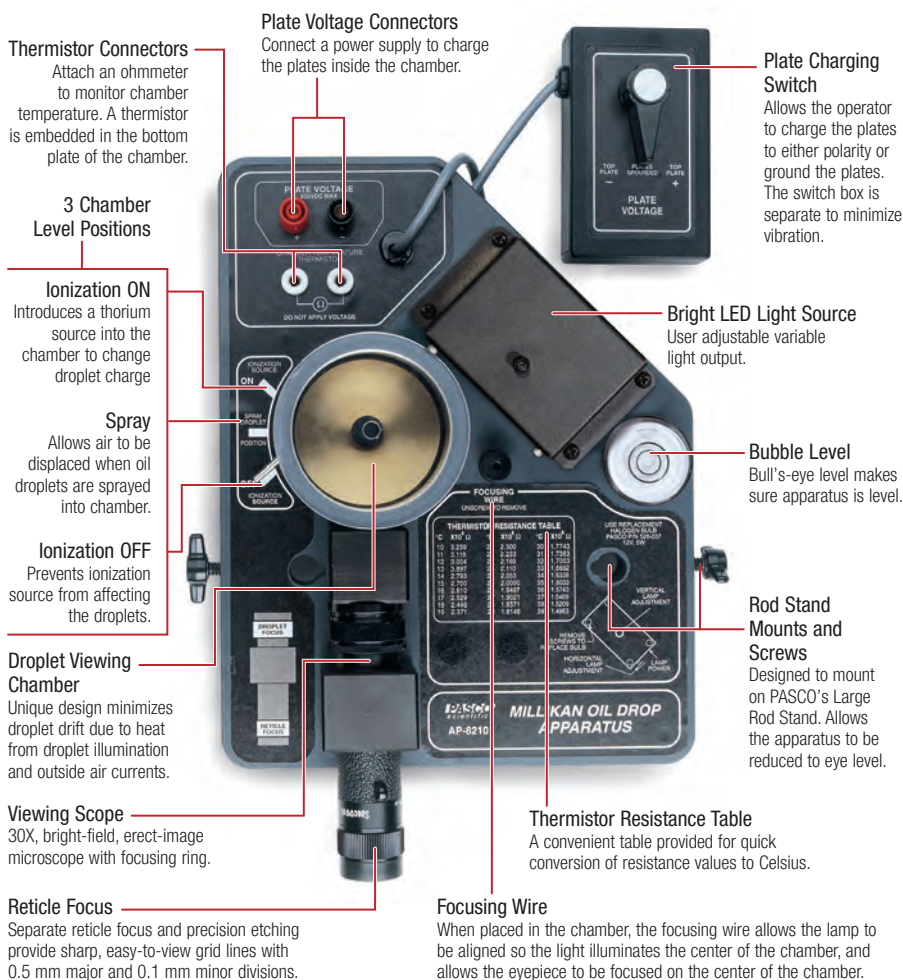
Millikan Oil Drop Apparatus

AP-8210A

- ▶ Nobel Prize-quality physics in the student lab
- ▶ Ionization source for changing droplet charge
- ▶ Measures the charge of an electron to within $\pm 3\%$

The Millikan Oil Drop Experiment is one of the most popular experiments in undergraduate physics for several reasons:

- ▶ The experimental principle is straightforward and easy to understand.
- ▶ It measures a fundamental atomic constant using a method that won its originator, Robert Millikan, the Nobel Prize.
- ▶ The observation of the effects of one or more electrons upon oil drops in an electric field provides a striking demonstration of the quantized nature of electricity.



See complete experiment on page 362



The Millikan Oil Drop Apparatus mounted on a rod stand for easy, eye-level viewing

Specifications:

Maximum Plate Voltage: 500 VDC

Light Source: Cool LED

Reticle Line Separation:

0.5 mm major divisions

0.1 mm minor divisions

Plate Spacing: 7.62 mm

Plate Diameter: 60 mm



Includes:

- Millikan Oil Drop Apparatus with Switch
- Non-volatile Oil and Atomizer
- 12 VDC Lamp Power Adapter

Order Information

Millikan Oil Drop Apparatus	AP-8210A	
Required:		
Basic Digital Multimeter	SE-9786A	p. 230
High Voltage Power Supply	SF-9585A	p. 253
Recommended for mounting unit at eye level on a standard lab table:		
Large Rod Base	ME-8735	p. 186-187
45 cm Stainless Steel Rod	ME-8736	p. 186-187
Complete System:		
Charge of an Electron Experiment	EX-9929A	p. 362
Replacement Parts:		
4 oz Bottles of Mineral Oil (Qty 4)	AP-8211	
Millikan LED Light Source	AP-8212	

Clear droplet observation and low droplet drift are essential for success with Millikan's classic experiment. PASCO's apparatus uses a pre-aligned optical system and special condenser to achieve these conditions.

Accuracy in the Oil Drop Experiment depends on the student's ability to precisely measure all the variables involved: plate voltage, plate separation, time and distance of droplet rise and fall, temperature, oil density, etc. Extreme care taken in the design and manufacture of this unit ensures that the student's best efforts will be rewarded with more accurate results. Typically, a careful student can achieve results within 3% or less of the accepted value.

e/m Apparatus

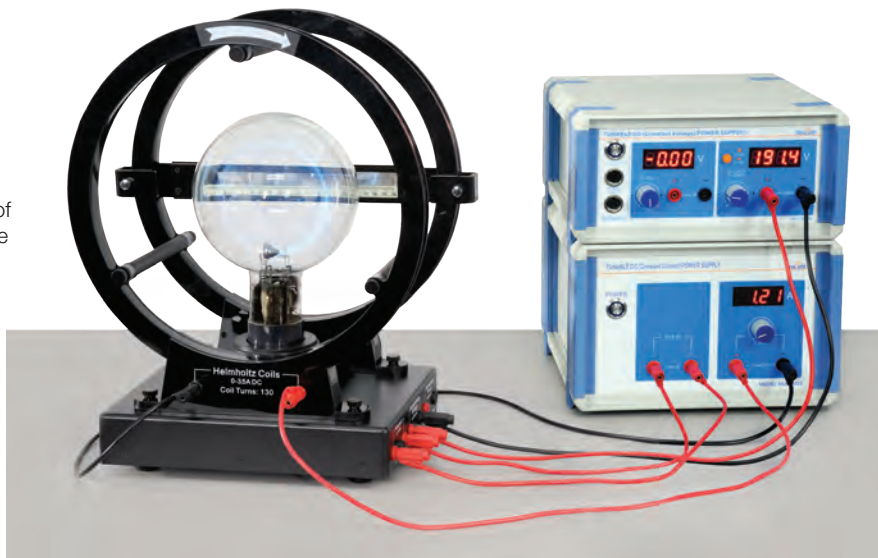
SE-9629

- ▶ Sharp, clearly visible electron beam
- ▶ Phosphorescent mirrored scale eliminates parallax errors
- ▶ Tube rotates for general study of electrons in a magnetic field

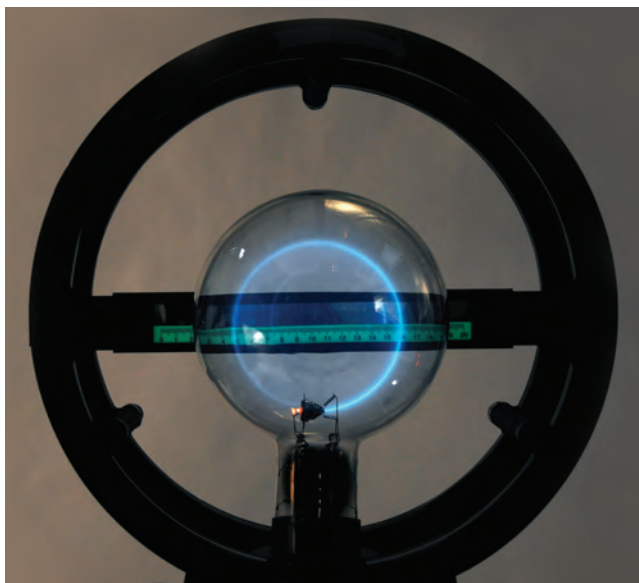
In 1897, J. J. Thomson showed that the mysterious cathode rays were actually negatively charged particles—he had discovered the electron. In the same year he measured the charge-to-mass ratio of the electron, providing the first measurement of one of the fundamental constants of the universe.

The Charge-to-Mass Ratio System reproduces one version of Thomson's landmark experiment, providing an accurate measurement of the charge-to-mass ratio of the electron. And, since the electron tube can be rotated through 90°, students can also make a more general study of the behavior of electrons in a magnetic field.

This apparatus also has deflection plates, so students can study the effect of an electric field on moving electrons.



Complete Charge-to-Mass Ratio System includes the power supplies, which can also be used in other experiments (such as Franck-Hertz experiment, see page 305).



Fluorescent scale shows behind the electron beam in a dark room.

Includes:

- Helmholtz coils for e/m: SE-9626
- Replacement e/m Tube: SE-9651
- Tunable DC Power Supply (Constant Current): SE-9622
- DC Power Supply II (Constant Voltage): SE-9644
- Red and Black Patch Cords

For more information about power supplies, see page 250.

How It Works

A large, helium-filled electron tube is mounted between a pair of Helmholtz coils. The tube contains an electron gun, which generates a focused beam of electrons. A measured current is applied to the Helmholtz coils so that the magnitude of the magnetic field within the electron tube can be calculated. A measured accelerating potential (V) is then applied to the electron gun. The magnetic field (B) deflects the electron beam in a circular path with a radius (r) that is measured using the illuminated mm scale. From these measured values, the charge-to-mass ratio of the electron is calculated:

$$e/m = 2V/B^2r^2.$$

(The details of the calculations are fully described in the manual.)

Specifications:

- Helmholtz Coil Radius:** 16 cm
- Number of Turns:** 130
- Maximum Current:** 3.5 A
- Filament Voltage:** 6.3 VAC
- Acceleration Voltage:** 0 - 200 V
- Tube Diameter:** 15.5 cm

Order Information

e/m Apparatus	SE-9629
If you already have power supplies, you will need:	
Helmholtz coils for e/m	SE-9626
Replacement e/m Tube	SE-9651
Replacement Parts:	
Replacement Mirror Scale for e/m Apparatus	SE-9649

Ampere's Law

Ampere's Law Accessory

EM-6720

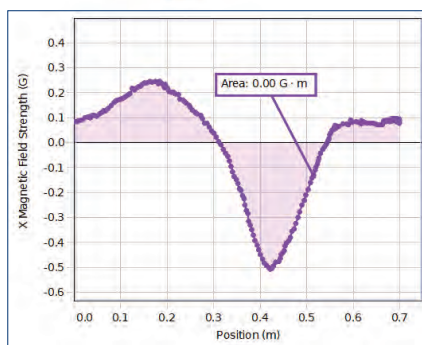
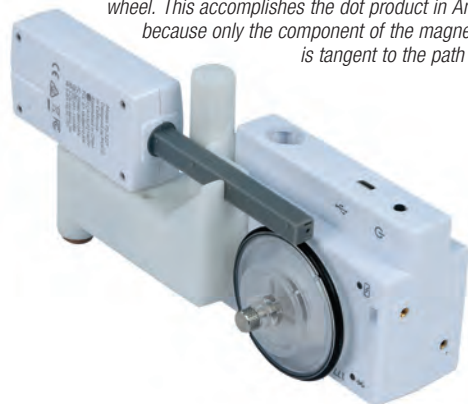
- ▶ Verify Ampere's Law
- ▶ Plot magnetic field tangent to path
- ▶ Closed integral is area under B vs. Distance plot
- ▶ Choose to enclose current in path or not

Students can verify Ampere's Law experimentally by graphing the magnetic field strength that is tangent to the path taken along a closed path that encloses a current source.

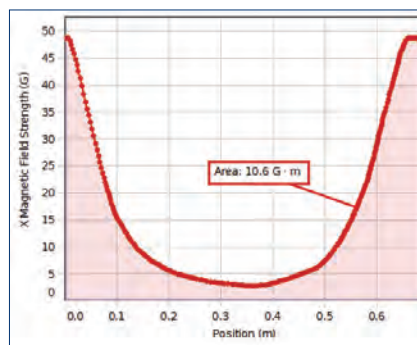
The magnetic field strength is measured with a Wireless Magnetic Field Sensor which rides on a Rotary Motion Sensor. The student pushes the Rotary Motion Sensor, which rolls on its wheel, along a closed path.

If you traverse a path that does not enclose any current source, the area under the curve is zero. The magnetic field of the Earth or any nearby source is measured, but they will cancel out in a closed loop that encloses no current.

The key to making this work is that the Magnetic Field Sensor element is positioned tangent to the Rotary Motion Sensor's wheel. This accomplishes the dot product in Ampere's Law because only the component of the magnetic field that is tangent to the path is recorded.



No current enclosed: Area is zero.



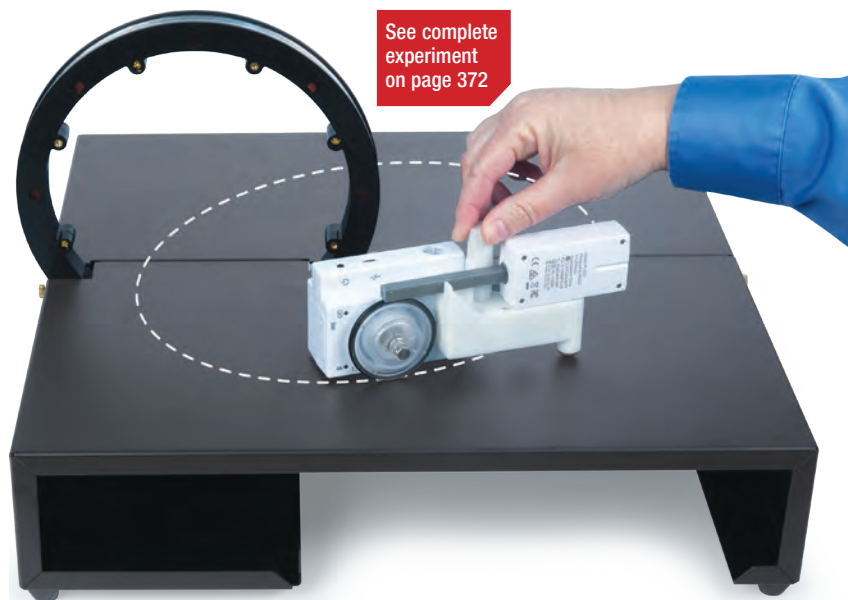
Current enclosed: Area is $\mu_0 NI$.

Includes:

- Aluminum Table (46 cm x 46 cm x 11 cm)
- Sensor Bracket



See complete experiment on page 372



The Wireless 3-Axis Magnetic Field and Rotary Motion sensors allow students to move in any shaped path without wires getting wrapped around the coil. Students can choose any path they want; you don't have to follow a circular path because the sensors are recording the field tangent to any path.

Ampere's Law

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 NI$$

Area under B vs. Distance curve = μ_0 (# of coil turns enclosed in path) (Current)

Order Information

Ampere's Law Accessory	EM-6720	
Required:		
Wireless Magnetic Field Sensor	PS-3221	p. 56
Wireless Rotary Motion Sensor	PS-3220	p. 51
500-Turn Field Coil	EM-6723A	p. 236
PASCO Capstone Software		p. 68-71

Basic Current Balance

SF-8607

- ▶ Measure Force vs. Current, Wire Length, Magnetic Field and Angle
- ▶ Use a Gram Balance to Measure Force

One to six magnets are mounted on an iron yoke, which is placed on a gram balance. A conductor is suspended between the magnets. The weight of the magnets and yoke is measured, then a current (0-5 A) is passed through the conductor. The change in the reading of the balance (0-4 grams) measures the force between the conductor and the magnetic field.



Basic Current Balance
measuring the force on a current-carrying wire in a magnetic field

Six conductors of different lengths are provided and can be easily changed while maintaining a repeatable position with respect to the magnetic field.



Includes:

- Iron Yoke (holds magnets)
- Removable Magnets (6)
- Conductors (6)
(1, 2, 3, 4, 6 and 8 cm in length)
- Mount (to hold position conductors)

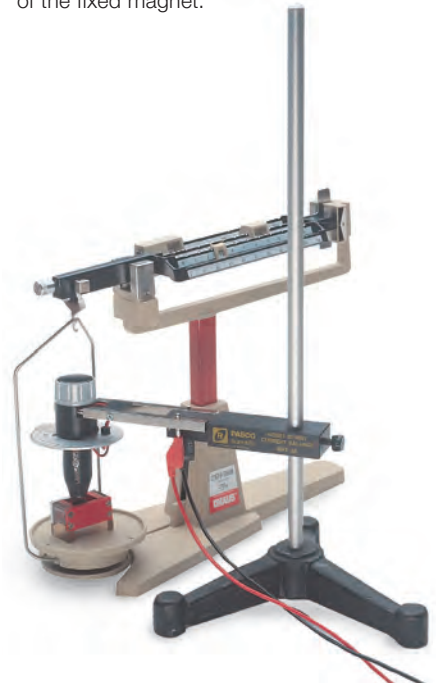
Order Information

Basic Current Balance.....	SF-8607	
Required:		
Ohaus Cent-O-Gram Balance.....	SE-8725	p. 196
Low Voltage AC/DC Power Supply	SF-9584B	p. 254
Base and Support Rod	ME-9355	p. 187
Recommended:		
Basic Digital Multimeter.....	SE-9786A	p. 257
Tesla Meter.....	SF-7579A	p. 246
Shown in use with:		
2 Meter Patch Cord Set.....	SE-9415A	p. 228

The Current Balance Accessory Kit

SF-8608

This kit completes the Basic Current Balance, allowing the angle between the conductor and the magnetic field to be varied. The experiment is the same as with the Basic Current Balance, but a 10-turn rectangular coil is used. The coil can be turned through a full 180°, and a built-in degree scale lets students accurately measure the angle between the coil and the field of the fixed magnet.



Includes:

- Fixed Magnet with Yoke
- 10-turn Rectangular Coil

Order Information

The Current Balance Accessory Kit.....	SF-8608
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Superconductivity

Superconductor Magnetic Levitation

These high-temperature superconductors conduct electricity without energy loss when cooled to liquid nitrogen temperature (77 K). Because a superconductor expels external magnetic fields by forming surface currents, which cancels the external field, it will levitate above a magnet.

Mini MagLev Pro

SE-7720



- ▶ Demonstrate superconducting levitation
- ▶ Levitating superconductor glides around the circular magnetic track



Experience Quantum Levitation with this portable, lightweight, and easy-to-use MagLev track. The track uses super-strong NdFeB magnets in a unique double-ring design to achieve maximum levitation height. The included handheld magnetic device (Starter Kit) can be passed around for a captivating hands-on experience. Please note that this product requires liquid nitrogen.



Demonstrate frictionless motion in both levitation and suspension.



Includes:

- Round MagLev track (diameter 40 cm, 15.7 in)
- Wooden stand
- Medium Standard Superconductor
- Medium Enhanced Superconductor
- MagLev Starter Kit
- User manual

Order Information

Mini MagLev Pro..... SE-7720
 Required:
 Liquid Nitrogen
 Recommended:
 Wireless Force
 Acceleration Sensor PS-3202

Magnetic Levitation

SE-7721

- ▶ Perfect for large science demonstrations
- ▶ Undergraduate and high school experiments in quantum physics
- ▶ Science museums



The 72 cm diameter Magnetic Levitation kit is perfect for large audience demonstrations at science museums, science fairs and student classes. The circular frictionless motion never ceases to amaze. The kit is supplied with large and medium Quantum Levitators, which can be levitated simultaneously in a double levitation configuration. Both suspension below the track and levitation above it can be demonstrated. A handheld magnetic device (MagLev Starter Kit) is included for a complete experience. Please note that this product requires liquid nitrogen.

Includes:

- Round MagLev Track (diameter 72 cm, 28 in)
- Stand
- Standard Medium and Large Superconductors
- MagLev Starter Kit
- User and experiment manual

Order Information

Magnetic Levitation SE-7721
 Required:
 Liquid Nitrogen
 Recommended:
 Wireless Force
 Acceleration Sensor PS-3202

MagLev Starter Kit

SE-7732



The MagLev Starter Kit is the most fundamental entry level for classroom demonstrations of quantum levitation and flux pinning. Perfect for high school students as well as university undergraduates, the kit is easy to use, highly durable and portable. Use the rectangular magnetic setup to witness the quantum locking phenomena and the round magnetic setup to demonstrate frictionless motion. When used with a force sensor, the handheld magnetic device serves as a unique experimentation platform where quantum phenomena such as the Meissner effect and flux pinning can be investigated. Please note that this product requires liquid nitrogen.



Includes:

- Standard Medium Superconductor
- Starter Magnetic Kit
- Plastic tweezers
- User manual

Order Information

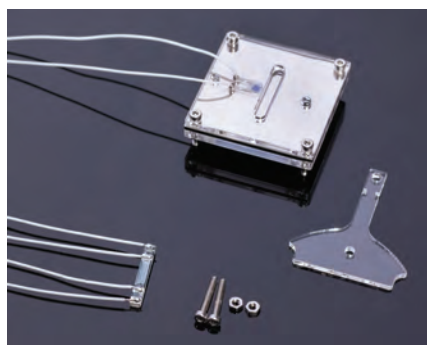
MagLev Starter Kit..... SE-7732
 Required:
 Liquid Nitrogen
 Recommended:
 Wireless Force
 Acceleration Sensor PS-3202

4-Point Wired Superconductor

SE-7734



Measuring the transition temperature of superconductors is one of the basic and most educational experiments in superconductivity and is now available to students with an easy and instructive experiment that is on par with state-of-the-art scientific research. The 4-Point Wired Superconductor includes a superconducting Bi-2223 bar with four wires attached to it. Students can experiment with 4-wire and 2-wire resistance measurements and learn how to measure the critical temperature of superconductors. The superconductor is thermally attached to a metallic plate to which a Pt100 resistance thermometer is also attached. Please note that this product requires liquid nitrogen.



Includes:

- Replaceable Bi-2223 superconductor bar with attached 4-wire set
- Thermal base with Pt100 RTD thermometer
- Perspex® handle
- User manual

Order Information

4-Point Wired Superconductor SE-7734

Required:
Liquid Nitrogen

MagLev Outreach Set

SE-7733



QUANTUM LEVITATION

This is the ultimate outreach package for quantum levitation and quantum locking. This set contains portable, easy-to-use experiments that can be used outside the lab and allow a hands-on experience with quantum levitation. Please note that this product requires liquid nitrogen.



Includes:

- Round MagLev track (diameter 40 cm, 15.7")
- Wooden stand
- DIY MagRail track
- Handheld magnetic device
- Standard Superconductors (2 medium, 1 large)
- Plastic tweezers
- User manual

Order Information

MagLev Outreach Set SE-7733

Required:
Liquid Nitrogen



Powered by
THEVA
www.theva.com



Superconducting Levitators

These superconducting levitators are easy to use and highly durable.

They are provided with a 6 month, no-questions-asked warranty.

Standard Superconductors

The Standard Superconductors are able to carry only their own weight plus liquid nitrogen.

Enhanced Superconductors

The Enhanced Superconductors, having extra superconducting material, are able to carry a light weight (< 200 g) when used in conjunction with a suitable magnetic setup or track.

Extended Duration Superconductors

The Extended Duration Superconductors offer the optimal balance between levitation strength and levitation time.

These new levitators offer two- to three-times longer levitation times compared to the standard ones.

Order Information

Standard Medium Superconductor SE-7735

Standard Large Superconductor SE-7736

Enhanced Medium Superconductor SE-7737

Enhanced Large Superconductor SE-7738

Extended Duration Medium Superconductor SE-7741

Extended Duration Large Superconductor SE-7742

Magnetism Supplies

Horseshoe Magnet

SF-7225



This Alnico Horseshoe Magnet includes a steel keeper.

Dimensions: 8.0 x 12.5 x 3.0 cm

Field Strength: 600 gauss at pole surface

Order Information

Horseshoe Magnet..... SF-7225

Bar Magnets (2 Pack)

SE-8604

These cylindrical magnets (10 x 50 mm) are small, strong, and color-coded for polarity. Plastic case and keeper plates included.



Order Information

Bar Magnets (2 Pack)..... SE-8604

Tesla Meter

SF-7579A

- ▶ 0–2 Tesla range
- ▶ Range autoscaling

A 6–12 V DC power supply is required to use the Tesla Meter.

Specifications:

Resolution: 0.1 mT (0 – 200 mT)
1 mT (200 mT – 2T)

Accuracy: $\pm 5\%$ of measurement



Cow Magnet (Pair)

SE-7722



These strong smooth magnets are convenient for showing magnetic induction by moving one through a coil connected to an ammeter. As the name suggests, the primary purpose of these magnets is to collect metal objects in a cow's first stomach to prevent internal damage.

Length: 7.5 cm

Field Strength: 1400 gauss at pole surface

Order Information

Cow Magnet (Pair) SE-7722

Alnico Bar Magnets (2 Pack)

EM-8620



These magnets (150 x 13 mm) are stronger and last longer than iron magnets. They fit a St. Louis motor and the north poles are notched. Case included.

Order Information

Alnico Bar Magnets (2 Pack)EM-8620

Neodymium Magnets, 16 Pack, solid

EM-8648B

Neodymium magnets are some of the strongest commercial magnets available. Also available with a protective coating to prevent the brittle metal from chipping (EM-8621).

Size: 13 mm dia. x 5 mm

Plastic case included.



WARNING
This product contains small magnets. Swallowed magnets can stick together across intestines causing serious infections and death. Seek immediate medical attention if magnet(s) are swallowed or inhaled.

Order Information

Neodymium Magnets, 16 Pack, solidEM-8648B

Zero Gauss Chamber

EM-8652



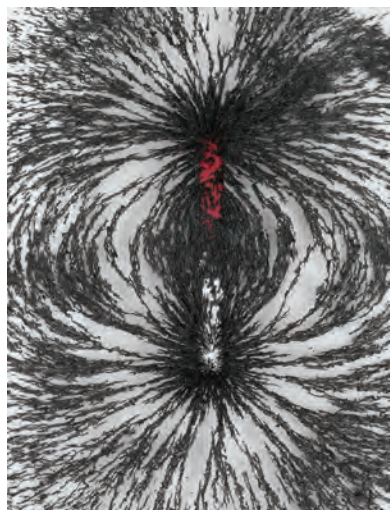
This double-walled, high permeability metal chamber produces a zero gauss field within the chamber. By placing the Magnetic Field Sensor probe into the chamber and pushing the "Tare" button, the sensor may be zeroed. Highly recommended for measurement of Earth's magnetic field.

Order Information

Zero Gauss Chamber EM-8652

Iron Filings (1 lb)

SE-7723



Iron filings sprinkled over a bar magnet instantly make the magnetic field visible.



Order Information

Iron Filings (1 lb) SE-7723

3-D Magnetic Field Demonstrator

SE-8603



(Magnet not included.)

The 3-D Magnetic Field Demonstrator suspends iron filings in oil within a sealed acrylic container. Magnet(s) are inserted into the 10 mm, causing the filings to create magnetic field lines. The demonstration can be viewed directly or with an overhead projector.

Order Information

3-D Magnetic Field DemonstratorSE-8603
 Recommended:
 Bar Magnets (2 Pack).....SE-8604 p. 246

Liquid-Filled Compasses (5 Pack)

EM-8631A



This compass is perfect for investigating the magnetic fields around straight wires. It has a 4.5 cm diameter liquid-filled plastic case and a 2.5 cm long needle with the north end marked in red.

Order Information

Liquid-Filled Compasses (5 Pack) EM-8631A
 Replacement part for CASTLE Kits (EM-8624A and EM-8654)

Plotting Compass Set (20 Pack)

SE-8680



(Appearance may vary.)

This Plotting Compass provides an economical way to conduct magnetism labs. Includes 20 compasses marked in red with North-South and East-West lines. Students can place several compasses around a bar magnet and draw the magnetic field lines. Each compass has a diameter of 19 mm.



Order Information

Plotting Compass Set (20 Pack)SE-8680

Magnaprobe

SE-7390



The Magnaprobe is a great way to demonstrate the 3-D nature of magnetic fields. The probe features a gimbal-mounted Alnico magnet, which is free to move in the x, y, and z dimensions. Suggested activities are included with each probe.

Magnaprobe is 12 cm long.



Order Information

Magnaprobe SE-7390

Dip Needle

SF-8619



This rotatable compass has durable and almost frictionless bearings. Use it horizontally as a standard compass or vertically to find the dip angle of the Earth's magnetic field. Instruction sheet included.

Order Information

Dip Needle SF-8619

Magnetism Supplies

Painted Bar Magnet (Pair)

SE-7593



This pair of AlNiCo bar magnets are perfect for studies of magnetism, magnetic polarity, and magnetic field strength. Both magnets are coated with red and blue paint, each color indicating the polarity of that part of the magnet. Bar magnet dimensions: 75 mm x 11.2 mm x 6.1 mm.

Specifications:**Dimensions:** 75 mm x 11.2 mm x 6.1 mm**Material:** AlNiCo**Order Information**

Painted Bar Magnet (Pair) SE-7593

NEW

Laplace Force Demo with Magnet

SF-7279

- ▶ Demonstrates the forces on a current-carrying wire in a magnetic field



When the conducting rod is placed on the rails and a current (maximum 10 A) runs through the rails, the rod will be affected by a force, making it roll perpendicular to the magnetic field along the rails. The apparatus consists of a pair of rails with 4 mm diameter terminals. The conductor consists of a bar with plastic discs that is placed across the rails. The included alnico Horseshoe Magnet (SF-7225) is used as a magnet.

Product Rails: 15.5 cm long; 5 cm apart**Includes:**

- Laplace Force Demonstration (SF-7261)
- Horseshoe Magnet (SF-7225)

Order Information

Laplace Force Demo with Magnet SF-7279

Required:

Power Supply (18 VDC, 5 A)..... SE-9720A p. 252

Banana Cords

Available separately:

Laplace Force Demonstration SF-7261

(Includes rails and moveable conductor shown above; magnet not included.)

Horseshoe Magnet..... SF-7225

Horseshoe Magnet

SF-7225



This Alnico Horseshoe Magnet includes a steel keeper.

Dimensions: 8.0 x 12.5 x 3.0 cm**Field Strength:** 600 gauss at pole surface**Order Information**

Horseshoe Magnet..... SF-7225

Lenz's Law Demonstrator

MG-8600

Magnet 6 cm long
19.8 mm OD

1.5 meter tube

Drop a mass through the 1.5 m tube. It takes about half a second to drop. Then drop a magnet with an identical mass. It takes over 10 times as long to fall. As the magnet falls, it generates a current in the tube, moving in one direction above the magnet and in the opposite direction below. Both currents obey Lenz's Law and induce magnetic fields that oppose the magnet's motion. See the difference in time as the magnet falls through the tube.

Includes:

- Lenz's Law Magnet
- Unmagnetized Slug
- 1.5 m Aluminum Tube (2 cm ID, 0.28 cm wall)
- 10-turn Rectangular Coil
- Attachment Bracket for Spring Scale
- Ohaus Spring Scale 10N

Order Information

Lenz's Law DemonstratorMG-8600

Digital LCR Meter

SE-8792

Measure inductance, capacitance, and resistance. Test leads are included, along with a battery, a protective holster, and a manual.



Features:

- ▶ **Accuracy:** 1% or better on most ranges
- ▶ **Easy to Use:** Push-button selection for all measurements
- ▶ **Digital Display:** 4-1/2 digit backlit LCD
- ▶ **Built-in Tilt Stand:** For convenient tabletop use
- ▶ **Built-in RS232:** with optional Windows compatible software

Specifications:

Inductance: 2000.0 μ H, 20.000 mH, 200.00 mH, 2000.0 mH, 20.000 H, 200.00 H, 20.000 H ($\pm 0.7\%$ rdg + Lx/10000 + digit)

Capacitance: 2000.0 pF, 20.000 nF, 200.00 nF, 2000.0 nF, 20.000 μ F, 200.00 μ F, 2000.0 μ F ($\pm 0.7\%$ rdg + 5 digit)

Resistance: 20.000 Ω , 200.00 Ω , 2.0000 k Ω , 20.000 k Ω , 200.00 k Ω , 2.0000 M Ω , 20.000 M Ω ($\pm 0.5\%$ rdg + 8 digit)

Power: 9 V alkaline battery (included)

Accessories: Test leads (2), alligator clips (2), protective holder

Order Information

Digital LCR Meter..... SE-8792

Heavy-Duty Voltmeter

SF-9568A

The Voltmeter has three ranges and is switch-selectable to measure AC or DC voltages.



Specifications:

DC Ranges: 0 to 3 V/15 V/30 V

AC Ranges: 0 to 3 V/15 V/30 V

Accuracy: $\pm 2\%$

Sensitivity: 10 k Ω /V

Order Information

Heavy-Duty Voltmeter SF-9568A

Decade Capacitance Box

SE-8689



This Decade Capacitance Box supplies five decades of capacitance from 100 pF to 11.111 μ F in 100 pF steps. Add or subtract capacitance with slide switches. Three color-coded binding posts provide reliable connections.

Specifications:

Accuracy: $\pm 5\%$

Maximum Voltage: 50 VDC

Order Information

Decade Capacitance Box SE-8689

Heavy-Duty Ammeter

SF-9569A

The Ammeter has three ranges and is switch-selectable to measure AC or DC values. All ranges are overload-protected up to 15 amps.



Specifications:

DC Ranges: 0 to 50 mA/500 mA/5 A

AC Ranges: 0 to 50 mA/500 mA/5 A

Accuracy: $\pm 2\%$

Order Information

Heavy-Duty Ammeter..... SF-9569A

Decade Resistance Box

SE-7124



Resistance is plainly displayed with this six-decade resistance box since a rotary switch selects the resistance within each decade. With 1% accuracy and 1/2 W resistor, it will accommodate most student experiments.

Specifications:

Resistance:

0 to 1, 111, 110 Ω in 1 Ω increments

Accuracy: $\pm 1.0\% \pm 0.1 \Omega$

Power Dissipation: 1/2 W resistors

Order Information

Decade Resistance Box..... SE-7124

Heavy-Duty Galvanometer

SF-9500A

A "push-to-read" switch protects the galvanometer during hookup by shunting the current through an equivalent resistor.



Specifications:

Current Ranges: 50 μ A/500 μ A/5 mA

Internal Resistance: 1.5 k Ω /170 Ω /17 Ω

Accuracy: $\pm 2\%$

Order Information

Heavy-Duty Galvanometer SF-9500A

Power Supplies

Power Supplies and a Current Amplifier for Advanced Physics Experiments

The power supplies and instruments on this page are used in various advanced physics experiments involving finding fundamental constants (Photoelectric Effect, Franck-Hertz, and e/m). Since each experiment uses some combination of these, it is possible to purchase one of each to perform all three experiments, one at a time.

Connect to a 550 or 850 Interface:

These instruments can be used stand-alone by reading the digital displays. However, they have special data collection ports that connect a 550 or 850 Universal Interface (see pp. 26-28) to record data and analyze it in PASCO Capstone. Each type of voltage and current reading is automatically identified when the power supply is connected to a 550 or 850 analog port with the special cable (included).

Experiment	DC Power Supply I	DC Power Supply II	DC (Constant Current) Supply	DC Current Amplifier
Photoelectric Effect (page 300)	X			X
Franck-Hertz (page 297)	X	X		X
e/m (page 299)		X	X	

Order Information

Analog 8-Pin DIN Extension
Male-to-Male Adapter UI-5219

DC Power Supply I (Constant Voltage)

SE-6615

- ▶ 0 to 6.3 V DC, 1 A maximum
- ▶ -4.5 to 0 V DC, 10 mA maximum
- ▶ -4.5 to 30 V DC, 10 mA maximum

The (0 to 6.3 V) output is independent of the (-4.5 to 0 V) and (-4.5 to 30V) outputs, which share an output and are selected by pushing a button.



Specifications:

Independent floating ground reference

Ripple: <1%:

Includes:

- Includes cords to connect to the 550 and 850 Interfaces.

Order Information

DC Power Supply I (Constant Voltage) SE-6615

Tunable DC Power Supply (Constant Current)

SE-9622

- ▶ 0 to 3.5 A DC, 20 V maximum
- ▶ Fixed 6.3 V AC, 1 A maximum



This constant current power supply has a digital readout for the current, which can be tuned from 0 to 3.5 A DC. It also has a 6.3 V AC power supply for heating filaments. A High Current Sensor (PS-2193 or CI-6740) can read the current when using this power supply with interfacing experiments. Both DC and AC outputs are available simultaneously on separate floating output terminals.

Order Information

Tunable DC Power Supply (Constant Current) SE-9622

DC Power Supply II (Constant Voltage)

SE-9644

- ▶ 0 to 12 V DC, 1 A maximum
- ▶ 0 to 100 V DC, 30 mA maximum
- ▶ 0 to 200 V DC, 30 mA maximum

The (0 to 12 V) output is independent of the (0 to 100 V) and (0 to 200V) outputs, which share an output and are selected by pushing a button.



Specifications:

Independent floating ground reference

Ripple: <1%:

Includes:

- Includes cords to connect to the 550 and 850 Interfaces.

Order Information

DC Power Supply II (Constant Voltage) SE-9644

DC Current Amplifier

SE-6621

- ▶ Measures picoamp currents
- ▶ Six ranges from 10^{-8} A to 10^{-13} A

DC Current Amplifier designed for Franck-Hertz and Photoelectric Effect experiments.



Specifications:

Maximum Voltage Input: 15 V

Zero drift: $\leq 0.2\%$ of full range 10^{-13} A after 30 min.

Includes:

- Includes cords to connect to the 550 and 850 Interfaces.

Order Information

DC Current Amplifier SE-6621

Tunable DC Power Supply 6A

SE-9656

- ▶ Used in Zeeman Effect experiment
- ▶ Can be used in the e/m experiment to power the coils
- ▶ Maximum current of 6 A



The Tunable DC Power Supply supplies power to the pen-type mercury lamp and the electromagnet (SE-9655) in the Zeeman Effect Apparatus (SE-9654). The output for the mercury lamp is 1500 V AC and the output for the electromagnet is zero to 6 A with a maximum voltage of 36 V DC.

Specifications:

AC Output: Fixed 1500 V, maximum current 145 mA

DC Output: Constant current adjustable from zero to 6 A

Maximum voltage: 36 V

Extra fuse included: 250 V T5A

DC Programmable Power Supply

PI-9880

- ▶ 1 A at 18 VDC
- ▶ Digital display
- ▶ Ramp or step positive voltage up or down

Power Output
Standard banana jacks allow the DC Power Supply to be easily connected to circuits.

Indentations
For stacking during storage

Red LEDs make the display easy to read.

Provides a current of 1 A at 18 V, with a resolution of 0.01 V and typical ripple of 10 mV. This DC power supply has added features to cycle the voltage on and off, to ramp the voltage up or down between the maximum and minimum set, and to change the voltage in steps. A positive offset can be introduced so the ramp can start at a voltage other than zero. Minimum period is 0.1 sec (10 Hz) and the maximum period is 999 seconds.

The digital display has four digits (0.76 cm high) and can display voltage, current, or time. The time is displayed to set the period, duration, or duty cycle.

There are both coarse and fine adjustment knobs. As a safety factor, a maximum current and a maximum voltage can be set to protect your students' external circuits. The output is voltage-regulated but not current regulated.

The power supply is connected to AC power using a universal power adapter.



Display Selection
Current, voltage, cycle time; green LED indicates which measurement has been selected.

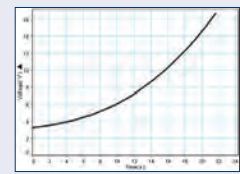
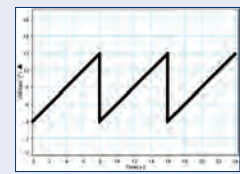
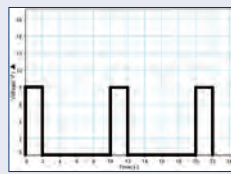
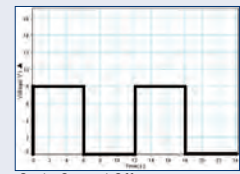
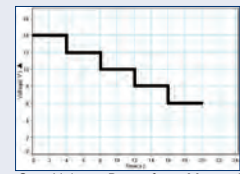
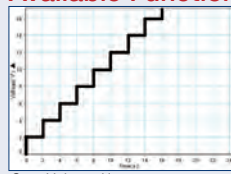
Start/Stop

Cycle
Choice of steps, ramps, or cycle on and off.

Amplitude Adjustment
Sets maximum current, voltage, and cycle period.

Small and lightweight; 12 cm x 13 cm x 5.5 cm high and approximately 300 g.

Available Functions:



Includes:

- DC Power Supply
- Universal Power Adapter



Order Information

DC Programmable Power Supply.....PI-9880

Order Information

Tunable DC Power Supply 6ASE-9656

DC Power Supplies

Power Supply (18 VDC, 5 A)

SE-9720A

- ▶ 0-18 VDC at 0-5 A
- ▶ Serial and parallel operation



This power supply has a remote control connector and switch on the rear panel, so units can be connected in series or parallel with each other to provide higher voltage, higher current, and higher power output.

Specifications:

Digital Meters: Voltage and current; LED

Constant Voltage Output: continuously variable, coarse and fine control

Constant Voltage Line Regulation:
 $\leq 0.01\% \pm 3 \text{ mV}$

Constant Voltage Load Regulation:
 $\leq 0.01\% \pm 3 \text{ mV}$

Constant Voltage Ripple and Noise:
 $\leq 0.5 \text{ mVrms}$

Constant Current Output: continuously variable, coarse and fine control

Constant Current Line Regulation:
 $\leq 0.02\% \pm 3 \text{ mA}$

Constant Current Load Regulation:
 $\leq 0.02\% \pm 3 \text{ mA}$

Constant Current Ripple and Noise:
 $\leq 3 \text{ mArms}$

Power Source: AC 100, 120, 220, 240 V $\pm 10\%$, 50/60 Hz; Protection – overload and reverse polarity protected

Dimensions: 29 x 13 x 15 cm (5.5 kg)

Includes:

- Instruction Manual
- Test Lead

Order Information

Power Supply
(18 VDC, 5 A).....SE-9720A

Student Power Supply, 18 VDC, 3 A

SE-8828

- ▶ 0-18 VDC at 0-3 A
- ▶ Constant voltage or current
- ▶ Short-circuit protected
- ▶ Current limiting
- ▶ Low noise/ripple



This high-quality, compact power supply provides the DC voltage and current levels necessary for most introductory student labs.

Specifications:

Digital Meters: Voltage and current; Backlit LCD

Constant Voltage Output: continuously variable

Constant Voltage Line Regulation:
 $< 0.01\% \pm 3 \text{ mV}$

Constant Voltage Load Regulation:
 $< 0.01\% \pm 2 \text{ mV}$

Constant Voltage Ripple and Noise:
 $< 0.5 \text{ mVrms}$

Constant Current Output: continuously variable

Constant Current Line Regulation:
 $< 0.2\% \pm 3 \text{ mA}$

Constant Current Load Regulation:
 $< 0.2\% \pm 3 \text{ mA}$

Constant Current Ripple: $< 3 \text{ mArms}$

Power Source: AC 100, 120, 220, 240 V $\pm 10\%$, 50/60 Hz; Protection – overload and reverse polarity protected

Dimensions: 34 x 26 x 15 cm (11.5 kg)

Order Information

Student Power Supply
(18VDC, 3A)SE-8828

Triple Output Power Supply

SE-8587

- ▶ 0-30 VDC at 0-3 A
- ▶ Digital Voltage and Current Meters



This power supply offers adjustable voltage output (0-30 V), adjustable current output (0-3 A), and two independent constant voltage outputs (5 V and 12 V) with easy snap terminals. Digital displays of both current and voltage allow students to easily gather data. Features overload and short-circuit protection.

Specifications:

Digital Meters: Voltage and current; 3 digits; LCD

Constant Voltage Output: continuously variable

Constant Voltage Line Regulation:
 $\leq 0.05\% \pm 10 \text{ mV}$

Constant Voltage Load Regulation:
 $\leq 0.05\% \pm 10 \text{ mV}$

Constant Voltage Ripple and Noise:
 $\leq 0.5 \text{ mVrms}$

Constant Current Output: continuously variable

Constant Current Line Regulation:
 $\leq 0.05\% \pm 10 \text{ mA}$

Constant Current Load Regulation:
 $\leq 0.05\% \pm 10 \text{ mA}$

Constant Current Ripple and Noise: $\leq 3 \text{ mArms}$

Fixed Output Voltage: 5 V at 0.5 A continuous; 1 A max. 12 V at 0.5 A continuous; 1 A max.

Power Source: AC 110/220 VAC, 50/60 Hz

Dimensions: 29 x 13 x 15 cm (5.5 kg)

Order Information

Triple Output
Power Supply.....SE-8587

Power Supply (30 VDC, 6 A)

SE-9721B

- ▶ 0-30 VDC at 0-6 A
- ▶ 0.01% high regulation
- ▶ Constant voltage or current



This single output linear DC power supplies is suitable for high-end precision bench top applications. Low load and line regulation for both constant voltage and constant current mode ensure reliable, predictable output. Overload and reverse polarity protection as well as internal selection for dynamic or constant load are standard.

This power supply has a built-in digital panel control design to replace conventional control method.

Specifications:

Output Voltage: 0 to 30 VDC

Output Current: 0 to 6 A

Constant Voltage Operation:

Line Regulation $\leq 0.01\% + 3 \text{ mV}$

Constant Voltage Operation:

Load Regulation $\leq 0.01\% + 3 \text{ mV}$
(rating current $\leq 3\text{A}$); $\leq 0.02\% + 5 \text{ mV}$
(rating current $\leq 3\text{A}$)

Constant Voltage Operation:

Ripple & Noise $\leq 1 \text{ mVrms}$ (5Hz-1MHz)

Constant Voltage Operation:

Recovery Time $\leq 100\mu\text{s}$
(50% Load Change, minimum load 0.5A)

Constant Current Operation:

Line Regulation $\leq 0.2\% + 3 \text{ mA}$

Constant Current Operation:

Load Regulation $\leq 0.2\% + 3 \text{ mA}$

Product Constant Current Operation:

Ripple & Noise $\leq 3 \text{ mArms}$

Dimensions: 210(W)x 155(H) x 306(D) mm

Product Mass: Approx. 7kg

Includes:

- Instruction Manual
- Test Lead

Order Information

Power Supply
(30 VDC, 6 A).....SE-9721B

High Voltage Power Supply

SF-9585A

- ▶ 0 to 50 VDC at up to 50 mA
- ▶ 0 to 500 VDC at up to 50 mA
- ▶ 2 to 7 VAC at up to 3 A



Appearance may vary.

Here is a versatile and reliable supply for experiments requiring medium to high voltages at relatively low currents, such as the Millikan Oil Drop experiment. The 50 and 500 VDC outputs are independently variable, providing up to 50 mA, and the output displays can be switch-selected to read voltage and current in either range. A separate set of output terminals provides 2, 4, 5, 6 and 7 VAC at up to 3 A, a convenient source for electron tube filaments.

Note: The positive terminal of the 50 V supply is internally connected to the negative terminal of the 500 V supply.

Specifications:

Ripple: Less than 0.1%, ± 1 digit line

Regulation: $< 1\%$ at 98-130 V (line voltage)

Load Regulation: $< 1\%$ at 0-100% load

Displays: Digital readouts 0-50 V, 0-500 V,
0-50 mA (switch-selectable)

Power Source: 115/220 VAC, 50/60 Hz

Dimensions: 21 x 29 x 11 cm
(8 x 12 x 4 in.)

Order Information

High Voltage
Power Supply.....SF-9585A

Kilovolt Power Supply

SF-9586B

- ▶ 0 to 6 kVDC
- ▶ 6.3 VAC, 2 A filament source
- ▶ Digital readout



Appearance may vary.

This Kilovolt DC Power Supply is used for electron tubes and electrostatics.

The high voltage section is by design "floating" relative to ground. This means that either the black (negative) terminal or the red (positive) terminal may be connected to ground to give a voltage range of 0 to +6 kV, resp. 0 to -6 kV relative to ground.

The output is well regulated, and the current is limited for safety.

(The maximum short circuit current is 2 mA).

Specifications:

DC – Output Voltage: 0-6 kV stabilized,
continuously adjustable

Short Circuit Current: 2 mA (max.)

Ripple and Noise (max.): less than 1%

Readout Accuracy: better than 1%
+ 1 digit

AC – Output Voltage: 6.3 V

Output Current (max.): 3 V

Dimensions: (W x D x H)
312 x 225 x 117 mm

Order Information

Kilovolt Power Supply SF-9586B
Recommended:
High Voltage
Patch Cord Set..... SE-9269

AC/DC Power Supplies

**AC/DC Power Supply
(12V, 3A)**

SF-9581

- ▶ Combined DC and AC supply at a low price
- ▶ Stabilized, continuously adjustable DC: 0 to 12 V
- ▶ AC presets: 2, 4, 6 and 12 V
- ▶ Currents up to 3 A for both outputs
- ▶ Outputs are overload protected

*Appearance may vary.*

This power supply delivers a stabilized DC voltage that is adjustable between 0 and 12 V. Moreover, an AC voltage is supplied, which can be set to 2, 4, 6, or 12 V. The two outputs can simultaneously supply up to 3 A with overload protection. The DC portion is electronically protected and resets automatically, while AC protection is provided with a circuit breaker that must be reset manually if it trips.

Specifications:

DC Output Voltage: 0-12 V (stabilized), continuously adjustable

Maximum DC Output Current: 3 A

Maximum Ripple: 100 mV

AC Output Voltage: 2, 4, 6, 12 V, stepwise adjustable

Maximum AC Output Current: 3 A

Power Consumption: 110 W (max)

Fuse: T 1A (slow)

Dimensions: 20.3 x 20.5 x 11.7 cm

Order Information

AC/DC Power Supply
(12V, 3A)SF-9581

**Low Voltage AC/DC
Power Supply**

SF-9584B

- ▶ 0 to 24 VDC at 0 to 10 A
- ▶ 0 to 24 VAC at up to 6 A
- ▶ Digital readouts

*Appearance may vary.*

The Low Voltage Power Supply has been designed specifically for use in teaching physics, chemistry, and other science subjects. It can provide both direct current (DC) and alternating current (AC). The Power Supply can provide both types of electrical power at the same time, and they can be adjusted independently of one another. Separate digital displays are provided for DC and AC output.

Specifications:

DC – Output Voltage: 0 to 24 V DC

Meter: Digital display (volts/amps); 1% \pm 2 LSD; Ripple <25 mVpp

AC – Output Voltage: 0 to 24 V AC, continuously adjustable

Current: 0 to 6 A

Overload Protection Meter: Digital display (volts/amps); 2% \pm LSD

Power Source: AC 115/230 VAC, 50/60 Hz

Power Use: 320 W

Dimensions: 30 x 23 x 12 cm
(12 x 9 x 5 in.)

Order Information

Low Voltage AC/DC
Power SupplySF-9584B

**Student Function
Generator**

SF-7208

- ▶ Sine, triangle, square waves
- ▶ 7.5 V peak at 1 A



This affordable alternative to the advanced Function Generator PI-8127 covers the most common experiments.

The function generator is operated with three buttons: Waveform, Frequency, and Amplitude. There is a single output, provided with 4 mm safety sockets. The frequency is displayed on the LCD display.

The output can easily drive a speaker or vibrator with ample amplitude for resonance. The frequency range extends well beyond the audible range. The lowest frequencies are suitable for slow-motion AC experiments.

Specifications:

Waveforms: sine, triangle, square

Distortion (sine): 10 Hz

Frequency Drift: 1 A peak
(overload protected)

Supply Voltage: 12 V (1.5 A)
(adapter included)

Accessories: BNC to insulated clips

Order Information

Student Function
GeneratorSF-7208

Wide Range Function Generator

SB-9549A



This function generator is similar to the Basic Function Generator, but it provides a wider frequency range and greater output voltage.

Specifications:

Ranges: 0.2 Hz to 5 MHz in seven ranges, (± 1 count)

Waveforms: sine (distortion $< 1\%$ below 100 kHz); square (2% symmetry, 50 nS max rise and fall time); triangle (98% linearity below 100 kHz, 95% above 100 kHz)

Outputs: 20 V_{p-p} no load, 10 V p-p max into 50 Ω load; continuously variable, 20 dB range with 20 dB step; DC offset: ± 10 V (no load), ± 5 V (50 Ω load); TTL/CMOS-compatible pulse

Sweep: external voltage-controlled oscillator, 0-10 V signal can produce 100:1 frequency change

Power Source: 115/220 VAC, 50/60 Hz

Accessories: BNC to insulated clips

High-Frequency, High-Power Function Generator

SF-9580

- ▶ Wide frequency range: 0.001 Hz to 10 MHz
- ▶ 10 W up to 100 kHz to drive speakers
- ▶ Sweep mode
- ▶ Step mode



Appearance may vary.

Simple design

For basic use, you just operate two large buttons: one for frequency, one for amplitude. That's it. If you want to change waveform or to utilize the new step and sweep modes, the display keeps you updated on the status of the generator.

Unique frequency control

The frequency is set by a speed sensitive button. Turn slowly to set the display's last digit. Turn faster and the response accelerates softly. We have designed this function to work intuitively in practical experiments with common physics equipment.

Drive speaker and vibrators directly

The built-in 10 W power amplifier effortlessly drives power-consuming equipment such as a vibrator or speaker. The amplifier can deliver more than 1 A for all frequencies between 0.001 Hz and 100 kHz.

Advanced features

The generator connects to your PC through a standard USB cable. Custom defined waveforms (e.g. created by means of a spreadsheet) can be saved to the generator. Sequences of settings can be programmed for automatic execution.

Specifications:

Bipolar: Sine, triangle, square

Positive: Square pulse, triangle pulse, ramp up, ramp down

Distortion (sine): $< 0.1\%$ up to 20 kHz; $< 1\%$ otherwise

Frequency Range: 50 Ω and sync outputs: 0.001 Hz to 10.00 MHz; Power output: 0.001 Hz to 100.0 kHz

Frequency Stability: Better than 0.005%

Amplitude: 50 Ω output, no load: 0 to 10 V (20 V p-p for bipolar waveforms); Sync output: 5 V (TTL signal: 0 to 5 V); Power output: 0 to 10 W (20 V p-p for bipolar waveforms)

Max Current: 50 Ω output, short circuit: 200 mA (only briefly); 50 Ω output, into 50: 100 mA (unlimited); Power output: 1 A (unlimited)

Power Consumption: 85 W (max); 21 W (idle)

Dimensions (WxDxH): 31.2 x 20.5 x 11.7 cm

Order Information

Wide Range Function GeneratorSB-9549A

Order Information

High-Frequency, High-Power Function GeneratorSF-9580

Function Generator

Function Generator

PI-8127

- ▶ 0.001 Hz to 150 kHz
- ▶ Programmable frequency sweep
- ▶ 10 V at 1 A
- ▶ Use for circuits and/or driving speakers
- ▶ Use the ramp function to vary the speed of DC motors
- ▶ Frequency resolution of 0.001 Hz over entire range



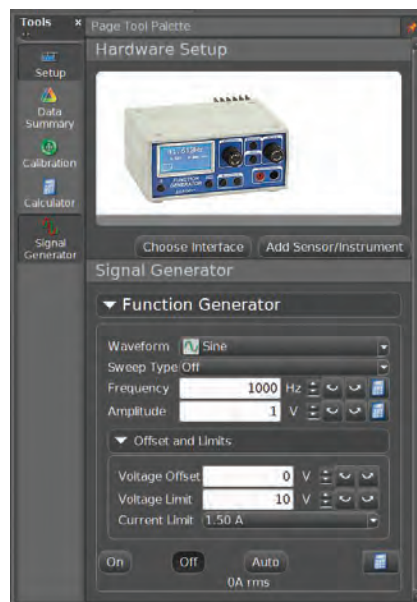
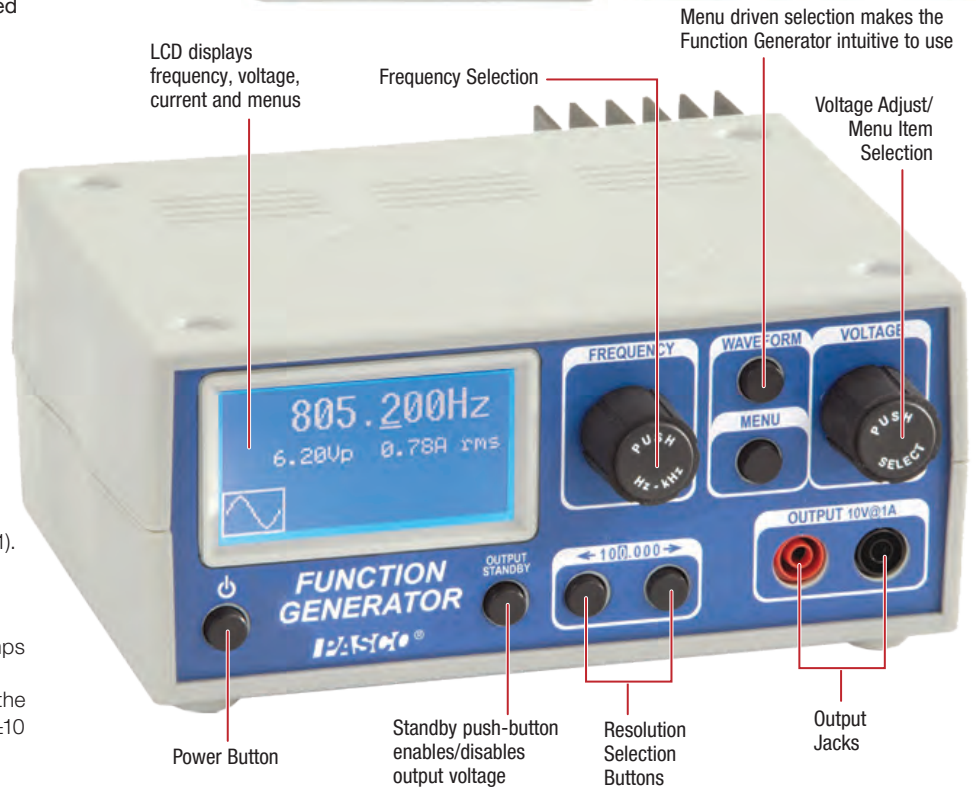
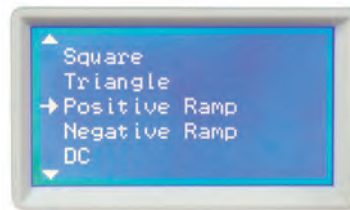
Upgradable Firmware

Download the latest features for your PI-8127: The built-in USB port allows users to access and upgrade firmware whenever the unit is attached to a computer running current versions of PASCO Capstone™ software (pp. 68-71).

Features

The Function Generator outputs sine, square, triangle, positive and negative ramps with a frequency range of 0.001 Hz to 150 kHz in addition to DC. (A replacement for the PI-9587C). Its powerful output, 1 Amp at ± 10 Volts, makes it useful for driving speakers, string vibrators, and circuits.

- ▶ **LCD Readout:** The LCD displays frequency, voltage, current, waveform, and menus. For viewing demonstrations, there is a Large Digits Mode for increased readability of the frequency. The backlight has both low and high levels, which are selectable in the menu. The low backlight is useful for dark rooms.
- ▶ **Frequency/Range Selection:** There are two ranges, 0.001 to 100 Hz and 0.001 to 100 kHz, selected using the range push-button switch (integrated with frequency knob).
- ▶ **Output Standby:** Pushing the standby button disables the output without changing settings.
- ▶ **Output Current/Voltage Maximum:** The maximum current or maximum voltage can be set using the menu. This is useful when the instructor needs to limit the voltage applied in a light bulb.
- ▶ **Offset Voltage:** Any waveform may be offset with a DC voltage ranging from -10 V to +10 V, provided the peak voltage does not exceed 10 V.
- ▶ **Frequency Sweep:** Sweep between any two frequencies at a selectable rate.



Use the Function Generator as a stand-alone or connect it to a computer via USB cable and control all its functions from PASCO Capstone™. Use it with PASPORT interfaces and sensors.

Specifications:

Input Power: 15 V @ 1.6 A

Voltage Output: ± 10 V @ 1 A

Frequency Range: DC to 100 kHz.
Sine wave retains its form to 150 kHz.

Frequency Resolution: 0.001 Hz over entire range

Offset Voltage: ± 10 V

Waveforms: Sine, Triangle, Square, Positive Ramp, Negative Ramp, DC

External Voltage Input: ± 10 V Maximum

Trigger Output: TTL Compatible; BNC jack on back of unit

Display: LCD Graphics Monochrome Display, 128 x 64, with two-level backlight

Displays: Frequency, Waveform, Voltage, Current, Offset Voltage.

Amplitude Modulation: Modulate the signal of one function generator using another.

Order Information

Function Generator PI-8127

Digital Storage Oscilloscope (100 MHz)

SB-9621A

- ▶ 2-Channel 100 MHz bandwidth
- ▶ 2 M points of memory gives finer detail
- ▶ FFT/FFTrms/Zoom FFT
- ▶ Delay on/off
- ▶ USB flash storage and data logger
- ▶ Go/NoGo function
- ▶ Print directly to printer
- ▶ PC remote control software

This 2-channel oscilloscope is designed to meet educational demands. With fast waveform process capability, more advanced triggering functions, and a lightweight design, this oscilloscope is an excellent replacement for an analog scope.

Via the USB Device port, the user can easily build a remote control program to manipulate the machine, storing data directly into a flash drive for further analysis.

Several acquisition modes and 27 auto measurement functions help the user accurately measure waveform properties.

A total of 15 waveforms can be saved into the internal memory for later recall and display, and two saved reference waveforms plus two live waveforms can be shown on the screen at the same time for comparison.



Specifications:

Bandwidth: 100 MHz, 2 Input Channels

Sampling Rate: 1 GSa/s Real-Time and 25 GSa/s Equivalent-Time

Record Length: 2 Mega Points

Vertical Scale: 2 mV to 10 V

Horizontal Range: 1 ns to 50 s

Number of Auto Measurements: Up to 27

Functions: +, -, x, FFT, FFTrms, Zoom FFT

Display: 5.7" Color TFT LCD

Ports: USB Host and Device Ports

Data Logger

See www.pasco.com for complete specifications.

Order Information

Digital Storage Oscilloscope (100 MHz).....SB-9621A

Basic Digital Multimeter

SE-9786A

This basic meter includes all the functions and ranges needed for most introductory lab work.

Features:

- ▶ 10 amp range
- ▶ Backlit display with 25 mm digits
- ▶ Soft rubber boot for drop protection
- ▶ Built-in tilt stand
- ▶ Type K thermometer built in for surface or air measurements
- ▶ Auto power off saves battery life



Specifications:

DC Voltage: 0.1 mV to 600 V with $\pm 0.5\%$ accuracy

AC Voltage: 1 mV to 600 V with $\pm 0.3\%$ accuracy

DC Current: 0.1 μ A to 10 A

AC Current: 0.1 mA to 10 A

Resistance: 0.1 Ω to 20 M Ω

Additional Functions: Input fuse protection, audible and visible misconnection signals, data hold freezes display reading

Display: 3-1/2 digit display with 25 mm digits, polarity indication, low battery indication

Power: 9 V battery (included)

Precision Digital Multimeter, Component Tester and Thermometer

SB-9631B

This is an excellent general purpose multimeter that features high-accuracy overload protection on all ranges and a built-in digital thermometer.

It can measure capacitance and transistor gain (hFE).



Specifications:

DC Current: 200 μ A, 2 mA, 20 mA, 200 mA; $\pm (1\% + 1 \text{ digit})$

AC Current: 200 μ A, 2 mA, 20 mA, 200 mA; $\pm (1.2\% + 4 \text{ digits})$

Capacitance: 20 nF, 200 nF, 2 μ F, 20 μ F, 200 μ F; $\pm (3\% + 10 \text{ digits})$

Temperature: 4° to 1400°F; 4° F to 900°F; $\pm 2.0\%$ reading + 4°F; 900°F to 1,400°F; $\pm 3.0\%$ reading + 4°F

Power: 200-hour life on 9 V alkaline (battery included).

Test leads, temperature probe and battery are included

DC Voltage: 200 mV, 2 V, 20 V, 200 V, 1000 V; $\pm (0.5\% + 1 \text{ digit})$
10 M Ω input impedance

AC Voltage: 200 mV, 2 V, 20 V, 200 V; $\pm (1\% + 4 \text{ digits})$ 750 V;
 $\pm (1.5\% + 4 \text{ digits})$ 10 M Ω input impedance

Product Resistance: 200 Ω ; $\pm (1\% + 3 \text{ digits})$ 2 k Ω , 20 k Ω , 200 k Ω ,
2 M Ω ; $\pm (0.8\% + 1 \text{ digit})$ 20 M Ω ; $\pm (3\% + 3 \text{ digit})$

Additional Functions: Diode test, transistor hFE, audible continuity test, fold-out stand

Display: 3-1/2 digit LCD display, 17 mm high digits, polarity indication, low battery indication

Drop Resistant

Order Information

Precision Digital Multimeter,
Component Tester and ThermometerSB-9631B
Replacement Supplies
Thermocouple Probe.....SB-9632

Order Information

Basic Digital Multimeter.....SE-9786A

Ripple Tank

Ripple Tank System

WA-9899

- ▶ Completely redesigned system
- ▶ More affordable
- ▶ Integrated strobe/ripple generator simplifies operation
- ▶ Foam "beach" design dramatically reduces reflections from walls
- ▶ Silent operation

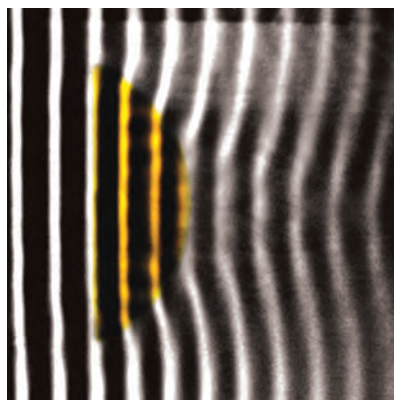
The redesigned Ripple Tank System is easier to use, more reliable, and more affordable. The strobe and rippler are controlled by the same unit, and a new feature makes it possible to introduce a small frequency difference between the strobe and the rippler to make the waves appear to move slowly. A simple switch changes the phase of the two rippers from 0 to 180 degrees.

The rippler uses voice coil actuators for precise and silent operation. The frequency range (1.0 Hz to 50.0 Hz) includes those important low frequencies that make refraction more prominent. The LED digital frequency readout can be seen in low lighting. The rippler has knobs to easily adjust the dipper depth and the amplitude of the dipper stroke.

The new light source is a white LED that remains cool during operation and produces a bright, clear wave pattern. The light can be used as a strobe or in steady mode.

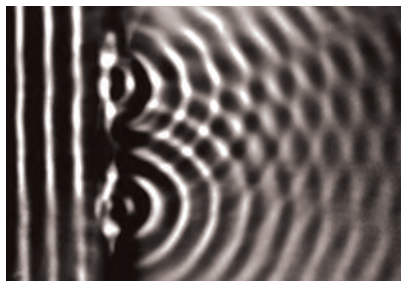
Applications:

- ▶ Speed of Wave Propagation
- ▶ Superposition of Waves
- ▶ Effects of Varying Water Depth
- ▶ Reflection, Refraction, and Diffraction



The yellow convex lens focuses the plane water waves. The waves show a pronounced refraction due to the abrupt change in the depth of the water over the plastic lens.

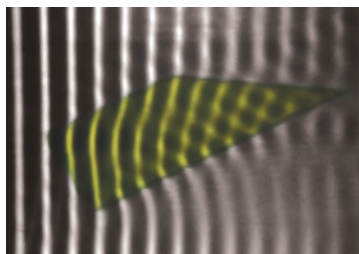




Diffraction Barriers are used to create a double slit to show interference. The barriers can be changed to adjust the slit width and slit separation.



The Doppler effect is clearly demonstrated by moving the dipper. In this picture the movement is downward.



Refraction occurs at the boundaries of this rhomboid shape.

Ripple Tank Specifications (WA-9897):

Viewing Area: 34 cm x 34 cm

Usable Tank Depth: 1 cm

Projection Screen: 35.6 cm x 38.8 cm

Acrylic Mirror: 49.8 cm x 38.8 cm

Light Source Support Rod: 46 cm long

Drain Tube: 30 cm long

Water Resistant Storage Box:

64 cm x 52 cm x 17 cm

Ripple Generator/Light Source Specifications (WA-9896):

Voice Coil Actuator Frequency Range:

1.0 to 50.0 Hz with 0.1 Hz Resolution

Adjustable Delta Frequency between Ripple Generator and Strobe:

±45% frequency setting in steps of 9%

Light Source:

5 W White LED

Light Source Modes:

Strobe or Steady Modes

Digital LED Display:

Frequency/Delta

Phase Switch:

0 or 180 degrees

Power Supply: 1

5 VDC at 1.5 A with On/Off Switch

Rippler Case Dimensions:

10.5 cm x 16.3 cm x 3.9 cm



Includes:

- Ripple Tank (complete components list at right)
- Ripple Generator/ Light Source
- Water Resistant Storage Box (64 cm x 52 cm x 17 cm)

Ripple Tank

WA-9897



Includes:

- Tank with Legs
- Projection Mirror and Screen
- Strobe Mounting Rod
- Refractors (convex, concave, rhomboid)
- Curved Reflector
- Diffraction Barriers (2 long, 1 short, 1 mini)
- Plastic Storage Box for components
- Surfactant
- Drainage Tube (30 cm) with Clamp
- 1 L Plastic Beaker
- Pipette
- Clear Plastic Ruler
- Water Resistant Storage Box for Entire System

Order Information

Ripple Tank Assembly WA-9897

Ripple Generator/ Light Source

WA-9896

Includes:

- Ripple Generator/ Strobe Driver with Power Adapter
- LED Strobe Assembly
- Plane Wave Generator with Multi-point Dippers
- Point Sources (3 sizes)



Order Information

Ripple Generator & Light Source WA-9896

Ripple Tank Replacement Set

WA-9898 See specifications at left.

Includes:

- Plastic Storage Box for Components
- Dippers
- Refractors
- Pipette
- Curved Reflector
- Foam Beach
- Diffraction Barriers

Order Information

Ripple Tank Optics Replacement Set .. WA-9898

Ripple Tank Screen and Mirror

WA-9881

- Includes screen and mirror

Order Information

Ripple Tank Screen WA-9881

Order Information

Ripple Tank System	WA-9899	
Required:		
90 cm Stainless Steel Rod	ME-8738	p. 186
Large Rod Base	ME-8735	p. 186
Replacement:		
Ripple Tank Optics Replacement Set	WA-9898	

Standing Waves

String Vibrator

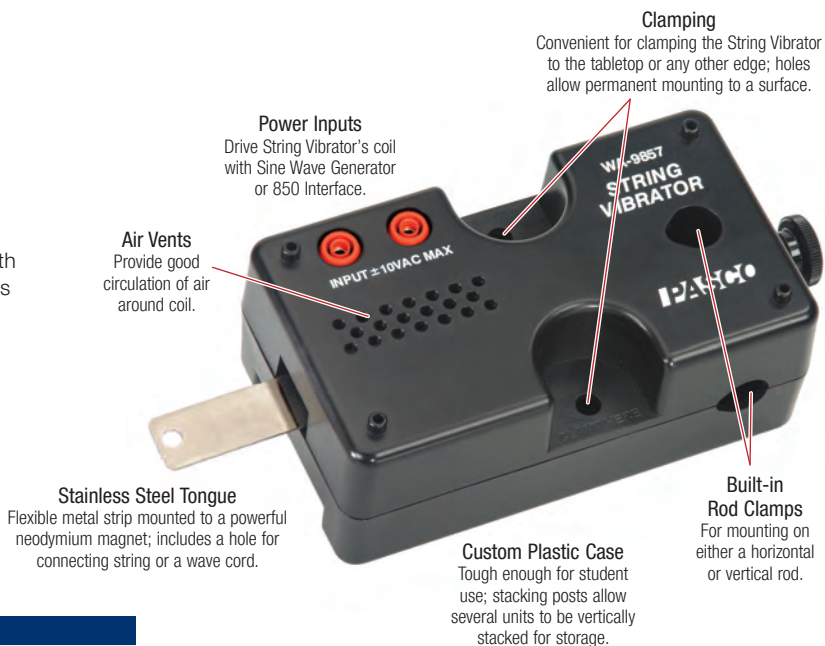
WA-9857A

- ▶ Great tool for mechanical wave demonstrations
- ▶ Uses magnetic field to drive flexible tongue

The String Vibrator transforms mechanical wave demonstrations into hands-on activities that every lab group can easily perform. Featuring an elegant design with no motors or speakers, the String Vibrator allows students to study the fundamental characteristics of mechanical waves including wave speed, frequency, wavelength, amplitude, interference, and resonance.

Includes:

- String Vibrator Unit
- 3 Meter Wave Cord (not shown)



Order Information

String Vibrator.....	WA-9857A
Required:	
Sine Wave Generator	WA-9867

Strobe System

ME-6978

- ▶ 1 Hz to 500 Hz
- ▶ Variable intensity
- ▶ Low cost
- ▶ External trigger

This unique modular design makes it easy to light any geometry. The Strobe includes the Strobe Control Box and one Strobe Module. Additional Strobe Modules can be purchased separately (see below) for up to a total of four lamp modules per controller, and multiple control boxes can be connected together using the External Trigger. The Strobe Modules have a tilting lamp head on a sturdy base that sits on the table or fastens to a rod stand.



Accuracy: 0.1%

Frequency Range: 1 Hz to 500 Hz

Resolution: 0.1 Hz

Lamp Life: 50,000 hours

Brightness: 230 lumens (peak) per module

Includes:

- Control Box
- Strobe Module

Order Information

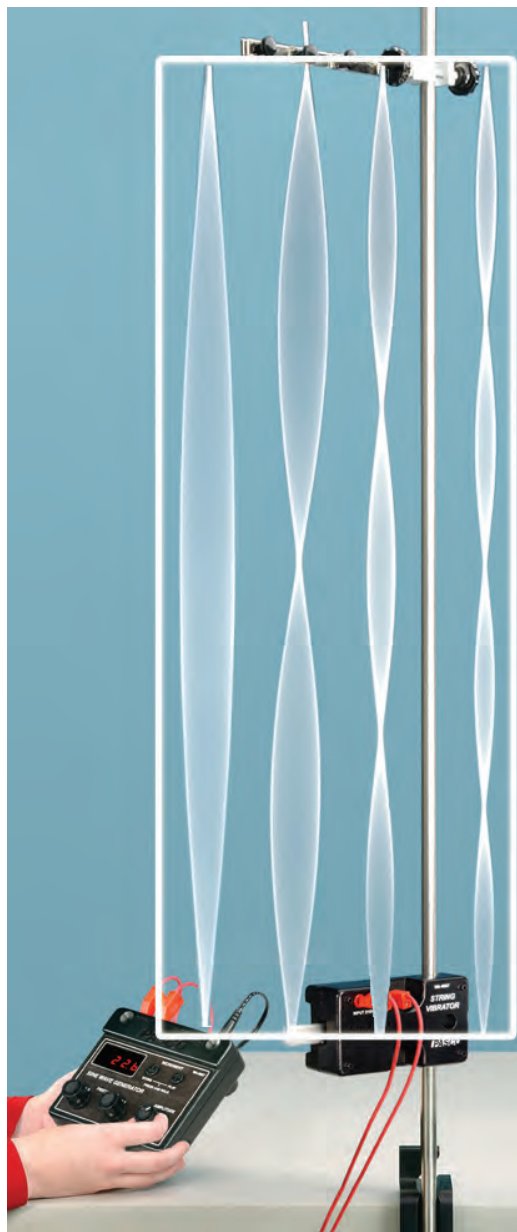
Strobe System	ME-6978	
Shown in use with:		
String Vibrator.....	WA-9857A	
25 cm Stainless Steel Rod (2, threaded).....	ME-8988	p. 186
Aluminum Table Clamp (2)	ME-8995	p. 189
Sine Wave Generator	WA-9867	
Multi-Clamp.....	ME-9507	p. 188



Sine Wave Generator

WA-9867

- ▶ Sine wave output up to 800 Hz
- ▶ Ideal for driving speakers and wave drivers
- ▶ Built-in memory for storage of fundamental frequency
- ▶ Auto-scan of resonant frequencies



Includes:

- Sine Wave Generator
- Power Supply: 15 VDC 2A



High Power Output
To drive speakers

- ▶ **Custom Plastic Case:** Stackable plastic case includes angled rubber feet and a rear rod clamp for dynamic mounting options
- ▶ **Digital Display:** Frequency is digitally displayed with 0.1 Hz resolution using red LEDs
- ▶ **Frequency Adjustment:** Adjust the frequency of the output with either the fine (0.1 Hz) or coarse (1.0 Hz) knobs. The knobs include a “Smart Scan” feature so they change frequency more quickly when continuously turned.
- ▶ Smart Scan feature enables knobs to change frequency more quickly when continuously turned.
- ▶ **Amplitude adjustment:** Change the voltage of the sine wave signal.
- ▶ **“Learn” Frequency:** The Sine Wave Generator can store a frequency increment, then it will cycle through the selected frequency range by the increment automatically, which is very useful for resonance demonstrations or activities.

Order Information

Sine Wave Generator	WA-9867	
Recommended:		
String Vibrator.....	WA-9857A	p. 260
Mechanical Wave Driver.....	SF-9324	p. 263
Open Speaker.....	WA-9900	p. 264
Economy Resonance Tube	WA-9495	p. 264
Shown in use with:		
2 Meter Patch Cord Set.....	SE-9415A	p. 232

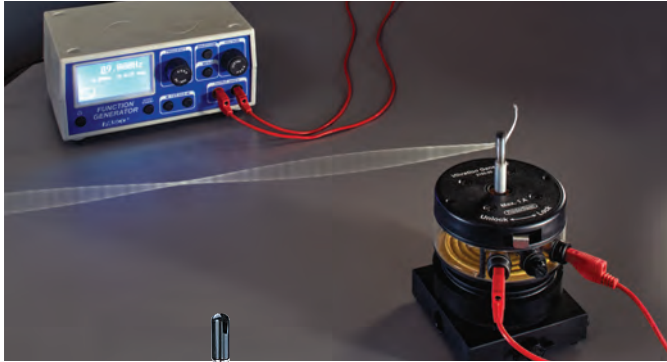
Mechanical Waves

Mechanical Wave Driver Accessories

Mechanical Wave Driver

SF-9324

- ▶ Drive any wave experiment at specified frequencies
- ▶ Variable amplitude
- ▶ Tough and versatile



SF-9324
8 Ω Impedance

Powering the Wave Driver

Different PASCO products can be used to power the Wave Driver; see below.

- ▶ **Frequency Response:** From 0.1 to 5000 Hz with an amplitude of approximately 5 mm up to about 50 Hz.
- ▶ **Mounts Vertically or Horizontally:** Designed to sit upright on a table, on its side or mounted on a 12.7 mm (1/2 inch) rod.
- ▶ **Driving Signal Required:** Requires a function generator with a minimum of ±8 V at 0.5 A. An accurate measurement of frequency is necessary for quantitative resonance experiments.

Order Information

Mechanical Wave Driver.....	SF-9324	
Required:		
Banana Plug Cord-Black (5 Pack).....	SE-9751	p. 228
Plus one of the following function generators:		
Sine Wave Generator	WA-9867	p. 261
Function Generator	PI-8127	p. 256
850 Universal Interface	UI-5000	p. 14
Equivalent function generator providing up to 1 A to 8 Ω impedance.		
Shown in use with:		
2 Meter Patch Cord Set.....	SE-9415A	p. 228
Recommended:		
Slot String Holder (set of 4).....	SF-9322	p. 263

Longitudinal Wave Spring

WA-9401

Using the Longitudinal Wave Spring accessory, it is easy to demonstrate and visualize the nodes and antinodes of longitudinal waves. Unstretched length is 13 cm.



Longitudinal waves can be easily demonstrated with the Longitudinal Wave Spring.

Order Information

Longitudinal Wave Spring..... WA-9401

Chladni Violin Plate

SE-7319

This 40-cm-long plate is shaped like a standard violin. Place sand on the plate and excite with either a violin bow or wave driver. Includes a standard banana jack connector for use with the Mechanical Wave Driver.



Order Information

Chladni Violin Plate SE-7319

Chladni Plates Kit

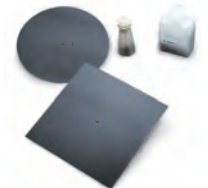
WA-9607

In the early nineteenth century, Ernst Chladni added another dimension to wave experiments by sprinkling sand on a thin plate and using a violin bow to induce vibrations. The sand that collected along the nodal lines of the wave patterns painted clear and beautiful pictures of the various modes of vibration.



The Chladni Plates Kit and a Wave Driver allow continuous vibrations to be produced at measurable frequencies. Students can determine the resonant frequencies of the plates and examine the modes of vibration at any frequency.

The Chladni Plates Kit includes a 24 cm x 24 cm square plate, round plate, 0.8 kg of extra-fine sand, and a sand shaker. The round plate can be vibrated about its center or about an offset point to investigate both symmetric and asymmetric modes of vibration.



WARNING! This product can expose you to crystalline silica, which is known to the State of California to cause cancer. For more information go to www.P65Warnings.ca.gov.

Order Information

Chladni Plates Kit..... WA-9607

Mechanical Wave Driver Accessories

Metal Resonance Strips

SF-9404

These resonance strips demonstrate standing waves, harmonics, and the relationship between length, frequency, and resonance.



Investigate the unique resonant frequencies of the Metal Resonance Strips.

Order Information	
Metal Resonance Strips	SF-9404

Resonance Wire Loop

SF-9405

Use this wire loop (29 cm diameter) to introduce Bohr's quantum atom with a classical model.



Order Information	
Resonance Wire Loop	SF-9405

Slot String Holder (set of 4)

SF-9322



4 mm diameter banana plugs with string holder slot are designed for use in the shaft of the Mechanical Wave Driver (SF-9324).

Order Information	
Slot String Holder (set of 4)	SF-9322

Structures Resonance Structures System

PASCO's Structures System is ideal for demonstrating resonance in complex systems. The plastic I-Beams clearly show two different bending moments and can be connected together to build a variety of structures.

The long plastic I-Beam is constructed of components from the Advanced Structures Set (p. 148). It is driven using the Mechanical Wave Driver and the Function Generator (PI-8127), and can be used to demonstrate the three lowest harmonics.



See EX-5555 Shaking Tower Experiment on page 349.

Composite I-Beam (1.2 m tall)

Order Information		
Advanced Structures Set	ME-6992B	pp. 148-149
Large Slotted Mass Set	ME-7566	p. 197
45 cm Stainless Steel Rod	ME-8736	p. 186
Large Rod Base	ME-8735	p. 186

Resonance

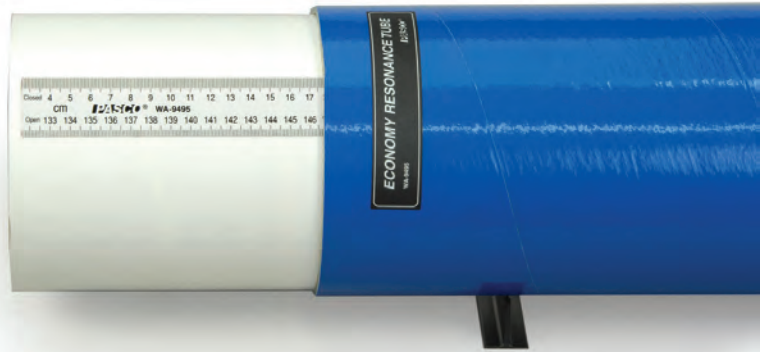
Demonstrate Acoustic Resonance

Economy Resonance Tube

WA-9495



Metric Scale
Directly measures length of air column for open and closed tube.



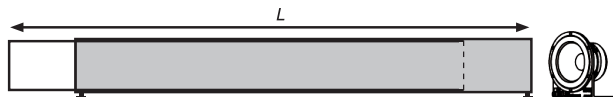
Students will have no difficulty hearing resonant frequencies from this tube. Two nested cardboard tubes allow the length of the air column to be easily varied. And the inner tube contains a removable end-cap to change from a "closed" to an "open" tube. The length of the resonating column can be read directly off the metric scale for both open and closed operation.



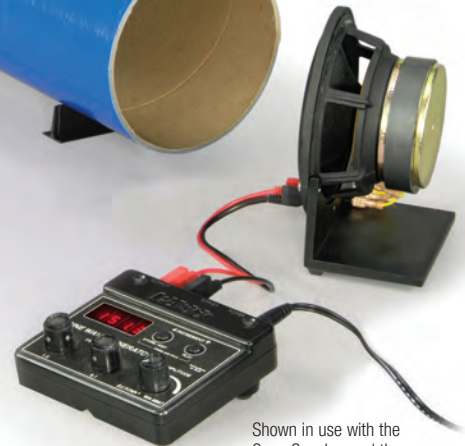
The removable end-cap on the inner tube allows the air column to act as either an "open" or a "closed" tube.



Closed tube (with end cap in place)



Open tube (with end cap removed)



Shown in use with the Open Speaker and the Sine Wave Generator.

Open Speaker WA-9900

Features a high-quality, 13.3 cm woofer mounted on a sturdy base with standard banana jack inputs. The Open Speaker is not enclosed inside a case, making it perfect for resonance experiments.

Frequency Response: 80 - 8000 Hz

Impedance: 8 Ohms

Input Power: 60 W (max)



Includes:

- Outer Tube Length 1.3 m; Diameter 0.15 m
- Inner Tube (includes measuring tape and removable end-cap)
- Tube Stands (2)

Order Information

Open Speaker WA-9900

Order Information

Economy Resonance Tube WA-9495

Shown in use with:

Open Speaker WA-9900

Sine Wave Generator WA-9867

2 Meter Patch Cord Set SE-9415A

p. 261

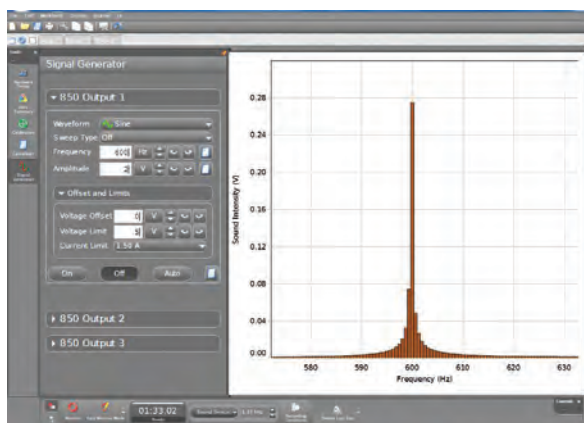
p. 228

Resonance Air Column with Speaker

WA-9594

- ▶ Very loud resonance
- ▶ Tough polycarbonate tube
- ▶ Use with speaker or tuning fork

The Resonance Air Column (WA-9606) emits a very loud sound when the plunger is moved to a node position. It works as well as a water column but without the mess. The secret is in the long molded piston head, which is very efficient in reflecting the sound waves. The plunger handle is made of flexible acetyl so it will not break.



PASCO Capstone controls the sine wave output of the 550 Universal Interface to drive the speaker. The FFT display of the Sound Sensor data shows the tube's resonant response.



The Resonance Air Column has a polycarbonate tube, so it will not break or chip like inferior acrylic. It includes eight plastic snap-on rings that can be slid along the tube to mark the nodes. A meter stick is used to read the positions of the rings.

The Sound Sensor (UI-5101) has a microphone on a 1.4 m long wire, so it can be used to find the nodes inside the Resonance Air Column.



The Resonance Air Column can be used as a closed or open tube. In the closed mode, tuning forks or speakers are suitable for sound sources. In the open mode, a speaker with a signal generator is required to vary the frequency until the tube sounds a resonance.



WA-9594 includes:

- Resonance Air Column (WA-9606)
- Mini Speaker (WA-9605)

WA-9606 includes:

- Tube and plunger
- Node markers (8)
- Detachable stands (2)

Mini Speaker WA-9605

The Mini Speaker (WA-9605) is specially made to work with the Resonance Air Column. It can be powered with the Function Generator (PI-8127), an 850 Universal Interface (UI-5000), or a 550 Universal Interface (UI-5001). It is also useful as a stand-alone speaker for doing interference demonstrations. Two Mini Speakers acting as point sources can output the same frequency and the spatial interference pattern can be explored.

- Voltage:** 10 V
- Power:** 2 W
- Impedance:** 8 Ω
- Protection Resistor:** 15 Ω , 2 W



- Material:** Polycarbonate
- Length:** 4.0 ft (1.2 m)
- Diameter:** 1.5" O.D. (3.8 cm)
- Wall Thickness:** 1/16" (1.6 mm)
- Plunger Length:** 4.2 ft (1.3 m)
- Plunger Handle:** Acetyl

Order Information

Resonance Air Column with Speaker.....	WA-9594	
Resonance Air Column.....	WA-9606	
Shown in use with:		
550 Universal Interface.....	UI-5001	p. 16
Sound Sensor with Microphone.....	UI-5101	p. 22
Tuning Fork Set.....	SE-7342	p. 269
2 Meter Patch Cord Set.....	SE-9415A	p. 228
Meter Sticks, 6 Pack.....	SE-8827	p. 192

Order Information

Mini Speaker WA-9605

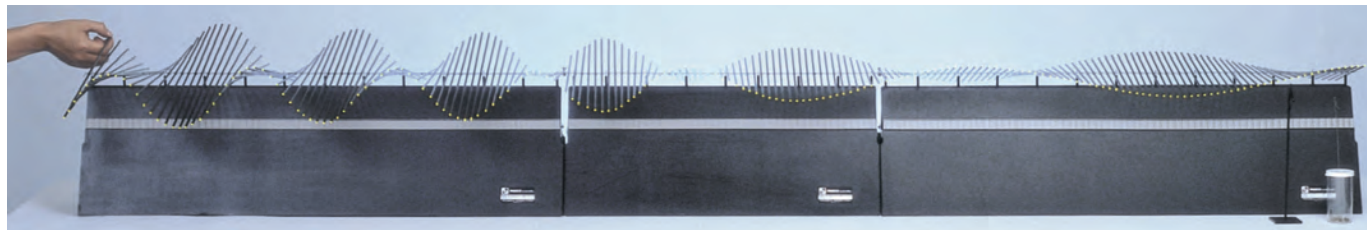
Transverse Waves

Complete Wave Motion Demonstrator

SE-9600

The PASCO Complete Wave Motion Demonstrator allows mechanical waves to be created to demonstrate the behavior and properties common to many types of waves.

- ▶ Produces slow-moving, high-amplitude transverse waves
- ▶ Demonstrates all basic wave phenomena



The complete Wave Motion Demonstrator in three sections: The high-amplitude, slow-moving waves provide a fascinating introduction to basic wave phenomena.

How It Works:

A series of steel rods is attached at their centers to a torsion wire. When a rod is displaced and released, a wave propagates along the rod. Velocity depends on the torsion constant of the wire and the moment of inertia of the rods.

Features:

- ▶ **2.3 Meters Long:** Plenty of room to watch the wave develop and interact.
- ▶ **Three Wave Sections:** Each section has rods of different lengths, allowing reflection and transmission demonstrations.
 - Section 1 is 92 cm long with 46 cm rods.
 - Section 2 is 92 cm long with 23 cm rods. The resulting wave velocity is three times as fast.
 - Section 3 is 46 cm long with rods that vary exponentially from 46 cm to 23 cm. This section acts as an impedance-matching unit.
- ▶ **Yellow Rod Tips:** For easy viewing and to highlight the wave motion.
- ▶ **Folds:** For compact storage.
- ▶ **Easy Setup**

Order Information

Complete Wave Motion Demonstrator SE-9600

Wave Motion Actuator

SE-7125

- ▶ Sinusoidal driver
- ▶ Reproducible pulse
- ▶ Digital readout

The Wave Motion Actuator sinusoidally drives the Complete Wave Motion Demonstrator (above). It can also generate a reproducible pulse. The Actuator arm is magnetically coupled to the rod of the Wave Demonstrator.

The frequency of the sine wave is continuously variable from 0.1 Hz to 3 Hz and the frequency and period are displayed on the digital readout.



Demonstrate:

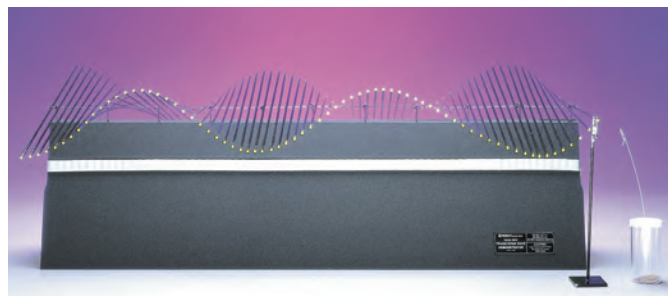
- Wave propagation velocity
- Wave reflection boundary conditions
- Wave interference and standing waves

Order Information

Wave Motion Actuator SE-7125

Single Section Wave Motion Demonstrator

SE-9601



A-frame design collapses for easy storage.

Includes:

- Section with 46 cm long rods (total length = 92 cm)
- Length of section: 92 cm
- Clamp for rigid termination
- Dash pot for liquid damping

Order Information

Single Section Wave Motion Demonstrator SE-9601

Essential Physics Waves and Sound Kit

EP-3578

Perform experiments to study wave properties, amplitude, wave length, frequency, resonance, and period.

Includes:

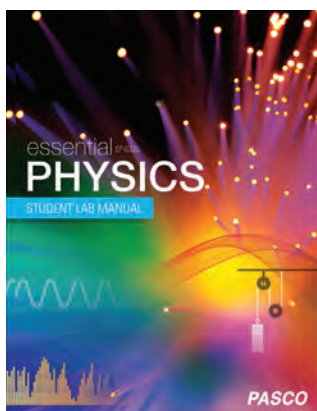
- Steel Transverse Wave “Snakey” Spring (1.8 m)
- Extra-large Steel Longitudinal Wave “Slinky” Spring
- Extension Spring (25 cm)
- Pendulum/Spring Hanger
- Resonance Lever
- Aluminum Pendulum Ball (1” dia.)
- Resonance Tube
- Tuning Forks (4)
- Forces Accessories
- Tripod
- Gratnells® Storage Tray



Essential Physics Student Lab Manual

EP-6326

Are you looking for more hands-on physics labs? The *Essential Physics Student Lab Manual* includes 46 labs and activities, six of which are for Oscillations, Waves, and Sound.



Oscillations, Waves, and Sound Labs

- ▶ Oscillators
- ▶ Resonance
- ▶ Waves
- ▶ Interference
- ▶ Resonance and Sound
- ▶ Design a Musical Instrument

Go to page 92 to see PASCO's complete *Essential Physics* solution, including the *Essential Physics* Student Textbook and e-Book, the Student and Teacher Lab Manuals, and the all-digital Teacher Resources.

Order Information

Oscillations, Waves, and Sound Equipment Kit..... EP-3578
Essential Physics Student Lab Manual EP-6326

Also available (see page 96):

Essential Physics Teacher Lab Manual (print) EP-6329
Essential Physics Teacher Lab Manual (digital) EP-6329-DIG
Essential Physics Teacher Lab Manual Resources (digital) EP-6328-DIG

Bell Jar

SE-7725

This thick glass bell jar with base plate includes an electric bell on a rubber mount to demonstrate that sound does not propagate in a vacuum. Remove the air from the jar and the sound from the bell gradually fades.

Vacuum Pressure:

≤ -0.06 MPa

Voltage: 3 V DC

Jar: 6.5” dia. x 9.75” tall
 (inside: dia. 6.25” x 8” tall)

Base: 8” dia. x 1.5” high



Includes:

- Glass bell jar
- Vacuum base plate
- Gasket
- Hose
- Battery-operated electric bell (removable)

Order Information

Bell Jar SE-7725
 Required: 2 AA batteries, Vacuum Pump

Wave Media

Sound Pipe

SE-7724



When a student spins this pipe, the pipe produces an audible tone similar to that produced by blowing across the mouth of a bottle. As the pipe is spun faster, the resonant frequency increases. Five different frequencies can be achieved.

(One pipe included. Color may vary.)

Order Information

Sound Pipe SE-7724

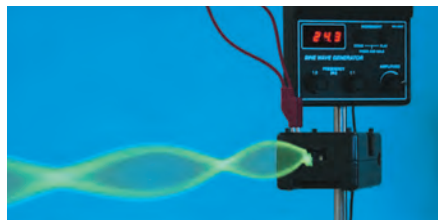
Glow String (2 Pack)

SE-8690



String color may vary.

This stretchy "string" glows in the dark after being exposed to light. Use it to demonstrate wave motion, including resonance and standing wave patterns. Two rolls are included, totaling over 15 meters of string.



Glow String forming a standing wave using PASCO's String Vibrator WA-9857, Sine Wave Generator WA-9867, and a UV Light Source.

WARNING
CHOKING HAZARD
Small parts. Not for children under 3 years.

Order Information

Glow String (2 Pack) SE-8690

Snakey

SE-7331



This extra-long metal spring is ideal for studying mechanical waves. The Snakey has an unstretched length of 2 meters. Pull the convenient end loops more than 10 meters apart to demonstrate transverse, longitudinal, and standing waves.



Easily create clear standing wave patterns.

Order Information

Snakey SE-7331

Double-Length Slinky

SE-8760



The Slinky is an excellent tool for demonstrating transverse and longitudinal wave phenomena. This Double-Length Slinky is twice as long as a traditional Slinky, allowing students to create well-defined wave pulses and standing wave patterns. The tension in the Slinky is very low, causing wave pulses to travel slowly throughout its length.

Order Information

Double-Length Slinky SE-8760

Elastic Wave Cord

SE-9409

This highly visible elastic cord can be used to set up standing transverse waves, or pluck it to watch wave propagation. Approximately 3 mm diameter and 90 meters in length.

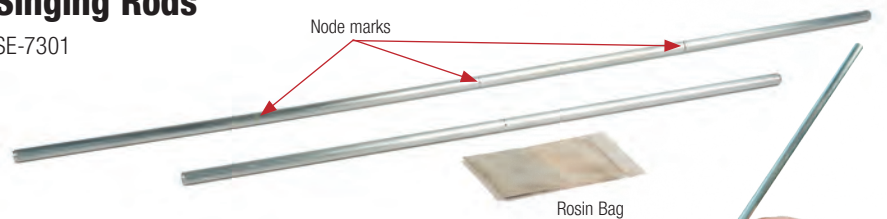


Order Information

Elastic Wave Cord SE-9409

Singing Rods

SE-7301



These rods emit a VERY LOUD pure tone when stroked. The nodes are marked on these rods to indicate where you should hold the rod. Standing longitudinal waves are set up in the rod by stroking the rod with your fingers (coated with the included rosin). Investigate the effects of different lengths and holding the rod at different nodes.

Includes:

- Two Aluminum Rods Approx. length: 20" (500 mm) and 30" (750 mm).
- Bag of crushed rosin to lightly coat your fingertips



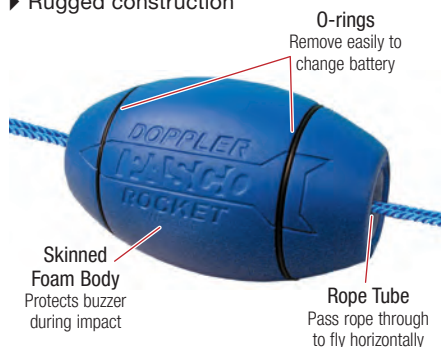
Order Information

Singing Rods SE-7301
Replacement Supplies:
Rosin Bag SE-6659

Doppler Rocket

WA-9826

- ▶ Experience the frequency shift of sound waves
- ▶ Easily generate high velocity motion
- ▶ Rugged construction



Fly Horizontally

A set of two ropes can be passed through the center of the unit. This allows students to use the included handles to propel the Doppler Rocket across the room at high velocities.

The unit is guided by the ropes. Students hear the change in pitch as the Doppler Rocket flies past them.



The Doppler Rocket combines the elements of a toy with an audio Doppler shift to create an educational experience students won't forget. The Doppler Rocket emits a true, sinusoidal sound waveform at a constant frequency of approximately 620 Hz. The circuit and speaker are housed in skinned foam that protects the unit during normal impacts. The circuit is powered by a 9 V battery. As the Doppler Rocket passes the students, they hear a noticeable shift in frequency. Velocities of 10 m/s can be easily achieved, resulting in a 20 Hz shift in frequency.

Includes:

- Doppler Rocket
- Rope (30 m)
- Handles (4)
- Handle Cushions (4)
- Battery (9 V)

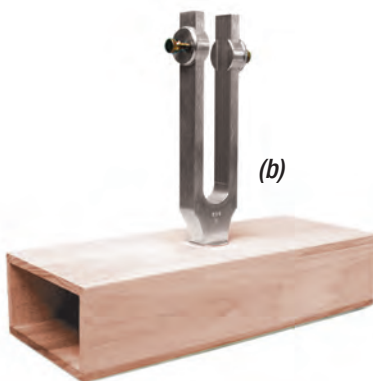
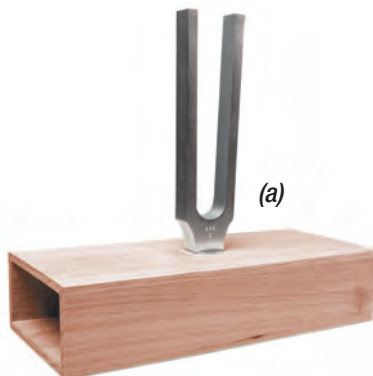


Order Information

Doppler Rocket..... WA-9826

Sympathetic Resonance Box Set

SE-7345



Resonance boxes are great instruments for amplifying sound from a tuning fork. These boxes are constructed from hardwood and feature an A4 tuning fork mounted directly to the box. Use Capstone software and a sound sensor (UI-5101) to measure the sound waves and beat frequencies created by these resonance boxes.

Includes:

- Hardwood resonance box with a 256 Hz A4 tuning fork
- Hardwood resonance box with an adjustable tuning fork

Order Information

Sympathetic Resonance Box Set..... SE-7345

Recommended:
 Sound Sensor UI-5101
 850 Universal Interface UI-5000
 PASCO Capstone

Tuning Fork Set

SE-7342



The tuning fork has long been the tool of choice to help students understand the relationship between wave frequency and pitch. These high-quality aluminum tuning forks are both rugged and economical. The set includes eight forks representing a full octave of frequencies, a soft protective case, and a rubber mallet.

Note	Frequency
C	256 Hz
D	288 Hz
E	230 Hz
F	341.3 Hz
G	384 Hz
A	426.7 Hz
B	480 Hz
C	512 Hz

Order Information

Tuning Fork Set..... SE-7342

Tuning Fork Technical Set

SE-7728

This tuning fork set consists of six aluminum tuning forks: 125, 250, 500, 1000, 2000, and 4000 Hz. The frequencies are stamped on the forks.



Order Information

Tuning Fork Technical Set SE-7728

Basic Optics System

Basic Optics System

OS-8515C

- ▶ Geometric and ray optics
- ▶ Concave and convex lenses
- ▶ Concave/convex mirror

PASCO's Basic Optics System is easy-to-use, affordable, and ruggedly designed. Large, 50 mm diameter optics components are mounted in protective holders that snap directly onto the aluminum track, allowing students to easily adjust components by snapping or sliding them along the track.

Image and object distances for both lenses and mirrors can be measured quickly and accurately with the built-in metric tape. The Light Source doubles as a tabletop ray box for studies in reflection, refraction, color addition, and Snell's Law. All of the components, with the exception of the track, fit in the included storage box.

Viewing Screen

White plastic screen snaps into the optics bench and the position of the screen can be read directly on the bench scale.

Adjustable Lens Holder

Use your own lenses (from 19 mm to 75 mm in diameter) or choose from our lens sets.

Four 50 mm Diameter Lenses

+100, +200, +250, -150 mm lenses are mounted in protective holders.

Concave/Convex Mirror

50 mm diameter plastic mirror with reflective surface on both sides; includes "half-screen" upon which the image is focused.

Ray Optics Kit

Includes concave/convex lenses, concave/convex/plane mirrors, acrylic rhomboid for prism spreading of white light and refraction experiments, and hollow lens for teaching the Lensmaker's Equation. Also includes storage tray that can be used as a water tank for the hollow lens.

Optics Bench (1.2 m)

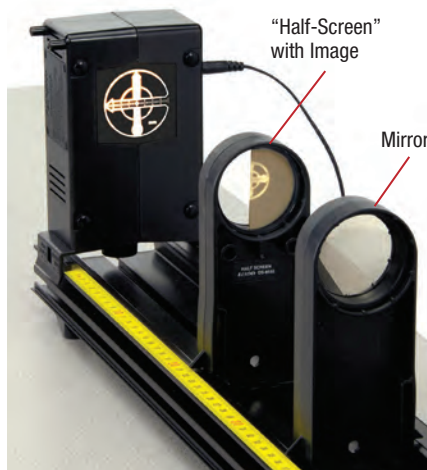
The lenses, mirrors, light source, and screen snap into this rugged aluminum extrusion. The metric tape makes position measurements easy.

Ray Table

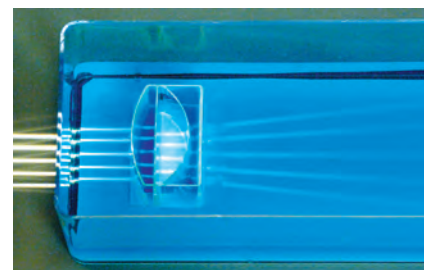
Two-piece construction allows the table to be rotated to study Snell's Law or the Law of Reflection. Includes D-shaped acrylic lens.



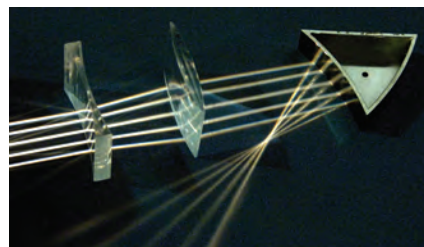
Ray Table in use showing both the reflected and refracted rays



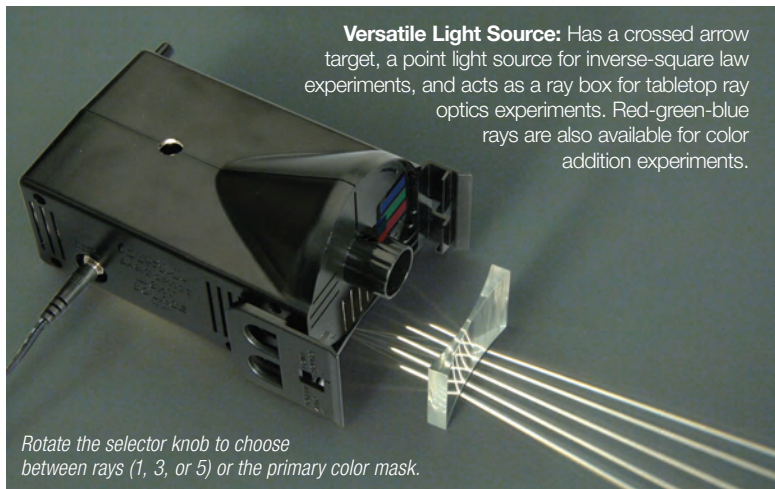
Light Source: Has a lighted crossed arrow target with metric scale for focusing images through lenses or for use with the concave mirror.



The storage tray is used to create a "hollow" air-filled convex lens. Note that the rays diverge.

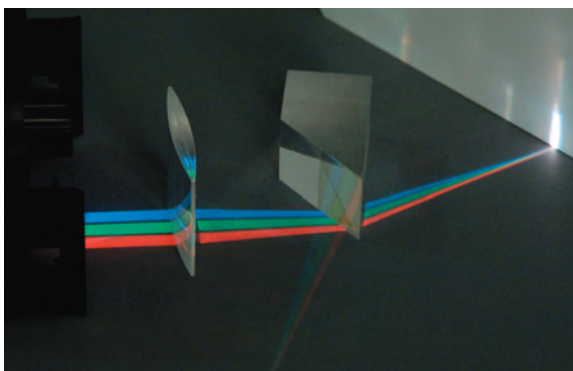


Components from the Ray Optics Kit showing refraction and reflection



Versatile Light Source: Has a crossed arrow target, a point light source for inverse-square law experiments, and acts as a ray box for tabletop ray optics experiments. Red-green-blue rays are also available for color addition experiments.

Rotate the selector knob to choose between rays (1, 3, or 5) or the primary color mask.

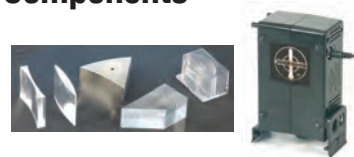


The primary color mask allows experiments in color addition using components from the Ray Optics Kit.

Basic Optics Components and Accessories

System Components

pp. 272-275



Color Mixer

p. 276



Lens Sets

pp. 274-275



System Accessories

pp. 274-275
278-279



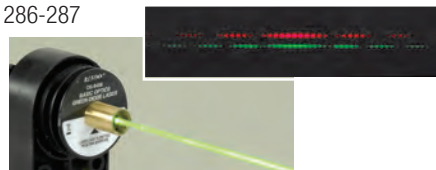
Human Eye Model

pp. 280-281



Diffraction

pp. 286-287



Dynamics Track Optics

p. 288



Perform These Experiments:

- ▶ Color Addition
- ▶ Prism
- ▶ Reflection
- ▶ Snell's Law
- ▶ Total Internal Reflection
- ▶ Convex and Concave Lenses
- ▶ Hollow Lens
- ▶ Lensmaker's Equation
- ▶ Apparent Depth
- ▶ Reversibility
- ▶ Dispersion
- ▶ Focal Length and Magnification of a Thin Lens
- ▶ Focal Length and Magnification of a Concave Mirror
- ▶ Virtual Images
- ▶ Telescopes and Microscopes
- ▶ Index of Refraction
- ▶ Shadows

Basic Optics System Storage Box

All components (except the track) fit in the custom foam box. There are additional slots for accessory lenses (see pp. 274-275).



Includes:

- 1.2 m Optics Track: OS-8508
- Basic Optics Light Source: OS-8470
- Accessory Lens Set: OS-8519
- Adjustable Lens Holder: OS-8474
- Ray Optics Kit: OS-8516A
- Basic Optics Viewing Screen: OS-8460
- Basic Optics Ray Table: OS-8465
- Basic Optics Geometric Lens Set: OS-8456
- Storage Box

Order Information

Basic Optics System OS-8515C

Basic Optics Components

Basic Optics Light Source

OS-8470

- ▶ One, three, or five parallel rays
- ▶ Three primary color source
- ▶ Crossed arrow object and point source

The Basic Optics Light Source is an excellent source for a variety of optics experiments. A single 10-watt quartz-halogen bulb provides bright, easy-to-see illumination without a lot of heat. By turning the box to a different side, it becomes a:

- Crossed Arrow Object with Metric Scale: ideal for showing images, focal point, and magnification.
- Bright Point Source: The very small filament of the halogen bulb provides an excellent point source for experimenting with shadows or the Inverse Square Law.
- Three Primary Colors Source: The red, green, and blue filters provide three rays of light that are easily combined with a lens for color mixing.
- One, Three or Five Ray Sources: Just rotate the knob in front of the light source to vary the number of rays produced.



Rotate the selector knob to choose between rays (1, 3, or 5) or the primary color mask.

The Basic Optics Light Source provides a point source and an extremely bright crossed arrow target. Use free-standing or easily clip directly to Basic Optics Track.



Includes:

- Universal AC Adapter
- Spare Bulb (stored under access cover)

Order Information

Basic Optics Light Source OS-8470

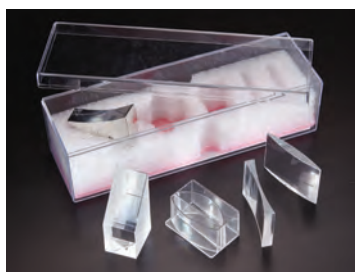
Ray Optics Kit

OS-8516A

The Ray Optics Kit is a basic set of optic components for ray and color experiments.

Includes:

- Double-Convex Lens
- Double-Concave Lens
- Rhomboid
- Eye-Dropper
- Triangular mirror accessory with concave, convex, and plane reflective surfaces
- Hollow lens to fill with a liquid or use as an air lens.



Order Information

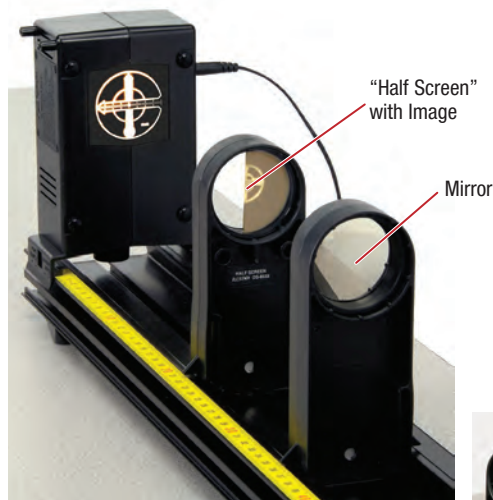
Ray Optics Kit OS-8516A

Concave/Convex Mirror

OS-8457

- ▶ 50 mm diameter
- ▶ ±100 mm focal length
- ▶ Plastic mirror

This double-sided convex/concave plastic mirror is mounted in a lens holder for easy placement on the Basic Optics Track. This accessory also includes a "half screen" that allows light to pass through on one side, and an opaque screen on the other half to focus the real image formed by the concave mirror.



Includes:

- Concave/Convex Mirror
- Half Screen

Order Information

Concave/Convex Mirror OS-8457

Basic Optics Ray Table

OS-8465

- ▶ Angle of reflection
- ▶ Snell's Law
- ▶ Total internal reflection

The Ray Table provides an excellent viewing surface for ray optics. The table can be rotated about its axis to quickly change the incident angle of the ray. The resulting angles of reflection and refraction are easily measured directly off the polar grid printed on the table. The included acrylic cylindrical D lens simplifies the experiment by having the rays bend at only one surface. Investigate Snell's Law for both cases of rays either entering or leaving the acrylic.



Includes:

- Table
- D-shaped Lens

Order Information

Basic Optics Ray Table OS-8465

Aperture Accessories

OS-8524

Aperture Disk:

Simulate the compound lens system of a camera using the Aperture Disk. Simply snap the disk onto one face of a lens. The disk offers six different f-number settings for controlling the amount of light that reaches the viewing screen.



The *f*-number is designated as $f / \#$, where $\#$ equals the focal length of the lens (f) divided by the diameter of the aperture (D). Example uses a +100 mm lens.

<i>f</i> -Number	Aperture Diameter (mm)
$f / 4$	25.0
$f / 5.6$	17.7
$f / 8$	12.5
$f / 11$	8.8
$f / 16$	6.3
$f / 22$	4.4

The Peripheral Mask passes light through the center only.



Spherical Aberration Attachments:

Do the center and outside parts of a lens focus light differently? With the Spherical Aberration Attachments, students will be surprised by the answer. Simply snap the attachments onto a lens from the Basic Optics System and compare the image distance (d_i) for each attachment.



Peripheral Mask shown mounted on +250 mm lens



The Center Mask passes light through an outside ring.

Includes:

- Aperture Disk and Holder
- Spherical Aberration Attachments

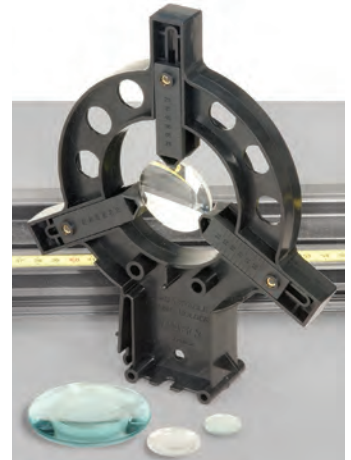
Order Information

Aperture Accessories OS-8524

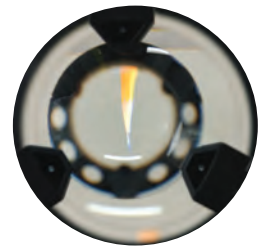
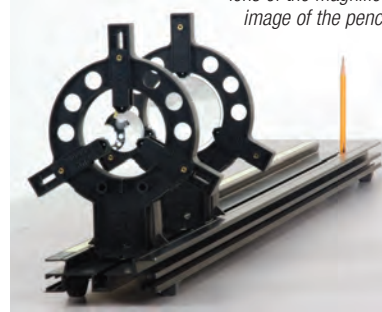
Adjustable Lens Holder

OS-8474

The Adjustable Lens Holder for the Basic Optics System is designed for use with lenses and mirrors with diameters between 19 mm and 75 mm. Simply place the lens or mirror in the holder and adjust the three arms to hold it. A set screw in each adjustable arm ensures that the mirror or lens will remain in place. The holder snaps into the Basic Optics Track and is designed to position all mirrors and lenses at the same height as the rest of the Basic Optics System components.



Actual view through the lens of the magnified image of the pencil



Build a telescope or microscope; shown with 1.2 m Basic Optics Track OS-8508.

Includes:

- Adjustable Lens Holder (lenses not included)

Order Information

Adjustable Lens Holder OS-8474

Lens Holder Set

OS-8522

These holders for the Basic Optics System are an excellent way to permanently mount 50 mm diameter lenses.

Just push in the two retaining rings to hold the lens in place.



Order Information

Lens Holder Set OS-8522

Basic Optics Accessories

50 mm Diameter Lens Assortment

SE-7581

This set of 6 lenses is made of polished glass with ground edges, and comes in a wooden storage box.

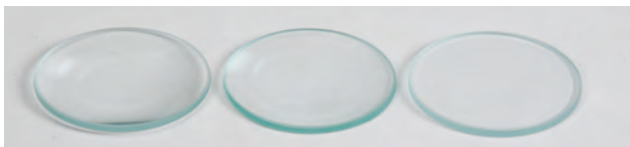
Focal Length (mm)	Description	Focal Length (mm)	Description
+1000	double convex	-1000	double concave
+300	double convex	-200	double concave
+150	double convex	-150	double concave

Order Information

50 mm Diameter Lens Assortment.....SE-7581

Geometric Lens Set

OS-8466A



This is a set of three unmounted 50 mm diameter glass lenses with focal lengths of +100 mm, +200 mm, and -150 mm. These are the same lenses included in the Dynamics Track Optics Kit (OS-8471A) and the Beginning Optics System (OS-8459). They can be mounted in the Adjustable Lens Holder (OS-8474).

Order Information

Geometric Lens Set OS-8466A

Lens Sets

Basic Optics Geometric Lens Set (Set of 2)

(+200, +100 mm) OS-8456

Accessory Lens Set (Set of 2)

(+250, -150 mm) OS-8519



Each lens is mounted in a lens holder for protection and easy storage. The lens holder clips directly to the Basic Optics Track.

Order Information

Basic Optics Geometric Lens Set..... OS-8456
Accessory Lens Set OS-8519

Ground Glass Lenses (Set of 6)

SE-9013



These precision ground glass lenses provide a useful range of focal lengths. Each lens has a 50 mm diameter – small enough for easy mounting, yet large enough for effective viewing. The set of six comes in a convenient storage box.

Focal Length	Description	Focal Length	Description
500 mm	concave convex	-150 mm	double concave
300 mm	plano convex	-300 mm	plano concave
150 mm	double convex	-500 mm	convex concave

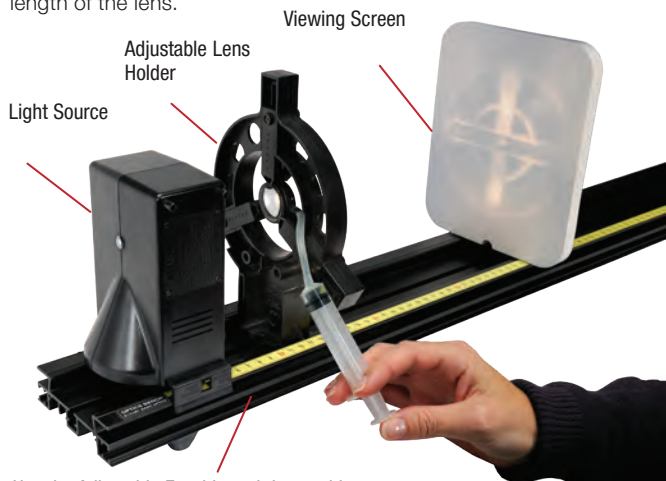
Order Information

Ground Glass Lenses (Set of 6) SE-9013

Adjustable Focal Length Lens

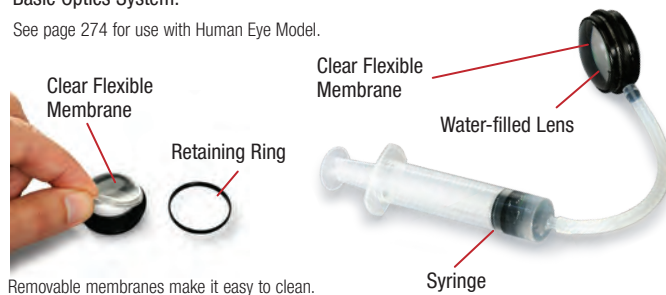
OS-8494

Using the syringe to adjust the amount of water in the lens changes the curvature of the clear flexible membranes and, therefore, the focal length of the lens.



Use the Adjustable Focal Length Lens with your Basic Optics System.

See page 274 for use with Human Eye Model.



Removable membranes make it easy to clean.

Includes:

- 10 mL Syringe
- 1 ft. Silicon Tubing
- Lenses (2)

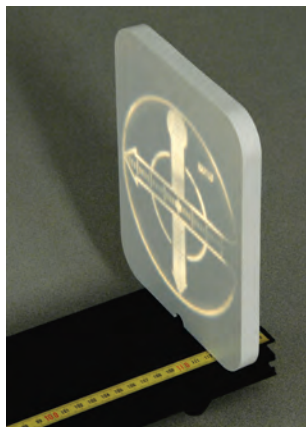
Order Information

Adjustable Focal Length Lens.....OS-8494
Shown in use with:
Basic Optics System OS-8515C p. 270

Basic Optics Viewing Screen

OS-8460

This white plastic screen is used with the Basic Optics System. The screen snaps into the optics bench, and the position of the screen can be read directly on the bench scale. Also fits the Dynamics Track Optics Carriages (OS-8472 on page 280) for use with a Dynamics Track.



Order Information

Basic Optics Viewing Screen OS-8460

Basic Optics Spares Kit

OS-8510

All parts are organized in a plastic case for easy storage.



The Basic Optics Spares Kit includes many of the small parts that are sometimes lost after student use. Also includes two replacement bulbs for the Light Source. Suitable for all versions of the Basic Optics System (OS-8515).

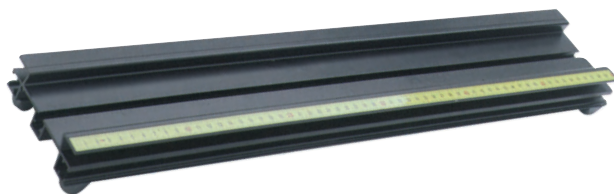
Includes:

- 10 W bulb for Basic Optics Light Source OS-8470 or OS-8517 (2)
- 6-32 1-1/2" Screw for the Basic Optics Light Source OS-8517A (8)
- 3/8" Screw for optics accessories (6)
- 3/8" Brass thumbscrew for optics track brackets (4)
- 1/4-20 1/2" Nylon thumbscrews (8)
- 1/4-20 Square nuts (20)
- Nylon washers (6)
- 1/4-20 9/16" Round steel thumbscrews (4)
- 1/4-20 3/8" Round steel thumbscrews (4)
- 6-32 5/8" Round steel thumbscrews (6)
- 6-32 3/8" Round steel thumbscrews (4)
- 4-40 5/16" Round steel thumbscrews (4)
- 6-32 3/16" Round steel thumbscrews (4)
- Replacement rubber feet for optics bench (6)
- Replacement rubber feet for Basic Optics Light Source OS-8517 (15)
- Replacement screws for Basic Optics Light Source OS-8470 (4)
- Plastic storage box

Order Information

Spares Kit OS-8510

Optics Benches



Optics Bench (60 cm)

OS-8541

This short optical bench is for experiments such as polarization and spectrophotometry.

1.2 m Optics Track

OS-8508

The 1.2 m optics bench is the perfect length for studying the inverse square law, diffraction/interference patterns, and the behavior of light traveling through lenses or off of curved mirrors. It is made of extruded aluminum and has a wide central channel for PASCO optics components, such as mounted lenses, mirrors, and light boxes.

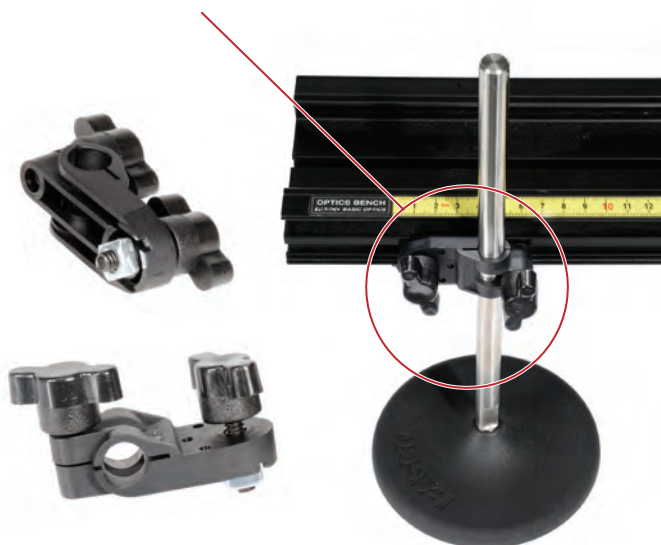
Order Information

Optics Benches (60 cm) OS-8541
1.2 m Optics Track OS-8508

Optics Bench Rod Clamp (Set of 2)

OS-8479

Rod Clamps are used to elevate Basic Optics benches to match the height of various light sources.



Includes:

- Rod Clamps (2)

Order Information

Optics Bench Rod Clamp (set of 2) OS-8479
Shown in use with:
Round Base with Rod ME-8270

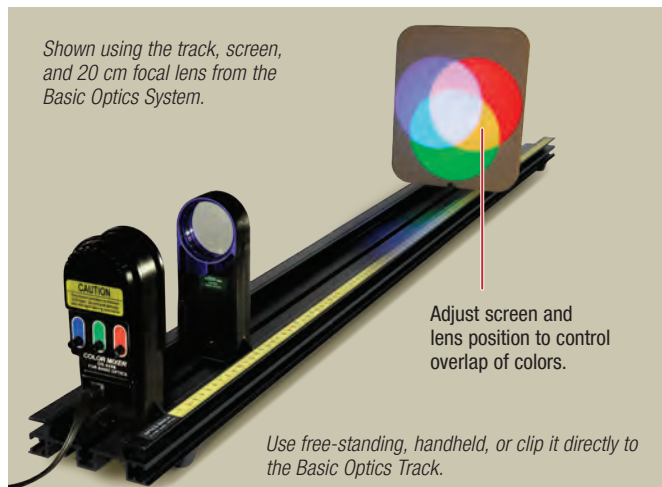
Color

Color Mixer

OS-8496

- ▶ Demonstrates additive color mixing
- ▶ Accessory to Basic Optics System

Three independently controllable LEDs offer a simple way to explore light and color. The Color Mixer can be used as both a demonstration tool and as an expansion piece to the Basic Optics System.



The intensity of the red, green and blue LEDs of the Color Mixer can be individually adjusted to easily vary the intensity of any or all of them. Demonstrating additive color mixing is as simple as using any flat surface to project the light upon.



Includes:

- Tri-color light source
- Power supply



Order Information

Color Mixer OS-8496

Color Mixer Accessory Kit

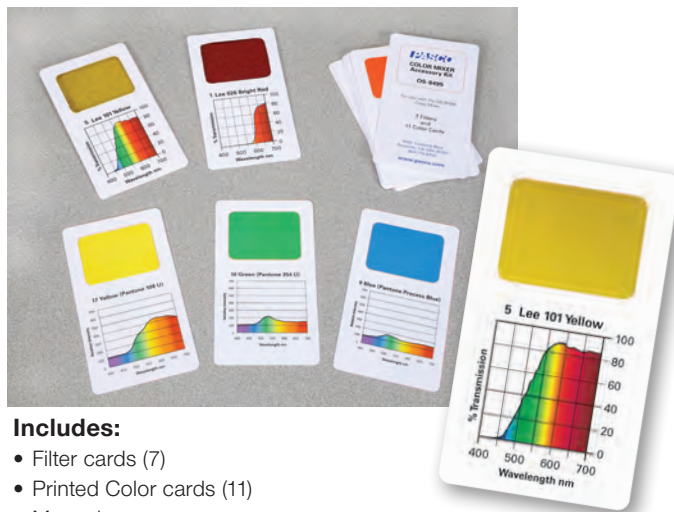
OS-8495

- ▶ Accessory to the Color Mixer
- ▶ 7 filter cards
- ▶ 11 printed color cards
- ▶ Manual with 9 lab activities



The red filter's spectral chart shows it transmits only red light. Students observe that the blue and green circles disappear and the overlapping areas of magenta, yellow, and white become red.

The Color Mixer Accessory Kit has 18 cards (64 mm x 89 mm) and a manual with 9 associated lab activities. Each of the 7 filter cards has its transmission spectrum printed on the card. Each of the 11 color cards is printed with a different color and its associated relative reflectance spectrum. Printed colors are defined by the Pantone color matching system. This accessory kit was designed especially for use with the Color Mixer.



Includes:

- Filter cards (7)
- Printed Color cards (11)
- Manual

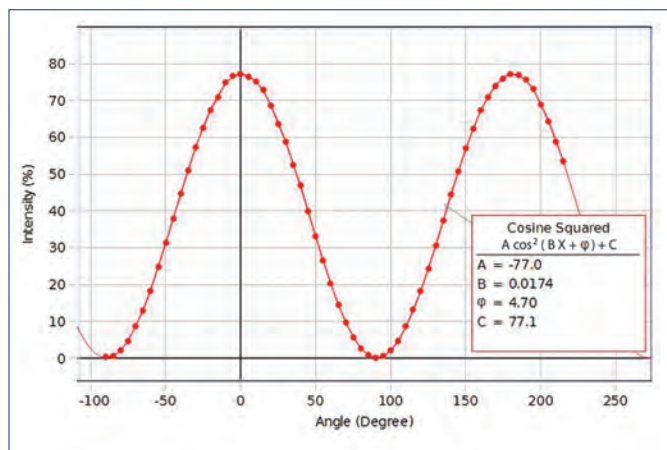
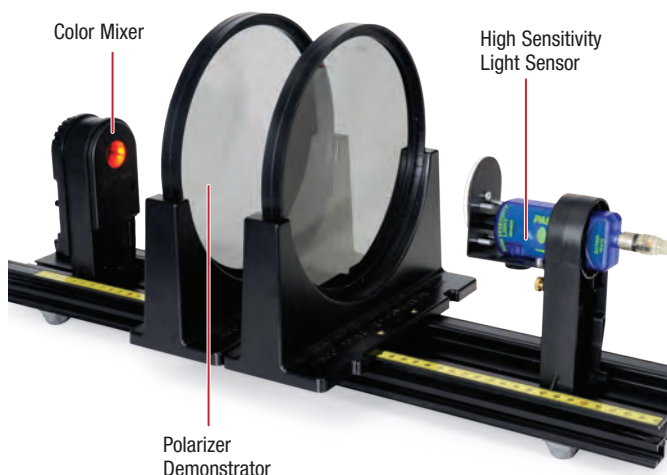
Order Information

Color Mixer Accessory Kit OS-8495

Polarizer Demonstrator

OS-9477A

Confirm Malus' Law using the Polarizer Demonstrator and a Light Sensor. The angle is read directly from the polarizer, which is marked in 5° increments. Any light source can be used, but the experiment works especially well with the Color Mixer, as shown here.



As the polarizer is rotated, the intensity of the light varies as the square of the cosine of the angle between the two polarizers.

Includes:

- Round Polarizer Discs with Stands

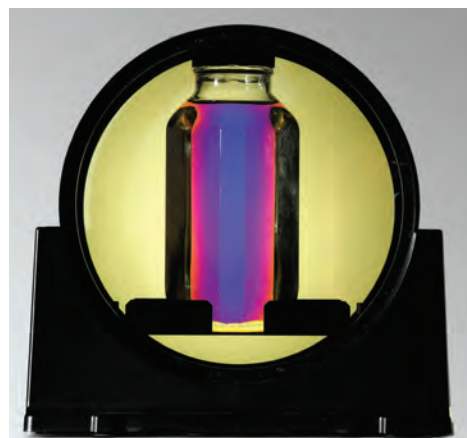
Order Information

Polarizer Demonstrator	OS-9477A	
Shown in use with:		
Optics Benches (60 cm)	OS-8541	p. 275
Aperture Bracket.....	OS-8534A	p. 287
Color Mixer	OS-8496	p. 276
PASPORT High Sensitivity Light Sensor	PS-2176	p. 35

Polarizer Demonstration Accessory

OS-8172

This accessory adds a central platform and diffuser to the Polarizer Demonstrator (OS-9477A). Put sugar water in one of the two supplied square glass bottles and put it on the platform between crossed polarizers. Use a desk lamp or Color Mixer (OS-8496) behind the diffuser and rotate one of the polarizers to see the sugar water change colors as the axis of polarization of different colors rotates to different angles.



Demo with Karo® corn syrup shows wavelength dependence of optical rotation. The light source used was a compact florescent (not included).



Includes:

- Square Glass Bottles (2)
- Metal Stand for Bottles
- Diffusion Screen



Order Information

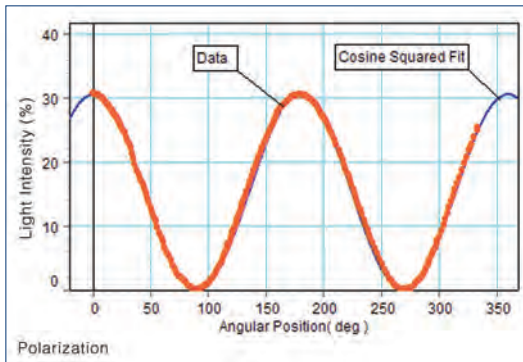
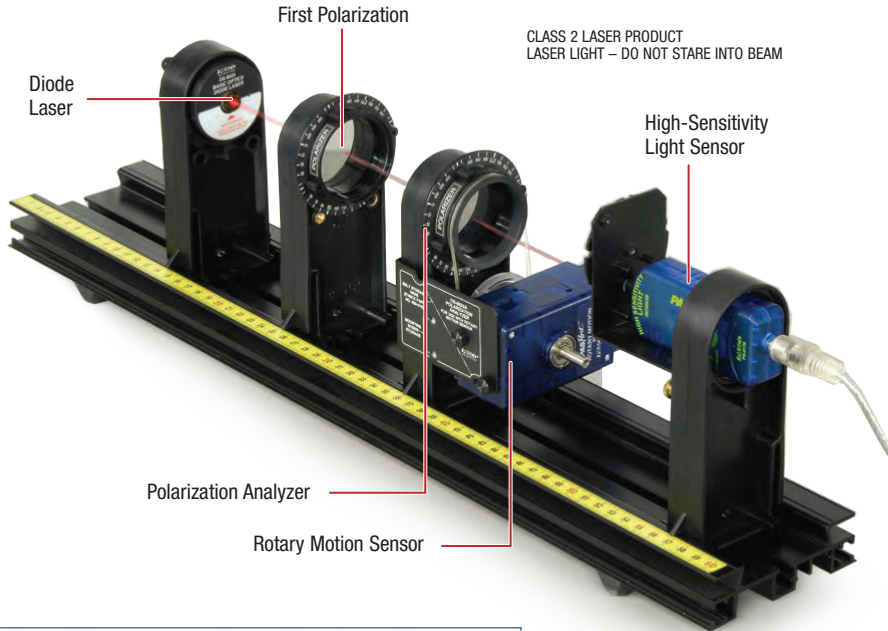
Polarizer Demonstration Accessory	OS-8172	
Required:		
Polarizer Demonstrator	OS-9477A	
Suggested:		
Color Mixer	OS-8496	p. 276

Polarization

Polarization Analyzer

OS-8533A

Students can confirm Malus' Law of Polarization by using the Polarization Analyzer with the Basic Optics System. All components mount directly to PASCO's Basic Optics Bench OS-8541. The Rotary Motion Sensor is used to measure the angle between the two polarizing disks. The Light Sensor measures the intensity of light that passes through both polarizers.



Shown with Optics Bench OS-8541, 60 cm track

As the polarizer is rotated, the intensity of the light varies as the square of the cosine of the angle between the two polarizers.



Includes:

- Polarizer Disks (2)
- Polarizer Holder
- Aperture Bracket
- Accessory Holder with Mounting Bracket
- Accessory Holder for Aperture Bracket
- Retarder Disk

Order Information

Polarization Analyzer OS-8533A

Required:

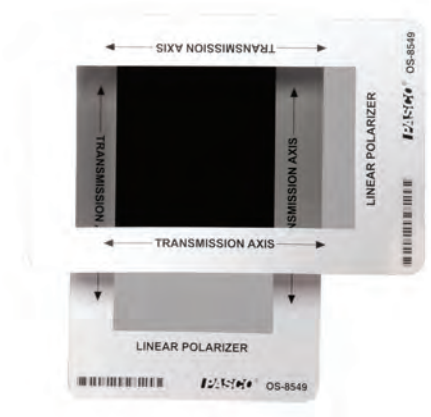
PASPORT Rotary Motion Sensor	PS-2120A	p. 28
PASPORT High Sensitivity Light Sensor	PS-2176	p. 35
Basic Optics System	OS-8515C	p. 270
Red Diode Laser	OS-8525A	p. 287

See page 380 for complete experiment.

Linear Polarizer (2-Pack)

OS-8549

This pair of rectangular polarizers are mounted in cardboard frames. The polarizing film dimensions are 3.5" x 6". Includes two polarizers.



Order Information

Linear Polarizer (2-Pack)..... OS-8549

Polarizer Set

OS-8473

This accessory set includes two polarizer disks and an optics holder. Rotate the polarizers relative to one another to view the effect on light intensity.



Order Information

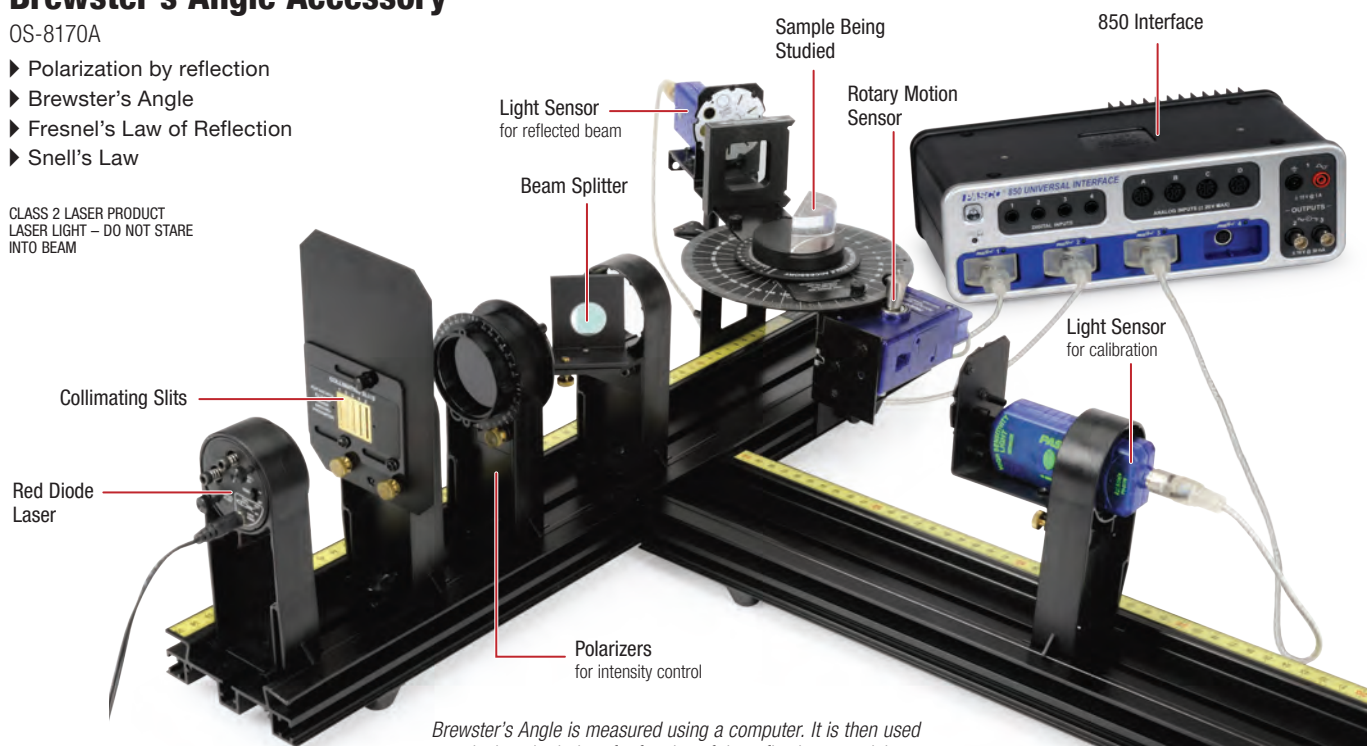
Polarizer Set OS-8473

Brewster's Angle Accessory

OS-8170A

- ▶ Polarization by reflection
- ▶ Brewster's Angle
- ▶ Fresnel's Law of Reflection
- ▶ Snell's Law

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE
INTO BEAM



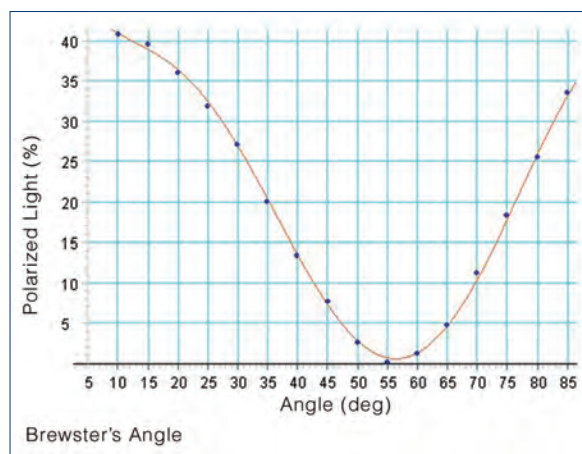
Brewster's Angle is measured using a computer. It is then used to calculate the index of refraction of the reflecting material.

When light reflects off a nonconducting material, the reflected light is partially polarized. The amount of polarization depends on the incident angle and the index of refraction of the reflecting material. The incident angle that gives maximum polarization is called Brewster's Angle.

Light from a diode laser (wavelength = 650 nm) is reflected off the flat side of an acrylic semicircular lens. The reflected light passes through a polarizer and is detected by a Light Sensor. The angle of incidence is measured by a Rotary Motion Sensor mounted on the spectrophotometer table. The intensity of the reflected polarized light vs. incident angle is graphed to determine the angle at which the light intensity is a minimum. This is Brewster's Angle, which is used to calculate the index of refraction of acrylic.

Developed using original ideas from P.J. Ouseph, Professor of Physics at University of Louisville, KY: "Polarization of Light by Reflection and the Brewster Angle" by P.J. Ouseph, Kevin Driver, and John Conklin, Am. J. Phys. 69, 1166 (2001). This modification to the experiment was suggested by Cristian Bahrim and Wei-Tai Hsu in the American Journal of Physics article: "Precise measurement of the refractive indices for dielectrics using an improved Brewster angle method," Vol. 77, page 337 (2009).

The intensity of the reflected polarized light as a function of the incident angle; see Brewster's Angle Experiment on page 381.



Includes:

- Acrylic semicircular lens
- Lens platform
- Polarizers with holder (2)
- Analyzing polarizer
- Beam splitter



Order Information

Brewster's Angle Accessory OS-8170A
 Basic Optics Beam Splitter OS-8171
 For other required equipment, see the Brewster's Angle experiment EX-5544A on page 381.

Optics of the Human Eye

Human Eye Model

OS-8477A

- ▶ Classic eye model at an affordable price
- ▶ 3-D working model of the human eye

Features:

▶ Working Model of the Human Eye:

Two lenses are used to form images on the retina. Sealed tank holds water to simulate the vitreous humor. Size and orientation of the illuminated object can be easily measured.

▶ Study the Optics of Normal Vision and Vision Correction:

Use the included plastic lenses to create images for normal vision, far-sightedness, near-sightedness, and astigmatism. Additional lenses are placed in front of the eye to correct for vision problems.

▶ Fixed Corneal Lens and Interchangeable Crystalline Lens:

The crystalline lens is surrounded by water (vitreous humor). By changing the crystalline lens, the eye can focus on both near and far objects.

▶ Movable Retina:

Three positions demonstrate near-sightedness, far-sightedness, and normal vision.

▶ Variable Pupil Size:

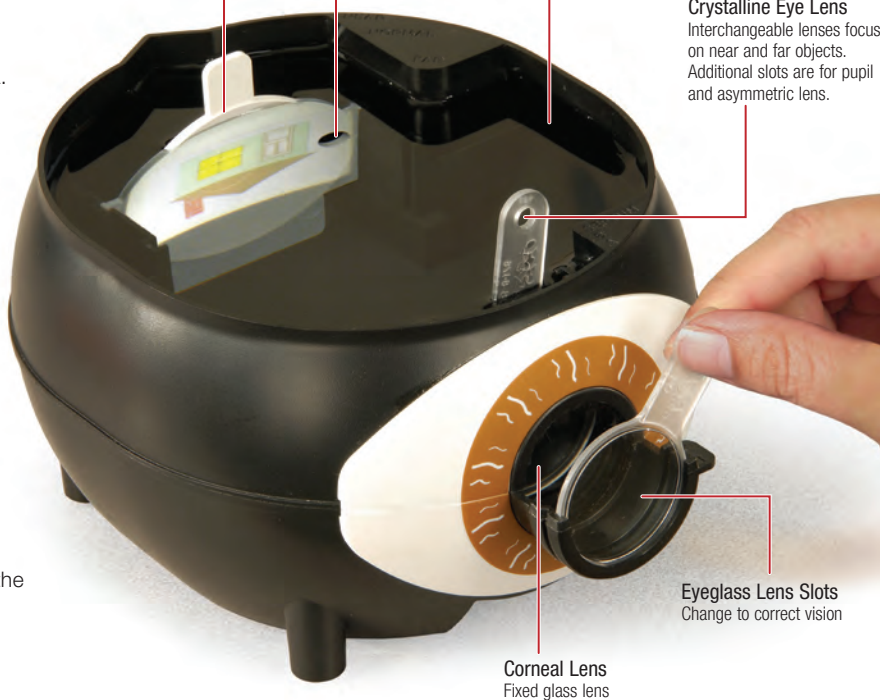
Students can observe the change in brightness and clarity of the image as the pupil size is reduced.

Retina
Three positions for near-sighted, far-sighted, and normal vision

Blind Spot
Simulates retina attachment point

Plastic Eyeball
Holds water to simulate the vitreous humor

Crystalline Eye Lens
Interchangeable lenses focus on near and far objects. Additional slots are for pupil and asymmetric lenses.



Eyeglass Lens Slots
Change to correct vision

Corneal Lens
Fixed glass lens

Pupil Aperture



Use the Pupil Aperture to reduce the pupil size or to change the shape to a "cat's eye."



The Eye Model can image any illuminated picture, or use it with the Basic Optics System and Eye Model Bracket on page 281.

Includes:

- Molded Plastic Eyeball
- Plastic Lenses (2 sets of 6)
- Pupil Aperture
- Retina Screen
- Optics Caliper
- Adjustable Focal Length Lens with Syringe, Tubing, and 2 Flexible Lenses
- Experiment Manual



Specifications:

Focal Lengths in Air of Plastic Lenses: +62 mm (+16d), +120 mm (+8.3d), +400 mm (+2.5d), -1000 mm (-1.0d), -128 mm (-7.8d) cylindrical, +307 mm (+3.26d) cylindrical

Corneal Lens Focal Length in Air: +140 mm (+7.1d)

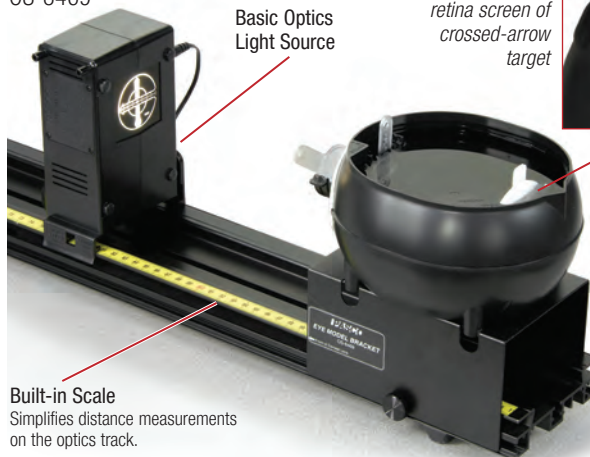
Dimensions: 15 cm x 17 cm x 10 cm high

Order Information

Human Eye Model.....	OS-8477A	
Recommended:		
Basic Optics Light Source	OS-8470	p. 272
Lens Replacement Set	OS-8476	
(includes lenses, screen, and pupil)		
Optics Caliper	OS-8468	p. 281

Eye Model Bracket

OS-8469



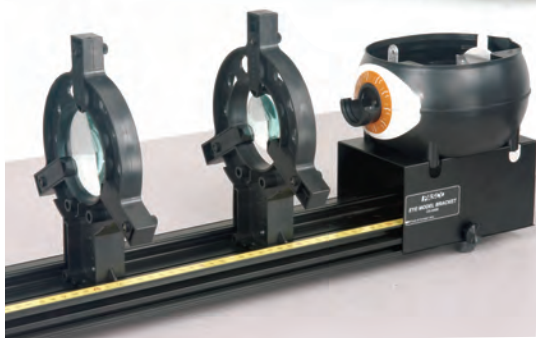
Built-in Scale
Simplifies distance measurements on the optics track.

Image on retina screen of crossed-arrow target



The Eye Model Bracket allows the Human Eye Model to be used with the Basic Optics System (OS-8515C). The bracket holds the Eye Model securely on the track at the correct optical height.

The illuminated crossed-arrow target on the Basic Optics Light Source makes the perfect object. Easily measure object and image distances, as well as the size of the object and image for calculations of magnification.



Eye Model and Bracket are shown with a telescope made using two Adjustable Lens Holders (OS-8474) and accessory lenses. Students can see the image through the telescope with their own eyes, and then place the Eye Model on the track and see the same image projected on the retina screen.

Includes:

- Bracket
- Two 1/4-20 thumb screws with nuts (2)

Order Information

Eye Model Bracket.....	OS-8469
Shown in use with:	
Basic Optics System	OS-8515C
Human Eye Model.....	OS-8477A

Optics Caliper

OS-8468

- ▶ Glow-in-the-dark tips
- ▶ Waterproof

This lightweight plastic caliper is perfect for measuring images in the dark. Simply span the object and then use a scale to measure the distance. For approximate measurements, use the built-in cm scale on the calipers.



The tips of the caliper glow in the dark. Activate with an incandescent or UV lamp.



Use the Optics Caliper to measure image sizes in the Human Eye Model. Glow-in-the-dark tips are activated using a UV light source.

Order Information

Optics Caliper (set of 5).....	OS-8468
--------------------------------	---------

Adjustable Focal Length Lens

OS-8494

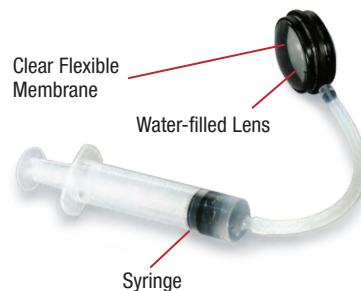
Using the syringe to adjust the amount of water in the lens changes the curvature of the clear flexible membranes and, therefore, the focal length of the lens.



Demonstrate accommodation:

Show how the eye lens changes focal length by changing its surface curvature.

See page 270 for use with Basic Optics System.



Includes:

- 10 mL Syringe
- 1 ft. Silicon Tubing
- Lenses (2)

Order Information

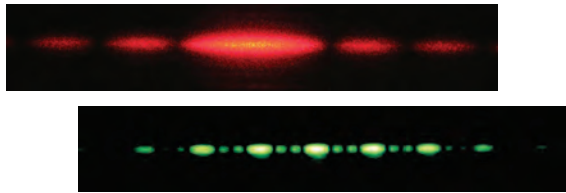
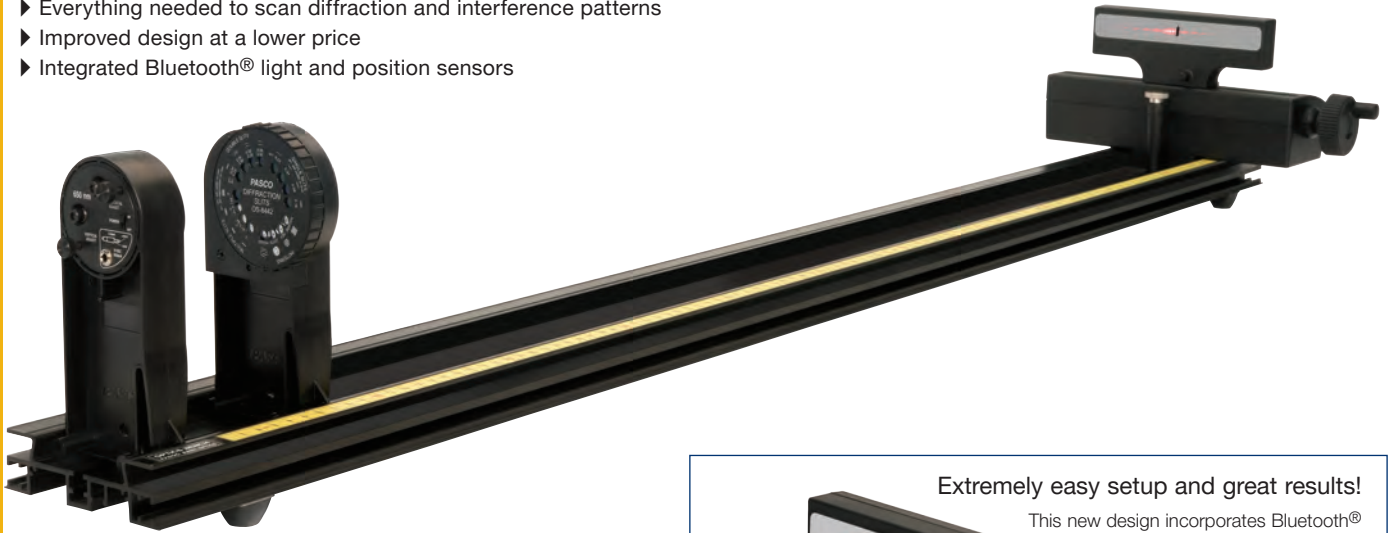
Adjustable Focal Length Lens.....	OS-8494
Shown in use with:	
Human Eye Model.....	OS-8477A

Wireless Diffraction System

Wireless Diffraction System with Track

OS-8439

- ▶ Everything needed to scan diffraction and interference patterns
- ▶ Improved design at a lower price
- ▶ Integrated Bluetooth® light and position sensors

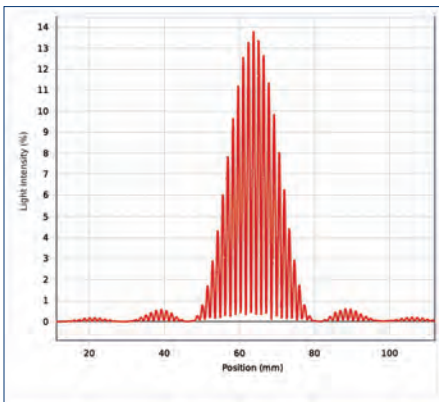


Four slits illuminated with a green laser reveal the expected two minor maxima.

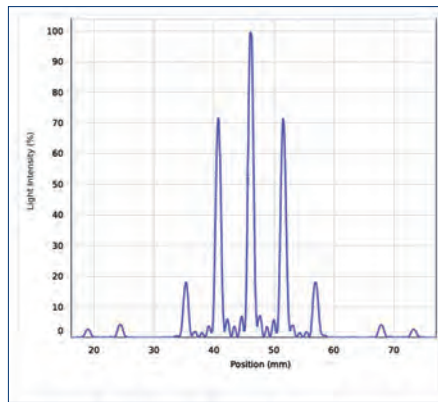


Extremely easy setup and great results!

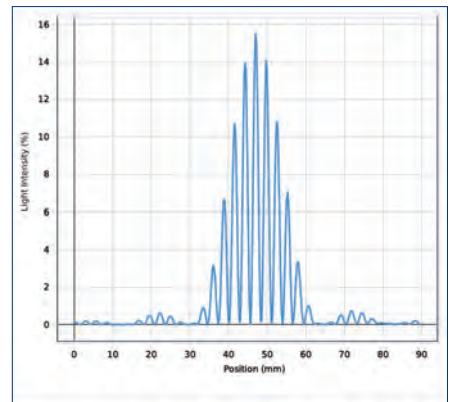
This new design incorporates Bluetooth® light and position sensors into one convenient unit. Smooth hand-cranked scanning is achieved with a precision worm gear. The reduced number of parts makes assembly and alignment very easy.



This system works so well that many orders of diffraction can be detected.



High resolution enables students to see the three minor maxima when scanning five slits.



Actual double-slit graph of Intensity vs. Distance looks just like the textbook illustrations.

Includes:

- Red Diode Laser: OS-8525A
- Diffraction Slits: OS-8442
- Wireless Diffraction Scanner: OS-8441
- 1.2 m Optics Track: OS-8508

Order Information

Wireless Diffraction System with Track	OS-8439
Recommended:	
Green Diode Laser	OS-8458B

Wireless Diffraction Scanner

OS-8441

- ▶ Real-time Intensity vs. Position graphs
- ▶ Single-slit diffraction
- ▶ Double-slit interference
- ▶ Precision hand crank for smooth, consistent travel
- ▶ Light sensor aperture adjustment
- ▶ 0.01 mm position measurement resolution
- ▶ Wireless Bluetooth® Low Energy technology

The Wireless Diffraction Scanner combines a position sensor with a light sensor for scanning diffraction patterns. Compatible with PASCO optics benches (or dynamics track adapter carriages), the Wireless Diffraction Scanner is the perfect update to existing PASCO-based optics systems that use the snap-in optics components. An included aperture setting allows for the adjustment of width-measurement resolution (and light attenuation). A hand crank allows for smooth scanning of diffraction patterns. Because of the wireless design, smooth scans are achieved effortlessly!

This unit enables students to scan many diffraction and interference patterns during one lab period. They can study the differences caused by changing the slit width, slit separation, and number of slits. And, by comparing patterns created by a Red Diode Laser to those of a Green Diode Laser, they can study the difference caused by a change in wavelength.

Measurement control is achieved using either PASCO Capstone or SPARKvue software (required). Connect to software using either USB or Bluetooth Low Energy.



Specifications:

Aperture Range: 0.1 mm to 1.5 mm

Position Resolution: .01 mm

Battery: Rechargeable Lithium-Polymer 1000 mA

Connectivity: USB or Bluetooth® Low Energy

Scan Travel: 155 mm

Includes:

- USB Charging Cable

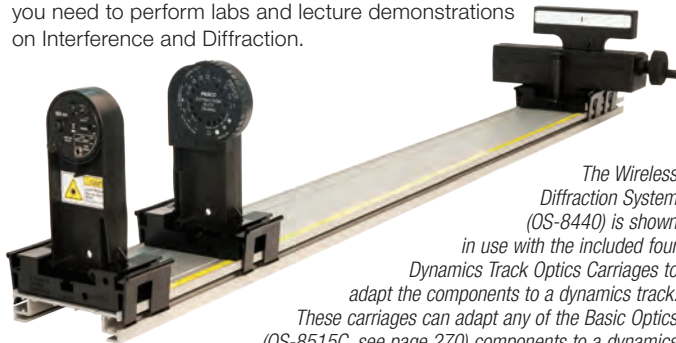
Order Information

Wireless Diffraction Scanner OS-8441

Wireless Diffraction System

OS-8440

If you already have a PASCO Optics Track, or a PASCO Dynamics Track, the Wireless Diffraction System contains all the equipment you need to perform labs and lecture demonstrations on Interference and Diffraction.



The Wireless Diffraction System (OS-8440) is shown in use with the included four Dynamics Track Optics Carriages to adapt the components to a dynamics track. These carriages can adapt any of the Basic Optics (OS-8515C, see page 270) components to a dynamics track, turning your dynamics track into an optical bench.

Includes:

- Red Diode Laser: OS-8525A
- Wireless Diffraction Scanner: OS-8441
- Diffraction Slits: OS-8442
- Dynamics Track Optics Carriages (Set of 4): OS-8472A

Order Information

Wireless Diffraction System OS-8440
 Required:
 1.2 m Optics Track OS-8508
 OR
 1.2 m Aluminum Dynamics Track ME-9493
 OR
 PASTrack ME-6960

Diffraction Slits

OS-8442

The Diffraction Slits include a selectable wheel with 16 interference patterns designed to match the height of the PASCO Diode Lasers. The slits are constructed using vacuum deposited chromium on glass and clip directly to a PASCO Optics Bench.



Specifications:

Compatible System:

PASCO Optics Track

Slit Width Tolerance (mm): ± 0.005

Slit Spacing Tolerance (mm): ± 0.010 (spacing > 0.125)

Slit Spacing Tolerance (mm): ± 0.005 (spacing < 0.125)

Printing Type: Vacuum-deposited Chromium on glass

Single Slit Width (mm): $a = 0.02, 0.04, 0.08, 0.16$

Double Slit Width, Separation (mm):

$a = 0.04, d = 0.25$; $a = 0.04, d = 0.50$

Double Slit Width, Separation (mm):

$a = 0.08, d = 0.25$; $a = 0.08, d = 0.50$

Multiple Slits (mm): 2, 3, 4, 5 ($a = 0.04, d = 0.125$)

Patterns: Square, Hexagonal, Dots, Holes

Order Information

Diffraction Slits OS-8442

Diffraction

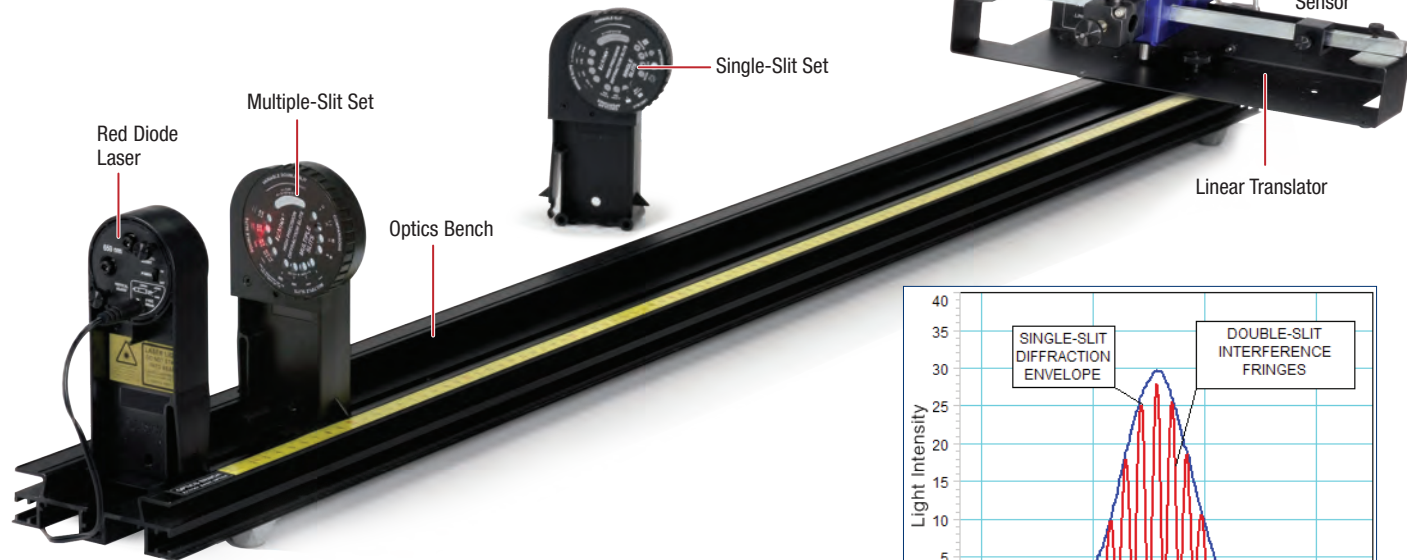
Sensor-Based Diffraction System

OS-8452

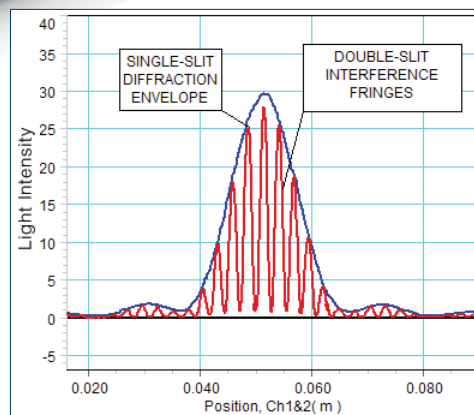
- ▶ Vacuum-deposited chromium on glass
- ▶ Single-slit diffraction

- ▶ Double-slit interference
- ▶ Real-time intensity graphs

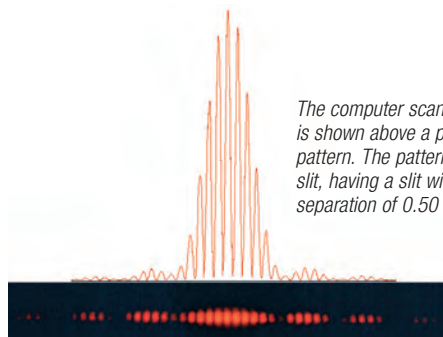
The Sensor-Based Diffraction System enables students to scan many diffraction and interference patterns during one lab period. They can study the differences caused by changing the slit width, slit separation, and number of slits. And, with the addition of the Green Diode Laser, they can study the difference caused by changing the wavelength.



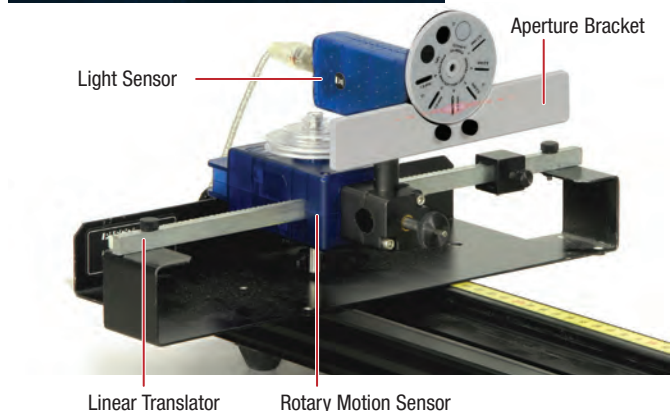
Scanning with the Linear Translator (on page 279): In this unique scanning system, the diffraction pattern is scanned using a light sensor attached to a Rotary Motion Sensor. As the wheel on the Rotary Motion Sensor is rotated by hand, the Rotary Motion Sensor moves along a gear rack (called the Linear Translator). Students make the association between the diffraction pattern they see and the real-time graph of the light intensity vs. position.



Computer scan of a single-slit and double-slit having the same slit width



The computer scan of an interference pattern is shown above a photograph of the actual laser pattern. The pattern was produced with a double-slit, having a slit width of 0.08 mm and a slit separation of 0.50 mm.



Includes:

- Red Diode Laser: OS-8525A
- Linear Translator: OS-8535A
- Aperture Bracket: OS-8534A
- 1.2 m Optics Track: OS-8508
- Precision Diffraction Slits: OS-8453



For components and accessories, see pages 286-287.

Order Information

Sensor-Based Diffraction System (with Optics Bench).....	OS-8452
Required for use with ScienceWorkshop:	
Light Sensor	CI-6504A
Rotary Motion Sensor	CI-6538
Required for use with PASPORT:	
PASPORT High Sensitivity Light Sensor	PS-2176
PASPORT Rotary Motion Sensor	PS-2120A
Recommended:	
Green Diode Laser	OS-8458B

p. 287

Diffraction Optics Kit

OS-8531A

Add this kit to the Basic Optics System to allow the investigation of a wide variety of diffraction slit patterns. The slits are constructed using vacuum-deposited chromium on glass.

The following patterns are included:

- ▶ Single Slit (four variations)
- ▶ Variable Width Single Slit
- ▶ Double Slit (four variations)
- ▶ Multiple Slit (3,4,5)
- ▶ Single Slit/Double Slit Comparison
- ▶ Variable Spacing Double Slit



Single Slit Pattern ($a = 0.04 \text{ mm}$)



Double Slit Pattern ($a = 0.08 \text{ mm}$, $d = 0.05 \text{ mm}$)

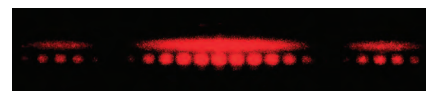
CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT
STARE INTO BEAM



Slit Accessory
Snaps into position on the bench for automatic slit alignment with laser. Rotate disk to select a different pattern.



4-Slit Pattern ($a = 0.04 \text{ mm}$, $d = 0.125 \text{ mm}$)



Single/Double Slit Comparison

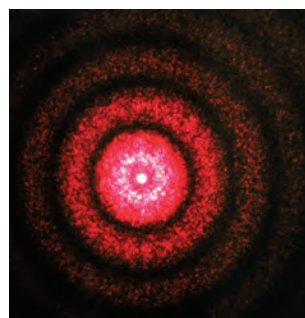
Easy Laser Alignment

The laser beam can be aimed through the slits using two thumb screws. Once the beam is aligned, either the laser or the slits can be removed from the optics bench and returned to the bench without re-aligning the beam.

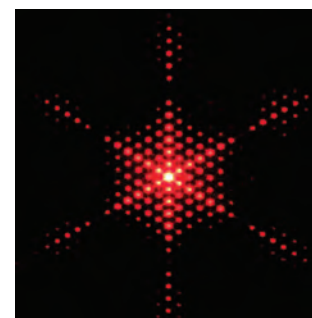


Change Slits in the Dark Without Re-aligning Everything

The slit wheels eliminate the frustration of trying to change the slits in a darkened room. Simply rotate to the next positive click to lock a different slit into position. The alignment of the disk only has to be done once. After that, all the slits on that wheel will be aligned.



Circular Diffraction Pattern

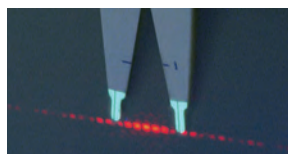


Hex Diffraction Pattern

Optics Caliper

OS-8468

This lightweight plastic caliper is perfect for measuring images in the dark. Simply span the object and then use a scale to measure the distance. For approximate measurements, use the built-in cm scale on the calipers. See page 281 for more information.



Order Information

Optics CaliperOS-8468

Includes:

- Red Diode Laser: OS-8525A
- Precision Diffraction Slits: OS-8453



For components and accessories, see pages 286-287.

Order Information

Diffraction Optics Kit.....	OS-8531A
Required:	
1.2 m Optics Track.....	OS-8508
Basic Optics Viewing Screen.....	OS-8460
Recommended:	
Green Diode Laser.....	OS-8458B

p. 287

Diffraction Components

Precision Diffraction Slits

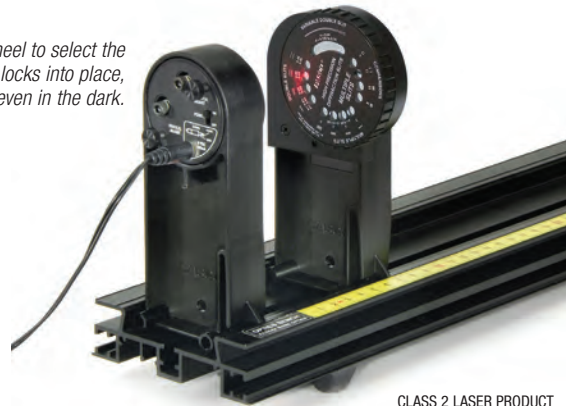
OS-8453

- ▶ Vacuum-deposited chromium on glass
- ▶ Single-slit and double-slit wheels

OS-8453 includes two slit wheels with holders designed to match the height of the slits to the height of the diode laser. All components clip directly to the Optics Bench from the Basic Optics System OS-8515C. The slit wheels eliminate the frustration of trying to change the slits in a darkened room. To change the slit being illuminated by the laser, the slit wheel is simply rotated to the next positive click, which locks another slit into position.

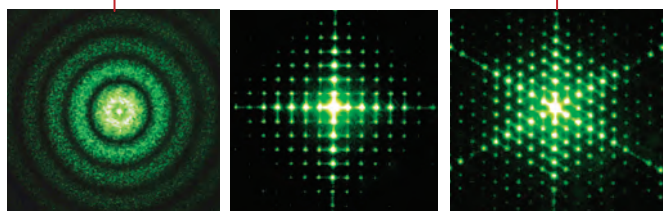
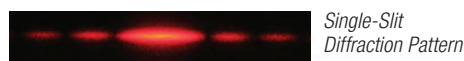
Shown in use with the red OS-8525A and green OS-8458 Diode Lasers.

Simply rotate the wheel to select the desired slit. Each position locks into place, making it easy to use, even in the dark.



CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT
STARE INTO BEAM

The Single-Slit Wheel includes four single slits of different widths, two circular apertures, one line/slit comparison, one opaque line, a variable width slit, and four patterns.



The Circular Diffraction pattern has the same dimensions for both the dots and the holes.

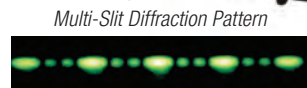
The diffraction geometry represents the structure of the Square and Hex patterns.

Includes:

- Single-Slit Wheel with Holder
- Multiple-Slit Wheel with Holder

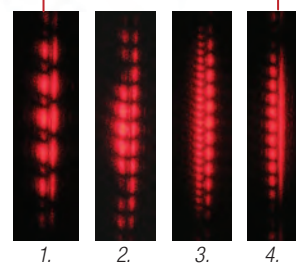


The Multiple-Slit Wheel includes four double slits, a set of four multiple slits having the same slit width and separation (2, 3, 4, and 5 slits), four slit comparisons, and a variable double slit.



The comparisons have two slits illuminated by the same red laser beam, so that the patterns can be viewed side by side.

1. Two-slit and three-slit comparison
2. Different slit widths
3. Different slit separation
4. Single-slit and double-slit



Order Information

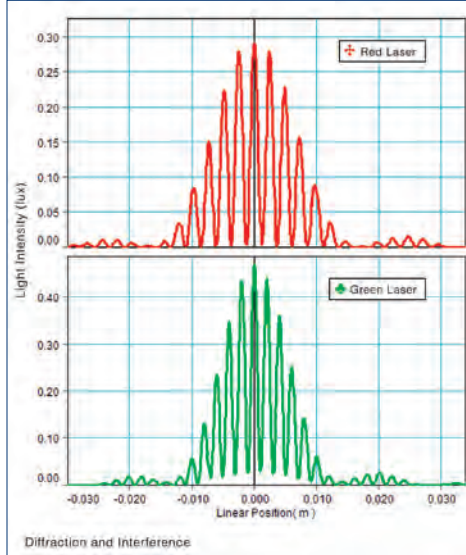
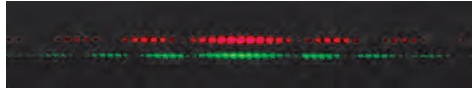
Precision Diffraction Slits	OS-8453	
Recommended:		
Basic Optics System	OS-8515C	p. 270
Red Diode Laser	OS-8525A	p. 287
Green Diode Laser	OS-8458B	p. 287

Red Diode Laser

OS-8525A

These unique diode lasers take the frustration out of aligning the laser beam with the diffraction slits. With both lasers, you can demonstrate the effect of changing wavelength on the diffraction and interference patterns.

A red laser beam was passed through a double slit. Then the Red Diode Laser was replaced by the Green Diode Laser by simply pulling the Red Laser off the optics track and clipping the Green Laser into its place. The recorded patterns from red and green lasers show clearly that the longer red wavelength is spread out more than the green.



Green Diode Laser

OS-8458B



Demonstrate the effect of changing wavelength on the diffraction and interference patterns.

CLASS 2 LASER PRODUCT
LASER LIGHT – DO NOT STARE INTO BEAM



The horizontal and vertical positions of the beam can be adjusted by turning the thumb screws on the back of the laser.

Specifications:

Output Power: <1 mW

Wavelength: 650 nm (OS-8525); 515 nm (OS-8458B)

Power Supply: 9 V adapter (included)

Order Information

Red Diode Laser	OS-8525A
Green Diode Laser	OS-8458B

Linear Translator

OS-8535A



The Linear Translator transforms a Rotary Motion Sensor into a linear motion device. The toothed rack of the Linear Translator fits into the slot in the side of the Rotary Motion Sensor. As the Rotary Motion Sensor pulley is rotated by hand, the Rotary Motion Sensor moves along the rack. Rotary Motion Sensors not included.

Specifications:

Resolution for Rotary Motion Sensor: 0.055 mm (CI-6538); 0.020 mm (PS-2120)

Maximum Travel: 20 cm

Order Information

Linear Translator.....	OS-8535A
------------------------	----------

Aperture Bracket

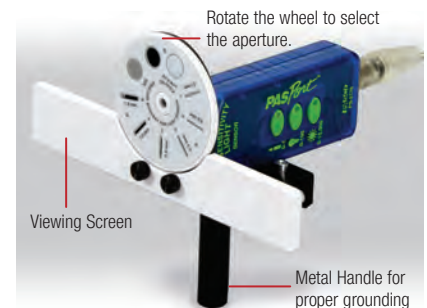
OS-8534A

The Aperture Bracket acts as a mask for a light sensor. The wheel is rotated to select different size slits, defining the spatial resolution. Narrow slits are used to scan diffraction patterns having fine detail. Wider slits are used to let in more light when scanning dimmer patterns. The diffuser selection is used for inverse square law experiments.

Specifications:

Six Slits: From 0.1 mm to 1.5 mm width

Open Aperture:
No reduction in intensity
10% transmittance
diffuser



Includes:

- Aperture Bracket with Screen
- Metal Handle
- Accessory Holder

Order Information

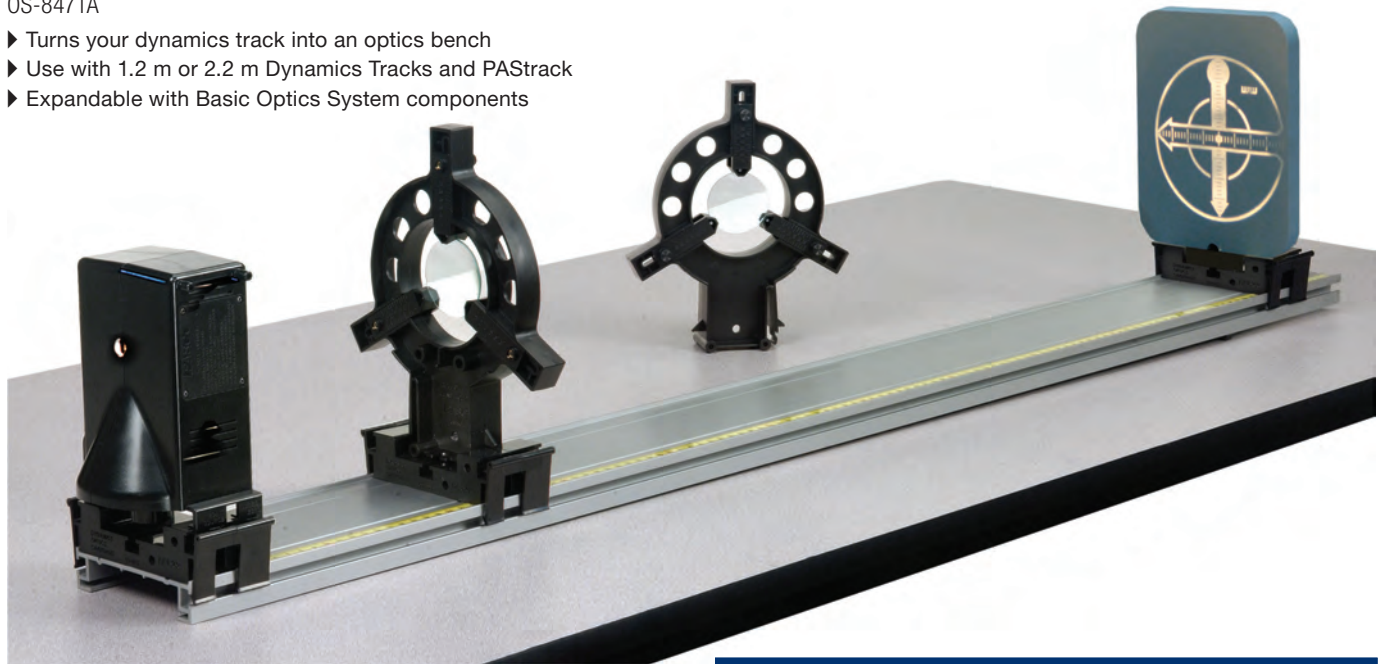
Aperture Bracket.....	OS-8534A
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Dynamics Track Optics

Dynamics Track Optics Kit

0S-8471A

- ▶ Turns your dynamics track into an optics bench
- ▶ Use with 1.2 m or 2.2 m Dynamics Tracks and PAsTrack
- ▶ Expandable with Basic Optics System components



The PASCO Dynamics Track Optics Kit includes specially designed slides (carriages) that snap on the dynamics track. PASCO Basic Optics components attach directly to the carriage for positioning anywhere on the track. Choose from a wide range of optics components to expand your system.

Includes:

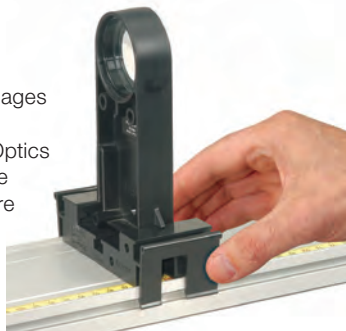
- Basic Optics Light Source
- Two Adjustable Lens/Mirror Holders +100 mm, +200 mm, and -150 mm Focal Length Lenses
- Viewing Screen
- Three Optics Carriages



Dynamics Track Optics Carriages (Set of 4)

0S-8472A

The Dynamics Track Optics Carriages are designed to snap onto the PASCO Dynamics Track. Basic Optics components attach directly to the carriages for positioning anywhere on the track.



Includes:

- Carriages (4)



Order Information

Dynamics Track Optics Carriages (Set of 4) 0S-8472A



Typical Experiments

- ▶ Focal Length and Magnification of a Thin Lens
- ▶ Telescope
- ▶ Microscope
- ▶ Shadows
- ▶ Virtual Images



To see the experiments, type the product number into the search box at www.pasco.com and download the manual.

Order Information

Dynamics Track Optics Kit.....0S-8471A
 Required:
 1.2 m Aluminum Dynamics Track.....ME-9493
 OR
 2.2 m Aluminum Dynamics Track.....ME-9779
 OR
 PAsTrack.....ME-6960

Essential Physics Light, Color & Optics Kit

EP-3558

The Light, Color, and Optics Kit is a complete laboratory for learning about light, color, and optical technology. Three 50-mm optics snap onto the track and slide easily. The light source makes a perfect illuminated “object” for optics experiments, and the fixed spacing of the colored LEDs makes it easy to observe and measure image properties such as magnification, inversion, and brightness.

Includes:

- 1.2 m Aluminum Track
- 50 mm Optics Mounts (3)
- Rechargeable Light Source
- AC Adapter/Charger
- Refraction Tank
- Triangular Prism
- Phosphorescent Plastic
- 50 mm Convex Lens - 10 cm f.l.
- 50 mm Convex Lens - 20 cm f.l.
- 50 mm Convex Lens - 50 cm f.l.
- 50 mm Concave Lens - 20 cm f.l.
- 50 mm Convex Mirror - 20 cm f.l.
- 50 mm Concave Mirror - 50 cm f.l.
- 50 mm Screen
- 50 mm Diffraction Grating
- Eyeglasses



Lens holders mount to PASCO tracks.



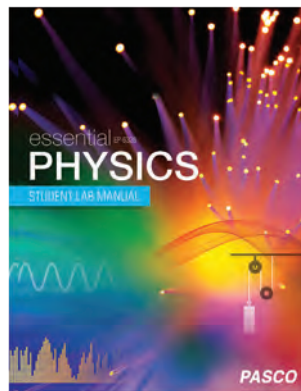
Essential Physics Student Lab Manual

EP-6326

This printed, student-consumable *Essential Physics* Student Lab Manual includes 46 labs that cover a full year of introductory physics. Created by physics teachers, these investigations are an ideal supplement to any algebra-based physics course. Each investigation is tightly integrated with our innovative software, sensors, and equipment

The Light, Color, and Optics labs in the student manual include:

- ▶ Magnification of Mirrors and Lenses
- ▶ Reflection in a Plane Mirror
- ▶ Refraction of Light
- ▶ Creating Real and Virtual Images with Lenses
- ▶ Image Formation for a Convex Lens
- ▶ Build a Microscope and Telescope
- ▶ Phosphorescence



Order Information

<i>Essential Physics</i> Light, Color & Optics Kit.....	EP-3558
<i>Essential Physics</i> Student Lab Manual	EP-6326
Also available (see page 92):	
<i>Essential Physics</i> Teacher Lab Manual	EP-6329
<i>Essential Physics</i> Teacher Lab Manual (digital)	EP-6329-DIG
<i>Essential Physics</i> Teacher Lab Manual – Electronic Resources	EP-6328-DIG

Ray Optics

Basic Optics Light Source

OS-8470

- ▶ One, three, or five parallel rays
- ▶ Three primary color source
- ▶ Crossed arrow object and point source

The Basic Optics Light Source is an excellent source for a variety of optics experiments. A single 10-watt quartz-halogen bulb provides bright, easy-to-see illumination without a lot of heat. By turning the box to a different side, it becomes a:

- Crossed Arrow Object with Metric Scale: ideal for showing images, focal point, and magnification.
- Bright Point Source: The very small filament of the halogen bulb provides an excellent point source for experimenting with shadows or the Inverse Square Law.
- Three Primary Colors Source: The red, green, and blue filters provide three rays of light that are easily combined with a lens for color mixing.
- One, Three or Five Ray Sources: Just rotate the knob in front of the light source to vary the number of rays produced.



Rotate the selector knob to choose between rays (1, 3, or 5) or the primary color mask.

The Basic Optics Light Source provides a point source and an extremely bright crossed arrow target. Use free-standing or easily clip directly to Basic Optics Track.



Includes:

- Universal AC Adapter
- Spare Bulb (stored under access cover)

Order Information

Basic Optics Light Source OS-8470

Ray Optics Kit

OS-8516A

The Ray Optics Kit is a basic set of optic components for ray and color experiments.

Includes:

- Double-Convex Lens
- Double-Concave Lens
- Rhomboid
- Eye-Dropper
- Triangular mirror accessory with concave, convex, and plane reflective surfaces
- Hollow lens to fill with a liquid or use as an air lens



Order Information

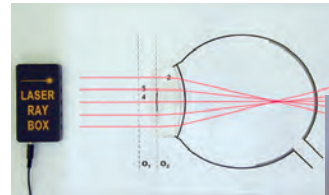
Ray Optics Kit OS-8516A

Ray Optics Laser System

SE-8506

CLASS 2 LASER PRODUCT
LASER LIGHT –
DO NOT STARE INTO BEAM

- ▶ No need to dim the lights
- ▶ Wide variety of optical components
- ▶ Templates simulate real-world optical devices



The laser rays are focused in front of the retina by the myopic lens used with the human eye template.



The laser rays are redirected by the converging lens and focused on the "film" of the camera template.

This demonstration optics set uses a Laser Ray Box that has bright, well-defined rays because it uses lasers rather than an incandescent light source. The Laser Ray Box projects five parallel laser beams onto any flat surface. It contains five 1 mW diode lasers (wavelength 635 nm). The laser beams are spread out into clearly visible lines by cylindrical lenses inside the box.

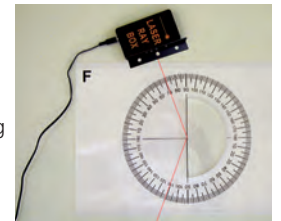
The ray box has a magnetic back for mounting on any steel board. The unit is powered by an included AC adapter.

This exceptional optics set includes six magnetically-backed templates that have guidelines showing where to put components to perform different demonstrations, including:

- ▶ Modeling the human eye and eyeglasses
- ▶ How a camera works
- ▶ Two types of telescopes
- ▶ Spherical aberration
- ▶ Refraction and reflection

Each component has a magnetic backing for mounting on any steel board.

The included protractor template can be used to demonstrate refraction.



Specifications:

- Dimensions:** 11 cm x 6 cm x 2 cm
- Laser Ray Separation:** 1.8 cm
- Power Adapter:** 3 VDC, 300 mA (included)
- Wavelength:** 635 nm

Includes:

- Laser Ray Box
- Laser Ray Mask
- Double-convex lenses (4)
- Double-concave lens
- Plano-concave lens
- "D" lenses (4.5 cm and 7.5 cm radius) (2)
- Plane, convex, and concave mirrors
- Right-angle prism
- Rectangle (6 cm x 10 cm)
- Optical fiber (2 cm x 20 cm)
- Templates (6)
- Steel whiteboard (56.5 cm x 41.5 cm)
- Most components are 10 cm tall and 1.7 cm thick.

Order Information

Ray Optics Laser System SE-8506
Laser Ray Box SE-8505

Mirage

SE-7302

These two concave mirrors create a real image of any object you place at the opening in the top and when students try to touch it, they find that it is only an image, not the real thing!



Includes:

- Concave mirror (14 cm diam.)
- Plastic frog

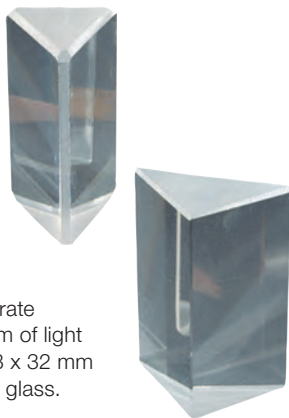
Order Information

Mirage.....SE-7302

Equilateral Prism

SE-9021A

Demonstrate the dispersion and refraction of white light with this high-quality glass prism. It's 30 mm on a side and 50 mm long.



Right Angle Prism

SE-9022A

Use this Right Angle Prism to demonstrate chromatic dispersion or to bend a beam of light by 90 degrees. It's 50 mm long with 23 x 32 mm sides, and made of high-quality optical glass.

Order Information

Equilateral Prism.....SE-9021A
Right Angle Prism.....SE-9022A

Demonstration Mirror, Convex

SE-7574

This convex large mirror comes with a convenient stand and is ideal for demonstrating the formation of real and virtual images. Diameter is 60 cm.



Demonstration Mirror, Concave

SE-7573

This concave large mirror comes with a convenient stand and is ideal for demonstrating the formation of real and virtual images. Diameter is 60 cm. Stand is included.

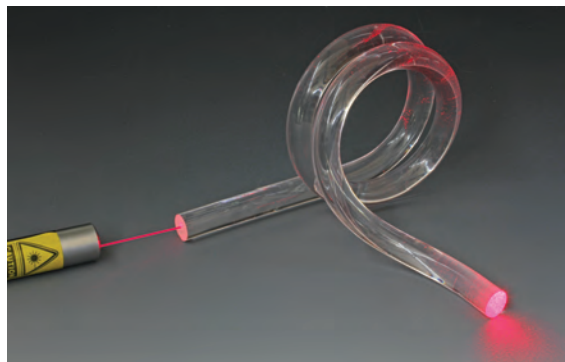
Order Information

Demonstration Mirror, Convex.....SE-7574
Demonstration Mirror, Concave.....SE-7573

Optical Fiber Model

SF-7201

This bent acrylic rod simulates the operation of optical fibers. The laser beam undergoes repeated total internal reflections and is emitted at the other face of the rod as a divergent beam.



Specifications:

Dimensions: 50 cm length and 1.0 cm diameter, with two windings of approx. 5 cm diameter.

Order Information

Optical Fiber Model.....SF-7201
Required:
Red Diode Laser Pointer.....SE-9716C

Spectrometer

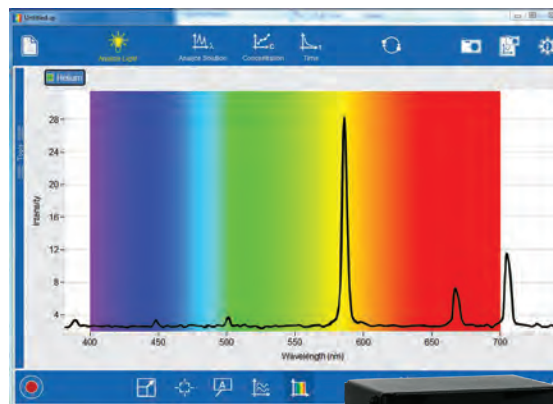
Wireless Spectrometer (VIS)

PS-2600

For iOS, Android™, Computers, and Chromebooks™

Now includes Spectrometry 2.0 functionality!

- ▶ Measures intensity, absorbance, transmittance, and fluorescence.
- ▶ Works on all computing platforms
- ▶ Bluetooth® or USB connectivity
- ▶ Includes free award-winning Spectrometry software



Helium spectrum

Shown using the optional Fiber Optic Cable (shown below)



Specifications:

Resolution: 2–3 nm FWHM

Detection Range: 380–950 nm

Fluorescence Excitation Wavelengths:
405 nm and 500 nm

Light Source: LED-boosted tungsten

Bluetooth: Bluetooth 2.0 (classic)

You can perform these labs with the Wireless Spectrometer:

- ▶ Emission Spectra of Light
- ▶ Absorbance Spectra
- ▶ Beer's Law
- ▶ Kinetics
- ▶ Fluorescence



Includes:

- Cuvettes (10)
- Spectrometry Software

Fiber Optics Cable

PS-2601

This 1m Fiber Optic Cable extends PASCO's Wireless Spectrometer's capabilities beyond simple cuvette investigations. The cable is transparent to support the entire range reported by the Wireless Spectrometer PS-2600.



Order Information

Fiber Optics Cable.....PS-2601

Order Information

Wireless Spectrometer (VIS).....PS-2600

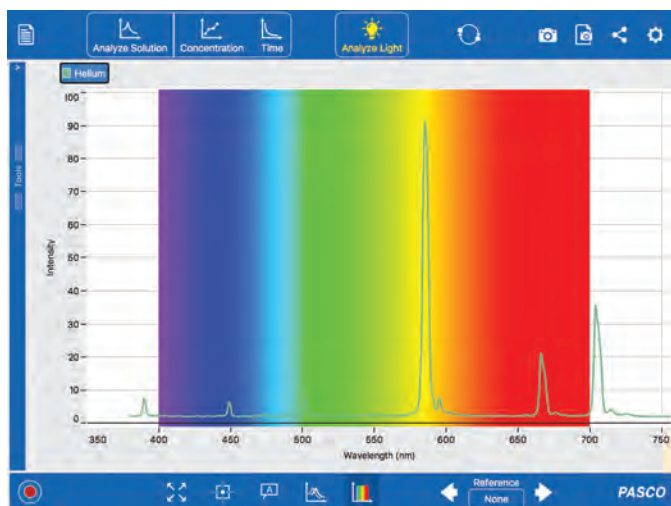
PASCO's Free Spectrometry Software Puts Learning First

PASCO's award-winning software for iOS, Android™, Computers, and Chromebooks*

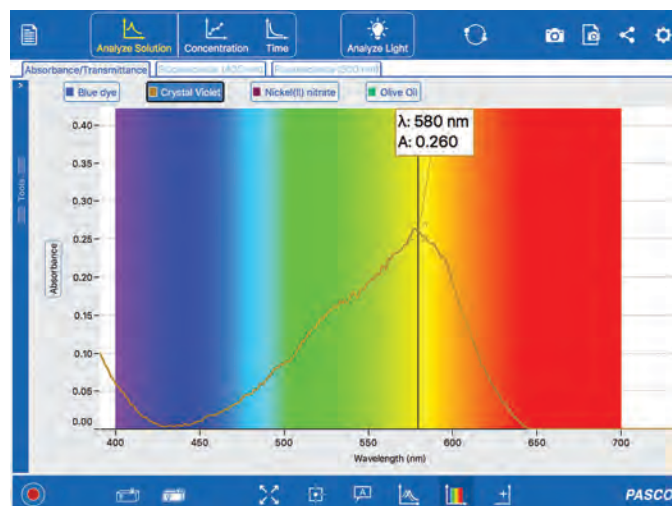
- ▶ Designed by teachers
- ▶ Specialized software specifically targets spectrometry activities
- ▶ Program guides students through the four common types of spectrometer uses
- ▶ Calibration routine is made obvious

The four specially targeted activities are:

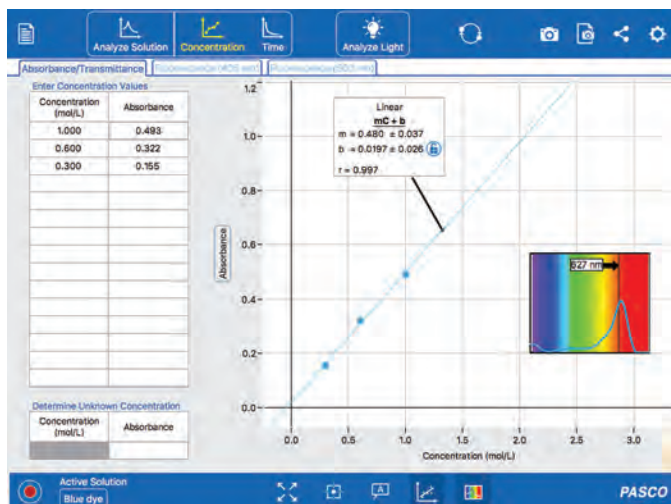
1. Analyze light sources with the optional fiber optic cable.
2. Analyze the absorbance, transmittance, and fluorescence of colored solutions.
3. After the analysis wavelength is set, you can easily create calibration curves and determine the unknown concentration.
4. Observe the kinetics of a reaction involving a colored solution. Easily create the required graphs ($\ln(x)$, $1/x$) to determine the order of the reactants.



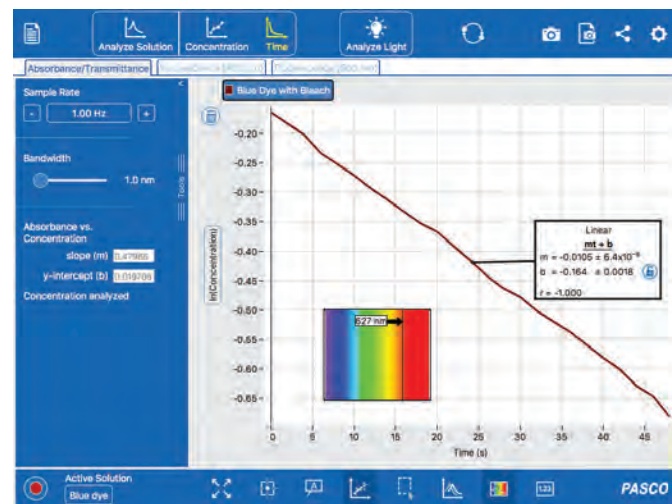
Analyze light sources with the optional Fiber Optic Cable.



Full visible spectrum analysis of solutions



Create Beer's Law plots to relate absorbance and concentration.



Quickly plot calculations of Concentrations vs. Time to determine the order of the reaction.

The Wireless Spectrometer comes with PASCO's FREE award-winning Spectrometry software.

- ▶ Free software for iOS, Android™, and Mac®.
- ▶ Will run on Chromebooks™ with Google Play store.
- ▶ Designed specifically for introductory spectrometry experiments.

Download at [pasco.com/downloads](https://www.pasco.com/downloads)

*Our list of compatible Chromebooks is expanding rapidly. Check [pasco.com/spectrometer](https://www.pasco.com/spectrometer) for the latest updates.

Spectrophotometer

Educational Spectrophotometer System

OS-8450 (PASPORT)

OS-8539 (ScienceWorkshop)

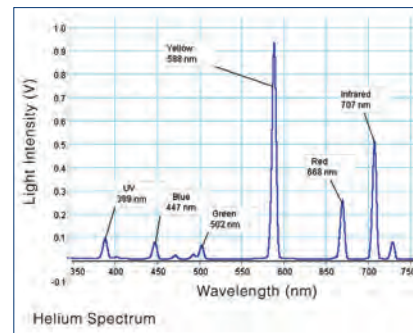
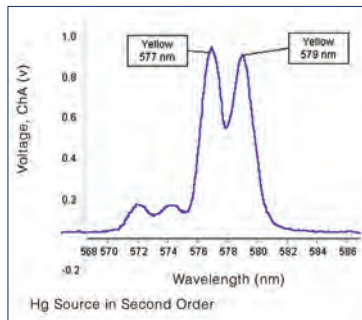
Educational Spectrophotometer Accessory Kit

OS-8537

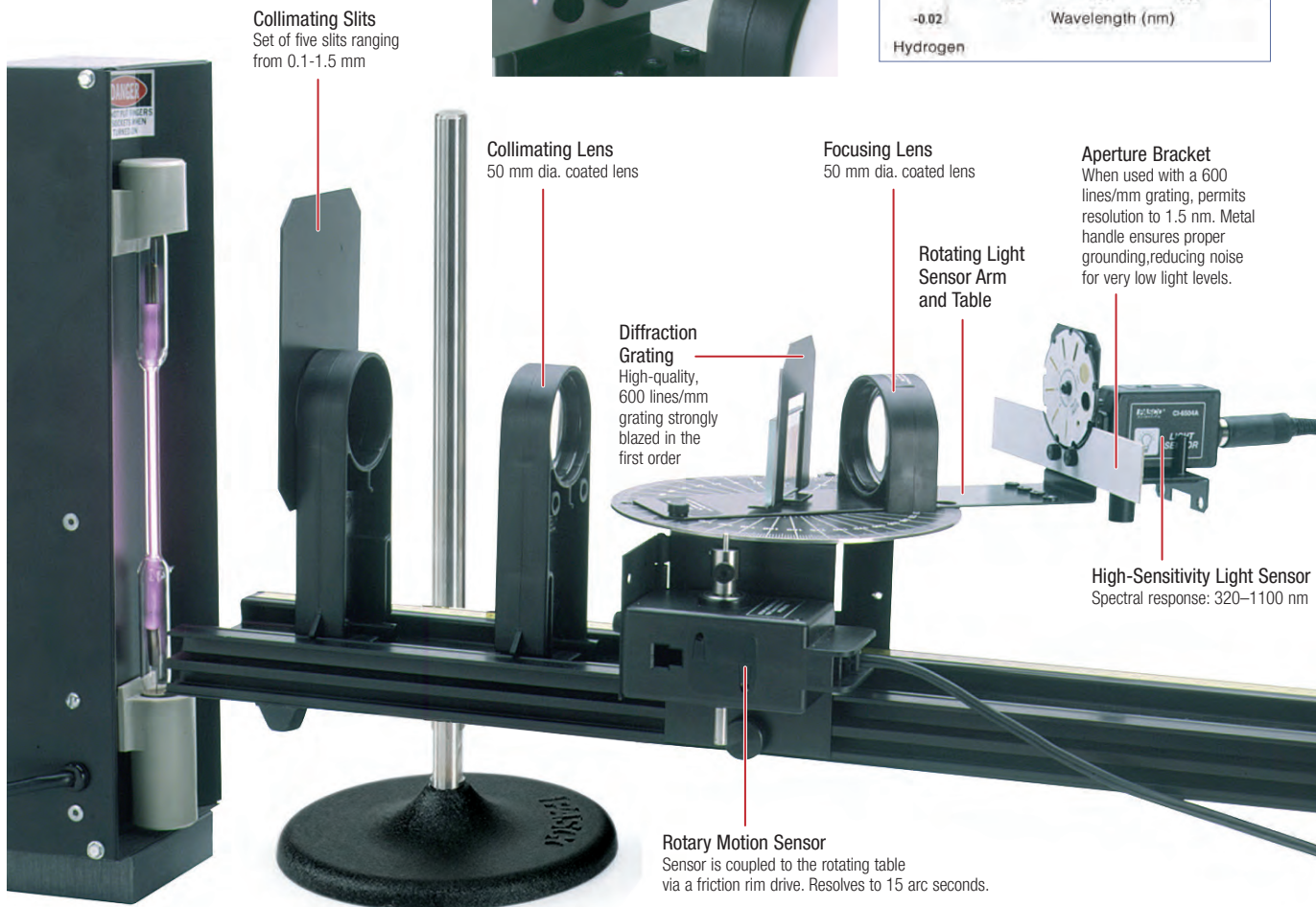
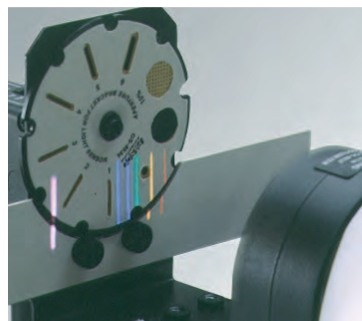
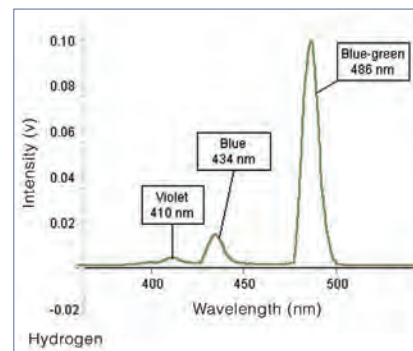
- ▶ Analyze and graph spectral lines
- ▶ Explore relationships between angle, wavelength, and intensity
- ▶ Versatile and inexpensive

PASCO's Educational Spectrophotometer teaches basic optical principles and allows quantitative measurements rivaling those of more expensive units.

When the Spectrophotometer is used with PASCO's Capstone software, students can explore the relationship between angle, wavelength and intensity and graph the spectral lines from discharge tubes. Lines from mercury, sodium, helium, neon, krypton and argon can be plotted— even the lines of the Balmer series in hydrogen can be detected.



Typical Spectrum Graphs



Educational Spectrophotometer Components

Teachers who already own a PASCO Interface and the Basic Optics System OS-8515C should purchase the Accessory Kit OS-8537 and any additional equipment needed from the list below.

The Spectrophotometer System includes:

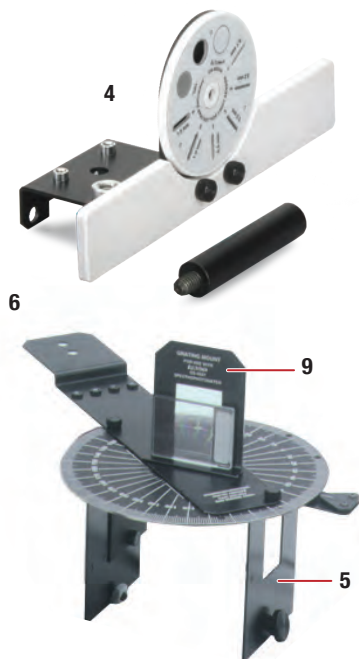
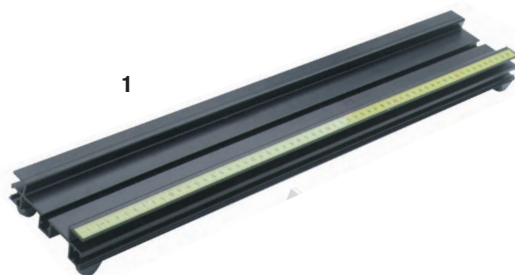
1. Optics Bench (60 cm) OS-8541
2. Rotary Motion Sensor
3. High-Sensitivity Light Sensor
4. Aperture Bracket OS-8534A
5. Spectrophotometer Table
6. Rotating Arm
7. Collimating Slits and Lens
8. Focusing Lens
9. Diffraction Grating and Holder
10. Optics Bench Rod Clamps (2) ME-9836

ScienceWorkshop
OS-8539

CI-6538
CI-6604

PASPORT
OS-8450

PS-2120A
PS-2176



The Spectrophotometer Accessory Kit (OS-8537) includes:

5. Spectrophotometer Table
6. Rotating Arm
7. Collimating Slits and Lens
8. Focusing Lens
9. Diffraction Grating and Holder
10. Optics Bench Rod Clamps (2) ME-9836

Note: The open design of this spectrophotometer accessory is ideal for education. It is not intended for industrial or research applications.

High-Quality Gratings 600 lines per mm

SE-9358

The 600 lines/mm grating is strongly blazed in the first order. It has excellent resolving power and produces bright, sharp spectral lines for spectrometer labs or for projecting spectra in lecture demonstrations.



Order Information

High-Quality Gratings 600 lines per mm..... SE-9358

Order Information

PASPORT Educational Spectrophotometer..... OS-8450
Educational Spectrophotometer System..... OS-8539
Educational Spectrophotometer Accessory Kit..... OS-8537

For use with PASPORT Sensors, see the Atomic Spectra experiment EX-5546 on page 382.

For adjusting height of optics bench to your light source:

Round Base with Rod..... ME-8270 p. 187

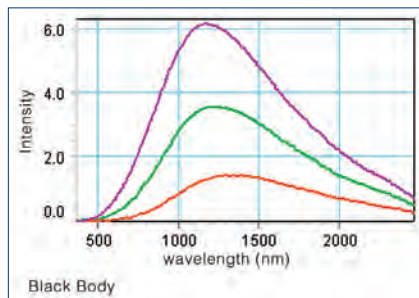
Spectrophotometers

Prism Spectrophotometer Kit

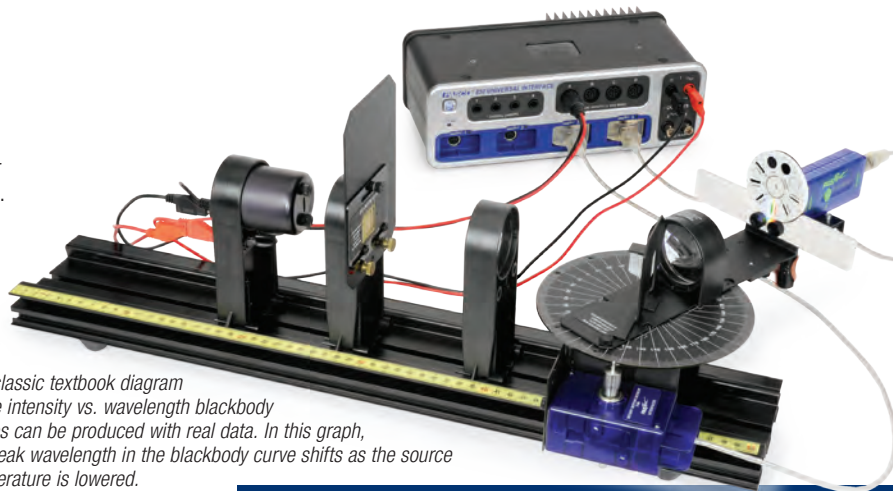
OS-8544

- ▶ High-quality prism
- ▶ Blackbody light source

Add this kit to the Educational Spectrophotometer System (pages 286-287) to plot blackbody curves. A prism is used to disperse the light (instead of a diffraction grating) so the infrared doesn't overlap the second order visible spectrum.



The classic textbook diagram of the intensity vs. wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the blackbody curve shifts as the source temperature is lowered.



Includes:

- Mounted Prism
- IR Filter
- Blackbody Light Source



Order Information

Prism Spectrophotometer Kit	OS-8544	
Required for experiment:		
PASPORT Broad Spectrum Light Sensor	PS-2150	p. 35
PASPORT Educational Spectrophotometer	OS-8450	
850 Universal Interface	UI-5000	p. 14
PASCO Capstone		pp. 68-71
Replacement Supplies:		
Replacement Light Bulbs (10)	SE-8509	
OR components of the system may be ordered separately		
Black Body Light Source	OS-8542	
Prism Mount	OS-8543	

Student Spectrometer

SP-9268A

- ▶ Wide aperture optics
- ▶ Precision vernier: resolves one minute of arc
- ▶ Durable and precise

Collimator
High-quality, large-aperture optics with a 6 mm long slit of adjustable width; the collimator can be independently focused, leveled, and aligned.

Durable Construction
Heavy aluminum castings provide a stable base for delicate measurements and ensure long-term durability.

Custom Prism/Grating Table
Threaded holes and engraved reference lines for accurate component placement

Vernier Scale
For precision measurements

Precision-Ground Bearings
The main bearings are ground as a single unit, so the movement is exceptionally smooth with virtually no backlash. This is essential for precise positioning.

Telescope
High-quality, large-aperture optics plus a 15x Ramsden eyepiece with a crosshair graticule; the telescope can be independently focused and aligned.

Magnifier
For reading the Vernier Scale

Dense Flint Glass Prism with Holder



The Vernier Scale resolves angle measurements within 1 minute of arc.

Features:

- ▶ **Resolution to 1 Minute of Arc:** The 127 mm diameter, precision-engraved degree plate is complemented by 2 precision-engraved verniers, one on each side of the instrument for convenient reading.
- ▶ **Wider Aperture Optics:** 32 mm wide apertures on the telescope and collimator provide more light for brighter and sharper images.
- ▶ **Rack and Pinion Focusing:** On both the telescope and the collimator. Focusing is easier and more precise.
- ▶ **Rotatable Table:** For greater flexibility in measurements. Turn the table by hand for coarse adjustments. Use the fine lead screw for delicate adjustments.

Order Information

Student Spectrometer	SP-9268A
Recommended:	
Spectral Light Sources	p. 298

UV Beads (1000)

SE-7729



Shining an ultraviolet flashlight on UV-sensitive beads causes them to change color.

UV-sensitive beads are white when indoors but change color instantly when exposed to UV radiation. These beads make students aware of UV radiation. Students can explore how much UV there is on a cloudy day and how much UV is blocked by car windows.

Each bead is created with a pigment that changes color as the ultraviolet energy is absorbed. When the UV radiation is removed, the beads will return to their pale white color. This process can be repeated many thousands of times. Each package includes 1000 beads.

Order Information

UV Beads (1000).....SE-7729

UV Flashlight

SE-7730



This ultraviolet flashlight with 51 UV LEDs is great for illuminating UV beads and activating fluorescent materials. The wavelength is centered on 385 nm. Powered by three AA batteries (not included).

Specifications:

Wavelength: 385 nm

Length: 14 cm

Bulb Type: 51x UV LED

Bulb Life: 50,000 hours

Battery Requirement: 3 AA (not included)

Battery Life: Approx. 20 hrs on new batteries

Body Material: Machined aluminum with rubber O-rings

Order Information

UV Flashlight.....SE-7730

Spectral Light Sources

Mercury Light Source

SE-6608

This bright mercury light source is perfect for studying spectra with the Educational Spectrophotometer (OS-8539). It is also used with the Photoelectric Effect experiment (SE-6609 and EX-5549A) and mounts on the extruded track in that experiment.



Includes:

- Mercury Light Source Housing
- Power Supply
- Replacement Hg Bulb: SE-6597

Order Information

Mercury Light SourceSE-6608

Replacement Supplies:

Replacement Hg BulbSE-6597

Light Sources

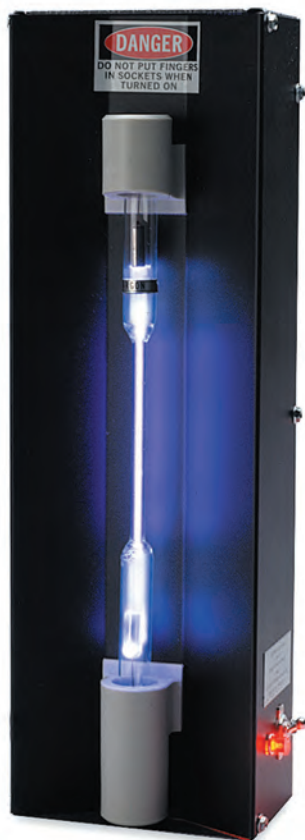
Spectral Tube Power Supply and Mount

SE-9460

This system is easy-to-use and inexpensive, with a variety of safety features that make it suitable for beginning labs. Mount any of the eight different spectral tubes into the power supply and turn it on. The 26 cm long tubes are capillary-thin over the middle 10 cm, providing sharp, bright spectra.

Features:

- ▶ **Student Safety:** The tubes mount from the front of the supply and snap into molded sockets that fully enclose the conductive ends. The all-metal case is electrically grounded.
- ▶ **Spectral Tube Safety:** A current limiting transformer protects the tubes. A protective shield also helps safeguard the tubes, while blocking unwanted ambient light for clear viewing. The glass does not transmit UV light.
- ▶ **Power Requirements:** 115 OR 220 VAC, 50/60 Hz.
- ▶ Emission tubes sold separately.



Power Supply and Mount

Order Information

Spectral Tube Power Supply and Mount SE-9460

Spectral Tubes

- ▶ Argon
- ▶ Carbon Dioxide
- ▶ Helium
- ▶ Hydrogen
- ▶ Krypton
- ▶ Mercury
- ▶ Neon
- ▶ Water Vapor



These spectral tubes are designed for use in the Spectral Tube Power Supply and Mount (at left).

Order Information

Spectral Tubes:	
Argon.....	SE-9463
Carbon Dioxide	SE-9464
Helium.....	SE-9462
Hydrogen.....	SE-9461
Krypton.....	SE-9465
Mercury.....	SE-9466
Neon.....	SE-9467
Water Vapor.....	SE-9468

X-Y Adjustable Diode Laser

OS-8526A

This versatile, inexpensive diode laser is designed to mount on a rod stand. The laser can be rotated through 360 degrees. There are x- and y-adjustment screws to align the laser beam. Easy set-up makes it perfect for refraction investigations and tracking the oscillation of the Cavendish gravitational balance.



Two knobs allow independent adjustment of horizontal and vertical alignment of the laser beam.

Specifications:

Output Power: <1 mW
Wavelength: 650 nm
Power Supply: 9 VDC, 500 mA adapter (included)

Order Information

X-Y Adjustable Diode Laser OS-8526A

Diode Laser – Basic Optics

OS-8525A (Red) OS-8458B (Green)

These diode lasers fit on the Basic Optics Benches (OS-8505 and OS-8541) and the Dynamics Track Optics Carriage (OS-8472).



CLASS 2 LASER PRODUCT
 LASER LIGHT – DO NOT STARE INTO BEAM

Specifications:

Output Power: <1 mW
Wavelength: 650 nm (OS-8525);
 515 nm (OS-8458B)

Power Supply: 9 V adapter (included)

Order Information

Red Diode Laser OS-8525A
 Green Diode Laser OS-8458B

Laser Pointers

SE-9716C (Red)

SE-8805A (Green)

- ▶ Push-button switch
- ▶ Inexpensive



CLASS II LASER PRODUCT
 LASER RADIATION – AVOID DIRECT EYE EXPOSURE

Specifications:

Source: Laser diode
Power: 5 mW max. (class II)
Wavelength: 645 nm (red pointer)
 532 nm (green pointer)
Battery: Alkaline AAA (2 included)
Dimensions: 143 mm x 12.7 mm (red pointer); 151 mm x 13.5 mm (green pointer)

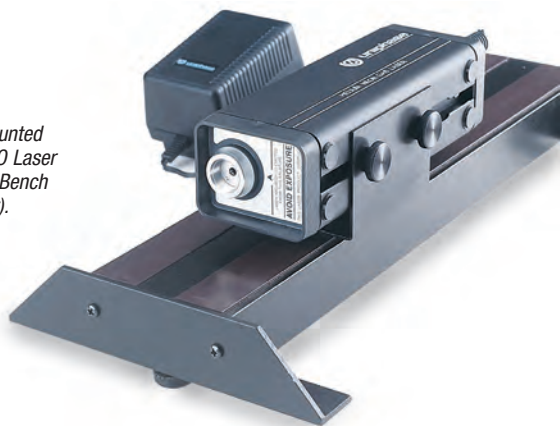
Order Information

Red Diode Laser Pointer.....SE-9716C
 Laser Pointer, Green.....SE-8805A

Mini Laser with Bracket

OS-8514

Shown mounted on a PASCO Laser Alignment Bench (see below).



CLASS II LASER PRODUCT
LASER RADIATION – DO NOT STARE INTO BEAM OR VIEW
DIRECTLY WITH OPTICAL INSTRUMENTS

This 0.5 mW Helium Neon Laser is ideal for use with the PASCO Advanced Optics System. It includes a mounting bracket that attaches to the PASCO Magnetic Optics Bench and permits adjustment of the laser beam in the x and y axes.

The aperture has a 15.8 mm (5/8") receptacle for mounting beam spreaders or spatial filters. An AC adapter is included, but the unit can be powered with any power source providing 0.7 A at 12 VDC.

Specifications:

Output: 0.5 mW min

Wavelength: 632.8 nm

Polarization: Random

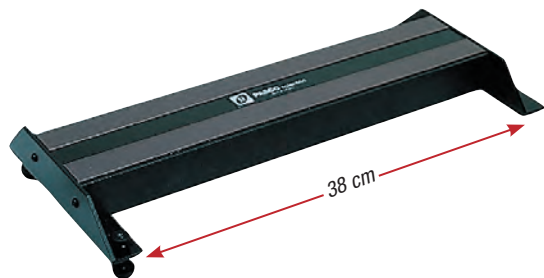
Power: 115/220 VAC, 50/60 Hz

Order Information

Mini Laser with Bracket OS-8514

Laser Alignment Bench

OS-9172



This Laser Alignment Bench connects to the Optics Bench with the included couplers, which leaves the full 1 m length of the Optics Bench free for experimental work.

Order Information

Laser Alignment Bench OS-9172

HE-NE Laser

SE-9449A

This Helium Neon Laser has two advantages over the other lasers:

- 1.5 MW:** The extra power makes laser experiments and demonstrations brighter (and often easier). It's especially useful for holography. A shorter exposure time can be used to minimize problems with vibrations.
- Modulation:** Connect a microphone to this laser, and students can transmit voice through the laser beam to a distant receiver. Or use this laser as a laser stroboscope for timing.

Note: Additional equipment, not available from PASCO, is required for laser communication experiments.



CLASS IIIa LASER PRODUCT
LASER RADIATION – DO NOT STARE INTO BEAM

Specifications:

Wavelength: 632.8 nm

Beam Diameter: 0.49 mm

Beam Divergence: 1.65 mRad

Housing Size: 32.8 x 7.2 x 7.4 cm

Modulation Range: 85-100% of full power

Input Signal Frequency: 50 Hz-600 kHz (± 3 dB); miniature phone jack accepts audio input signals at 100 mV peak-to-peak and 60 k Ω impedance.

Transmission Range: Effective up to several hundred feet; with a good collimator and detector, transmissions up to several thousand feet are possible.

Power: 115 VAC, 60 Hz (not available in 220 V)

Order Information

HE-NE Laser SE-9449A

Light Sensors

Wireless Light Sensor

PS-3213



- ▶ Four sensors in one
- ▶ Ambient lux
- ▶ Ultraviolet and infrared
- ▶ Detect RGB colors separately
- ▶ Bluetooth 4.0 wireless
- ▶ New enhanced features measure PAR and irradiant light!

The Wireless Light Sensor features two separate apertures - one for ambient light measurements and one for directional light measurements. The ambient sensor measures illuminance and UV Index, while the spot (directional) aperture measures light level and color intensity. Our software displays the relative intensities of Red, Green, and Blue light, then sums them to determine the level of White light. PAR and irradiance are also available as calculated measurements within PASCO Capstone (version 1.8 or later) and SPARKvue software (version 2.6 or later).



Use the ultraviolet sensor on the back side to measure the amount of UVA and UVB radiation that makes it through sunglasses.

Specifications:

- Spectral Response:** 300 nm to 1100 nm
- Illuminance Range*:** 0 to 131,000 lux
- Irradiance Range*:** 0 to 1362 W/m²
- PAR Range*:** 0 to 2400 μmol/m²/s
- UV Index Range:** 0 to 12 (typical in daylight)
- RGB and White Light Range:** 0 to 100%
- Maximum Sample Rate:** 2 Hz (ambient); 20 Hz (spot)
- Battery:** Coin cell
- Bluetooth 4.0:** Yes

Order Information

Wireless Light SensorPS-3213

PASPORT Infrared Light Sensor

PS-2148

- ▶ For heat studies



The Infrared Light Sensor is sensitive in the infrared portion (up to 40,000 nm) of the spectrum, but also detects the visible spectrum. It can detect the radiation from a person's hand. The response is linear over its entire frequency range.

Applications:

- ▶ Measure blackbody radiance
- ▶ Perform Leslie's Cube experiments
- ▶ Measure solar radiance
- ▶ Evaluate heat flow into or out of the sensor
- ▶ Simulate a non-contact temperature sensor

Specifications:

- Measure intensity:** in Watts/Meter
- Maximum Sample Rate:** 100 Hz
- Spectral Response:** 580 to 40,000 nm
- Built-in Thermistor:** to measure temperature of the "cold" side of the thermopile in °C, °F or K

Order Information

PASPORT Infrared Light SensorPS-2148

PASPORT Broad Spectrum Light Sensor

PS-2150

- ▶ For use with Spectrophotometer
- ▶ Ideal for Black Body Spectrum



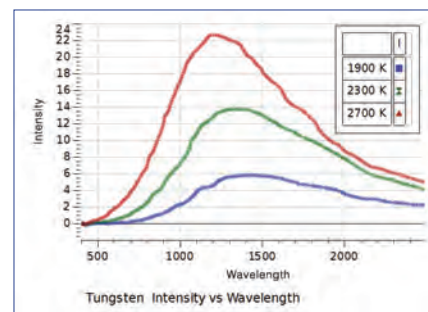
The Broad Spectrum Light Sensor is designed specifically for use with our Educational Spectrophotometer System OS-8539 and Prism Spectrophotometer Accessory OS-8543 for Black Body experiments. The Broad Spectrum Light Sensor uses a thermopile and window combination that respond to both the near infrared and visible light necessary for the Black Body experiment.

Applications:

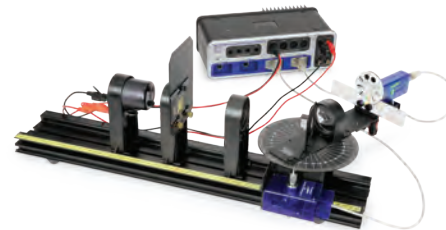
- ▶ Black Body Experiment

Specifications:

- Sensing Element:** BaF₂ window, xenon gas-filled thermopile
- Spectral Response:** 300 to 10,000 nm
- Maximum Sample Rate:** 100 Hz



The classic textbook diagram of the intensity versus wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the blackbody curve shifts as the source temperature is lowered.



Order Information

PASPORT Broad Spectrum Light SensorPS-2150

USB Camera Microscope

PS-2343

- ▶ Optical zoom from 1x to 60x
- ▶ Includes four white LED lights as a light source
- ▶ Can be used as a web camera
- ▶ Works with PASCO's SPARKvue and Capstone software
- ▶ Comes with 4" stand

The versatile USB Camera Microscope is ideal for a variety of applications in the science classroom. Its dual functionality means it can take pictures just like a digital camera, but it can also magnify like a microscope when it's up close to a specimen. It is especially useful for studying topics such as crystalline structures. You can also use it to capture lab setups, such as what materials look like before and after an experiment has been performed.

How It Works

Used with the video and image-capture features in PASCO Capstone, magnification of specimens can be done by adjusting the dial located on the front of the camera.



The USB Camera Microscope records the oscillation of the laser beam.

Specifications:

Magnification: 1x to 80x, 320x on 22" monitor

Lens & CMOS sensor: 2M pixels

Still Image Resolution: 1600x1200 pixels

Formats: JPEG, BMP

Video Resolution: 1600x1200 pixels

Formats: AVI

Frame rate: 30FPS on 640x480 pixels: AVI

PC Interface: USB 2.0; works on Windows, Mac, and Android phones with OTG functions

Light Source: 4 white LED lights



Shown in use with ME-8236 Materials Testing Machine (see page 160). As the tensile sample is being stretched, the force versus time data is graphed in sync with the movie.

See the USB Camera Microscope in use with the Universal Gravitational Constant Experiment (EX-5550) on page 335.

Includes:

- Camera
- Microscope
- Stand

Order Information

USB Camera Microscope	PS-2343	
Suggested Base Supports:		
Flex Rod	ME-8978A	p. 187
Small "A" Base	ME-8976	p. 186
Aluminum Table Clamp	ME-8995	p. 189

Interferometry

Introductory Michelson Interferometer

OS-8501

- ▶ Micrometer-controlled mirror movement
- ▶ Precision, front-surface optics
- ▶ Good quality, low price

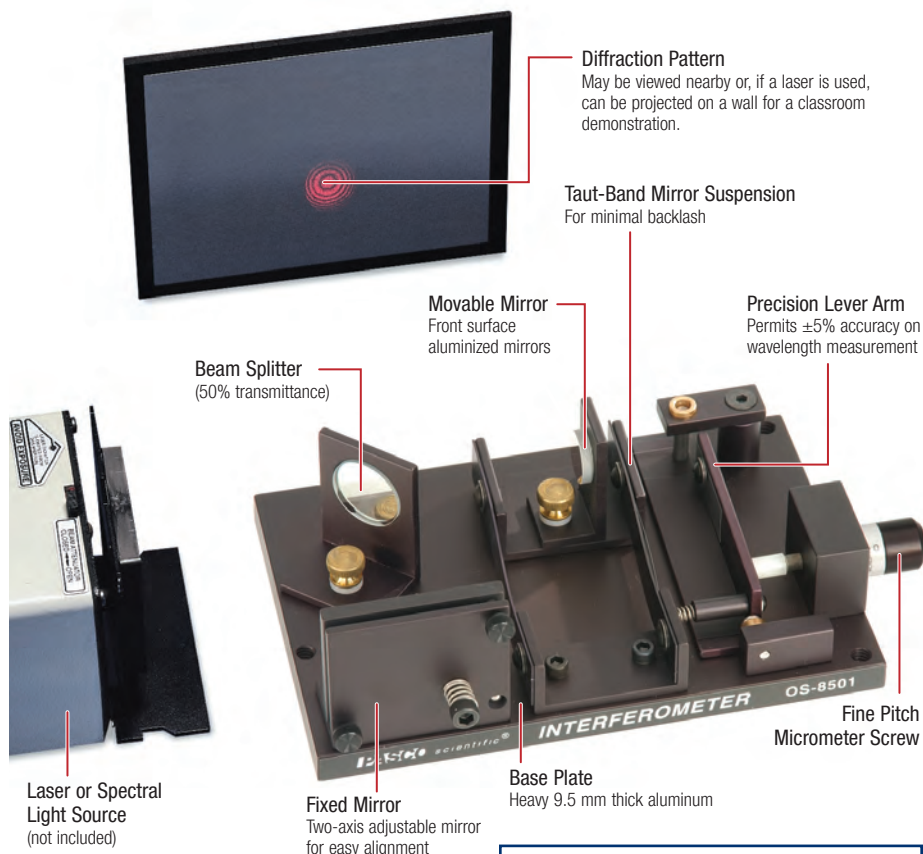
This interferometer is a precision instrument for the introductory lab. It's easier to use, more compact, and less expensive than PASCO's advanced interferometer (see page 303).

It's capable of measuring the wavelength of monochromatic light with an accuracy of better than 5%. The Michelson Interferometer can also be used for making precise measurements of the index of refraction of air.

Features:

- ▶ **Smooth Mirror Movement:** Uses a taut-band mirror movement similar to PASCO's more advanced interferometer, providing smooth movement with minimal backlash.
- ▶ **Built-in Micrometer:** Measures mirror movement to a fraction of a micron.
- ▶ **Easy Setup:** Especially easy with a laser and a PASCO Optics Bench. If a laser is unavailable, a spectral light source can be used.
- ▶ **Complete Manual:** Manual includes illustrated setup instructions, a detailed discussion of basic Michelson interferometry plus two copy-ready experiments (measure the wavelength of monochromatic light and measure the index of refraction of air).
- ▶ The Introductory Michelson Interferometer provides precision interferometry at an economical price (laser and screen not included). Manual included.

The Introductory Michelson Interferometer provides precision interferometry at an economical price (laser and screen not included).



Optics Bench

Note: While the interferometer is designed to be used with the Optics Bench of the Advanced Optics System OS-9103, it can also be used without the PASCO Optics Bench.

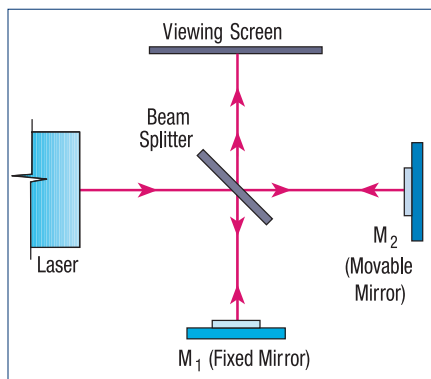
Includes:

- Michelson Interferometer
- Gas Cell
- Collimating Lens (18.4 mm focal length)
- Lens Holder
- Storage Case
- Manual



Order Information

Introductory Michelson Interferometer.....	OS-8501	
Recommended:		
Mini Laser with Bracket.....	OS-8514	p. 299
Hand Operated Vacuum Pump.....	OS-8502	



Beam-splitting schematic for a basic Michelson Interferometer

Hand Operated Vacuum Pump

OS-8502

This Hand-Operated Vacuum Pump with Gauge is required to measure the index of refraction of air using the Introductory Michelson Interferometer.



Order Information

Hand Operated Vacuum Pump.....	OS-8502
--------------------------------	---------

Complete Interferometer System

OS-9258B

- ▶ Three modes: Michelson, Fabry-Perot, Twyman-Green
- ▶ Large precision optics
- ▶ 5 kg machined aluminum base

No study of interferometry should overlook the historical importance of the Michelson interferometer. Yet in the laboratory, the Fabry-Perot and Twyman-Green interferometers can be more important tools: the first for high-resolution spectroscopy; the second for testing and producing optical components with aberrations that can be measured in fractions of a wavelength.

The PASCO Interferometer is a high-precision, movable-mirror interferometer that can be used to perform Michelson, Fabry-Perot, and Twyman-Green interferometry. The mirrors are attached with thumbscrews, so it's easy to set up and change configurations.

The PASCO Interferometer can be ordered in a variety of systems. The Precision Interferometer can be operated in either the Michelson or Fabry-Perot modes. The Complete Interferometer Systems also contain components for the Twyman-Green mode and a vacuum pump for the refractive index of air experiment. The Systems Component List shows the contents of each system.

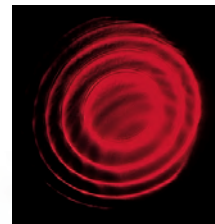
Features:

- ▶ **Stable:** The massive (5 kg) base is machined from a single block of aluminum ensuring extremely stable optics.
- ▶ **Smooth Mirror Movement:** With the taut-band suspension system, there's no starting or stopping friction and virtually no backlash (less than 0.5 micron).
- ▶ **Precise Measurements:** Mirror control is extremely fine: one micron per division of the micrometer head. The mirrors and beam-splitter are flat to 1/4 wavelength to ensure uniform interference patterns.
- ▶ **Larger Optics:** The 3.2 cm (1-1/4") diameter optics in the PASCO Interferometer produce larger and sharper interference patterns for better experimental results.
- ▶ **Complete:** The Basic Interferometer includes everything necessary to perform basic Michelson and Fabry-Perot interferometry.

Order Information

Complete Interferometer System OS-9258B
 Precision Interferometer OS-9255A
 Interferometer OS-9255A
 Accessories Kit OS-9256A

Fabry-Perot Interferometry:
 Two parallel, partially reflecting mirrors create clear, widely spaced interference fringes.



CLASS II LASER PRODUCT
 LASER RADIATION – DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS

The OS-9255A Interferometer in Michelson mode.

Add the Accessories Kit (OS-9256A)

(included in the Complete Interferometer System) to:

- ▶ Demonstrate that cross-polarized beams will not interfere
- ▶ Measure lens irregularities in Twyman-Green Mode

- ▶ Measure the indices of refraction for air and glass. The indices of refraction for user-supplied materials can also be measured.

Note: The fitted case will hold all components and accessories except the 5 kg base, which must be stored separately.

	A. OS-9258B: Complete Interferometer System with Laser	B. OS-9255A: Precision Interferometer	C. OS-9256A: Interferometer Accessories Kit
Systems Component List	A	B	C
Machined base—5 kg	1	1	
Three-point adjustable mirror	1	1	
Mounted beam-splitter	1	1	
Mounted movable mirror	1	1	
Accessory mounts	3	2	1
Viewing screen OS-9138	1	1	
Diffuser OS-9120	1	1	
Double convex lens (18 mm) OS-9132	1	1	
Compensator lens	1	1	
Fitted case	1	1	
Vacuum pump with gauge OS-8502	1		1
Gas cell	1		1
Calibrated polarizer OS-9109	2		2
Glass plate OS-9128	1		1
Rotating component holder	1		1
Twyman-Green lenses OS-9133, OS-9132	2		2
Mini laser with bracket OS-8514	1		
Laser alignment bench OS-9172	1		
Instruction manual	1	1	

Microwave Optics

Basic System

WA-9314C

Advanced System

WA-9316A

- ▶ Durable construction
- ▶ Parts are made of stainless steel or die-cast aluminum.

Ethafoam® Prism with Styrene Pellets
Used for refraction of microwaves.

Rotating 18 cm High Mounts
The transmitter and receiver rotate through a full 360° and minimize tabletop reflections.

Diffraction Slit Hardware

Magnetic Mounting
All components mount magnetically.

Long-Arm Goniometer
Built-in degree and millimeter scales

Receiver (WA-9800A) with Built-in Amplifier

Gunn Diode Transmitter
A stable, low-voltage source of linearly polarized microwaves (10.5 GHz, 15 mW)

The Microwave Optics Advantage

The large 3 cm wavelength makes it easy to understand and visualize electromagnetic wave interactions. Interference and diffraction slits are several centimeters wide, and polarizers are slotted sheets of stainless steel.

The heart of the Microwave Optics System is the Gunn Diode Transmitter and receiver. The transmitter is a low-voltage source of linearly polarized microwaves (10.5 GHz, 15 mW). The receiver has a built-in amplifier, as well as a variable sensitivity scale, ensuring accurate data for even the lowest intensity measurements.

The WA-9314C Basic Microwave Optics System Includes:

- Gunn Diode Transmitter with mounting stand
- Receiver with built-in amplifier and mounting stand
- Goniometer with fixed and rotatable arms and degree scale
- Fixed-arm assembly for interferometer experiments
- Component holders: two standard, one rotating
- Rotating table
- Reflectors: two full reflectors (metal), two partial reflectors (wood)
- Polarizers
- Diffraction slit hardware
- Prism (Ethafoam) with styrene pellets
- AC adapter
- Laboratory manual with 12 experiments

The WA-9316A Advanced Microwave Optics System Includes:

- Microwave Optics: Basic System: WA-9314C
- Microwave Accessory Package: WA-9315

Order Information

Microwave Optics: Basic System..... WA-9314C
 Advanced Microwave Optics System..... WA-9316A
 Recommended:
 The microwave transmitter and receiver assemblies may be purchased separately:
 Microwave Transmitter WA-9801
 Microwave Receiver WA-9800A
 Microwave Mounting Stand WA-9802

Microwave Detector Probe

WA-9319A

Investigate the nodes and antinodes in standing wave patterns with this microwave probe. It plugs directly into the (WA-9800A) receiver.

Not compatible with older versions of the receiver.



Order Information

Microwave Detector Probe..... WA-9319A

Microwave Accessory Package

WA-9315

(included in the WA-9316A Advanced System)

Includes a polyethylene panel for measuring Brewster's angle and a simulated crystal for Bragg diffraction experiments.

The crystal is a cubic lattice of 100 metal spheres in a 5 x 5 x 4 array, mounted in plastic foam.



Includes:

- Simulated Crystal Lattice
- Polyethylene Panel

Order Information

Microwave Accessory Package WA-9315

Franck-Hertz System

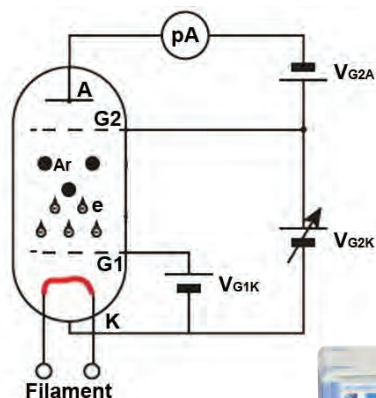
SE-9639

- ▶ Uses argon gas, so no heating is required
- ▶ Digital displays for stand-alone use
- ▶ Can be used with the 850 Interface and PASCO Capstone

See complete experiment on page 385.

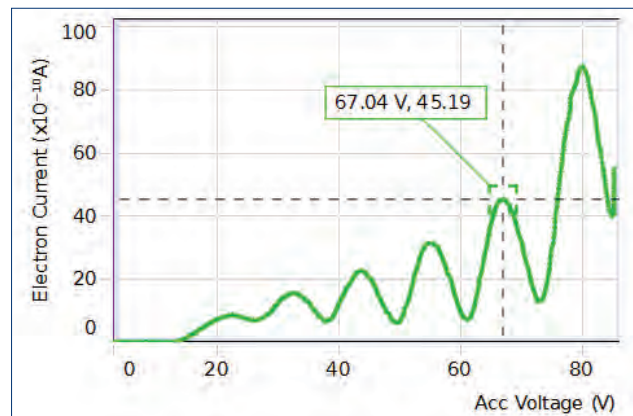
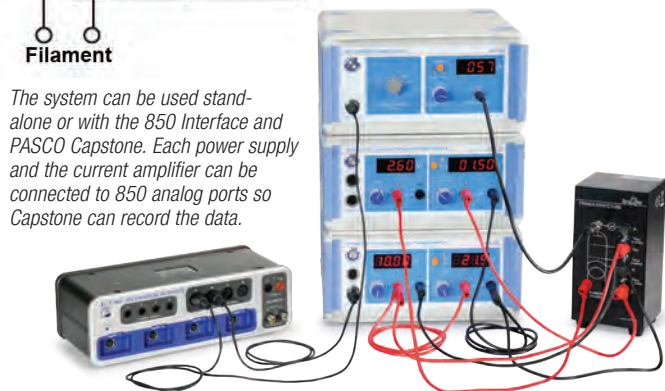
850 Universal Interface Connections for Instrument Readout

As early as 1914, James Franck and Gustav Hertz discovered in the course of their investigations an energy loss in distinct steps for electrons passing through mercury vapor and a corresponding emission at the ultraviolet line ($\lambda = 254$ nm) of mercury. They performed this experiment that has become one of the classic demonstrations of the quantization of atomic energy levels. They were awarded the Nobel Prize for this work in 1925.



This diagram shows the internal structure of the Franck-Hertz tube and the wiring diagram.

The system can be used stand-alone or with the 850 Interface and PASCO Capstone. Each power supply and the current amplifier can be connected to 850 analog ports so Capstone can record the data.



The advantage of using Capstone is that students are able to get many more data points compared to manually taking readings from the digital readouts. The peaks and troughs are easily measured using the coordinate tool.

How It Works

Electrons are accelerated by applying a known potential between two grids inside the argon tube. When an electron has sufficient kinetic energy to excite one of argon's outer orbital electrons and has an inelastic collision with an argon atom, the electron loses a specific amount of kinetic energy. This loss of electron kinetic energy causes a decrease in the electron current in the argon tube. Within a very short time, the excited argon electron will fall from the excited state back into the ground state level, emitting energy in the form of photons.

As the accelerating voltage is increased, the electrons undergo multiple collisions and the excitation energy of the argon atom can be determined by the differences between the accelerating voltages that cause a decrease in the current. Planck's Constant can be determined.

Specifications:

- Filling Gas:** argon
- Filament Voltage:** ≤ 6.3 VDC
- Accelerating Voltage:** ≤ 100 VDC
- Wave Crest (or Trough) Number:** 6
- Argon Tube Life Span:** ≤ 3000 hrs

Power supply and current amplifier specs: See page 250.

Includes:

- Franck-Hertz Tube Enclosure with Argon Tube: SE-9650
- DC Power Supply I (Constant Voltage): SE-6615
- DC Power Supply II (Constant Voltage): SE-9644
- DC Current Amplifier: SE-6621
- Red and Black Patch Cords

Order Information

Franck-Hertz System	SE-9639
Power supplies and amplifier can be purchased separately. See page 250. if you already have power supplies, you will need:	
Franck-Hertz Tube Enclosure with Argon Tube	SE-9650
Replacement Parts:	
Franck-Hertz Argon Tube	SE-9645

Electron Charge

Millikan Oil Drop Apparatus

AP-8210A

- ▶ Nobel Prize-quality physics in the student lab
- ▶ Ionization source for changing droplet charge
- ▶ Measures the charge of an electron to within $\pm 3\%$

The Millikan Oil Drop Experiment is one of the most popular experiments in undergraduate physics for several reasons:

- ▶ The experimental principle is straightforward and easy to understand.
- ▶ It measures a fundamental atomic constant using a method that won its originator, Robert Millikan, the Nobel Prize.
- ▶ The observation of the effects of one or more electrons upon oil drops in an electric field provides a striking demonstration of the quantized nature of electricity.

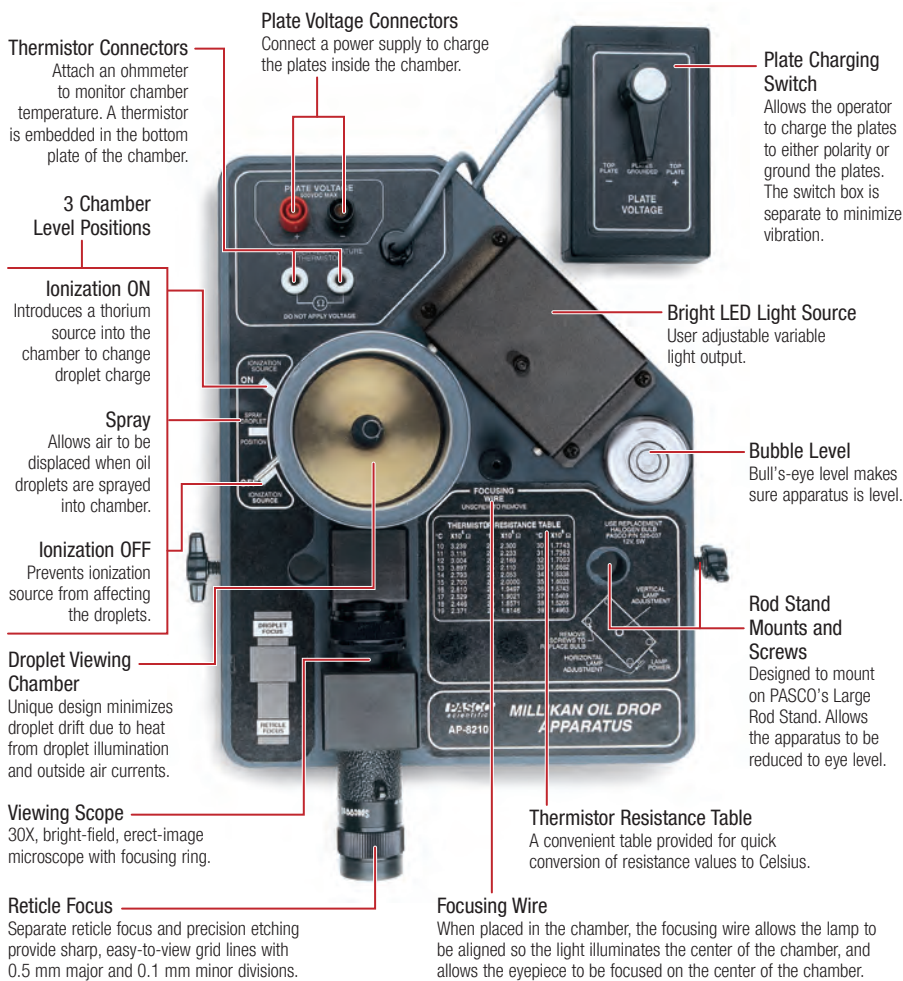
See complete experiment on page 362



The Millikan Oil Drop Apparatus mounted on a rod stand for easy, eye-level viewing

Specifications:

- Maximum Plate Voltage:** 500 VDC
- Light Source:** Cool LED
- Reticle Line Separation:** 0.5 mm major divisions, 0.1 mm minor divisions
- Plate Spacing:** 7.62 mm
- Plate Diameter:** 60 mm



Includes:

- Millikan Oil Drop Apparatus with Switch
- Non-volatile Oil and Atomizer
- 12 VDC Lamp Power Adapter

Order Information

Millikan Oil Drop Apparatus	AP-8210A	
Required:		
Basic Digital Multimeter	SE-9786A	p. 230
High Voltage Power Supply	SF-9585A	p. 253
Recommended for mounting unit at eye level on a standard lab table:		
Large Rod Base	ME-8735	p. 186-187
45 cm Stainless Steel Rod	ME-8736	p. 186-187
Complete System:		
Charge of an Electron Experiment	EX-9929A	p. 362
Replacement Parts:		
4 oz Bottles of Mineral Oil (Qty 4)	AP-8211	
Millikan LED Light Source	AP-8212	

Clear droplet observation and low droplet drift are essential for success with Millikan's classic experiment. PASCO's apparatus uses a pre-aligned optical system and special condenser to achieve these conditions.

Accuracy in the Oil Drop Experiment depends on the student's ability to precisely measure all the variables involved: plate voltage, plate separation, time and distance of droplet rise and fall, temperature, oil density, etc. Extreme care taken in the design and manufacture of this unit ensures that the student's best efforts will be rewarded with more accurate results. Typically, a careful student can achieve results within 3% or less of the accepted value.

e/m Apparatus

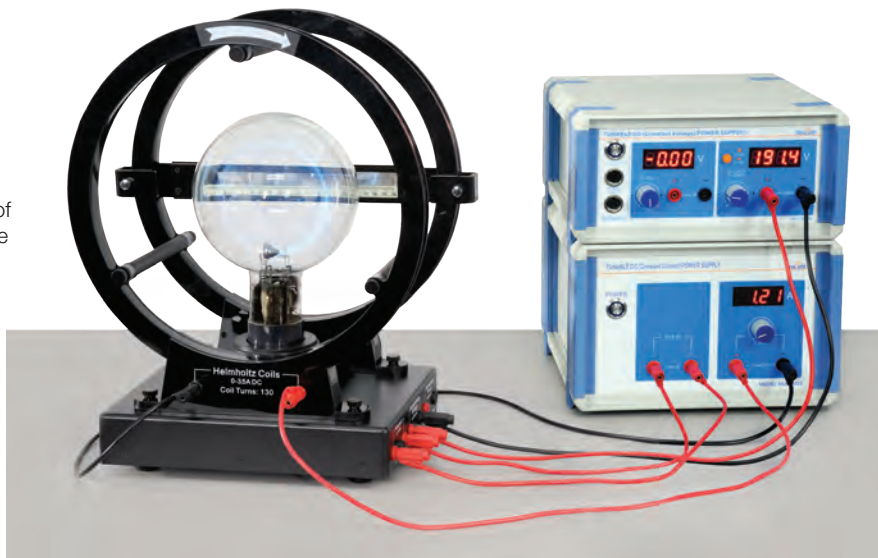
SE-9629

- ▶ Sharp, clearly visible electron beam
- ▶ Phosphorescent mirrored scale eliminates parallax errors
- ▶ Tube rotates for general study of electrons in a magnetic field

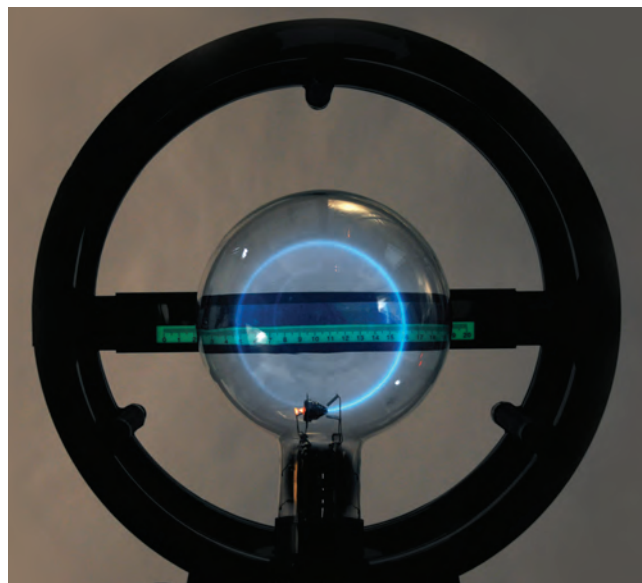
In 1897, J. J. Thomson showed that the mysterious cathode rays were actually negatively charged particles—he had discovered the electron. In the same year he measured the charge-to-mass ratio of the electron, providing the first measurement of one of the fundamental constants of the universe.

The Charge-to-Mass Ratio System reproduces one version of Thomson's landmark experiment, providing an accurate measurement of the charge-to-mass ratio of the electron. And, since the electron tube can be rotated through 90°, students can also make a more general study of the behavior of electrons in a magnetic field.

This apparatus also has deflection plates, so students can study the effect of an electric field on moving electrons.



Complete Charge-to-Mass Ratio System includes the power supplies, which can also be used in other experiments (such as Franck-Hertz experiment, see page 305).



Fluorescent scale shows behind the electron beam in a dark room.

Includes:

- Helmholtz coils for e/m: SE-9626
- Replacement e/m Tube: SE-9651
- Tunable DC Power Supply (Constant Current): SE-9622
- DC Power Supply II (Constant Voltage): SE-9644
- Red and Black Patch Cords

For more information
about power supplies,
see page 250

How It Works

A large, helium-filled electron tube is mounted between a pair of Helmholtz coils. The tube contains an electron gun, which generates a focused beam of electrons. A measured current is applied to the Helmholtz coils so that the magnitude of the magnetic field within the electron tube can be calculated. A measured accelerating potential (V) is then applied to the electron gun. The magnetic field (B) deflects the electron beam in a circular path with a radius (r) that is measured using the illuminated mm scale. From these measured values, the charge-to-mass ratio of the electron is calculated:

$$e/m = 2V/B^2r^2.$$

(The details of the calculations are fully described in the manual.)

Specifications:

Hemholtz Coil Radius: 16 cm

Number of Turns: 130

Maximum Current: 3.5 A

Filament Voltage: 6.3 VAC

Acceleration Voltage: 0 - 200 V

Tube Diameter: 15.5 cm

Order Information

e/m Apparatus	SE-9629
If you already have power supplies, you will need:	
Helmholtz coils for e/m	SE-9626
Replacement e/m Tube	SE-9651
Replacement Parts:	
Replacement Mirror Scale for e/m Apparatus	SE-9649

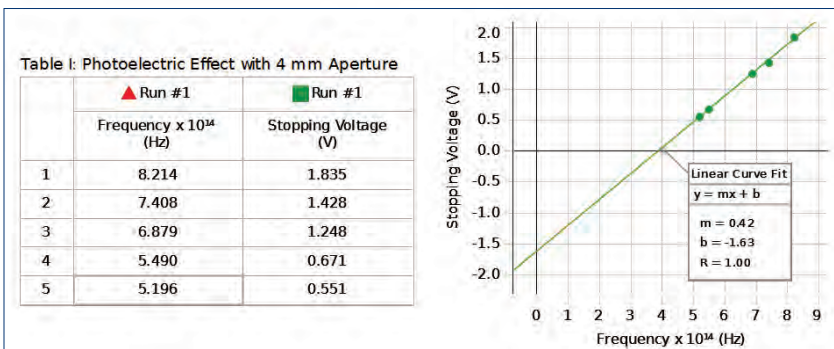
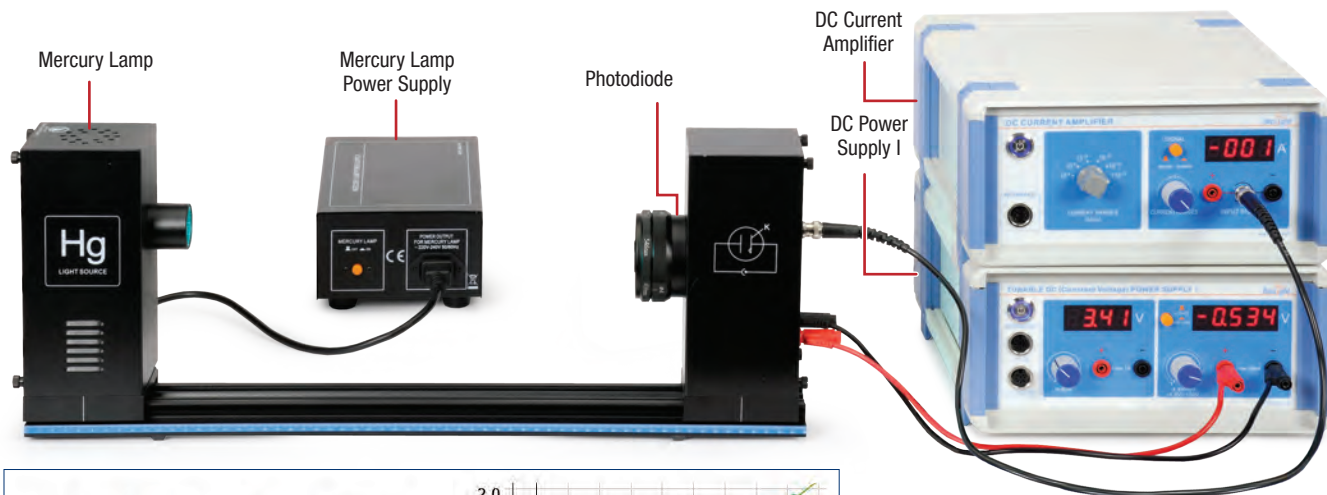
Photoelectric Effect

Photoelectric Effect System

SE-6609

- ▶ Experimentally determine Planck's Constant within 5%
- ▶ Verify that stopping potential is independent of light intensity
- ▶ Find characteristics of the material(s) inside the vacuum photodiode

The Photoelectric Effect System uses the conventional method to determine Planck's Constant within 5%. First, the metal plate in the photodiode is illuminated by various light frequencies; selected from a mercury lamp with filters. Then, the voltage is adjusted to stop the photoelectric current. The stopping voltage is then plotted against the frequency, and Planck's Constant is determined using the slope. Students can test whether the stopping voltage changes with light intensity using the various apertures and corresponding light intensities.



For the typical sample data shown, the graph of Stopping Voltage vs. Frequency gives a slope of 4.2×10^{-15} V-s. This results in a value for Planck's Constant of 6.7×10^{-34} J-s, which is 1.3% above the accepted value. This graph was generated using PASCO Capstone™ software and the 850 Interface.

The filters and the apertures are built into the front of the photodiode case, making it easy to clean and eliminating the need for a separate storage box. To change the aperture size, simply pull outward on the aperture ring and rotate it to a different aperture. The filter wheel rotates independently of the aperture ring to select different frequencies of light. The wheel clicks into place, assuring that the filter is aligned with the aperture.



SE-6609 Includes:

- Basic Photoelectric Effect Apparatus: SE-6614
- DC Current Amplifier: SE-6621
- DC Power Supply I (Constant Voltage): SE-6615

SE-6614 Includes:

- Photodiode Enclosure with tube
- Track, 60 cm and required cables
- Mercury Light Source (SE-6608)

Can be used with the 850 Interface (UI-5000, see p. 28) and PASCO Capstone

See complete experiment on page 383.

For Power Supply and Current Amplifier specs, see page 250

Specifications:

- Current Amplifier Measuring Range:** 10⁻⁸ to 10⁻¹³ A in six ranges
- Photoelectric Tube Voltage Adjustment:** -4.5 V to 0 V and -4.5 V to +30 V (two ranges)
- Photoelectric Tube Spectral Response Range:** 300 nm – 700 nm
- Photoelectric Tube Anode:** nickel ring
- Five Optical Filters with Central Wavelengths:** 365.0, 404.7, 435.8, 546.1, and 578.0 nm

Order Information

Photoelectric Effect SystemSE-6609
 If you already have the Power Supply and Amplifier, you will need:
 Basic Photoelectric Effect ApparatusSE-6614
 Replacement Parts:
 Photoelectric Tube with Box Plate.....SE-6612

Save

Share Instruments in Three Experiments

These three experiments use common power supplies and amplifiers. As long as these experiments are not performed simultaneously, you can save by not duplicating the instrumentation.

1. Photoelectric Effect

Complete Setup:
Photoelectric Effect SystemSE-6609

2. Franck-Hertz

Complete Setup:
Franck-Hertz SystemSE-9639

3. Electron Charge-to-Mass Ratio (e/m)

Complete Setup:
e/m ApparatusSE-9629

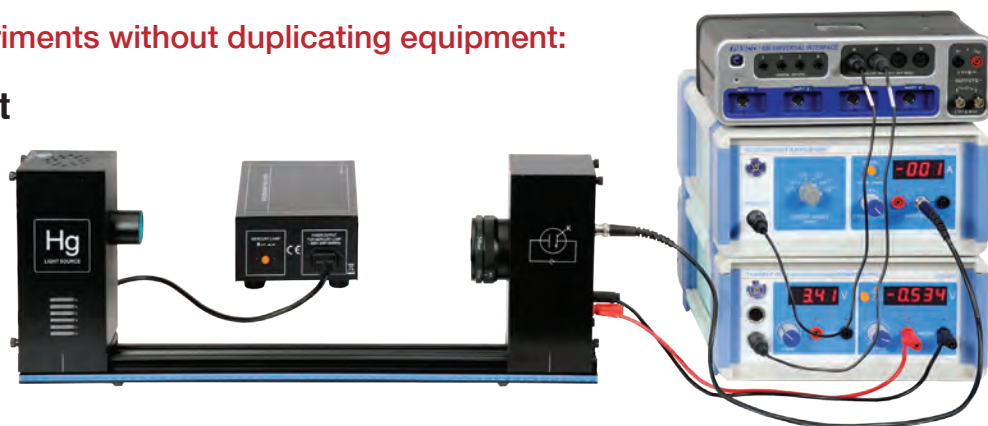
EXPERIMENT	DC Power Supply I	DC Power Supply II	DC (Constant Current) Supply	DC Current Amplifier
Photoelectric Effect	✓			✓
Franck-Hertz	✓	✓		✓
e/m		✓	✓	

To perform these experiments without duplicating equipment:

1. Photoelectric Effect

Photoelectric Effect System
SE-6609

This complete setup includes two instruments that can be used in the Franck-Hertz and e/m experiments.



2. Franck-Hertz

Add

Franck-Hertz Tube Enclosure with Argon Tube
SE-9650



Add

DC Power Supply II (Constant Voltage)
SE-9644



3. Electron Charge-to-Mass Ratio (e/m)

Add

Helmholtz Coils for e/m
SE-9626



Add

Tunable DC Power Supply (Constant Current)
SE-9622



Add

Replacement e/m Tube
SE-9651



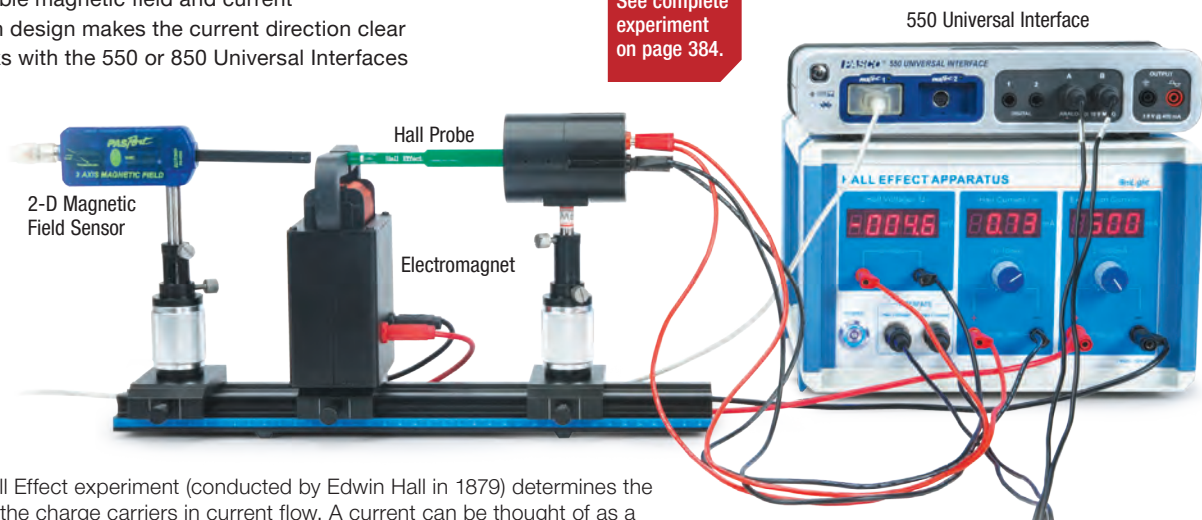
Hall Effect

Hall Effect n-Doped Semiconductor

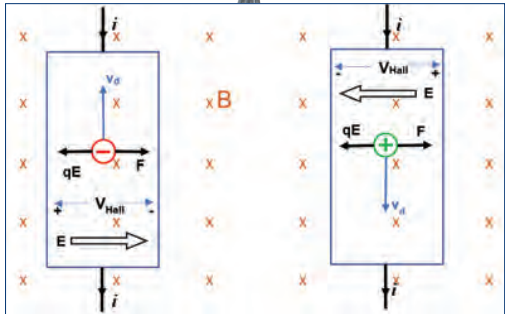
SE-7260

- ▶ Variable magnetic field and current
- ▶ Open design makes the current direction clear
- ▶ Works with the 550 or 850 Universal Interfaces

See complete experiment on page 384.



The Hall Effect experiment (conducted by Edwin Hall in 1879) determines the sign of the charge carriers in current flow. A current can be thought of as a negative charge moving in one direction or as a positive charge moving in the opposite direction. To determine which it actually is, the semiconductor is immersed in the magnetic field transverse to the direction of flow of current. The moving charge experiences a force, causing a charge build-up on one side of the semiconductor (creating an electric field), which in turn leads to a force. The direction of the electric field will depend on the sign of the charge carriers and the polarity of the Hall voltage across the semiconductor reveals this sign. The magnitude of the Hall voltage is dependent on the current, the charge carrier density, and the magnitude of the magnetic field. In modern day electronics, the Hall Effect is used to measure the magnitude and direction of magnetic fields.



PASCO Advantage

The open design of this Hall Effect apparatus makes it possible for students to see the direction of the current and the magnetic field, enabling them to use the sign of the Hall voltage to deduce the sign of the charge carriers.

Specifications:

- n-Doped Semiconductor Material:** GaAs
- Hall Sensitivity:** ≥ 150 mV/(mA-T)
- Magnet Space:** 10 mm
- U-core Electromagnetic Coil:** 1000 Turns
- Magnet Field:** 0 to 0.065 T (at 1A)
- Excitation Current:** 0 to 1 A DC
- Hall Voltage:** 0 to 1.9999 V
- Power Supply Digital Readout for Current, Hall Voltage, and Magnet Current**

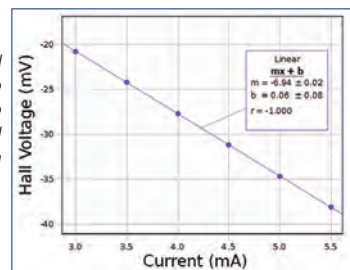
Includes:

- Hall Unit, n-Semiconductor (GaAs)
- Hall Effect Power Supply
- U-Core Electromagnetic Coil
- Track, Length 40 cm
- Optical Carrier (2)
- Adjustable Post Holder with 9 cm Post (2)
- Banana Cords (6)
- Connecting Cables for 550/850 Interface (2)
- Manual



The directions of the current and the voltage probe are clearly marked on the probe that holds the semiconductor.

Using the 550 Universal Interface to record data, this plot of the Hall Voltage vs. the Current was made in PASCO Capstone software. In this case, the magnetic field was held constant and the current through the semiconductor was varied.



Order Information

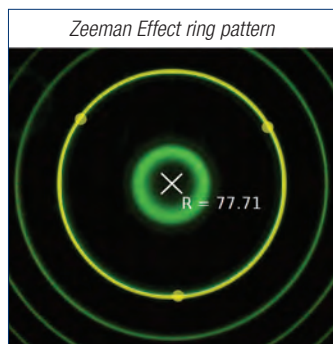
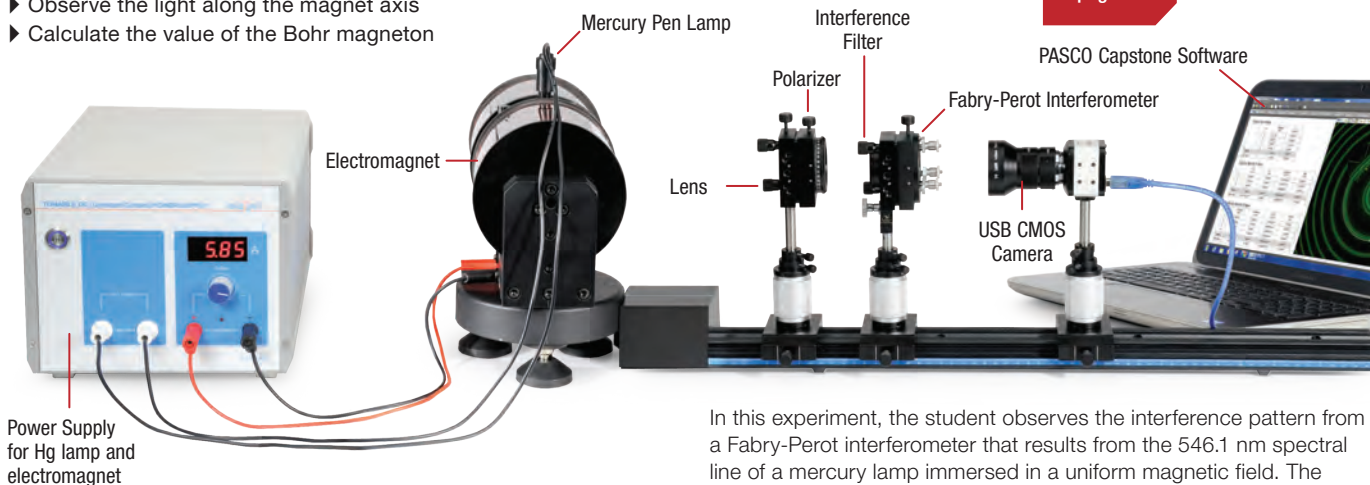
- Hall Effect n-Doped Semiconductor..... SE-7260
- Note: This apparatus can be used manually by reading the digital displays. Measuring the magnetic field requires a sensor or other Tesla meter. This apparatus includes connector cables for an 850 or 550 interface so data collection can be automated.*
- Required:
- PASPORT 2-Axis Magnetic Field Sensor PS-2162
- 850 or 550 Universal Interface UI-5000 or UI-5001 pp. 14, 16
- PASCO Capstone Software pp. 68-71

Zeeman Effect

SE-9654

- ▶ Measure the Zeeman Effect with polarization perpendicular and parallel to the field
- ▶ Observe the light along the magnet axis
- ▶ Calculate the value of the Bohr magneton

See complete experiment on page 386.



The optics and track come in an aluminum hard case with foam cutouts for each component.

In this experiment, the student observes the interference pattern from a Fabry-Perot interferometer that results from the 546.1 nm spectral line of a mercury lamp immersed in a uniform magnetic field. The magnetic field is varied from zero to nearly 1 Tesla.

Initially, the light is viewed along an axis perpendicular to the magnetic field axis. A polarizer is used to show the three lines due to light that is polarized parallel to the field axis and to show the six lines that are polarized perpendicular to the field axis. The pattern may also be viewed along the field axis where the light is circularly polarized.

Finally, the pattern that is polarized perpendicular to the field axis is used to calculate the Bohr magneton. All atomic magnetic moments are integral or half-integral multiples of the Bohr magneton.

Specifications:

CMOS Camera and Lens: 1/3", 2M pixels, f = 50 mm, RA = 1:4

Fabry-Perot Interferometer: $\lambda = 546.1$ nm

Collimating Lens: f = 125 mm

Mercury Lamp: 10A, 3W

Electromagnet: 5A, 1.2T, ~7.4 mm gap

Tunable DC Power Supply: 110V/220V, 6A

Precision Adjustable Optical Mount: $\Phi 45$ mm, 2D

Horizontal Optical Mount: $\Phi 45$ mm, travel = 36 mm, 2D

Track Length: 600 mm

Includes:

- Electromagnet
- Optics
- Power supply
- PASCO Capstone Single User License

Order Information

Zeeman Effect SE-9654

May be purchased separately:

Electromagnet SE-9655

Tunable DC Power Supply 6A SE-9656

Replacement Part:

Mercury Pen Lamp SE-9658

Optional:

Tesla Meter SF-7579A p. 246

Field strength as a function of the current supplied to the magnet is included in a chart. To directly measure field strength, order the optional Tesla Meter (SF-7579).

Gravitational Torsion Balance

Gravitational Torsion Balance

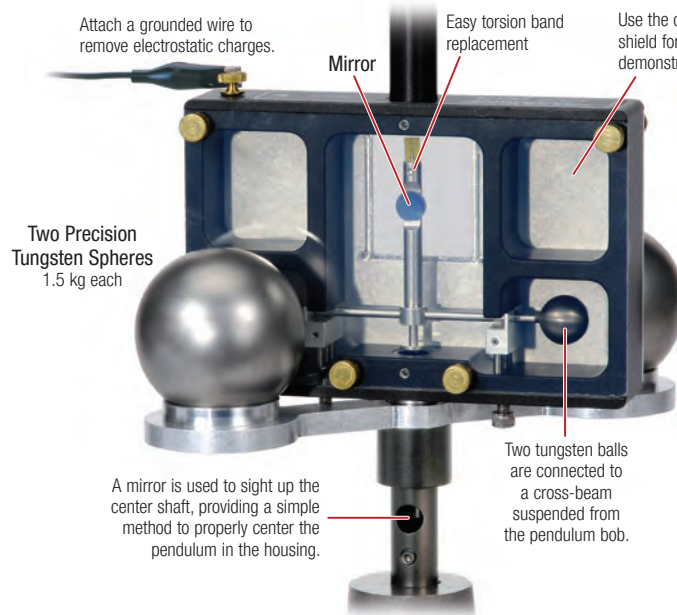
AP-8215A

- ▶ Measure the universal gravitational constant in a single lab period
- ▶ Adjustment and locking mechanisms decrease lab setup time
- ▶ Torsion band easily replaced

Features:

- ▶ View the pendulum bob's position through a mirror in the unit's central shaft. Use the leveling screws in the cast-iron base to accurately center the bob.
- ▶ A special "U"-shaped groove in the locking mechanism is used to dampen the oscillation of the small tungsten balls.
- ▶ Easily adjust pendulum height with a single screw.
- ▶ The smooth action of the rotating large tungsten ball support ensures that the balls can be moved easily without disturbing the motion of the small tungsten balls.

Computerized Version
 See the Universal Gravitational Constant experiment (EX-5550) on page 335 for a new video analysis method of tracking the laser beam.



Specifications:

- Torsion Band:** Beryllium copper ribbon, 36 cm long with a cross section of 0.0178 x 0.15 mm
- Small Masses:** Two tungsten balls of 38 g each
- Large Masses:** Two tungsten balls of 1.5 kg each
- Period of Oscillation:** Eight minutes (approx.)
- Accuracy:** 5% (approx.)

Includes:

- Torsion Balance Assembly
- Large Rod Base ME-8735
- Extra Torsion Band
- Manual

Order Information

Gravitational Torsion Balance	AP-8215A	
Required:		
X-Y Adjustable Diode Laser	OS-8526A	p. 298
45 cm Stainless Steel Rod	ME-8736	p. 186
Large Table Clamp	ME-9472	p. 189
Replacement Supplies:		
Torsion Bands (2 Pack) –		
Gravitational Torsion Balance	AP-8218	p. 312
Gravitational Torsion Balance		
Replacement Spheres	AP-8219	p. 312

Coulomb's Law Apparatus

ES-9070

- ▶ Accurately measure charge, force, and distance
- ▶ Symmetric design minimizes stray and mirror charges
- ▶ Magnetic damping for quick, accurate measurements

How It Works:

A conductive sphere is mounted on the end of an insulating, counterbalanced rod and suspended from a thin torsion wire. An identical sphere is mounted on a calibrated linear track. This second sphere can be positioned at various distances from the first. When the conductive spheres are charged, the force between them is proportional to the twist of the torsion wire that is required to bring the balance back to its equilibrium position. Beginning students can determine the Inverse Square Law in a simple experiment. Advanced students can perform a more sophisticated investigation into all the variables of electrostatic repulsion.

Specifications:

Torsion Balance:

Torsion Assembly: 38 mm dia. conductive sphere on 12 cm rod with counterbalance vane

Torsion Wire: equals 10-6 Newtons/degree

Degree Plate: 1° increments

Magnetic Damping: dampens oscillations for quick measurements

Calibrated Linear Track:

Sphere: 38 mm dia. conductive sphere

Range of Movement: 350 mm in 1 mm increments

Material: phenolic (to minimize mirror charges)

Miscellaneous Equipment:

Charging Probe: 17 cm long plus 1.5 m cable; banana plug connector; 200 $\mu\Omega$ internal resistance

Calibration Masses: 50 mg (1), 20 mg (2)

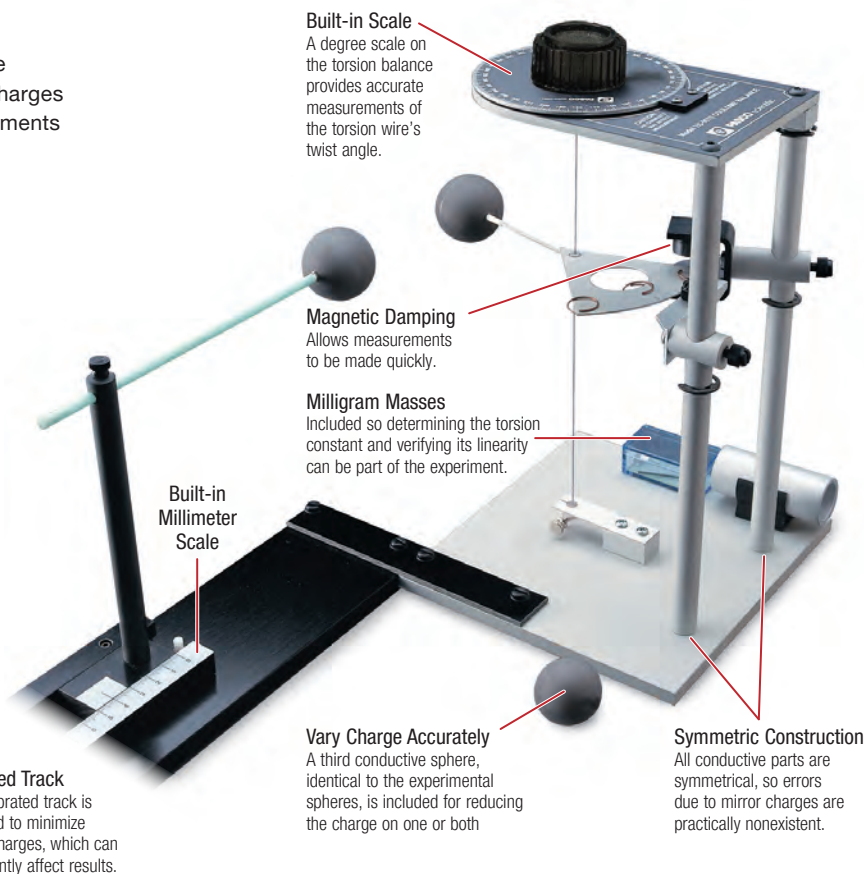
Conductive Sphere on Insulating Thread: for reducing charge by fixed ratios

Spare Torsion Wire: 3 m

Shipping Information:

Size: 28 x 38 x 61 cm (11 x 15 x 24 in.)

Weight: 9.5 kg, 21 lbs



Insulated Track
The calibrated track is designed to minimize mirror charges, which can significantly affect results.

Built-in Scale
A degree scale on the torsion balance provides accurate measurements of the torsion wire's twist angle.

Magnetic Damping
Allows measurements to be made quickly.

Milligram Masses
Included so determining the torsion constant and verifying its linearity can be part of the experiment.

Built-in Millimeter Scale

Vary Charge Accurately
A third conductive sphere, identical to the experimental spheres, is included for reducing the charge on one or both

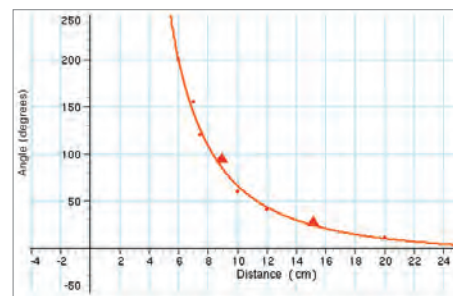
Symmetric Construction
All conductive parts are symmetrical, so errors due to mirror charges are practically nonexistent.

Additional Equipment

To perform a basic experiment, the conductive spheres can be charged with a piezoelectric gun or by contact with a charged rod. This allows the Inverse Square Law to be verified with reasonable accuracy. However, for more accurate and thorough investigations, we strongly recommend the following additional equipment (see ordering information):

- **Kilovolt Power Supply**, which provides a fixed and repeatable charge. The charge can be refreshed before each measurement, which practically eliminates errors due to leakage currents.

- **Basic Electrometer and a Faraday Ice Pail**, for accurate measurement of the charge on the spheres (required only if you wish to measure the Coulomb Constant).



Actual data of the Angle (force) vs. Distance

Order Information

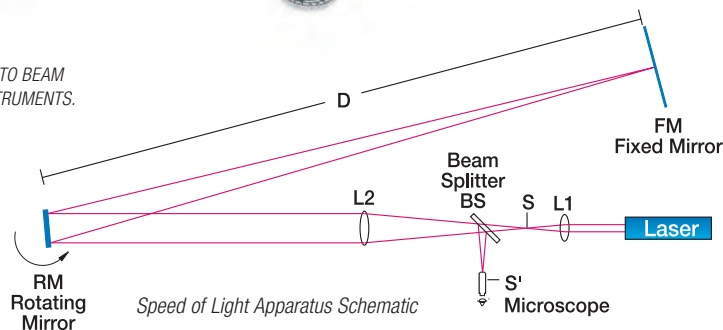
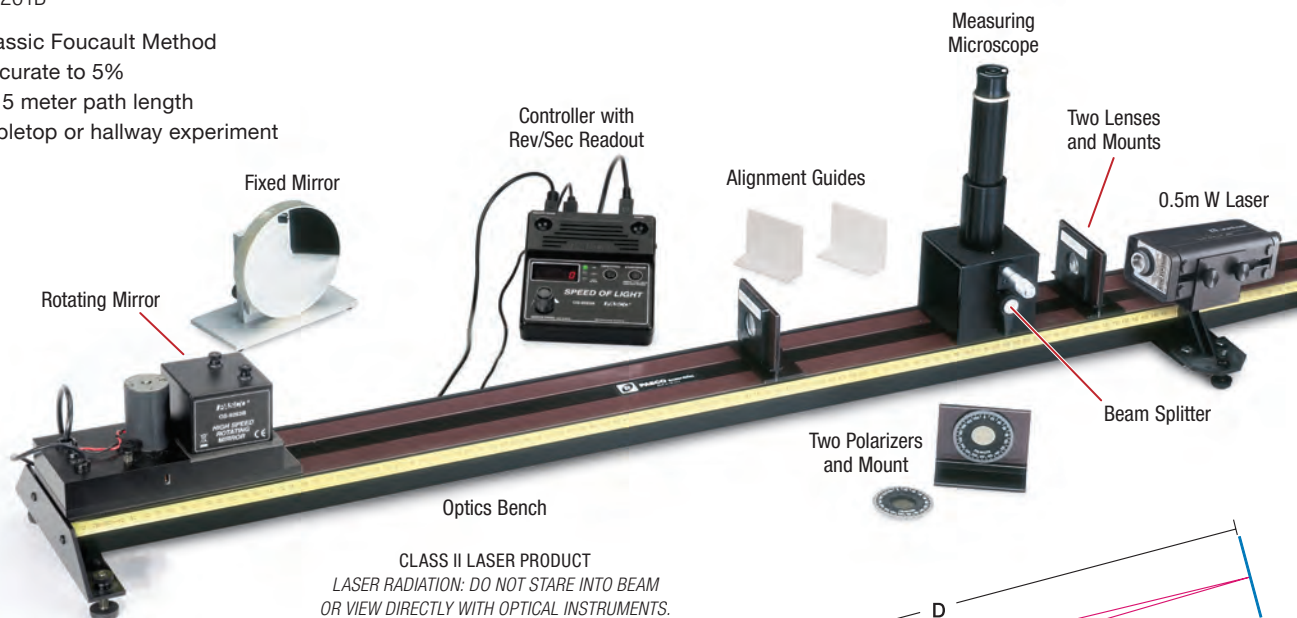
Coulomb's Law Apparatus.....	ES-9070	
Recommended:		
Kilovolt Power Supply.....	SF-9586B	p. 253
Basic Electrometer.....	ES-9078A	p. 214
Faraday Ice Pail	ES-9042A	p. 215
Charge Producers and Proof Plane	ES-9057C	p. 215
Coulomb's Law Experiment	EX-9930B	p. 361

Speed of Light

Complete Speed of Light Apparatus

OS-9261B

- ▶ Classic Foucault Method
- ▶ Accurate to 5%
- ▶ 1-15 meter path length
- ▶ Tabletop or hallway experiment



How It Works – The Foucault Method

1. The first observation is made when the rotating mirror is not rotating. Light from a He-Ne laser is reflected from the rotating mirror and focused onto the fixed mirror. The fixed mirror reflects the image back onto the rotating mirror, which in turn reflects the light back through the lenses to reform the image, where it can be observed with the microscope.
2. The second observation is made when the rotating mirror is rotating. Since it takes a finite amount of time for the light to traverse the distance between the fixed and rotating mirrors, the rotating mirror is in a slightly different position when the light returns after reflecting off the fixed mirror. This produces a displacement, which can be measured with the microscope.
3. The displacement between the first and second observations is proportional to the transit time of the light to the angular velocity of the rotating mirror. With a very straightforward calculation, the speed of light can be calculated.

Order Information

Complete Speed of Light Apparatus	OS-9261B	
Parts Available Separately:		
Laser Alignment Bench	OS-9172	p. 299
Mini Laser with Bracket	OS-8514	p. 299
Speed of Light Experiment	EX-9932A	p. 377

OS-9261B Includes:

- 1 m Optics Bench
- Laser Alignment Bench
- Mini Laser with Bracket
- Double Convex Lens, 48 mm F.L.
- Plano Convex Lens, 252 mm F.L.
- Calibrated Polarizer
- Component Carrier

High Speed Rotating Mirror with Controller

OS-9263B



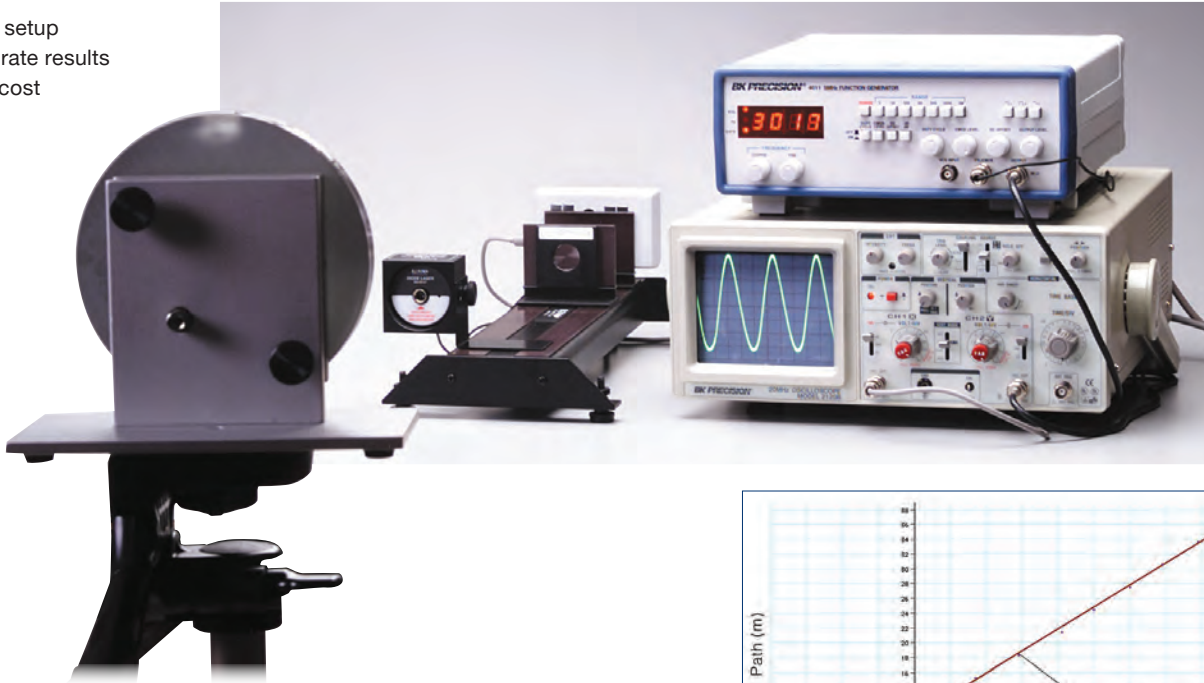
Order Information

High Speed Rotating Mirror	OS-9263B
----------------------------------	----------

Laser Speed of Light System

AP-8586

- ▶ Easy setup
- ▶ Accurate results
- ▶ Low cost

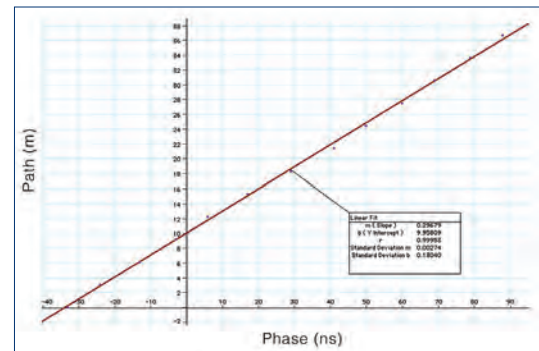
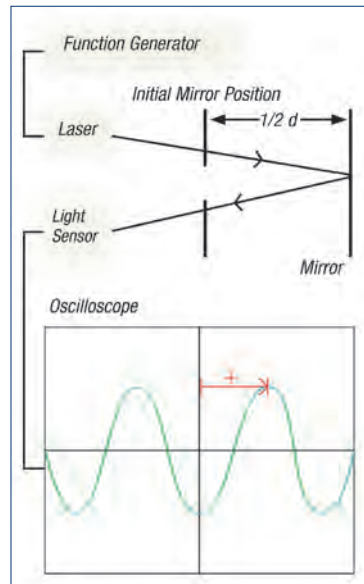


The Laser Speed of Light System is a low cost, yet effective method of measuring the speed of light. While it does not duplicate the classic Foucault Method, its ease of use gives every student the opportunity to perform the experiment.

How It Works:

A function generator is used to modulate the light from the laser at 3 MHz. This light is then reflected from a mirror and focused onto a light receiver. An oscilloscope is used to observe the modulated light, and the phase of the signal is noted as the baseline value for phase.

The mirror is moved back, increasing the distance that the light travels. Since it takes more time for the light to travel from the laser to the sensor, the phase of the signal on the oscilloscope increases. The phase at each successive mirror position is recorded and compared to the baseline value. The mirror is moved back several more times to get a reasonable number of data points. For each mirror position, the additional path length (d) is graphed versus the phase difference (t).



A linear fit is applied to the data, and the slope of the fit represents $\Delta d/\Delta t$, or the speed of light.

Includes:

- Diode Laser, Component Carrier (2)
- Laser Alignment Bench
- +127 mm Lens
- Light Receiver
- Stainless Steel Mounting Pads (4)
- Concave Mirror
- Coaxial Cable– RCA male to BNC male
- Coaxial Cable– 3.5 mm phone plug to BNC male
- Coaxial Cable– BNC male to male

Order Information

Laser Speed of Light System	AP-8586
Required:	
Wide Range Function Generator	SB-9549A
30 Meter Measuring Tape	SE-8712A
Standard Photo Tripod	
Digital Storage Oscilloscope (100 MHz)	SB-9621A
Replacement Part:	
Speed of Light Diode Laser	OS-8475

Speed of Light

Speed of Light - Reflector

SF-7203

- ▶ Measure the speed of light using short pulses of light
- ▶ Unique retro-reflector eliminates alignment problems



To measure the speed of light, pulsed light is reflected off a retro-reflector and the time between the pulse and the received reflection is measured with an oscilloscope. The progressive delaying of light pulses is observed as they travel farther and farther.

How It Works:

Very short but powerful pulses of light are emitted from the box. When the light pulses hit the special retro-reflective foil of the reflector, they are directed back toward the source with no need for tedious adjustments. The returning light pulses pass through a beam-splitter and strike a high-speed photodiode, converting the light pulses into electric pulses that are displayed on an oscilloscope. A separate synchronization signal marks the time of pulse emission, so time between emission and return can be timed.

The distance to the retro-reflector is increased a known distance and the resulting increase in return time allows the speed of light to be calculated by simply dividing the distance by the change in time.



Includes:

- Pulse-emitter box
- BNC cables (2)
- Retro-reflective screen

Order Information		
Speed of Light - Reflector	SF-7203	
Required:		
Digital Storage Oscilloscope (100 MHz)	SB-9621A	p. 257
Meter Sticks, 6 Pack	SE-8827	p. 192

Advanced Nuclear Spectroscopy System, (Win/Mac) USB

SN-7901B

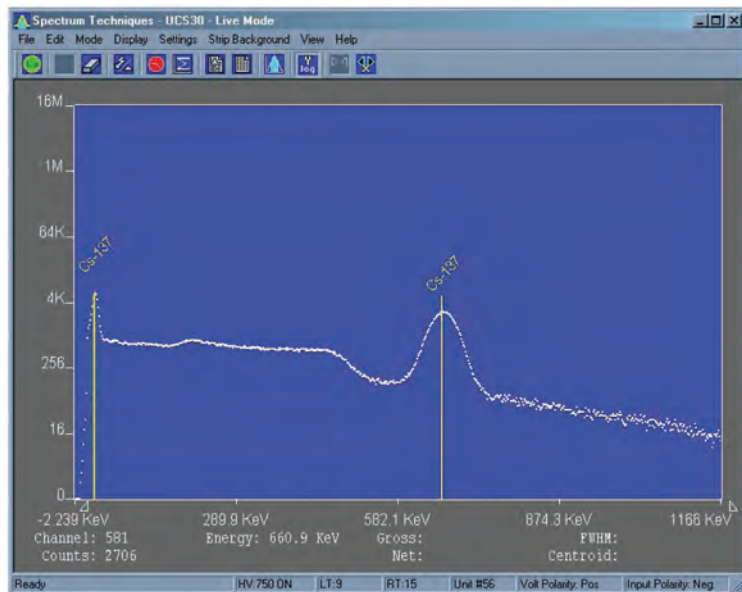
- ▶ Sophisticated spectroscopy system
- ▶ Multi-channel analysis

Designed for spectroscopy applications, the Universal Computer Spectrometer (1) offers complete support for standard scintillation detectors together with multi-channel scaling for decay and time-related studies. The multi-channel analyzer contains many advanced features, including computer-controlled amplifier and high voltage for G-M tubes, upper- and lower-level discriminators, data memory, and a comprehensive software package.

The sources are USNRC License Exempt (US only). Outside the US, consult your local laws and regulations.

Features:

- ▶ **Variable Voltage:** A regulated high voltage of 0 to 1280 V is supplied with computer control (1 mA maximum, 5 V increments).
- ▶ **Amplifier:** On-board combination preamplifier/amplifier for use with scintillation detectors and PMTs.
- ▶ **Complete Computer Control:** When used in MCA mode, the software provides complete computer control of all features including preset live/real-time, preset count, unlimited regions-of-interest and centroid, gross and net area calculations.
- ▶ **Multiple Memory Buffers:** In addition to on-board hardware data memory, the spectrometer provides three software memory buffers for holding spectra. A background spectrum may be collected over a long counting period and stored in the background buffer.
- ▶ **Peak Labeling:** With ISOMATCH, an isotope library file, users can quickly identify peaks by superimposing characteristic isotope emission lines over their spectrum. Isotope and energy information are also provided.



Main screen display for Universal Computer Spectrometer

Specifications:

Physical Hardware: Interface card or box includes pre-amplifier, amplifier, detector high voltage, 1024 channel analyzer with data memory, LLD and ULD

ADC: Wilkinson-type with 80 MHz clock and computer selected conversion gain of 256, 512, or 1024 channels

High Voltage: 0-1280 V, 1 mA maximum Amplifier: Preamplifier/amplifier combination; computer controlled coarse/fine gain from 2x to 1000x

Modes: MCA for pulse height analysis, or MCS for half-life decay or other time-related studies

Software Energy Calibration: 2-point linear or 3-point quadratic converts cursor position reading directly to energy units

Computer Software Display: Vertical scale adjusts from 32 to 16 M and LOG display; horizontal 1024 channels with expansion down to 128 channels

ISOMATCH Software: Isotope library text file with peak markers and labeling for overlaying on spectrum for quick isotope identification; library may be edited and expanded.

Includes:

- Universal Computer Spectrometer, USB
- NaI (TI) Scintillation Probe
- Gamma Sources (8)
- Connection Cables
- Installation, Instruction, and Experiment CDs (2)

Order Information

Advanced Nuclear Spectroscopy System,
(Win/Mac) USB..... SN-7901B

*Note: Purchased Sources are "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 400.

Nuclear Radiation

Intermediate Nuclear Laboratory System (Win/Mac)

SN-7900B

- ▶ Macintosh®, Windows®, or stand-alone option
- ▶ Complete system

PASCO's most sophisticated, stand-alone G-M System supports a wide range of experiments with alpha, beta and gamma radiation. Includes a versatile scaler, a G-M Tube with a mount and trays, and a full set of radioactive sources and absorbers.

The Sources are USNRC License Exempt (US only). Outside the US, consult local laws and regulations.

Features:

- ▶ **Preset Timing and Counting Intervals:** (in seconds) 1-9, 10-90, 100-900, 1K-9K, 10K-90K, 100K- 900K. Intervals are selected using the Preset switch.
- ▶ **Digital Display:** A bright 6-digit digital readout uses extra-large LEDs for clear readout in most ambient light conditions.
- ▶ **Built-in Power Supply:** 0 to 1200 volts for the G-M Probe.
- ▶ USB and serial interface to Mac and PC

Advanced Scaler/Timer

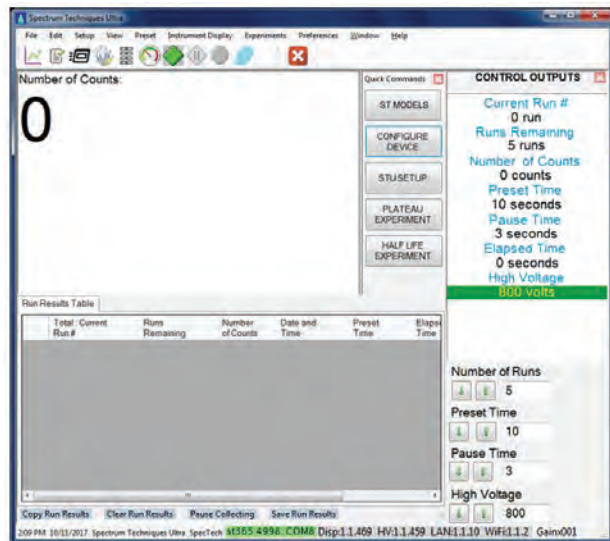
The Radiation Counter SN-7907 is a versatile, general purpose Scaler/Timer.

Sensitive G-M Probe

- ▶ Suitable for alpha, beta, and gamma radiation detection
- ▶ The rugged and versatile mount is made of sturdy plastic for years of rugged use. It comes with one sample holder and 10 shelf positions.

Large Variety of Absorbers

The Absorber Set SN-8111A includes four lead, ten aluminum sheets, two polyethylene, two plastic, and two aluminum foil absorbers, ranging from 5 mg/cm² to 7200 mg/cm²



Main screen display from Spectrum Techniques Ultra software

Computer Compatibility

The bi-directional STU software allows full control of the Radiation Counter from the computer. STU provides real-time display of a simulated analog rate-meter with auto-ranging, digital ratemeter in CPM or CPS, count, elapsed time, preset count, preset time, acquisition time, and run number. Data is loaded into spreadsheet-compatible files.

Five Radioactive Sources

1. Po-210: 0.1 μCi, 138 days, α
2. Sr-90: 0.1 μCi, 28.6 years, β
3. Co-60: 1 μCi, 5.27 years, β,γ
4. Tl-204: 0.25 μCi, 3.78 years, β,γ
5. Cs-137: 0.25 μCi, 30.2 years, β,γ

The five sources are USNRC License Exempt (US only). Outside the US, consult your local laws and regulations.

Includes

1. SN-7907 Radiation Counter with STU software and manual
2. SN-7970A G-M Probe (35 mm) and stand
3. USB Cable
4. SN-8111A Calibrated Absorber Set (20)
5. SN-7972A Radioactive Sources (5)
6. Two CDs with installation instructions and nuclear science experiments



Order Information

Intermediate Nuclear Laboratory System (Win/Mac) SN-7900B
 Required:
 Isotope Generator Kit (Barium-137 m)..... SN-7995A

*Note: Purchased Sources are "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 403.

The following sources are mounted in 2.5 cm diameter sealed plastic disks. All sources and isotopes on this page are USNRC License Exempt (US only). Outside the US, consult your local laws and regulations. Shown below are the isotopes, activity, half-life, and types of radiation (alpha- α , beta- β , gamma- γ).

Radioactive Sources (set of 3)

SN-8110



- | | | | |
|-----------|--------------|------------|-----------------|
| 1. Po-210 | 0.1 μ Ci | 138 days | α |
| 2. Sr-90 | 0.1 μ Ci | 28.6 years | β |
| 3. Co-60 | 1 μ Ci | 5.27 years | β, γ |

Order Information

Radioactive Sources (set of 3) SN-8110

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 403.

Radioactive Sources (set of 5)

SN-7972A



- | | | | |
|-----------|---------------|------------|-----------------|
| 1. Po-210 | 0.1 μ Ci | 138 days | α |
| 2. Sr-90 | 0.1 μ Ci | 28.6 years | β |
| 3. Tl-204 | 0.25 μ Ci | 3.78 years | β |
| 4. Co-60 | 1 μ Ci | 5.27 years | β, γ |
| 5. Cs-137 | 0.25 μ Ci | 30.2 years | β, γ |

Order Information

Radioactive Sources (set of 5) SN-7972A

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 403.

Individual Sources



Order Information

Po-210*	0.1 μ Ci	138 days	α	SN-9085
Sr-90*	0.1 μ Ci	28.6 years	β	SN-9796
Tl-204*	1 μ Ci	3.78 years	β	SN-9797
Co-60*	1 μ Ci	5.27 years	β, γ	SN-9794
Cs-137*	10 μ Ci	30.08 years	β, γ	SN-7938
Cs-137*	5 μ Ci	30.2 years	β, γ	SN-9795
Cs-137*	0.25 μ Ci	30.2 years	β, γ	SN-7942
Tl-204*	0.25 μ Ci	3.78 years	β	SN-7941

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 403.

Gamma Sources (set of 8)

SN-7949A



- | | | | |
|--|---------------|------------|-----------------|
| 1. Co-60 | 1 μ Ci | 5.27 years | β, γ |
| 2. Na-22 | 1 μ Ci | 2.60 years | β, γ |
| 3. Mn-54 | 1 μ Ci | 313 days | γ |
| 4. Cs-137 | 0.25 μ Ci | 30.2 years | β, γ |
| 5. Ba-133 | 1 μ Ci | 10.5 years | γ |
| 6. Cd-109 | 1 μ Ci | 464 days | γ |
| 7. Co-57 | 1 μ Ci | 270 days | γ |
| 8. "UNKNOWN": mixture of Cs-137 and Zn-65 for student testing. | | | |
- Cs-137 is 0.25 μ Ci or lower.

Order Information

Gamma Sources (set of 8) SN-7949A

Absorbers (set of 20)

SN-8111A



This set of 20 calibrated absorbers includes 4 lead, 2 plastic, 10 aluminum, 2 polyethylene, and 2 aluminum foil absorbers. Absorbers vary in density from 5 mg/cm² to 7200 mg/cm².

Order Information

Absorbers (set of 20) SN-8111A

WARNING! This product can expose you to Lead, which is known to the State of California to cause cancer, birth defects, or other reproductive harm. For more information go to www.P65Warnings.ca.gov.

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 403.

Isotope Generator Kit (Barium-137 m)

SN-7995A



This Cs-137/Ba-137m Isotope Generator is used to demonstrate the properties of radioactive decay. Based on the original Union Carbide patented design, it offers exceptional performance, ease-of-use, and safe operation.

Each generator contains 10 μ Ci of Cs-137. The generator can produce up to 1000 small aliquots of the short-lived Ba-137m isotope with a half-life of 2.6 minutes.

Each generator is supplied with 250 mL of eluting solution (0.9% NaCl in 0.04M HCl). The parent isotope Cs-137 with a half-life of 30.1 years beta decays (94.6%) to the metastable state of Ba-137m. This further decays by gamma emission (662 keV) with a half-life of 2.6 min. to the stable Ba-137 element. During elution, the Ba-137m is selectively "milked" from the generator, leaving behind the Cs-137 parent. Regeneration of the Ba-137m occurs as the Cs-137 continues to decay, re-establishing equilibrium in less than 1 hour.

Approximately 30 minutes after elution, the residual activity of the Ba-137m sample has decayed to less than one thousandth of its initial activity, making it safe for disposal. When used with the eluting solution supplied, bleed-through of the parent Cs-137 is less than 50 Bq/mL, affording a long working life. Each kit is supplied with the generator, syringe, tube, 250 mL of solution, and a storage case.

Order Information

Isotope Generator Kit (Barium-137 m) SN-7995A

***Note:** "Non-Cancellable" and "Non-Returnable". See Radioactive Source Disclaimer on the Order Information page 403.

Radiation Counters

Radiation Counter

SN-7907

- ▶ Available only for 110 VAC (See SN-7902 for 220 VAC version)



Wireless Radiation Counter has LCD display.

This radiation counter supports G-M detectors, as well as scintillation detectors. It can be used stand-alone or connected to a computer through USB, Ethernet, or Wi-Fi. The control software stores data in a format that can easily be transferred directly to common spreadsheet programs.

Specifications:

- Power:** 110 VAC Adapter 9 VDC at 1200 mA
- Variable High Voltage:** 0 to 1200 V, in 10 V increments
- Display:** 16 character LCD
- Housing:** Plastic housing with metal face plate
- Dimensions:** 21.6 cm W x 15.2 cm D x 6.4 cm H
- Computer Connectivity:** USB, Ethernet, or Wi-Fi for Mac and Windows
- Mobile Device Connectivity:** Wi-Fi
- Detector Connectors:** BNC and MHV
- Supported Detectors:** G-M and scintillation

Includes:

- Spectrum Techniques Ultra Software for Windows and Mac
- 110 VAC to 9 VDC Power Adapter

Order Information

Radiation CounterSN-7907

G-M Probe with Sample Holder

SN-7970A

Similar to the Student G-M Tube except that the larger, 35 mm diameter window provides excellent photon efficiency for detecting low activity samples. The SN-7970A G-M Probe has a 200 μ s dead time, contains 10 shelf positions and is designed to accommodate the larger G-M Probe. The probe can be removed from the holder and comes with a standard BNC connector cable.



Specifications:

- Mica Window:** ≤ 2 mg/cm²
- Probe Dimensions:** 11.25 x 3.5 cm (4.5 x 1.4 in.) OD, excluding connector
- Operating Voltage:** 900 V, 150 V plateau

Order Information

G-M Probe with Sample HolderSN-7970A

Handheld G-M Counter

SF-7220

- ▶ Sensitive to alpha, beta, and gamma radiation
- ▶ Shows rate (μ Sv/h or counts/second)
- ▶ The GM voltage can be adjusted between 400 and 700 V, while the count rate is displayed.
- ▶ Displays max, min, and average



The battery-operated Handheld Geiger Counter is a flexible device, specially developed for schools and other educational institutions. Use the built-in GM tube with protective cap for gamma radiation measurements; remove the cap when working with alpha and beta radiation.

Specifications:

- Battery:** 9 V
- Tube Window:** Diameter: 9.1 mm; Mica thickness: 1.5 to 2.0 mg/cm²
- Sound:** Clicks
- Measurement Periods:** 1, 10, 20, 30, 40, 50, 60 and 100 s

Order Information

Handheld G-M CounterSF-7220

Nuclear Experiments with a Computer Interface

G-M Tube/Power Supply

SN-7927A

The G-M Tube/Power Supply senses alpha, beta and gamma radiation. Power for the tube is supplied through the connection to an interface that supplies an operating voltage of +5 V.



Specifications:

- Sensitivity:** Beta, gamma, alpha
- Count Detection:** Audio signal
- Window Thickness:** 1.5 to 2 mg/cm², mica
- Starting/Operating Voltage for Tube:** 450 VDC/500 VDC
- Dead Time:** 90 μ s
- Gas Filling:** Neon, Argon, and Halogen

Order Information

G-M Tube/Power SupplySN-7927A

Diffusion Cloud Chamber

SE-7943

- ▶ No dry ice required
- ▶ View cosmic rays
- ▶ Built-in illumination

How It Works

The bottom of the chamber is cooled by circulating ice water through the base and further cooling it to -35°C with a Peltier device. Alcohol placed in the chamber wicks up the inside chamber lining where it evaporates in the warmer region of the chamber and diffuses downward. The alcohol vapor is then cooled near the chamber bottom and becomes super saturated.

As energetic alpha and beta particles from a radioactive source pass through the alcohol vapor, the vapor condenses, forming droplets that appear as tracks in the strong chamber cross-lighting.

Features:

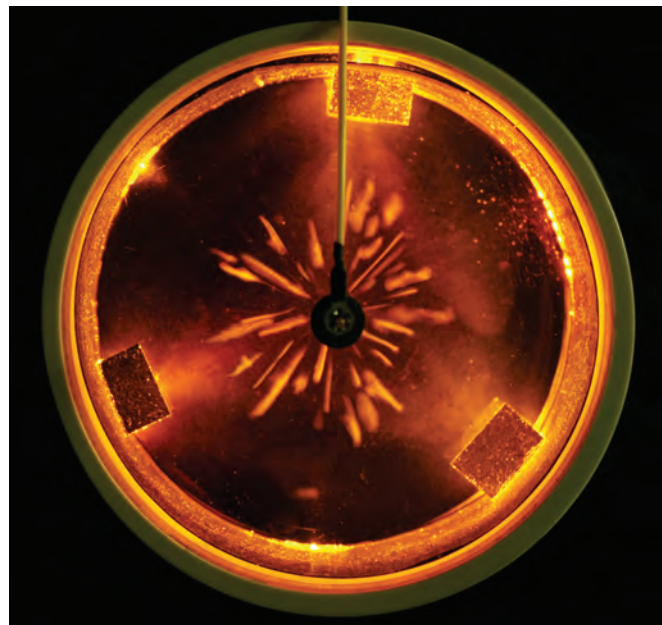
- ▶ Powered by 12V DC power adapter
- ▶ Built-in LED lamps for illuminating the particle trails
- ▶ Uses ice water instead of dry ice
- ▶ Water circulation pump
- ▶ Built-in high voltage (~800V) power supply for clearing the chamber of unwanted ions

Includes:

- Cloud Chamber
- 12 VDC Power Adapter (6 A)
- Water Circulation Pump
- Two Rubber Hoses
- Extraction Pipette
- Source Holder and Stopper
- High Voltage Connection Cable
- SpecTech™ Coupon for Pb-210 Source Needle



***Note:** Purchased Sources are “Non-Cancellable” and “Non-Returnable”. See Radioactive Source Disclaimer on the Order Information page 403.



Particle tracks are visible from radioactive particles given off by the Pb-210 source at the center. The dense straight tracks are produced by alpha particles and the fainter, crooked tracks are produced by beta particles.

Specifications:

- Diameter:** 15 cm 12 VDC Power Adapter (6 A)
- Water Circulation Pump:** 120 V/60 Hz, 3 W, 180 liter/hr
- Built-in High Voltage Source:** ~800 VDC with 108 Ω protection resistor
- Rubber Hoses:** 0.25" ID (6.4 mm ID), 60 cm long
- High Voltage Connection Cable:** 22 cm long, Banana plug to ring lug Eight Amber LEDs

Order Information

Diffusion Cloud Chamber (15 cm diameter).....	SE-7943
Diffusion Cloud Chamber (15 cm diameter) - No Source	SE-7940
Required:	
Ice Water	
Recommended	
Pb-210 Source Needle.....	SE-7945
The Needle Source is USNRC License Exempt (US only).	

Alpha Particle Spark Detector

SF-7219

- ▶ The alpha radiation can be both seen and heard.
- ▶ Clear demonstration of the alpha particle's ionization of the air
- ▶ Registers alpha radiation from radioactive minerals

Visualize alpha particles with this spark detector. When alpha particles ionize the air in the spark detector's aperture, sparks can be both seen and heard. The transparent lid allows observation from several different directions. The spark detector can be placed directly on a table or mounted in ordinary stand hardware using the supplied mounting post.

The spark detector needs to be connected to a high-voltage supply such as SF-9586. Normal operating voltage is between 2 and 5 kV.

Specifications:

- Dimensions:** 7.5 cm x 13 cm x 5 cm
- Operating Voltage:** Between 2 and 5 kV

Includes:

- Instruction Manual
- Experiment Ideas



Order Information

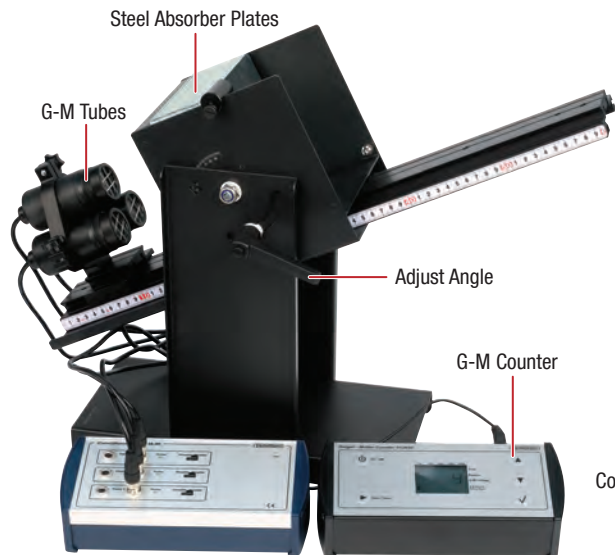
Alpha Particle Spark Detector.....	SF-7219
Required:	
Kilovolt Power Supply	SF-9586B

Muon Observatory

Complete Muon Observatory

SF-7278

- ▶ Detect cosmic rays
- ▶ Demonstrate the angular dependence



Shower Mode: Three G-M tubes are clustered together, pointed at the steel absorber sheets.



Telescope Mode: The three G-M tubes are arranged in a line and the telescope angle can be varied to see which angle gives the greatest radiation.

The apparatus can be configured for either **Shower Mode** or **Telescope Mode**:

1. In the **Shower Mode** setup, a shower is recorded as a coincidence event from three GM tubes arranged in a triangle. This geometry ensures that no single particle can be detected in all three tubes. Production of showers may be enhanced by allowing the radiation to pass through something that is slightly “thicker” than air (multiple steel plates are used). In shower mode you will typically align the muon observatory vertically. Measurement periods are approximately one day long.
2. In **Telescope Mode** three GM tubes are arranged in a line, and if a muon passes through all tubes in the setup, a pulse is output from the coincidence box. The angle of the telescope can be varied to detect the angular distribution of the muons.



Large Area Geiger Tube (SF-7266): The extra sensitive tube (28.6 mm mica window) is suitable for measurements of radon daughters, naturally radioactive minerals, cosmic radiation and other applications where a greater area of sensitivity, greater solid angle or more sensitive volume are desirable. This tube is supplied with a forked holder with a mounting post.

Includes:

- Geiger Tube, Lg Area (3-required): SF-7266
- USB Communication Adaptor: SF-7267

- Geiger Counter: SF-7268
- Coincidence Box: SF-7269
- Muon Observatory: SF-7270
- Software



Coincidence Box (SF-7269): To register coincidence between the three GM tubes, a coincidence box is required. The output from the coincidence box goes to a Geiger Counter (SF-7268), which is set to count with manual start and stop.



Geiger Counter (SF-7268): This Geiger counter can be set to start and stop manually and has a digital readout.

Order Information

Complete Muon Observatory.....	SF-7278
Available Separately:	
Muon Observatory	SF-7270
Geiger Counter.....	SF-7268
Geiger Tube, Lg Area (3 required)	SF-7266
Coincidence Box	SF-7269
USB Communication Adaptor	SF-7267

Download **FREE** PASCO Capstone Experiments

Over 60 classic physics experiments for use with PASCO equipment and software

The following pages present classic experiments in physics performed with PASCO apparatus.

Manuals can be downloaded at www.pasco.com. Interfaces and software, where indicated, should be ordered separately.

Everything else is included in the experiment: apparatus, sensors (when needed), and accessories.

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Download This Experiment

Each experiment manual and the PASCO Capstone™ workbook files may be downloaded free at

www.pasco.com/CapstoneExperiments

- ▶ **Experiment Manual:** A detailed experiment manual helps ensure student success. An electronic Word® version is included for modification by the teacher.
- ▶ **PASCO Capstone Workbook File:** PASCO Capstone workbook files are included for each experiment. These files contain workbooks with step-by-step instructions with embedded live data displays. Use these files with students. A file with sample data is also included.

Mechanics

Atwood's Machine Experiment

EX-5501

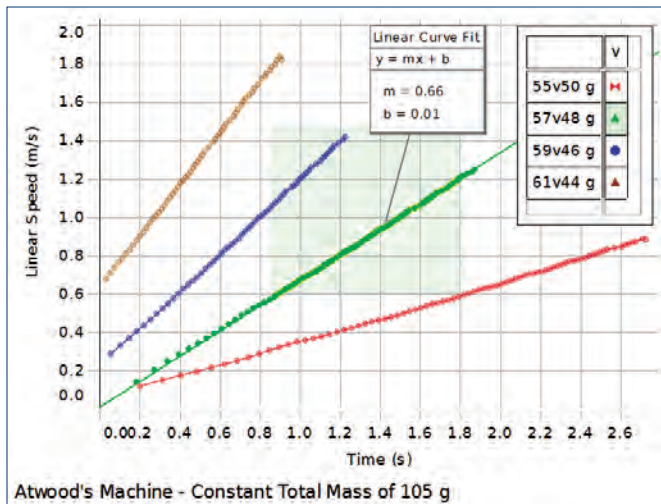
Concepts:

- ▶ Newton's 2nd Law of Motion
- ▶ Newton's 2nd Law of Rotational Motion
- ▶ Rotational Inertia

In this classic experiment, students use a very low mass/low friction pulley to measure the changing velocity of the unbalanced mass system. Students interpret the slope of the velocity graph as acceleration. They examine the effect of the pulley's rotational inertia and estimate the friction forces based on experimental data.

PASCO Advantage:

The Super Pulley/Photogate System makes it easy for students to set up the apparatus and take data. Analysis includes accounting for friction and the rotational inertia of the pulley.



The acceleration of the weights is determined using the slope of the Velocity vs. Time graph. From this, the acceleration due to gravity can be found.

Includes:

- Photogate & Pulley System ME-6838A
- Mass and Hanger Set ME-8979
- Universal Table Clamp ME-9376B
- Stainless Steel Rod, 60 cm Threaded ME-8977
- Multi-Clamp ME-9507
- Braided Physics String SE-8050

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Atwood's Machine Experiment..... EX-5501
 Required:
 550 or 850 Universal Interface*pp. 14-17
 PASCO Capstone Softwarepp. 68-71
 Balance or Scale p. 196
 Digital Calipers SE-8710 p. 192
 * This experiment can be performed using the 550 or 850 Universal Interface or AirLink with Digital Adapter.

Projectile Motion Experiment

EX-5502

Concepts:

- ▶ Independence of x- and y-motion
- ▶ Muzzle velocity vs. time of flight
- ▶ Angle vs. horizontal range



The Photogate and Time-of-Flight Accessory are used with the Mini Launcher to measure both muzzle velocity and time of flight.

Muzzle Velocity vs. Time of Flight

Students fire the projectile at three different velocities from the same height. The Photogate and Time-of-Flight Accessory are used to measure the time of flight at each muzzle velocity. Students are surprised to find that time of flight is not related to muzzle velocity at 0° launch angle.

Angle vs. Horizontal Range

The angle of launch is varied and the horizontal range is measured for each angle. Students produce a graph of angle vs. horizontal range, and use its equation to find the angle of maximum range. This experiment is conducted in two variations:

- Projectile is fired from a higher vertical position than its landing position
- Projectile is fired from the same vertical position as its landing position

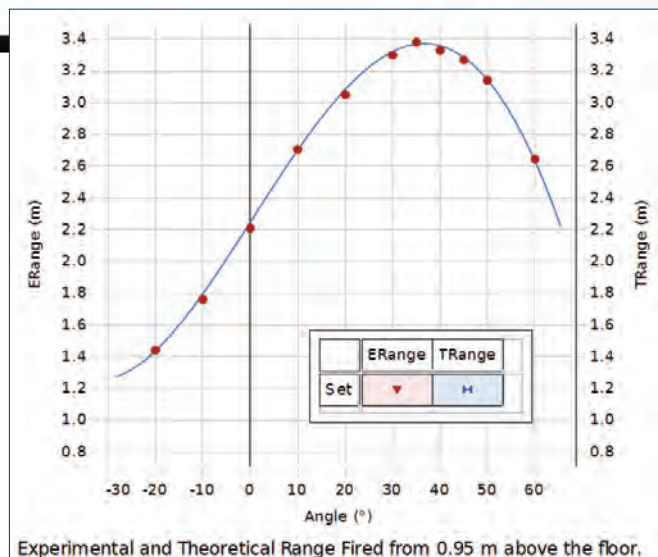
Students are asked to use the kinematics equations to predict the horizontal range, given a launch angle and muzzle velocity. Carbon paper and a bullseye can be used to test their hypothesis.

PASCO Advantage:

PASCO projectile launchers are designed for repeatable and accurate launches. In addition, photogates and other accessories are designed to work seamlessly with our projectile launchers. These features allow student predictions and calculations from the kinematics equations to be empirically verified.

Includes:

- Mini Launcher ME-6825B
- Time-of-Flight Accessory ME-6810A
- Phone Jack Extender Cable PI-8117
- Photogate Head (2) ME-9498A
- Photogate Mounting Bracket ME-6821A
- Carbon Paper (100 Sheets) SE-8693
- Large C Clamp (6 Pack) SE-7285
- Plumb Bobs (10 Pack) SE-8728
- 30 Meter Measuring Tape SE-8712A



Experimental and Theoretical Range Fired from 0.95 m above the floor.

Students can use their data to determine which launch angle produces the maximum horizontal range.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Projectile Motion Experiment.....EX-5502

Required:

550 or 850 Universal Interface*pp. 14-17
 PASCO Capstone Softwarepp. 68-71

* This experiment can be performed using the 850 Universal Interface, the 550 Universal Interface with 2 Digital Adapters, or any PASPORT interface with 2 ports and 2 Digital Adapters.

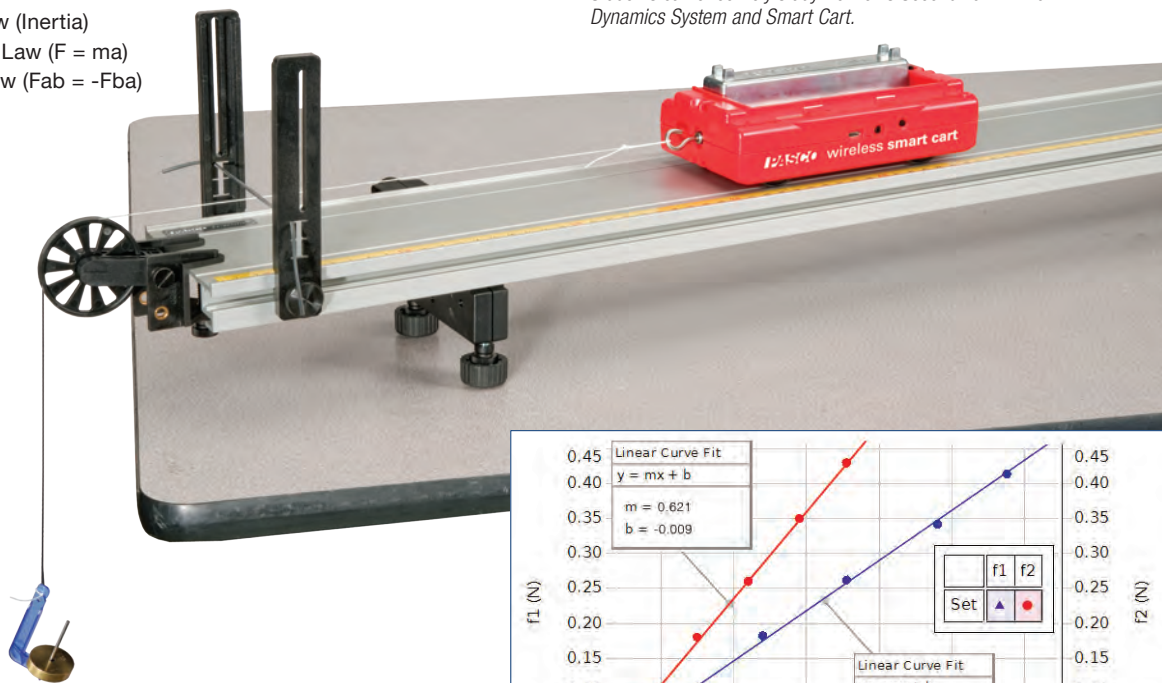
Mechanics

Newton's Laws Experiment

EX-5503B

Concepts:

- ▶ Newton's First Law (Inertia)
- ▶ Newton's Second Law ($F = ma$)
- ▶ Newton's Third Law ($F_{ab} = -F_{ba}$)



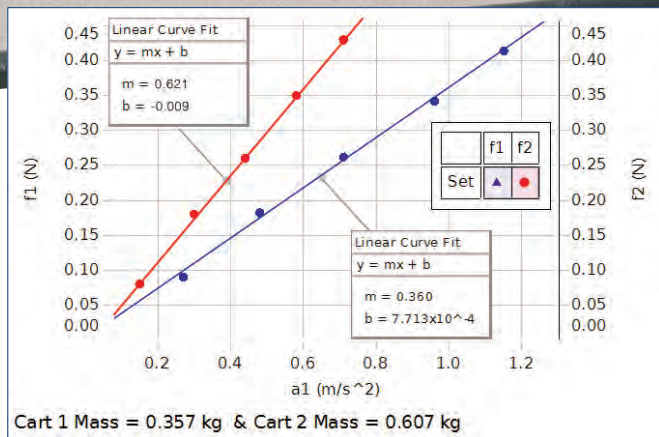
Students can effectively study Newton's Second Law with a Dynamics System and Smart Cart.

Students use this collection of equipment to discover or experimentally determine all three of Newton's Laws.

- **Newton's First Law** – Students examine an object's motion to see if it changes when forces are applied or not.
- **Newton's Second Law** – Students use the Smart Cart to discover the relationships between force, mass, and acceleration.
- **Newton's Third Law** – Using two Smart Cart Force Sensors, students prove that forces between objects are equal in magnitude yet opposite in direction. These experiments include both tug-of-war exercises and collisions between cars.

PASCO Advantage:

The Smart Cart has all the sensors required, which makes setup very quick and easy. The integration between the probeware and equipment helps students focus on the physics of each experiment.



Force vs. acceleration data for the cart as it experiences changing net force

Includes:

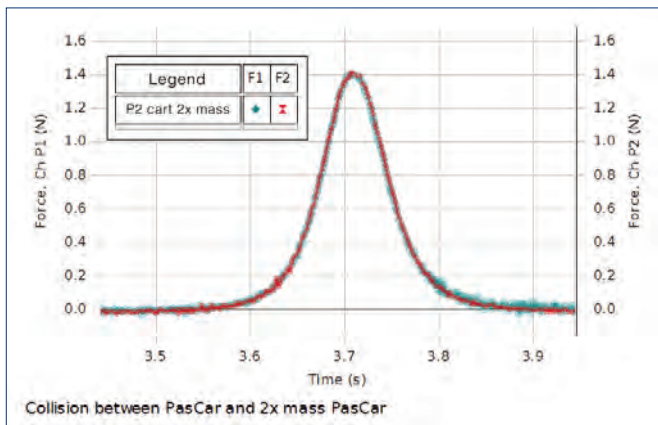
- Smart Cart (Red) ME-1240
- Smart Cart (Blue) ME-1241
- PAScar Cart Mass (set of 2) ME-6757A
- Dynamics Track Feet (Pair) ME-8972
- Mass and Hanger Set ME-8979
- Elastic Bumper ME-8998
- Super Pulley with Clamp ME-9448B
- 1.2 m Aluminum Dynamics Track ME-9493
- Friction Block - IDS ME-9807
- Braided Physics String SE-8050
- Smart Cart Rod Stand Adapter ME-1244

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Newton's Laws Experiment.....EX-5503B
 Required:
 Bluetooth 4.0 enabled computer
 PASCO Capstone Software.....pp. 68-71



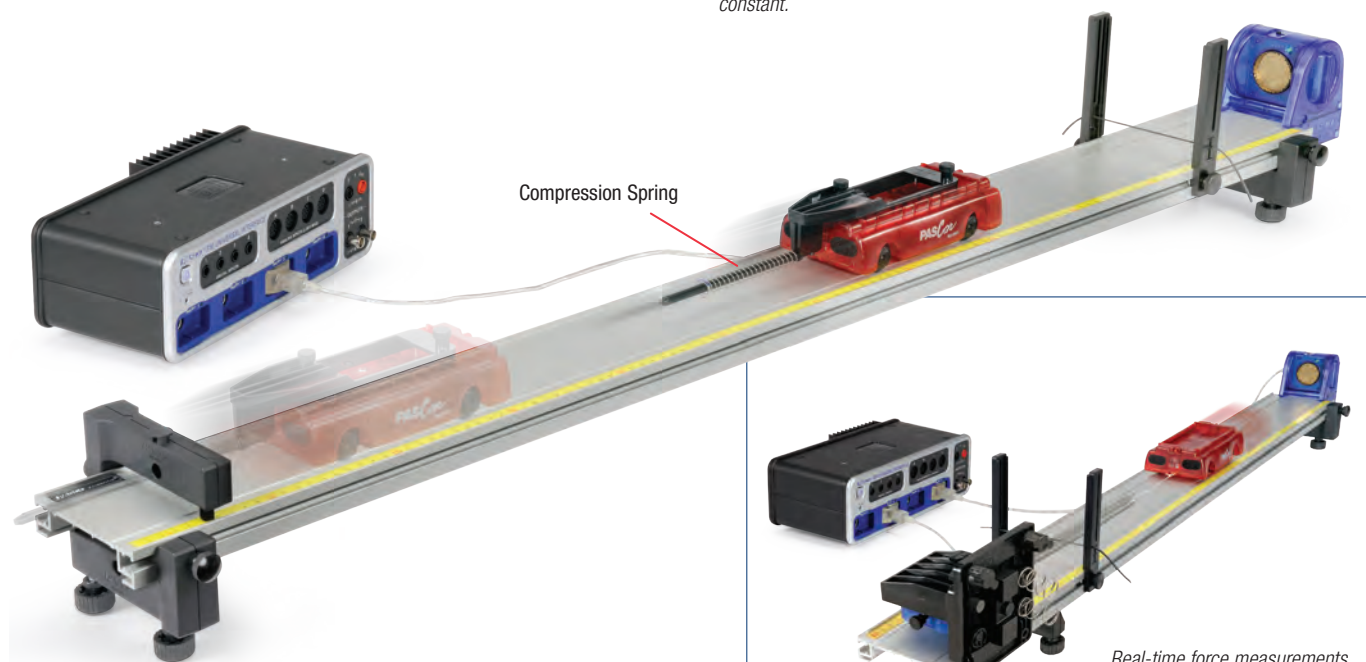
Hooke's Law and Spring Potential Experiment

EX-5504A

Concepts:

- ▶ Relationship between force and spring deformation
- ▶ Investigate both spring compression and extension
- ▶ Amount of energy stored in a spring

In this experiment, students use a High Resolution Force Sensor to measure the force exerted to either compress or extend various springs, and a Motion Sensor to measure position and speed. Students create a Force vs. Stretch (or Compression) graph. The slope of this graph is known as the spring constant, while the vertical intercept is the initial loading force. Various springs of different construction are included, so students can better understand the physical meaning of the spring constant. The spring is then compressed (or stretched) and released. The kinetic energy transferred to a PAScar is measured and compared to the potential energy lost by the spring.

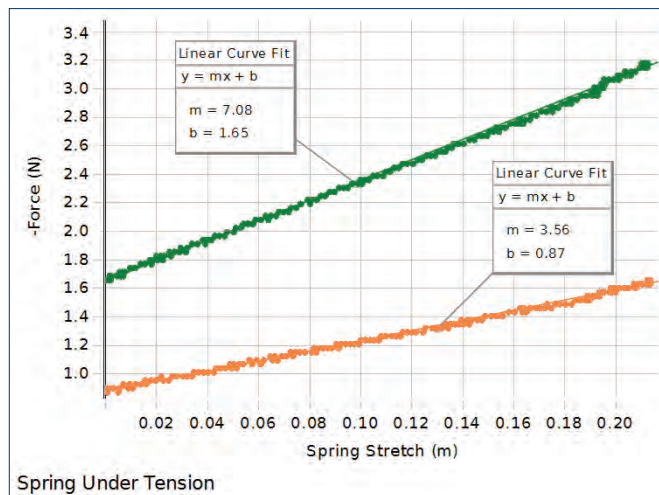


PASCO Advantage:

The High Resolution Force Sensor allows students to take direct measurements of force for each compression or elongation of the spring. This is superior to using a hanging mass to apply a force, since students don't have to convert from mass to force. In addition, students are applying the forces to the springs and will have a better kinesthetic feel for the amount of force being applied in each case. Energy changes are easily measured and very visual.

Includes:

- | | |
|--|----------|
| • PASPORT Motion Sensor | PS-2103A |
| • IDS Spring Kit | ME-8999 |
| • PASPORT High Resolution Force Sensor | PS-2189 |
| • Force Sensor Track Bracket | ME-6622 |
| • Spring Cart Launcher | ME-6843 |
| • Elastic Bumper | ME-8998 |
| • Braided Physics String | SE-8050 |



Spring Under Tension

The slope of the Force vs. Stretch graph is known as the spring constant. Various springs of different construction are included, each having a different spring constant.



Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Hooke's Law and Spring Potential Experiment EX-5504A
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Mechanics

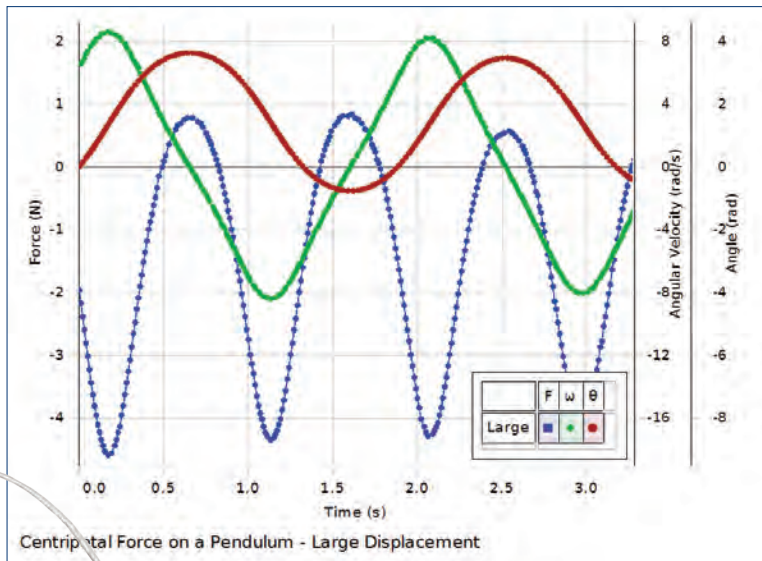
Centripetal Force on a Pendulum Experiment

EX-5505A

Concepts:

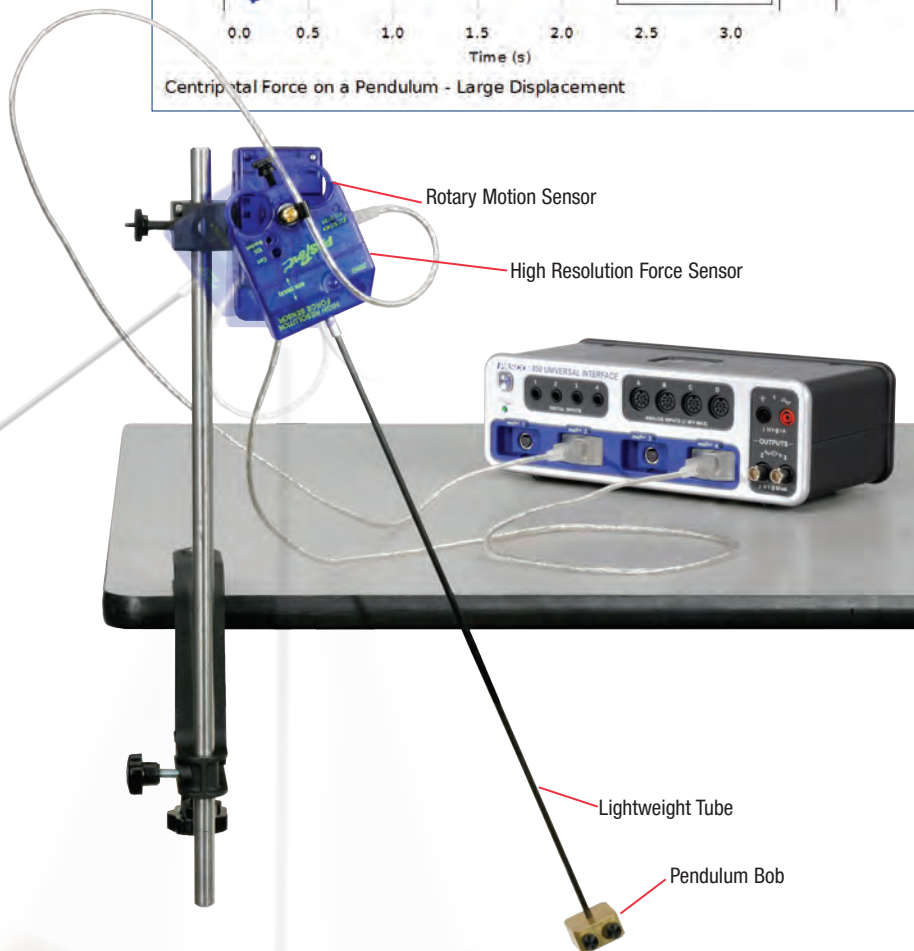
- ▶ Centripetal force
- ▶ Angular velocity
- ▶ Periodic motion

The force, position, and velocity can be monitored for the entire range of motion. Note that the position and velocity are not sinusoidal for this large amplitude pendulum.



Students explore the relationship between mass, radius of rotation, angular velocity, and centripetal force. By continuously measuring the force and angular velocity, students see not just peak values but also how these change during the entire motion of the pendulum. Students explore sources of error and magnitude of error.

Pendulum is pulled back by hand and then released.



Includes:

- PASPORT High Resolution Force Sensor PS-2189
- PASPORT Rotary Motion Sensor PS-2120A
- Centripetal Force Pendulum ME-9821
- Aluminum Table Clamp ME-8995
- 45 cm Stainless Steel Rod ME-8736

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

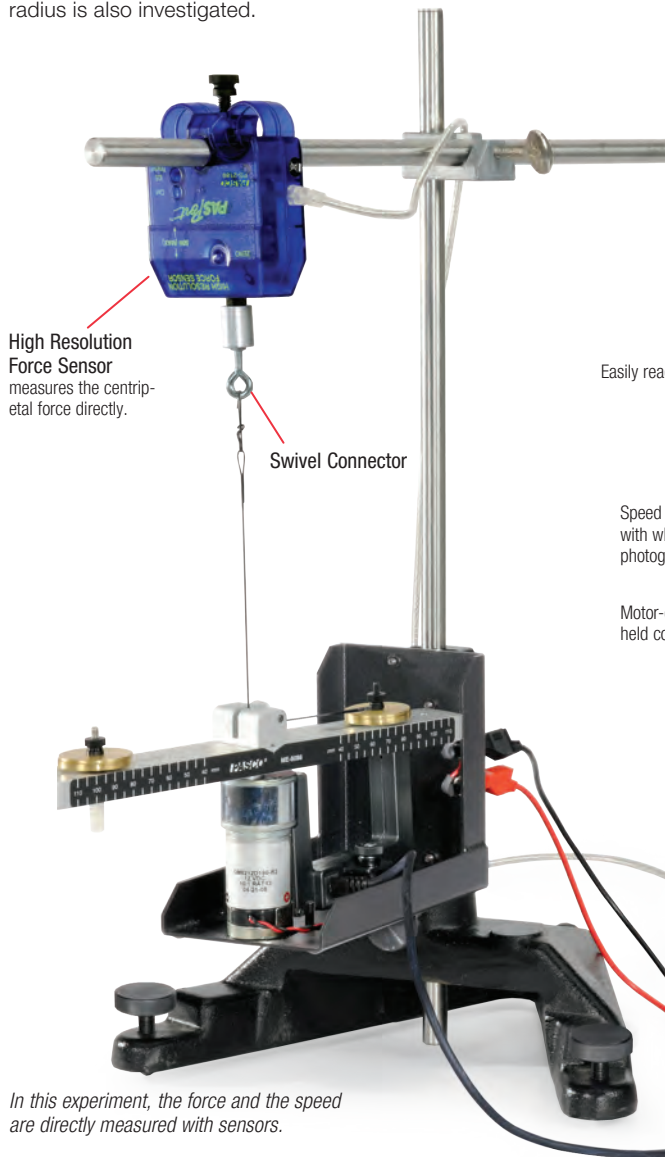
Centripetal Force on a Pendulum Experiment EX-5505A
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 Balance or Scale p. 196
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Centripetal Force Experiment

EX-5506

Concepts:

► How centripetal force depends on radius, mass, and speed
 Students explore the relationship between mass, radius of rotation, tangential speed, and centripetal force. By continuously measuring the force as the speed is varied, students clearly see the effect of speed on the centripetal force. The effect of changing the mass or radius is also investigated.



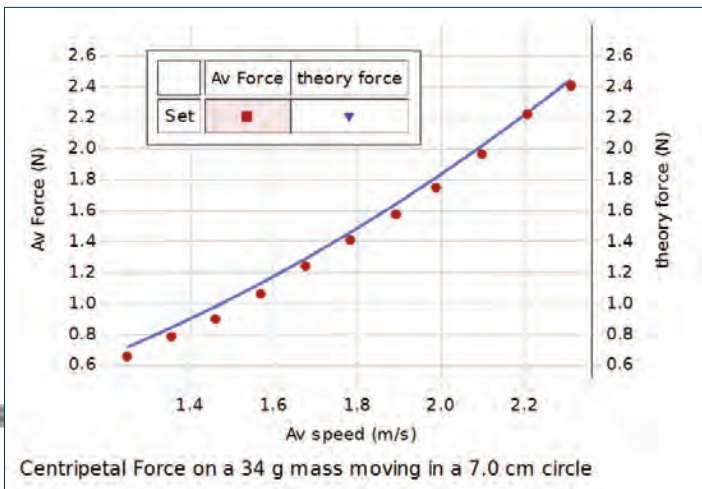
High Resolution Force Sensor measures the centripetal force directly.

Swivel Connector

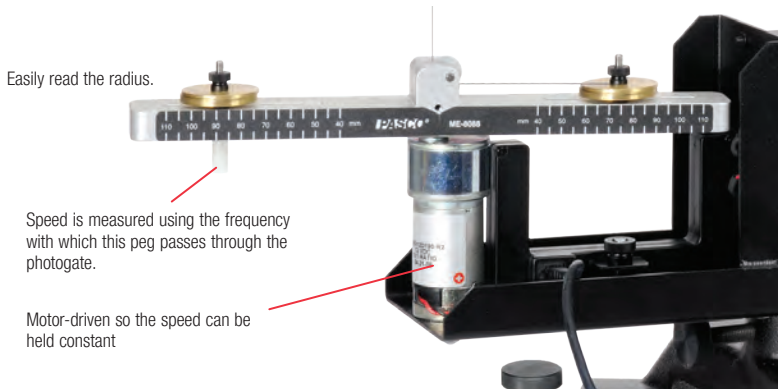
In this experiment, the force and the speed are directly measured with sensors.

Includes:

- Centripetal Force Apparatus ME-8088
- PASPORT High Resolution Force Sensor PS-2189
- Photogate Head ME-9498A
- Large Rod Base ME-8735
- 90 cm Stainless Steel Rod ME-8738
- Multi-Clamp ME-9507
- 45 cm Stainless Steel Rod ME-8736
- Banana Plug Cord-Red (5 Pack) SE-9750



Force vs. Velocity data is shown above with a solid line representing the theoretical frictionless case.



Easily read the radius.

Speed is measured using the frequency with which this peg passes through the photogate.

Motor-driven so the speed can be held constant



Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Centripetal Force Experiment.....	EX-5506
Required:	
550 or 850 Universal Interface*	pp. 14-17
PASCO Capstone Software.....	pp. 68-71

Mechanics

Sliding Friction Experiment

EX-5508

Concepts:

- ▶ Relationship between frictional force and normal force
- ▶ Coefficients of friction (kinetic and static)

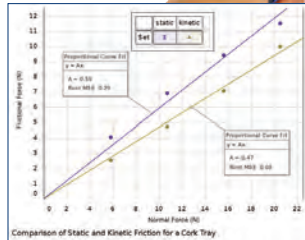
In this experiment, students use a High Resolution Force Sensor to discover frictional forces and their effect on the motion of an object. In addition, the coefficients of friction for various surface combinations can be empirically determined.

Includes:

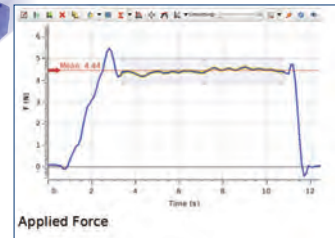
- Discover Friction Accessory ME-8574
- PASPORT High Resolution Force Sensor PS-2189
- PASPORT Motion Sensor PS-2103A
- PAScar Cart Mass (Set of 2) ME-6757A
- Braided Physics String SE-8050



Students pull the friction tray from rest to a constant velocity to measure both static and kinetic friction.



Students create a graph of Frictional Force vs. Normal Force to find the coefficients of static and kinetic friction.



The peak of the graph represents the maximum static frictional force. Once the friction tray begins to move, the kinetic frictional force is evident on the graph.

Order Information

Sliding Friction Experiment EX-5508
 550 or 850 Universal Interface* pp. 28-30
 PASCO Capstone Software pp. 72-75
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Impulse Experiment

EX-5509B

Features:

- ▶ Designed for use with the Smart Cart

Concepts:

- ▶ **Impulse:** Change in momentum
- ▶ **Impulse:** Area under a Force vs. Time curve
- ▶ Different shaped force curves for elastic and inelastic collisions

In this experiment, the impulse on a cart is determined in two ways: by measuring the change in velocity and by finding the area under a Force vs. Time curve.

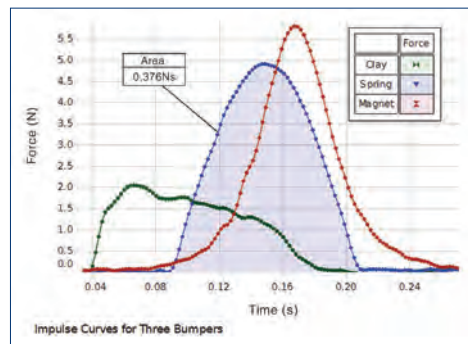
A Smart Cart runs down a slightly inclined track with its Force Sensor equipped with either a clay bumper, spring bumper, or magnetic bumper. The cart collides with the endstop. To determine the change in momentum (impulse), the velocities before and after the collision are recorded using the Smart Cart's encoder. To confirm the impulse, the force vs. time is plotted and the impulse is determined by finding the area under the curve.

PASCO Advantage:

Since the PASCO Smart Cart is capable of measuring both force and velocity, it eliminates the need for any external sensor. No interface is required. No wires interfere with the motion because the Smart Cart transmits the data over Bluetooth 4.0.

Includes:

- Force Sensor Track Bracket ME-6622
- PAScar Cart Mass (Set of 2) ME-6757A
- Smart Cart (Red) ME-1240
- Dynamics Track End Stop (2 Pack) ME-8971
- Dynamics Track Feet (Pair) ME-8972
- 1.2 m Aluminum Dynamics Track ME-9493
- Smart Cart Rod Stand Adapter ME-1244



Force vs. Time is shown for three different bumpers: clay bumper in green, spring bumper in blue, and magnetic bumper in red.



Magnetic, Spring, and Clay Bumpers

The impulse of a collision is determined by two methods.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Impulse Experiment EX-5509B
 Required:
 Bluetooth 4.0 enabled computer
 PASCO Capstone Software pp. 68-71
 Balance or Scale p. 196

Conservation of Momentum Experiment

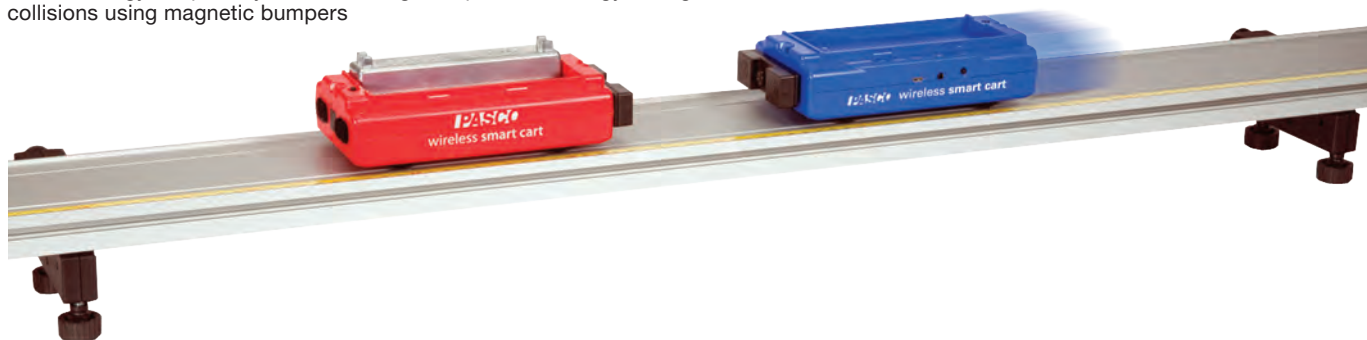
EX-5510C

Concepts:

- ▶ Conservation of momentum in elastic and inelastic collisions
- ▶ Kinetic energy not conserved in inelastic collisions
- ▶ Kinetic energy temporarily stored as magnetic potential energy during elastic collisions using magnetic bumpers

Features:

- ▶ Designed for use with 2 Smart Carts



The total momentum and total energy of carts undergoing elastic and inelastic collisions are measured. The values before and after the collisions are compared to verify that momentum is conserved in all collisions, while energy is only conserved in elastic collisions.

Elastic and inelastic collisions are performed with two dynamics carts of different masses. Magnetic bumpers are used in the elastic collision and Velcro bumpers are used in the completely inelastic collision. In both cases, momentum is conserved.

Cart velocities are recorded using the encoders inside the Smart Carts. A real-time graph of Velocity vs. Time is obtained for each cart, clearly showing when the collision occurred. This enables the student to determine the cart velocities immediately before and after the collision.

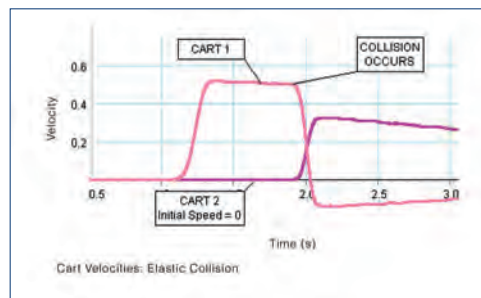
The kinetic energy before and after the collision is also studied. Kinetic energy is not conserved for inelastic collisions. It is also demonstrated that kinetic energy momentarily decreases during the elastic collision and then returns to the original value after the collision.

PASCO Advantage:

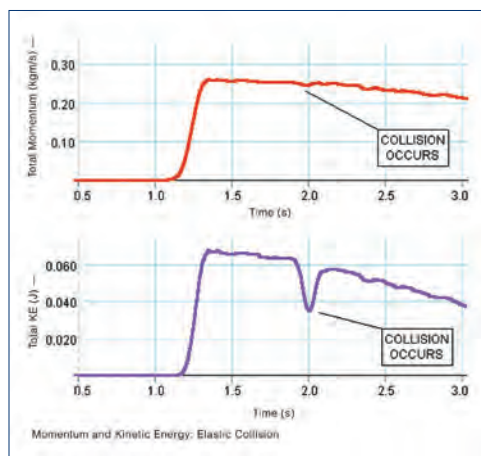
The magnitude and direction of the velocity of each cart is recorded continuously throughout the collision, which eliminates the problem in older methods of positioning photogates too close or too far from the point of collision.

Includes:

- | | |
|------------------------------------|----------|
| • PASCar Cart Mass (set of 2) | ME-6757A |
| • Smart Cart (Red) | ME-1240 |
| • Smart Cart (Blue) | ME-1241 |
| • Dynamics Track End Stop (2 Pack) | ME-8971 |
| • Dynamics Track Feet (Pair) | ME-8972 |
| • 1.2 m Aluminum Dynamics Track | ME-9493 |
| • Smart Cart Rod Stand Adapter | ME-1244 |



A real-time graph of Velocity vs. Time is obtained for each cart, clearly showing when the elastic collision occurred.



The top graph of the total momentum for the 2-cart system (as calculated in PASCO Capstone) shows no change throughout the elastic collision. The total kinetic energy, shown in the bottom graph, momentarily decreases during the collision because energy is stored as magnetic potential energy.

Order Information

Conservation of Momentum Experiment..... EX-5510C

Required:

Bluetooth 4.0 enabled computer

PASCO Capstone Software..... pp. 68-71

Balance or Scale..... p. 196

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Mechanics

Ballistic Pendulum Experiment

EX-5511A

Concepts:

- ▶ Modern approach to a classic experiment
- ▶ View graph of entire pendulum swing
- ▶ Conservation of momentum
- ▶ Conservation of energy

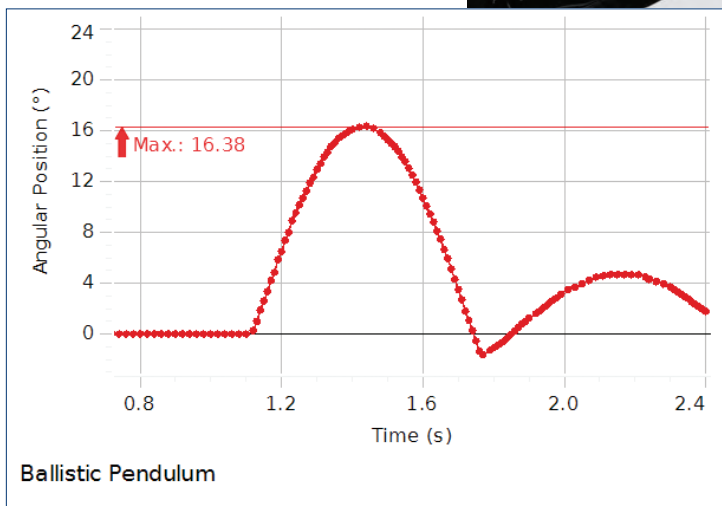
PASCO's Rotary Motion Sensor is the heart of this modern approach to a classic physics experiment. The Mini Launcher (ME-6825B) fires a steel ball into the foam catcher of the Ballistic Pendulum Accessory (ME-6829) mounted on the Rotary Motion Sensor. The Rotary Motion Sensor measures the angular displacement of the pendulum and it is plotted in real-time in PASCO Capstone.

There is no need to catch the pendulum at its maximum height because the angle is continuously measured. Using the analysis tools in PASCO Capstone, students can find the maximum angle.

Using Conservation of Momentum and Conservation of Energy, students can determine the initial speed of the ball as it leaves the projectile launcher. The initial speed of the ball is confirmed by using two photogates to time the flight of the ball for a short distance.



The ball is shot into a foam catcher at the end of a pendulum. The pendulum is mounted on a Rotary Motion Sensor to record the entire swing.



This graph of the angle of the pendulum vs. time is plotted in real-time in PASCO Capstone. The maximum angle is displayed on the graph.

Includes:

- | | |
|-------------------------------------|----------|
| • PASPORT Rotary Motion Sensor | PS-2120A |
| • Mini Launcher | ME-6825B |
| • Photogate Head | ME-9498A |
| • Photogate Mounting Bracket | ME-6821A |
| • Mini Ballistic Pendulum Accessory | ME-6829 |
| • Large C Clamp (6 Pack) | SE-7285 |
| • 45 cm Stainless Steel Rod | ME-8736 |

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Ballistic Pendulum Experiment..... EX-5511A
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or AirLink.

Conservation of Energy Experiment

EX-9935

Concepts:

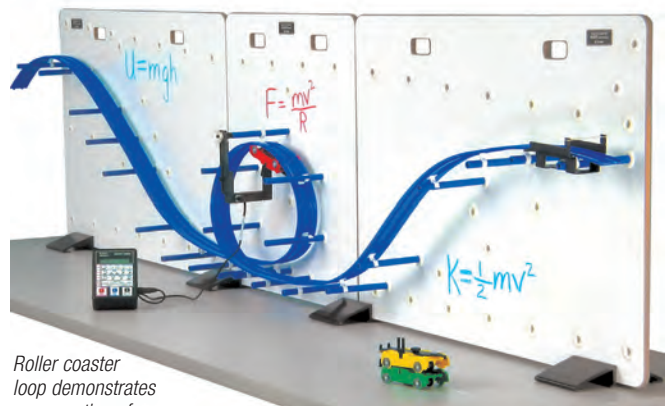
- ▶ Conservation of energy
- ▶ Centripetal acceleration
- ▶ Apparent weight

In this experiment, the Law of Conservation of Energy is verified by measuring the potential and kinetic energies of a car traveling over hills and loops on a curved track.

A car is started from rest on a variety of tracks (hills, valleys, loops, straight track). The speed of the car is measured at various points along the track using a photogate connected to a Smart Timer.

The potential energy is calculated from the measured height and the kinetic energy is calculated from the speed. The total energy is calculated for two points on the track and compared.

The height from which the car must be released from rest to just make it over the loop can be predicted from conservation of energy and the centripetal acceleration. Then the prediction can be tested on the roller coaster. If the car is released from the top of the hill so it easily makes it over the top of the loop, the speed of the car can be measured at the top of the loop and the centripetal acceleration as well as the apparent weight (normal force) on the car can be calculated.



Roller coaster loop demonstrates conservation of energy.

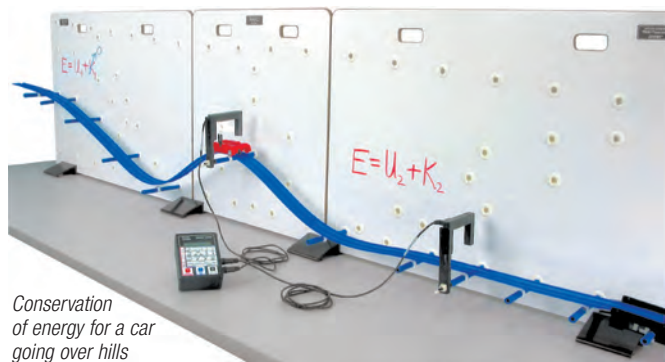
PASCO Advantage:

The Roller Coaster can be configured in many ways. The whiteboard background is convenient for writing calculations or making marks for measuring heights. The PASCO Roller Coaster differs from conventional roller coaster toys in three ways:

- Speed and height of the Roller Coaster car can be easily measured
- Loss of energy due to friction is generally only about 5%
- Cars will withstand repeated drops to the floor

Includes:

- Roller Coaster Complete System ME-9812
- Photogate Head (2) ME-9498A
- Smart Timer ME-8930



Conservation of energy for a car going over hills



Conservation of energy shows that the final speeds of these two cars are the same even though the red car takes much less time than the yellow car to reach the end of the track.



The different speeds of each of three linked cars as they go over the loop are measured using a photogate.

Download This Experiment

Search for EX-9935 at www.pasco.com

Order Information

Conservation of Energy Experiment.....EX-9935

Mechanics

Conservation of Energy II Experiment

EX-5512

Concepts:

- ▶ Potential energy of a falling ball
- ▶ Kinetic energy of a falling ball
- ▶ Use different size balls to change friction

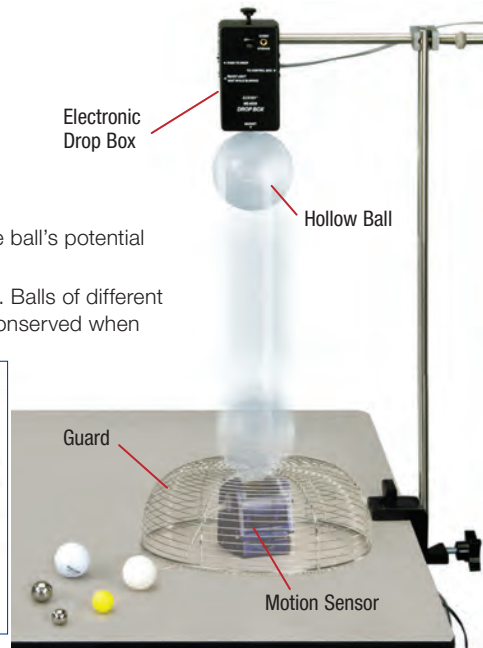
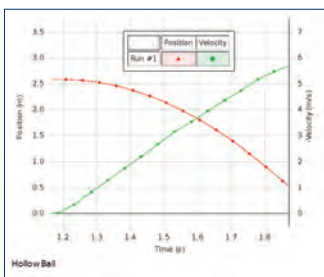
A ball is dropped from rest and its height and speed are recorded using a Motion Sensor. The ball's potential energy and kinetic energy are calculated at various points during the ball's fall.

The total energy of the ball is examined throughout the fall to determine if there is any change. Balls of different sizes are used to vary the amount of air friction, so that students can see that energy is not conserved when friction is appreciable.

Includes:

- PASPORT Motion Sensor PS-2103A
- Discover Freefall System ME-9889
- Large Rod Base ME-8735
- 120 cm Stainless Steel Rod ME-8741
- Multi-Clamp ME-9507
- 45 cm Stainless Steel Rod ME-8736
- Motion Sensor Guard SE-7256

As the ball falls, its height and speed are recorded and displayed in PASCO Capstone software.



Order Information

Conservation of Energy II Experiment.....EX-5512

Required:

550 or 850 Universal Interface*pp. 14-17

PASCO Capstone Software.....pp. 68-71

* This experiment can be performed using the 550 or 850 Universal Interface or AirLink.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Work Energy Theorem Experiment

EX-5513A

Concepts:

- ▶ Kinetic energy
- ▶ Potential energy
- ▶ Work energy theorem
- ▶ Conservation of mechanical energy

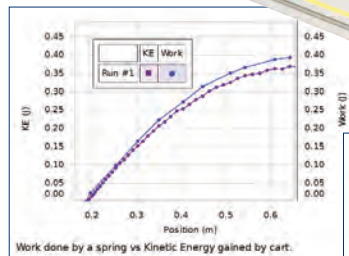
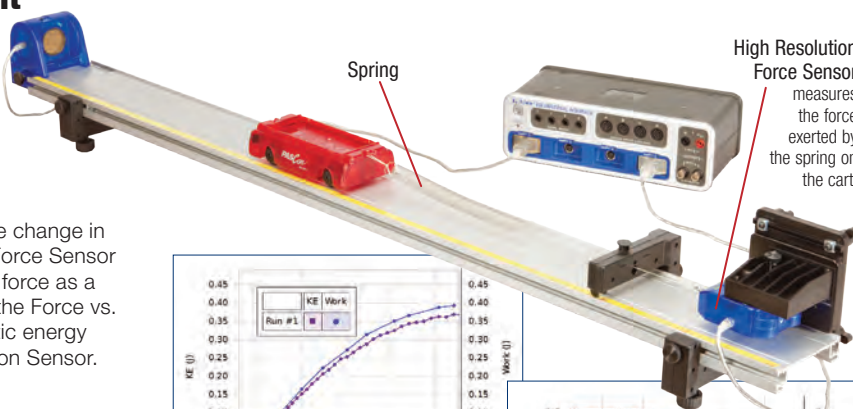
The total work done on an object is compared with the change in kinetic energy of the object. Using a High Resolution Force Sensor and a Motion Sensor, students record and display the force as a function of position. The work done is the area under the Force vs. Position plot. At any point during the experiment, kinetic energy is calculated from the velocity measured with the Motion Sensor. Students explore the meaning of dissipative forces.

PASCO Advantage:

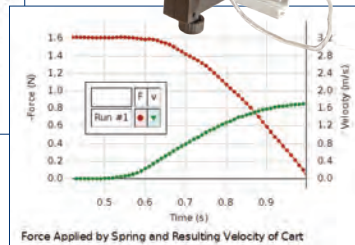
Instead of just focusing on the end points, real-time measurements of force, position, and velocity allow students to continuously examine the work done and the resulting kinetic energy of the cart during its entire trip down the track.

Includes:

- PASPORT High Resolution Force Sensor PS-2189
- PASPORT Motion Sensor PS-2103A
- Force Sensor Track Bracket ME-6622
- IDS Spring Kit ME-8999
- Braided Physics String SE-8050



Work done by a spring vs Kinetic Energy gained by cart.



Force Applied by Spring and Resulting Velocity of Cart

Work done by friction and ignoring the rotational kinetic energy of the wheels cause the cart kinetic energy to be approximately 5% lower.

Order Information

Work Energy Theorem ExperimentEX-5513A

Required:

550 or 850 Universal Interface*pp. 14-17

PASCO Capstone Software.....pp. 68-71

Balance or Scale.....p. 196

* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Universal Gravitational Constant Experiment

EX-5550

Concepts:

- ▶ Measure the Universal Gravitational Constant in less than three hours!
- ▶ Recreate Cavendish's historical experiment
- ▶ Uses PASCO Capstone Video Analysis

The attraction between a pair of small tungsten spheres and a pair of larger tungsten spheres is measured by the torsion of a beryllium ribbon. The large spheres are placed close to the small spheres and allowed to equilibrate. A laser is reflected from a mirror on the beryllium ribbon and shown on a screen or wall. The large spheres are then rotated through an angle to produce torque on the ribbon. The mirror rotates with the ribbon, so the laser reflection on the screen or wall is displaced. The displacement of the laser reflection is measured to find "G".

PASCO Advantage:

For the first time, the measurement of G using the Cavendish Balance can actually be performed in a three-hour lower division physics laboratory! Data collection is done using a webcam to video two periods of the oscillation for both ball positions in less than 45 minutes. The video data may then be transferred to the lab groups for analysis using the video analysis capability of PASCO Capstone. Fitting a damped sine curve to the video data allows an extremely precise determination of period of oscillation and where the final equilibrium positions would be. When analysis of small effects inherent in the method is included, an accuracy of better than 2% is possible.

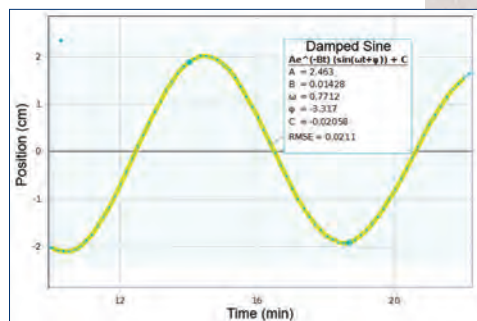
Includes:

- Gravitational Torsion Balance AP-8215A
- X-Y Adjustable Diode Laser OS-8526A
- USB Camera Microscope PS-2343
- Polarizer Set OS-8473

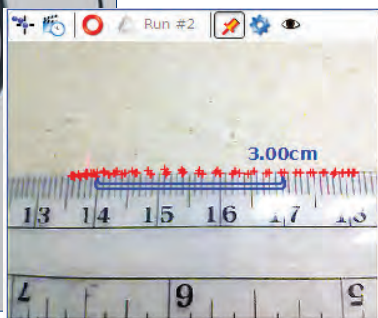
NOTE: No interface is required.



The USB Camera Microscope records the oscillation of the laser beam.



In PASCO Capstone, a damped sine fit is applied to the data to determine the equilibrium point.



This is a screenshot of the video analysis points (red plus signs) in PASCO Capstone.

Download This Experiment

Search for EX-5550 at www.pasco.com

Order Information

Universal Gravitational Constant ExperimentEX-5550
 Required:
 PASCO Capstone Software pp. 68-71
 Transparent Ruler and Meter Stick

Fluids

Piping Systems

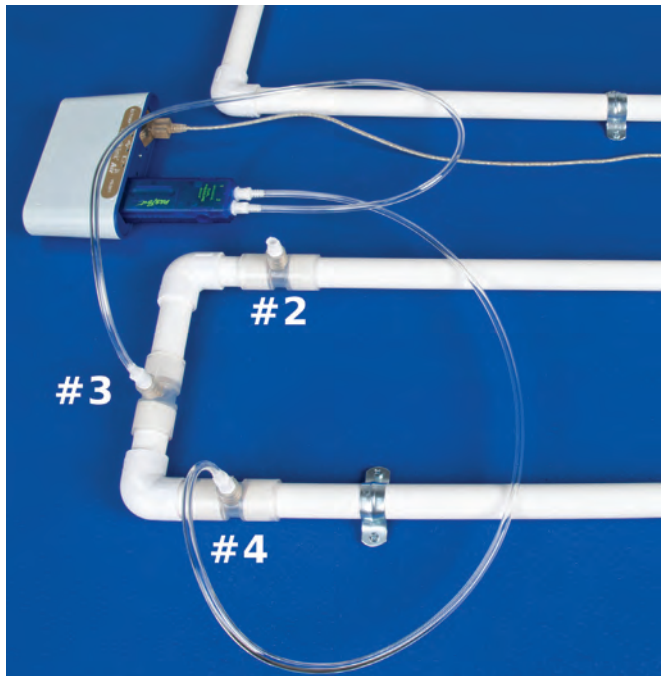
EX-5553

Concepts:

- ▶ Learn how to determine the friction factor
- ▶ Estimate the energy loss of water flowing at various flow rates through PVC pipe
- ▶ Estimate the energy loss of water flowing through an elbow
- ▶ Estimate the energy loss of water flowing through a valve



In this experiment, students determine the major losses due to friction in pipes and the minor losses due to elbows and valves. The loss over a long distance is measured between pressure taps #1 and #5 (shown in the picture above). The water velocity is measured using the Venturi tube attached to the General Flow Sensor.

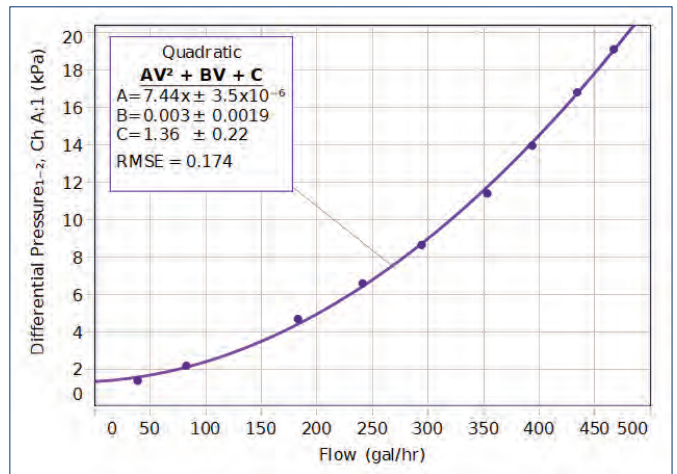


Includes:

- | | |
|--------------------------------|----------|
| • General Flow Sensor | PS-2222 |
| • Venturi Tube | ME-2220 |
| • PASPORT Dual Pressure Sensor | PS-2181 |
| • Pressure Taps (2 sets of 5) | ME-2224A |
| • Water Pump | SE-7727 |

Pipe not included.

PVC pipe and fittings must be purchased separately at a hardware store. Download the construction plans at pasco.com/engineering/pipes



The water velocity is varied to explore the dependence of the losses on velocity (see graph above).

The minor losses due to elbows are found by comparing the pressure at tap #3 and tap #4, as shown at left.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Piping Systems..... EX-5553
 Required:
 Bucket
 Pipe Network (see pasco.com/engineering/pipes for details)
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

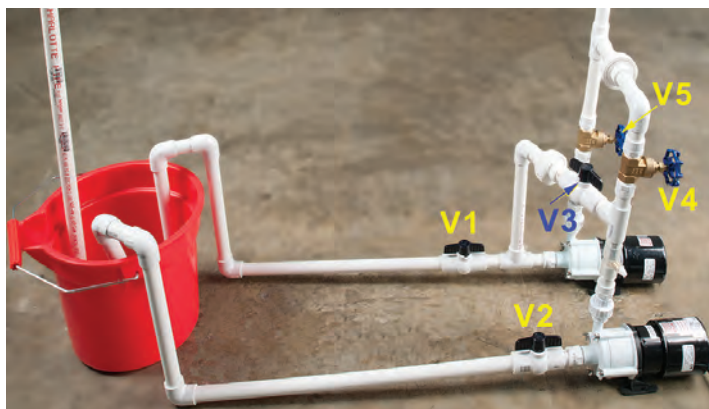
Pumping Systems

EX-5554

Concepts:

- ▶ Find the relationship between pump head and flow rate
- ▶ Creating pump performance curves:
 - Single pump
 - Pumps in parallel
 - Pumps in series

In this experiment, students determine the characteristic curves for two pumps and examine the impact of placing pumps in series and in parallel.



Two pumps are operated separately and then together in series and parallel.



The pressure is measured just above the pump as the water velocity is varied.



For this experiment, the water is pumped through the short section of pipe through valves #6 and #8. The water velocity is measured using the Venturi Tube attached to the General Flow Sensor. The pressure at the pump is measured for different velocities and a pump curve is created (at right). The maximum head is recorded. Then two pumps are operated at the same time. The effects of pumps in series and in parallel are explored.

Includes:

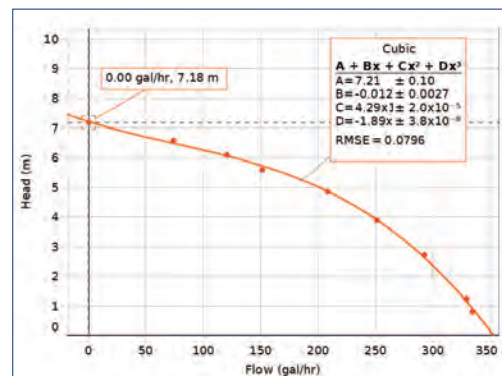
- | | |
|--------------------------------|----------|
| • General Flow Sensor | PS-2222 |
| • Venturi Tube | ME-2220 |
| • PASPORT Dual Pressure Sensor | PS-2181 |
| • Pressure Taps (2 sets of 5) | ME-2224A |
| • Water Pumps (2) | SE-7727 |

Pipe not included.

PVC pipe and fittings must be purchased separately at a hardware store. Download the construction plans at pasco.com/engineering/pipes

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.



Order Information

Pumping Systems.....	EX-5554
Required:	
Bucket	
Pipe Network (see pasco.com/engineering/pipes for details)	
SPARKlink Air Interface	PS-2011
PASCO Capstone Software.....	pp. 68-71

Fluids

Archimedes' Principle Experiment

EX-9909

Concepts:

- ▶ Archimedes' Principle
- ▶ Density
- ▶ Buoyant force

Archimedes' Principle states that the buoyant force on a submerged object is equal to the weight of the fluid that is displaced by the object.

The buoyant force on several objects is measured by weighing the water displaced by a submerged object. The buoyant force is also determined by measuring the difference between the object's weight in air and its apparent weight in water.

Some of the objects have the same density, some have the same volume, and some have the same mass. The density of each object is measured and the dependence of the buoyant force on density, mass, and volume is explored.

PASCO Advantage:

The provided objects have related volumes, masses, and densities to demonstrate that only the volume of water displaced affects the buoyant force.



The buoyant force is measured by weighing the water displaced by the object.



The mass and volume are measured to determine the dependence of the buoyant force on mass, volume, and density.

Includes:

- Density Set ME-8569A
- Overflow Can SE-8568
- Large Rod Base ME-8735
- 45 cm Stainless Steel Rod ME-8736
- Braided Physics String SE-8050
- Ohaus Triple-Beam Balance (with Tare) SE-8707
- Stainless Steel Calipers SF-8711
- 1000 ml Beaker
- 100 ml Beaker
- 50 ml Graduated Cylinder
- Archimedes' Principle Experiment Manual

Download This Experiment

Search for EX-9909 at www.pasco.com

Order Information

Archimedes' Principle Experiment.....EX-9909
(No interface required.)

Rotational Inertia Experiment

EX-5516B

Concepts:

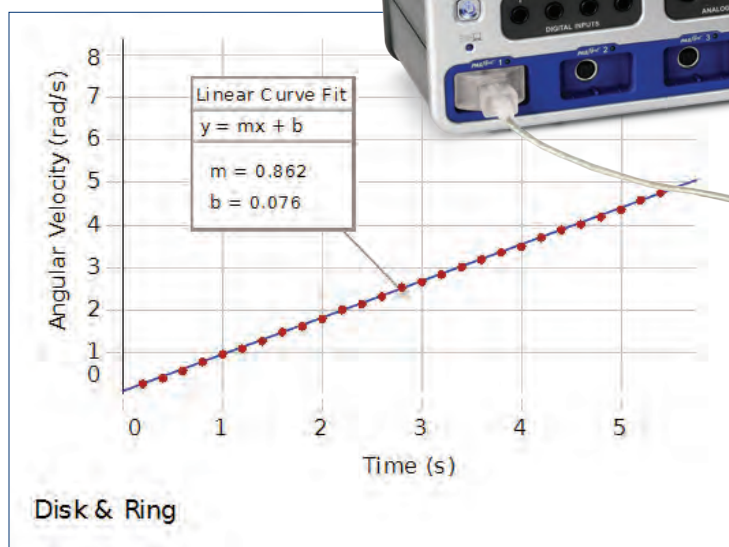
- ▶ Rotational inertia of a ring and a disk
- ▶ Torque

In this experiment, the rotational inertias of a ring and a disk are determined by applying a torque to the object and measuring the resulting angular acceleration.

A known torque is applied to the pulley on the Rotary Motion Sensor, causing a disk and ring to rotate. The resulting angular acceleration is measured using the slope of a graph of Angular Velocity vs. Time. The rotational inertia of the disk and ring combination is calculated from the torque and the angular acceleration. The procedure is repeated for the disk alone to find the rotational inertias of the ring and disk separately.



The Rotary Motion Sensor provides a sturdy, low-friction rotational platform for the Ring and Disk, in addition to measuring the resulting angular acceleration.



The rotational inertia of the ring and disk is calculated from the angular acceleration obtained from the slope of this Angular Velocity vs. Time graph.

A known torque is applied to the ring and disk by the weight hanging over the pulley. The rotational inertia of the ring and disk are determined from the resulting angular acceleration. The procedure is repeated for the disk alone.

PASCO Advantage:

Friction can be neglected in this compact setup. The Rotary Motion Sensor is a versatile tool that can be used in a variety of other experiments.

Includes:

- Large Rod Base ME-8735
- 90 cm Stainless Steel Rod ME-8738
- Mini Rotational Accessory CI-6691
- Mass and Hanger Set ME-8979
- PASPORT Rotary Motion Sensor PS-2120A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Rotational Inertia Experiment EX-5516B
 Required:
 550 or 850 Universal Interface*pp. 14-17
 PASCO Capstone Softwarepp. 68-71
 Balance or Scalep. 196
 Digital Calipers SE-8710 p. 192
 * This experiment can be performed using the 550 or 850 Universal Interface or AirLink.

Rotation

Physical Pendulum Experiment

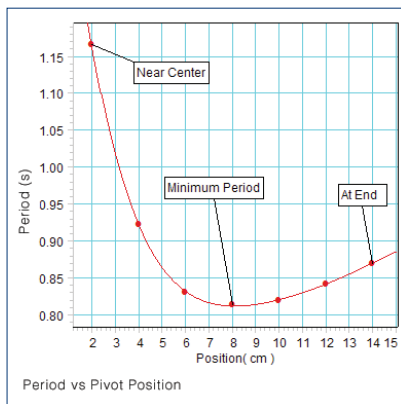
EX-5518A

Concepts:

- ▶ Parallel Axis Theorem
- ▶ Period of a physical pendulum
- ▶ Computer modeling of a system
- ▶ Rotational inertia

In this experiment, the period of a physical pendulum, a narrow bar, is determined as a function of the distance of the pivot from the center of mass. A computer model of the system is developed, which allows the student to vary the physical parameters of the model (gravity, length, c.m. position) to match the data. This makes it possible to obtain values for the physical parameters without direct measurement.

A second experiment verifies the parallel axis theorem. It also uses superposition to find the rotational inertia of a disk with an off axis circular hole.



The Pendulum Bar has holes spaced at 2 cm intervals. A graph of Oscillation Period vs. Pivot Hole Position shows that there is a unique placement that gives a minimum period. This location can be verified using calculus.



Apply a known torque and measure the angular acceleration to calculate the moment of inertia of the object. Multiple holes in the plate allow investigation of the Parallel Axis Theorem.

Center hole is at center of mass.



Unique design allows pivot exactly at the edge. Measure the period of the thick ring oscillating at either the inner or outer radius.



Includes:

- Large Rod Base ME-8735
- 45 cm Stainless Steel Rod ME-8736
- Physical Pendulum Set ME-9833
- PASPORT Rotary Motion Sensor PS-2120A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Physical Pendulum Experiment EX-5518A
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or AirLink.

Large Amplitude Pendulum Experiment

EX-5520A

Concepts:

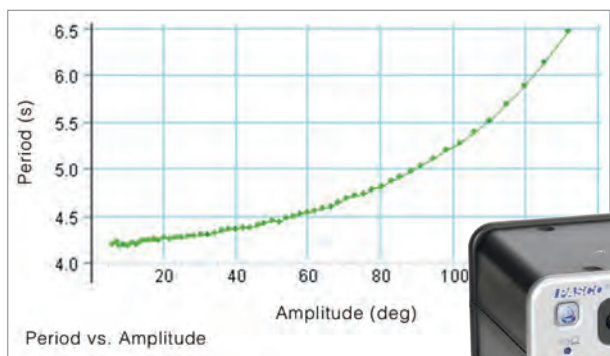
- ▶ Low amplitude approximation for the pendulum period
- ▶ Large amplitude period
- ▶ Shape of displacement, velocity, and acceleration curves for large amplitude

This experiment explores the dependence of the period of a simple pendulum on the amplitude of the oscillation. Also, the displacement, velocity, and acceleration for large amplitude are plotted versus time to show the difference from the sinusoidal motion of low amplitude oscillations.

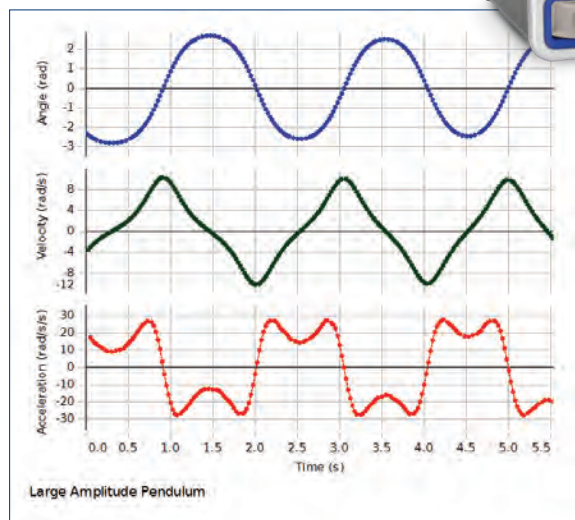
A rigid pendulum consists of a 35 cm long lightweight (28 g) aluminum tube with a 75 g mass on each end. The center of the tube is mounted on a Rotary Motion Sensor. One of the masses is slightly closer to the center than the other mass, so the pendulum will oscillate slowly. Students will have time to view the motion of the pendulum, while also watching the real-time graph of displacement, velocity, and acceleration versus time.

The period is measured as a function of the amplitude of the pendulum and compared to theory.

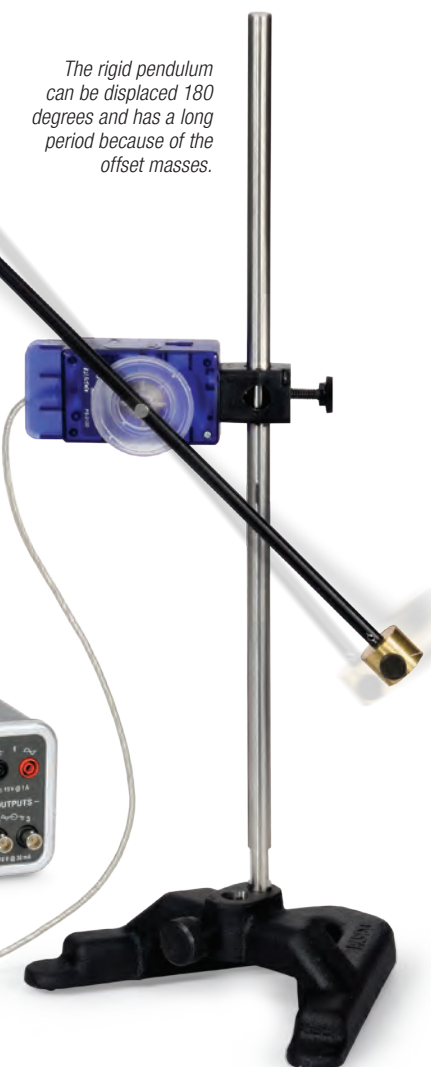
The rigid pendulum can be displaced 180 degrees and has a long period because of the offset masses.



The pendulum period is plotted versus amplitude.



Graphs of angular displacement, velocity, and acceleration vs. time are displayed for a pendulum oscillating with large amplitude.



PASCO Advantage

PASCO Capstone™ has a period function that can be plotted versus the amplitude in real-time as the pendulum's oscillation damps out. The pendulum is initially displaced almost 180 degrees and then, as the amplitude decreases because of friction, the period is automatically recorded as a function of amplitude.

Includes:

- Small "A" Base ME-8976
- Stainless Steel Rod, 25 cm Threaded ME-8988
- Pendulum Accessory ME-8969
- PASPORT Rotary Motion Sensor PS-2120A

Order Information

Large Amplitude Pendulum Experiment..... EX-5520A

Required:

550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71

* This experiment can be performed using the 550 or 850 Universal Interface or AirLink.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Oscillation

Variable-g Pendulum Experiment

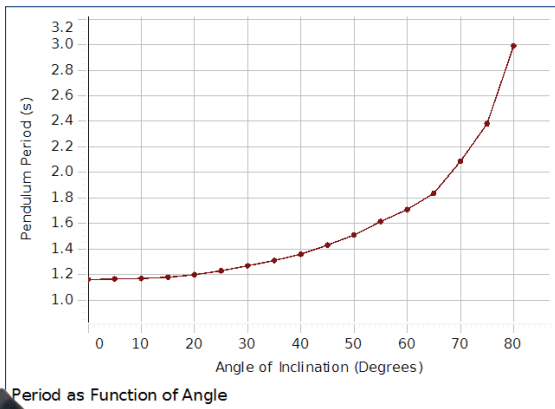
EX-5519A

Concepts:

- ▶ Period of a simple pendulum
- ▶ Effect of decreasing “g” on the pendulum period
- ▶ Large amplitude period
- ▶ Shape of displacement, velocity, and acceleration curves for large amplitude

This experiment explores the dependence of the period of a simple pendulum on the acceleration due to gravity and on the length and amplitude of the pendulum.

A simple rigid pendulum consists of a 35 cm long lightweight aluminum tube with masses at the end, mounted on a Rotary Motion Sensor. The pendulum is constrained to oscillate in a plane tilted at an angle from the vertical. This effectively reduces the acceleration due to gravity because the restoring force is decreased.



The period of the Variable-g Pendulum is plotted as a function of the angle of inclination to show the dependence of the period on g.



The period is measured for varying angles, simulating changing the acceleration due to gravity for the pendulum.

The Adjustable Angle Clamp makes it easy to adjust the angle from zero to 90 degrees, thus varying “g” from 9.8 m/s² to zero.

PASCO Advantage:

The rigid pendulum can be assumed to be a simple pendulum: the actual period is approximately 99% of the period of a simple pendulum of the same length.

Includes:

- Large Rod Base ME-8735
- 45 cm Stainless Steel Rod ME-8736
- Angle Indicator ME-9495A
- Adjustable Angle Clamp ME-8744
- Pendulum Accessory ME-8969
- PASPORT Rotary Motion Sensor PS-2120A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Variable-g Pendulum Experiment EX-5519A
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface.

Torsional Pendulum

EX-5521B

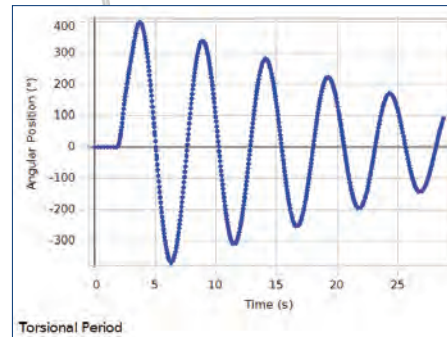
Concepts:

- ▶ Period of a torsional pendulum
- ▶ Rotational inertias of a disk, ring, and point masses
- ▶ Torque
- ▶ Torsional spring constant

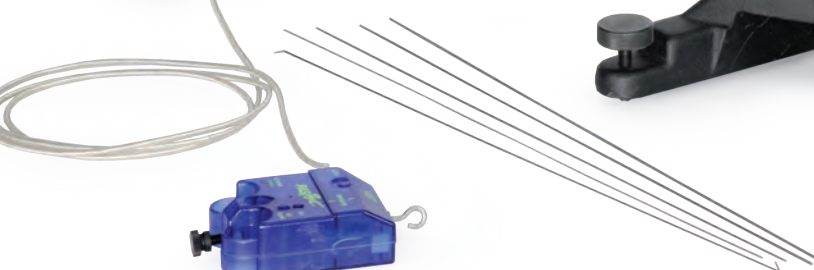
The period of a Torsional Pendulum is measured and compared to the theoretical value. The torsional pendulum consists of a torsion wire attached to a Rotary Motion Sensor with an object (a disk, ring, or rod with point masses) mounted on top of it. The period of oscillation is measured from a plot of the angular displacement versus time. To calculate theoretical period, the rotational inertia is determined by measuring the dimensions of the object. The torsional spring constant is determined from the slope of a plot of force versus angular displacement.



The torsional pendulum uses a Rotary Motion Sensor to record the oscillations.

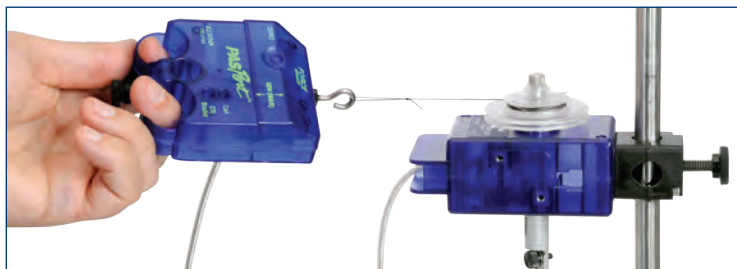
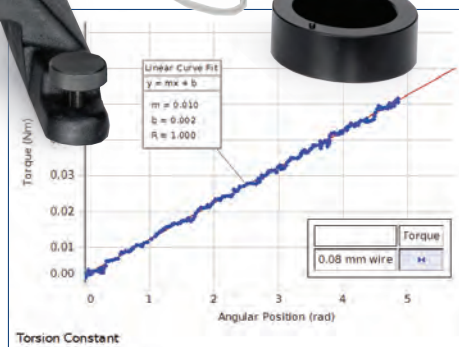


The period of the torsional pendulum is determined from a plot of angular displacement versus time.



To determine the torsional spring constant, a torque is applied by pulling with a Force Sensor.

The torsional spring constant is determined from a plot of torque versus angular displacement.



PASCO Advantage

To determine the torsional spring constant, the force versus angular displacement graph is quickly and easily obtained by pulling with a Force Sensor on a string wrapped around the Rotary Motion Sensor pulley.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Includes

- Rotational Inertia Accessory ME-3420
- Torsion Pendulum Accessory ME-6694
- Large Rod Base ME-8735
- 60 cm Long Stainless Steel Rod ME-8977
- PASPORT Rotary Motion Sensor PS-2120A
- PASPORT High-Resolution Force Sensor PS-2189

Order Information

Torsional Pendulum EX-5521B
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Rotation

Conservation of Angular Momentum Experiment

EX-5517C

Concepts:

- ▶ Conservation of angular momentum during collisions
- ▶ Easy determination of before and after points
- ▶ Calculation of energy lost during collision

The study of conservation of angular momentum during collisions is easy and fast using this system based on the Rotary Motion Sensor. The angular velocity of the spinning disk is graphed in real time as a non-rotating ring is dropped onto it.

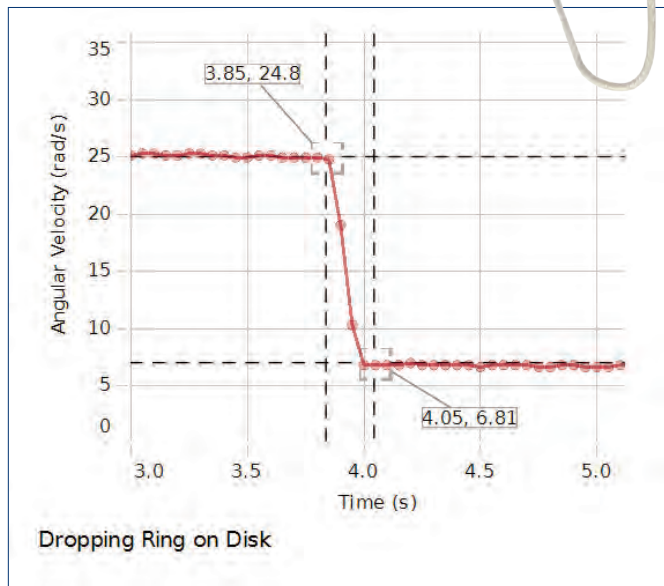
PASCO Advantage:

It is easy to measure the rotational speeds just before and after the collision since the entire collision is visible in the graph.

The rotational inertias of the ring and disk are calculated using the mass and dimensions of each. Then the total angular momentum before the collision is compared to the total angular momentum after the collision to show that it does not change.

The total kinetic energy before and after the collision is calculated to show the amount of energy lost during the inelastic collision.

As a non-rotating ring is dropped onto a rotating disk, the angular velocity decreases to about 1/6th of its initial value since the ring has a large rotational inertia compared to the disk.



The Rotary Motion Sensor provides a sturdy, low-friction rotational platform for the Ring and Disk, in addition to measuring the resulting change in angular velocity.

Includes:

- PASPORT Rotary Motion Sensor PS-2120A
- Mini Rotational Accessory CI-6691
- Stainless Steel Calipers SF-8711
- Large Rod Base ME-8735
- 45 cm Stainless Steel Rod ME-8736

Order Information

Conservation of Angular Momentum Experiment..... EX-5517C
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or AirLink.

Download This Experiment

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Chaos Experiment

EX-5523A

Concepts:

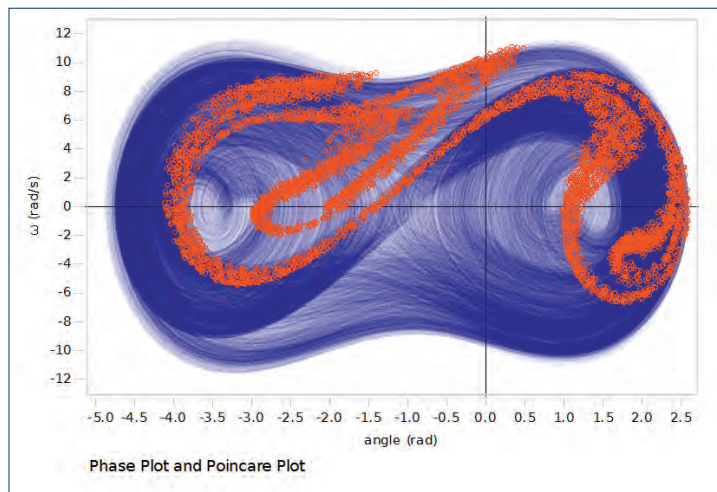
- ▶ Nonlinear oscillator
- ▶ Chaotic motion
- ▶ Phase space
- ▶ Poincare plot

The chaotic behavior of a driven nonlinear pendulum is explored by graphing its motion in phase space and by making a Poincare plot. These plots are compared to the motion of the pendulum when it is not chaotic. The oscillator consists of an aluminum disk connected to two springs. A point mass on the edge of the aluminum disk makes the oscillator nonlinear. The frequency of the sinusoidal driver can be varied to investigate the progression from predictable motion to chaotic motion. Magnetic damping can be adjusted to change the character of the chaotic motion. The angular position and velocity of the disk are recorded as a function of time using a Rotary Motion Sensor. A real-time phase plot is made by graphing the angular velocity vs. the displacement angle of the oscillation.

The Poincare plot is also graphed in real time and superimposed on the phase plot. This is achieved by recording the point on the phase plot once every cycle of the driver arm as the driver arm blocks a photogate.

PASCO Advantage:

PASCO Capstone can graph the motion in phase space and superimpose the Poincare plot in real time, showing students how the motion in phase space relates to the actual motion of the oscillator.

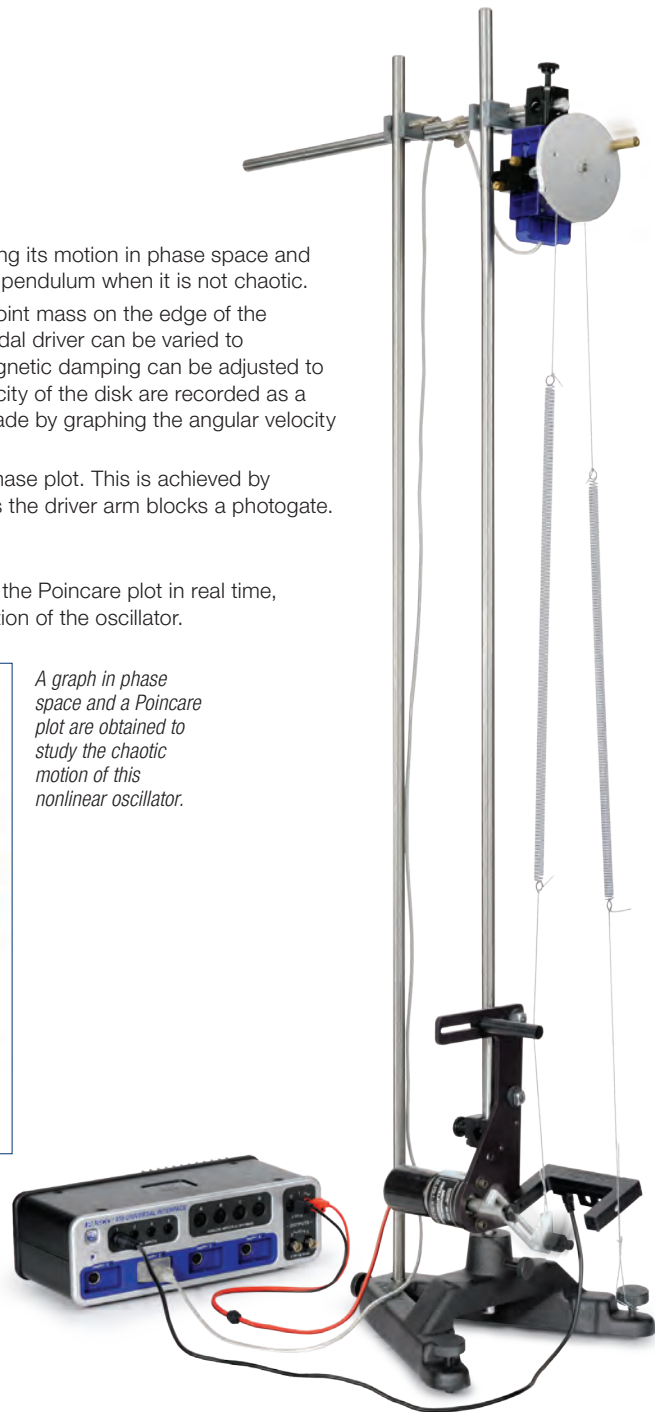


A graph in phase space and a Poincare plot are obtained to study the chaotic motion of this nonlinear oscillator.

The Poincare plot (in orange) shows the pendulum's velocity vs. position once per revolution of the driver. The purple background is the phase plot. This phase plot (angular velocity vs. angle) is graphed in PASCO Capstone using partial opacity, so the trace gets darker as it traces back over itself.

Includes:

- Large Rod Base ME-8735
- 120 cm Stainless Steel Rod ME-8741
- 45 cm Stainless Steel Rod ME-8736
- Multi-Clamps (2) ME-9507
- Chaos/Driven Harmonic Accessory CI-6689A
- Mechanical Oscillator/Driver ME-8750
- PASPORT Rotary Motion Sensor PS-2120A
- Photogate Head ME-9498A



Order Information

Chaos Experiment.....	EX-5523A
Required:	
550 or 850 Universal Interface.....	pp. 14-17
PASCO Capstone Software.....	pp. 68-71

Download This Experiment

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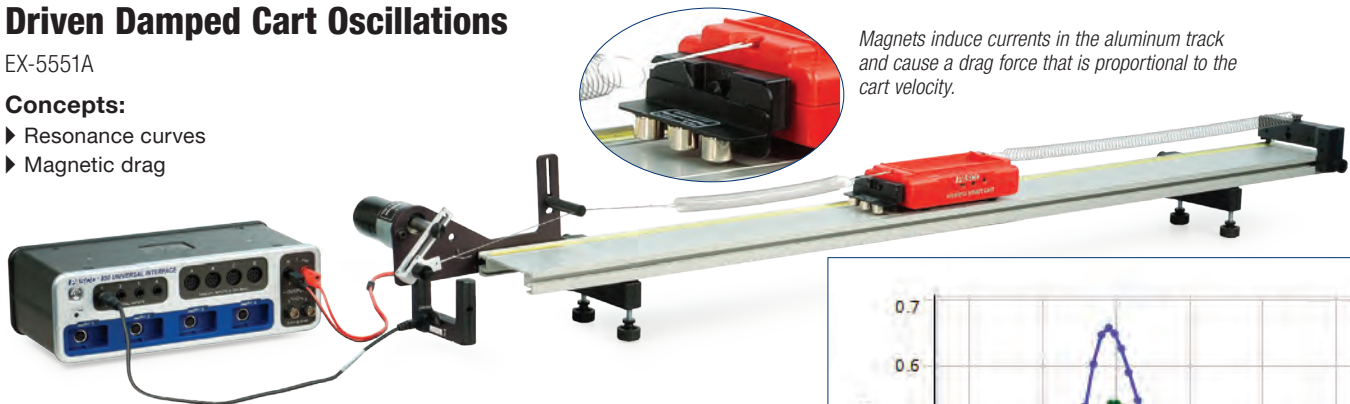
Rotation

Driven Damped Cart Oscillations

EX-5551A

Concepts:

- ▶ Resonance curves
- ▶ Magnetic drag



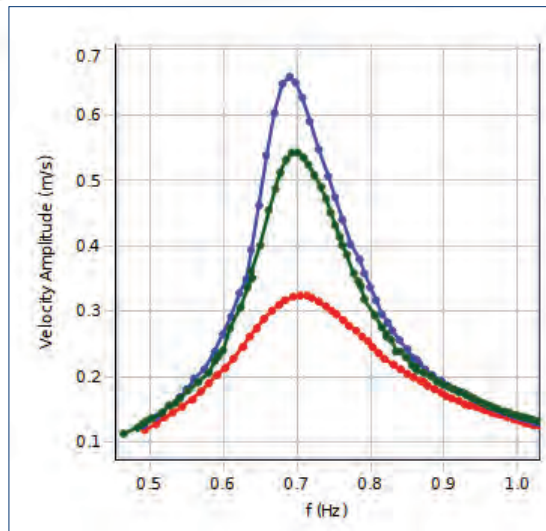
Magnets induce currents in the aluminum track and cause a drag force that is proportional to the cart velocity.

The oscillator consists of a Smart Cart attached to two springs. The damping is provided by magnets mounted on the Smart Cart that cause eddy currents in the aluminum track. The amplitude of the oscillation is plotted vs. the driving frequency for different amounts of magnetic damping. Increased damping is provided by moving adjustable magnets closer to the aluminum track.

$$\frac{d^2x}{dt^2} + \left(\frac{b}{m}\right) \frac{dx}{dt} + \left(\frac{k}{m}\right) x = F_0 \cos(\omega t)$$

$$x = \frac{F_0/m}{\sqrt{(\omega^2 - \omega_0^2)^2 + (b/m)^2 \omega^2}} \cos(\omega t - \phi)$$

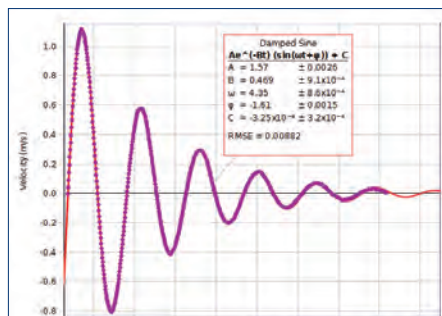
$$\omega = \sqrt{\frac{k}{m} - \frac{b^2}{4m^2}}$$



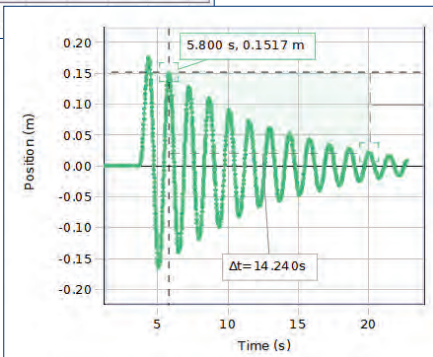
The amplitude of the cart's velocity is plotted vs. the driving frequency. The amount of drag is varied by changing the distance between the magnets and the track.

PASCO Advantage:

The Smart Cart wirelessly measures the position and velocity of the cart as well as the magnetic drag, since the magnetic drag bumper is attached to the Smart Cart's force sensor.



In PASCO Capstone, a damped sine wave curve fit is applied to the data to determine the spring constant, period, and damping coefficient.



The period can be directly measured to determine the resonant frequency.

Includes:

- Smart Cart (Red) ME-1240
- Mechanical Oscillator/Driver ME-8750
- Dynamics Cart Magnetic Damping ME-6828
- IDS Spring Kit ME-8999
- Photogate Head ME-9498A
- PAScar Cart Mass (Set of 2) ME-6757A
- 1.2 m Aluminum Dynamics Track ME-9493
- Dynamics Track End Stop (2 Pack) ME-8971
- Dynamics Track Feet (Pair) ME-8972
- Braided Physics String SE-8050
- Smart Cart Rod Stand Adapter ME-1244

Download This Experiment

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Order Information

Driven Damped Cart Oscillations.....	EX-5551A
Required:	
Ohaus Triple-Beam Balance (with Tare).....	SE-8707
850 Universal Interface.....	UI-5000 pp. 14-15
PASCO Capstone Software.....	pp. 68-71

Driven Damped Harmonic Oscillations Experiment

EX-5522A

Concepts:

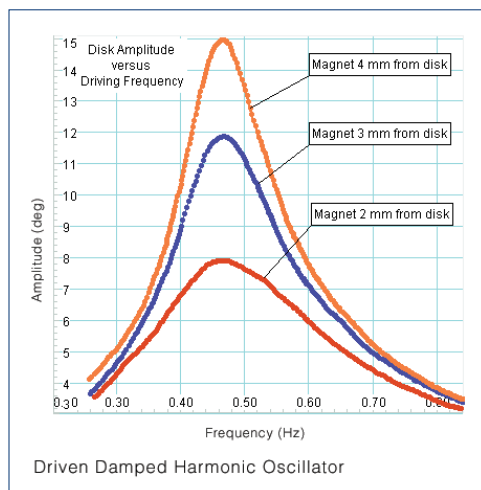
- ▶ Resonance curves for an oscillator: amplitude vs. frequency
- ▶ Resonant frequency
- ▶ Period of a pendulum
- ▶ Effect of magnetic damping on shape of resonance curve
- ▶ Phase difference between oscillator and driver at low, resonant, and high frequencies

In this experiment, the resonance of a driven damped harmonic oscillator is examined by plotting the oscillation amplitude vs. frequency for various amounts of damping.

The oscillator consists of an aluminum disk with a pulley connected to two springs by a string. The angular positions and velocities of the disk and the driver are recorded as a function of time using two Rotary Motion Sensors. The amplitude of the oscillation is plotted vs. the driving frequency for different amounts of magnetic damping. Increased damping is provided by moving an adjustable magnet closer to the aluminum disk.

PASCO Advantage:

The combination of PASCO Capstone software and the 850 Universal Interface has the power to sweep through the driver frequencies and the capability to plot the amplitude vs. the driver frequency in real time.



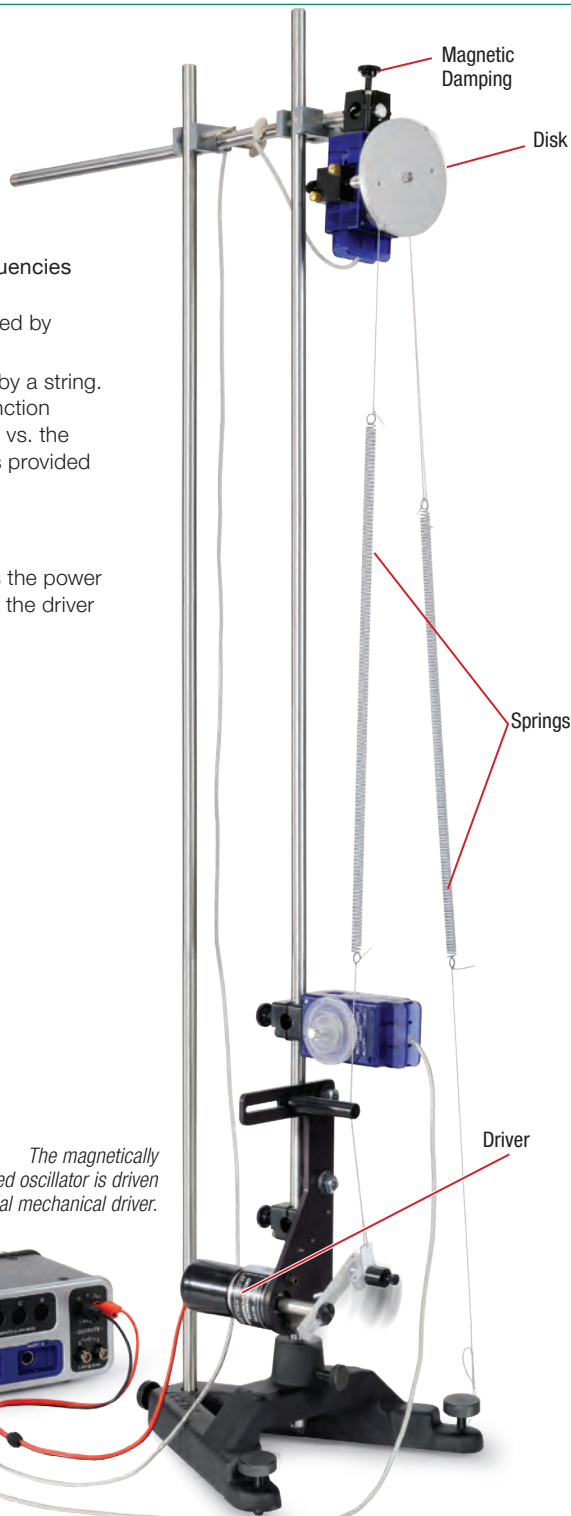
This graph shows the resonance curves (Amplitude vs. Frequency) for three different settings of magnetic damping.

Includes:

- PASPORT Rotary Motion Sensor (2) PS-2120A
- Mechanical Oscillator/Driver ME-8750
- Chaos/Driven Harmonic Accessory CI-6689A
- Large Rod Base ME-8735
- 120 cm Stainless Steel Rod ME-8741
- 45 cm Stainless Steel Rod ME-8736
- Multi-Clamps (2) ME-9507
- Braided Physics String SE-8050

Download This Experiment

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The magnetically damped oscillator is driven by a sinusoidal mechanical driver.

Order Information

Driven Damped Harmonic Oscillations Experiment.....	EX-5522A	
Required:		
850 Universal Interface.....	UI-5000	pp. 14-15
PASCO Capstone Software.....		pp. 68-71
Hooked Mass Set.....	SE-8759	p. 197
Digital Calipers.....	SE-8710	p. 192

Structures

Basic Bridges

EX-5556

Concepts:

- ▶ Learn about different types of bridges through hands-on exploration.
- ▶ Measure the tension/compression in beams for different bridge designs.

Measuring Loads

Each bridge is loaded by hanging a weight from the bridge. The tension and compression in the I-Beams are measured with load cells. The load cells can be moved around to explore the load in every beam in the bridge.

Rectangular Segments

First, students build a bridge with rectangular segments. Of course, bridges are never made this way, but students will never understand why until they try it.

Triangular Segments

Next, students build a Warren bridge with triangular segments. This shows how much stronger triangular segments are than rectangular segments.

Effect of Scale

Students build a second Warren bridge on a different scale to discover how the forces change in this bridge, which has twice the number of segments but spans the same distance.

Effect of Adding Verticals

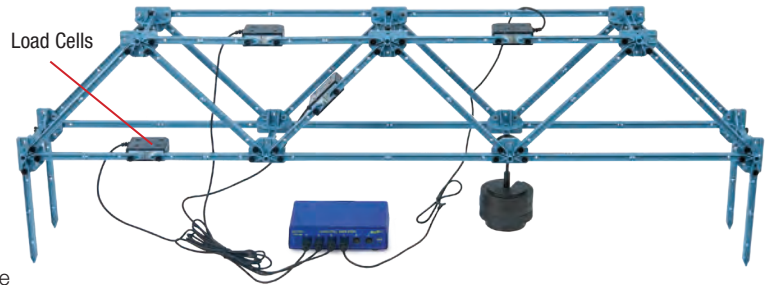
Verticals are added to the larger Warren bridge. Students will find that the loads do not change when the verticals are added; So why are verticals used?

Full Warren Bridge vs Pratt Bridge

Additional verticals are added to make a Full Warren bridge. Then the students change the Full Warren to a Pratt bridge. How are the forces different in a Pratt compared to a Full Warren?

Includes:

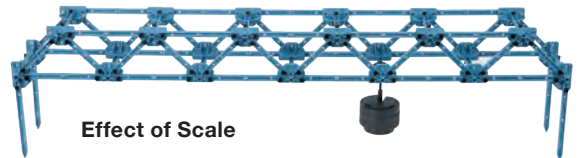
- Truss Set Members (3) ME-6993
- Truss Set Screws (3) ME-6994
- Structures #6 I-Beam Spares ME-7008
- Large Slotted Mass Set (2 kg Set) ME-7589
- PASPORT Load Cell Amplifier PS-2198
- 100 N Load Cells (4) PS-2200



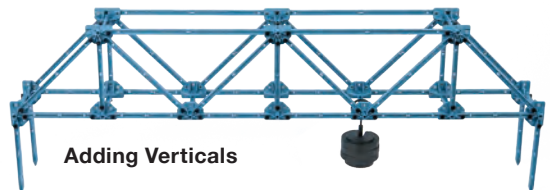
Rectangular



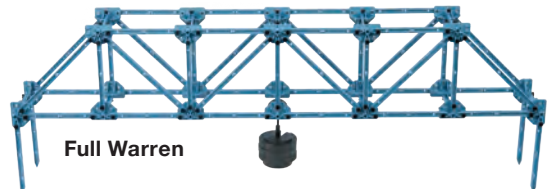
Triangular



Effect of Scale



Adding Verticals



Full Warren



Pratt

Download This Experiment

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Order Information

Basic Bridges.....	EX-5556
Required:	
550 or 850 Universal Interface.....	pp. 14-17
OR	
AirLink.....	p. 48
PASCO Capstone Software.....	pp. 68-71

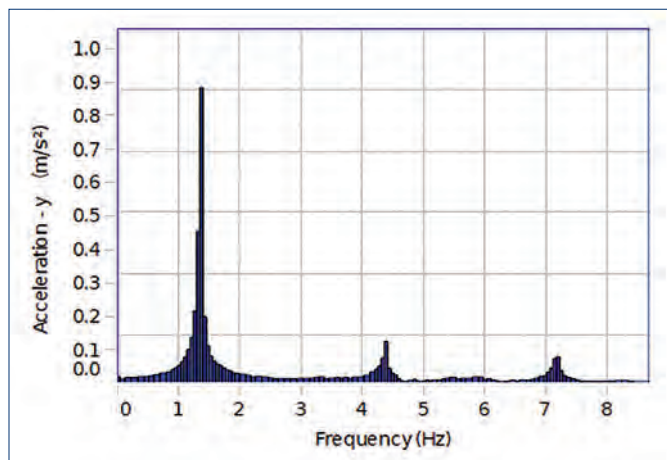
Shaking Tower Experiment

EX-5555

Concepts:

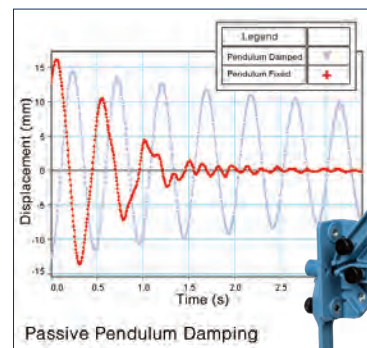
- ▶ Explore the resonance modes
- ▶ Measure accelerations with wireless sensors
- ▶ Demonstrate passive damping

Built from PASCO Structures beams, this tower is made to oscillate in its various resonance modes by a driver attached by a rubber band to the first floor of the tower. Wireless Load Cells with Accelerometers are attached to each floor to record how much shaking each floor experiences.

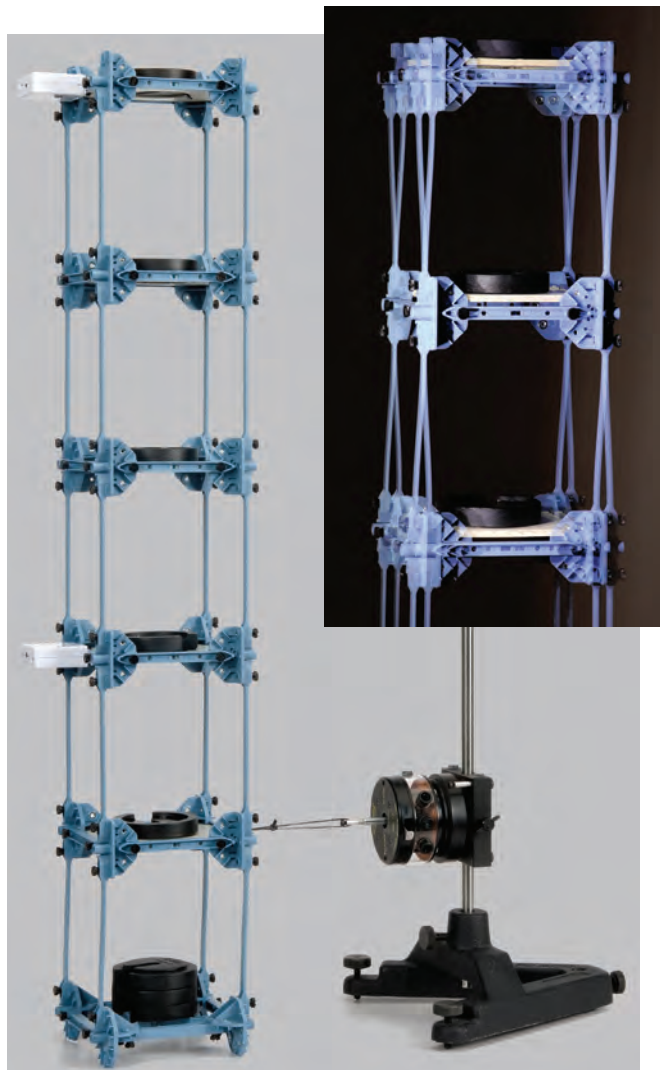
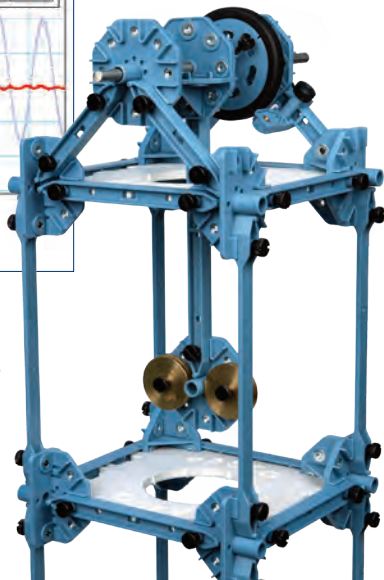


This FFT, generated in PASCO Capstone software, shows the frequency responses of the top Wireless Load Cell/Accelerometer.

In the second part of the experiment, a damping pendulum is installed on top of the tower. In modern buildings, passive damping mechanisms are installed to damp out oscillations during earthquakes. The damping pendulum in this tower quickly stops oscillations.



The gray graph, in PASCO Capstone software shows the oscillation without the pendulum. The red graph shows the damping caused when the pendulum is allowed to oscillate.



The tower is shaken by the Mechanical Wave Driver, which is powered by an 850 Universal Interface or Function Generator.

Includes:

- Shaking Tower ME-7018
- Mechanical Wave Driver SF-9324
- 2 Meter Patch Cord Set SE-9415A
- Large Rod Base ME-8735
- Stainless Steel Rod, 25 cm Threaded ME-8988
- Large Slotted Mass Set ME-7566
- Wireless Load Cell and Accelerometers (4) PS-3216

Download This Experiment

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Order Information

Shaking Tower Experiment.....	EX-5555
Required:	
850 Universal Interface.....	pp. 14-15
OR	
Function Generator	PI-8127 p. 256
PASCO Capstone Software.....	pp. 68-71

Structures

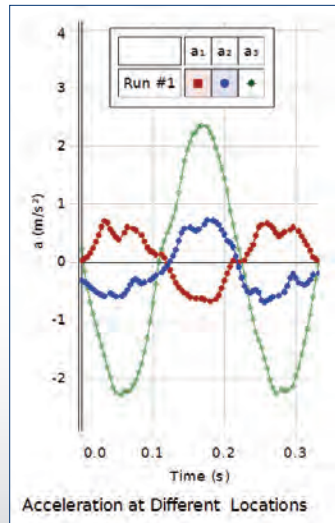
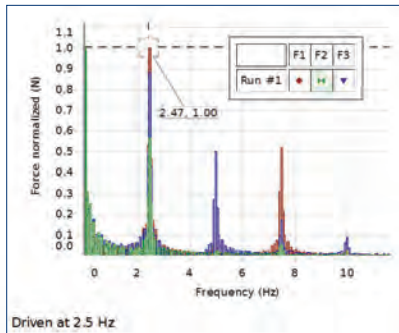
Bridge Vibrations Experiment

EX-5548

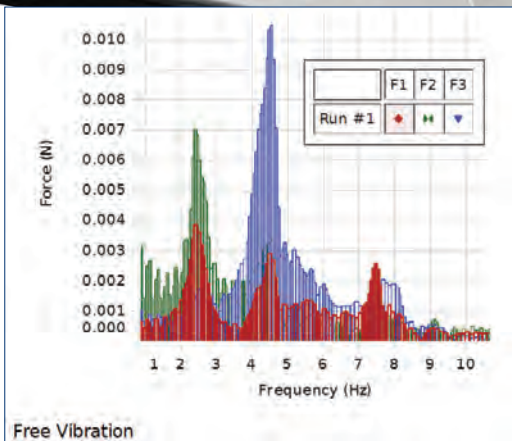
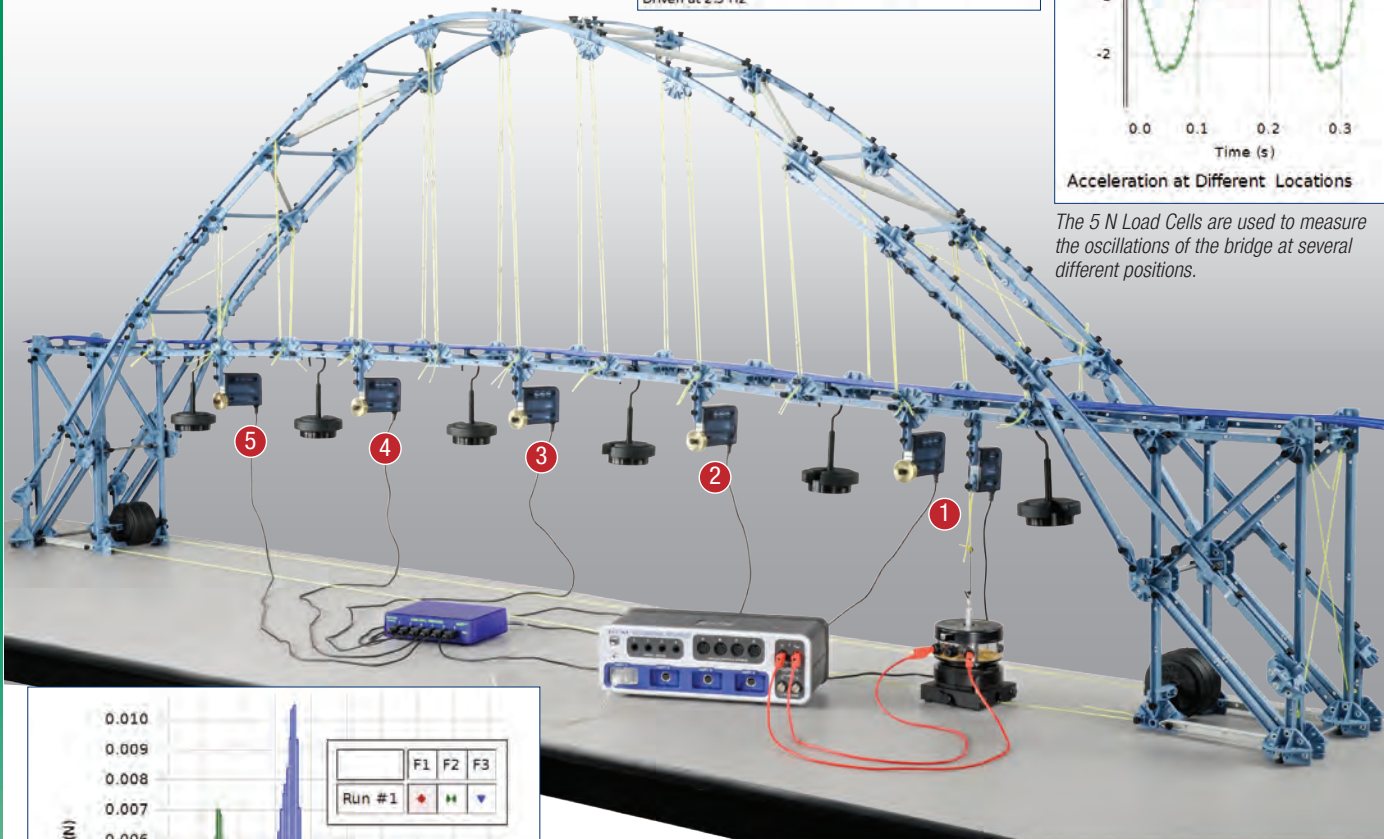
Concepts:

- ▶ Resonance in complex systems
- ▶ Driven vs. free vibrations

The resonance of the bridge is characterized by driving the bridge at different resonant frequencies. Note how different the amplitudes are at different locations on the bridge.



The 5 N Load Cells are used to measure the oscillations of the bridge at several different positions.



The bridge is struck by hand and allowed to freely oscillate. Using PASCO Capstone™, the FFT shows that there are several resonant frequencies. Note how different the amplitudes are at different locations on the bridge.

Includes:

- Large Structures Set ME-7003
- PASPORT Load Cell Amplifier PS-2198
- 100 N Load Cell PS-2200
- 5 N Load Cell (5) PS-2201
- Mechanical Wave Driver SF-9324
- Banana Plug Cord-Red (5 Pack) SE-9750
- Rubber Cord for IDS System (30m Spool) ME-8986
- Large Slotted Mass Set (2 kg Set) (4) ME-7589
- Short Mass Hanger (2) ME-7590
- 20 g Replacement Mass Set (3 sets of 6) ME-8983

Order Information

Bridge Vibrations Experiment	EX-5548
Required:	
850 Universal Interface	pp. 14-15
PASCO Capstone Software	pp. 68-71

Download This Experiment

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Tensile Testing Metals

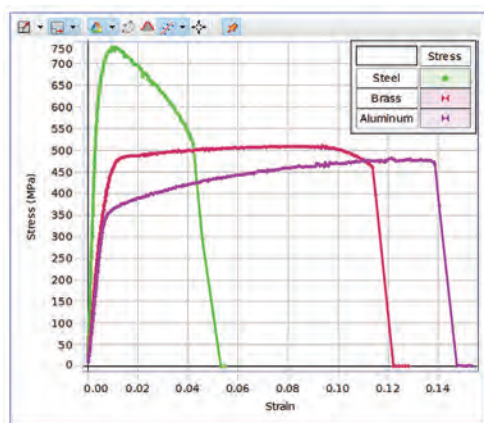
EX-5557

Concepts:

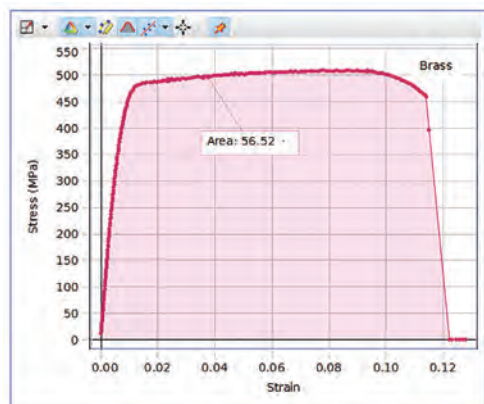
- ▶ Young's Modulus ▶ Ductility
- ▶ Yield Strength ▶ Modulus of Toughness
- ▶ Tensile Strength

The three metal tensile samples are made from 1018 Steel, 360 Brass and 2024-T3 Aluminum. The properties measured for these samples include Young's Modulus, Yield Strength, Tensile Strength, Ductility, and Modulus of Toughness. These properties are the same ones found in materials handbooks and databases and are used by engineers to design bridges, buildings, and machines.

- Measure the slope in the linear portion of the Stress vs. Strain graph to find Young's Modulus for the material.
- Estimate the Yield Strength by examining the Force vs. Position graph to see where the linear part of the curve ends.
- Find the maximum stress on the graph to determine the Tensile Strength.
- Find the maximum strain just before it breaks to determine the Ductility of the material.
- Take the area under the Stress vs. Strain graph to determine the Modulus of Toughness for the material.



The Stress vs. Strain graph for three metals is displayed in real time and can be played back in PASCO Capstone software.



The toughness of brass is determined by taking the area under the Stress-Strain curve in PASCO Capstone software.

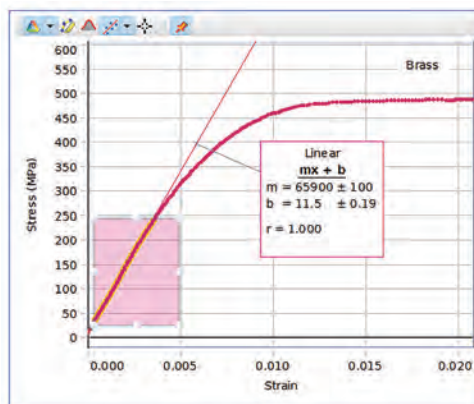
Download This Experiment

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PASCO Advantage

The hand-cranked Materials Testing Machine allows students to feel the different forces required to break different samples. Data is recorded live and can be played back in PASCO Capstone software.



Young's Modulus for brass is determined from the slope of the line.

Includes:

- Materials Testing Machine ME-8236
- Aluminum Tensile Sample (10) ME-8231
- Brass Tensile Sample (10) ME-8232
- Steel Tensile Sample (10) ME-8243
- Digital Calipers SE-8710

Order Information

Tensile Testing Metals.....	EX-5557
Required:	
AirLink Interface	PS-3200 p. 48
850 Universal Interface	pp. 14-15
PASCO Capstone Software.....	pp. 68-71

Materials

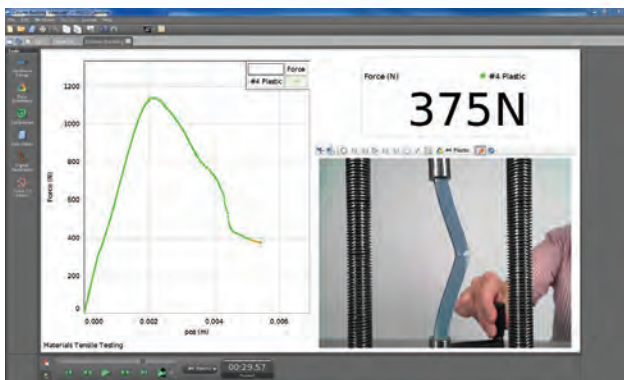
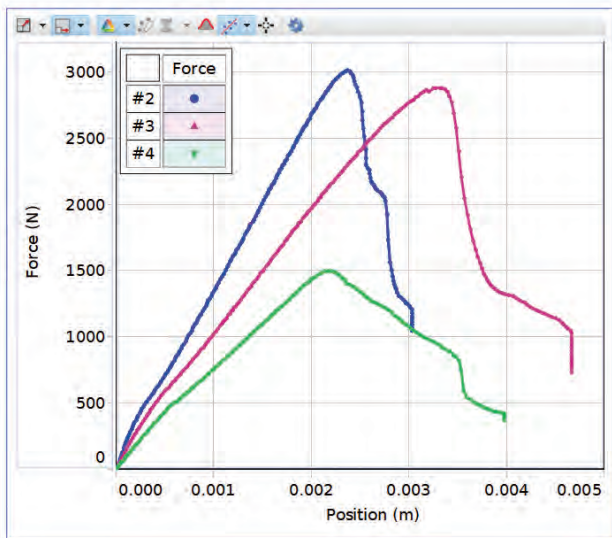
Column Buckling

EX-5558

Concepts:

- ▶ Column Buckling of I-Beams
- ▶ Slenderness Ratio
- ▶ Euler Column Equation

In part one, three different length plastic I-beams are tested under compression to investigate their method of failure. The way in which a member fails (buckling or not) is determined by its Slenderness Ratio, and this ratio is calculated for each beam. Topics covered also include the Radius of Gyration and the Area Moment of Inertia.

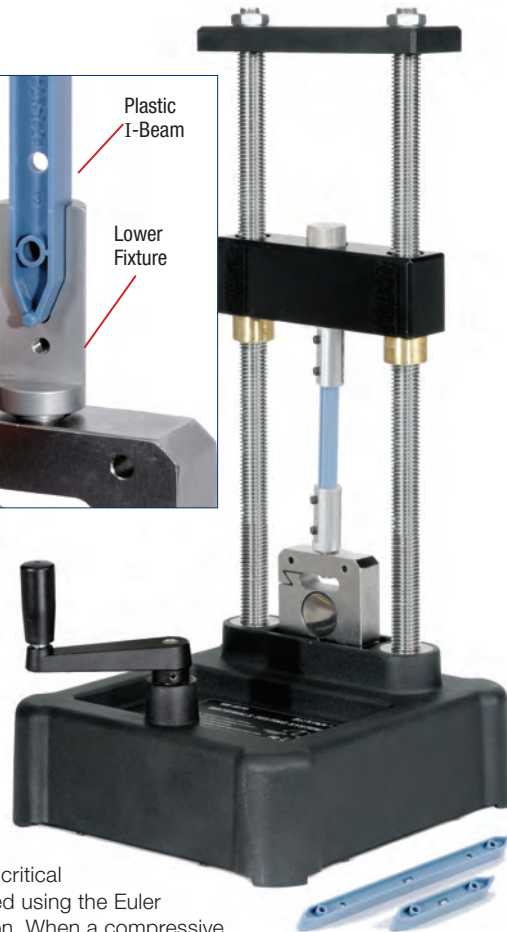
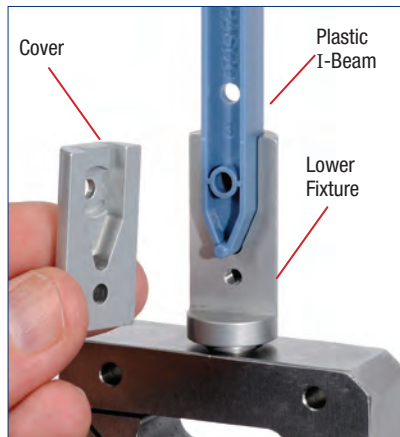


Includes:

- Materials Testing Machine ME-8236
- Structures Beam Fixture ME-8242
- Truss Set Members ME-6993
- Flat Structures Members ME-6987
- Thin I-Beams ME-7012
- Digital Calipers SE-8710

Download This Experiment

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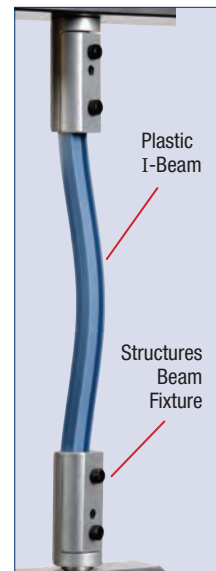


In part two, the critical force is predicted using the Euler Column Equation. When a compressive force is applied to a long straight column, it will elastically compress until a critical force is reached, and at this point the column will suddenly buckle. The relationship between this critical load and the column material and geometry is called the Euler Column Equation.

$$F_{crit} = \frac{4\pi^2 EI}{L^2}$$

PASCO Advantage:

PASCO Capstone software has the ability to embed live video from a webcam and sync the Materials Tester data to the recorded video. Then you can play back the video along with the data on the graph, stepping through one frame at a time to see the exact breaking point



Order Information

Column Buckling.....	EX-5558
Required:	
850 Universal Interface.....	pp. 14-15
PASCO Capstone Software.....	pp. 68-71

Bending: 3-Point and 4-Point

EX-5559

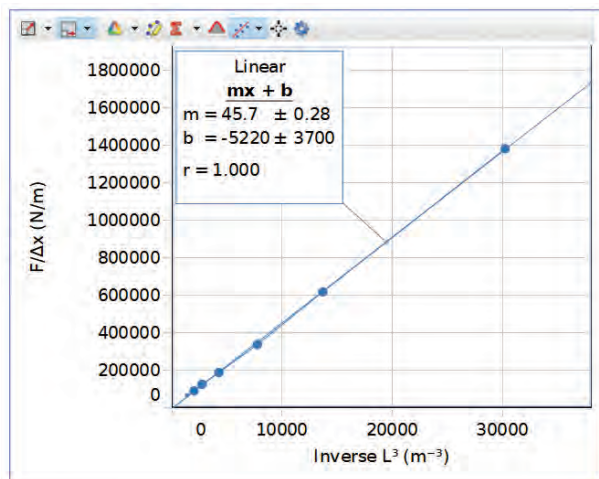
Concepts:

- ▶ 3-Point Bending
- ▶ 4-Point Bending
- ▶ Flexural Elastic Modulus

3-Point Bending

A Three-Point Bend test is performed on a round rod as shown. As a downward force (F) is applied in the middle of the rod, the flex (Δx) is recorded. The ratio ($F/\Delta x$) is the effective stiffness of the length of rod being tested.

The distance between the anvils is varied, and the resulting effect on the stiffness of the beam is measured. A graph of the resulting data yields the Flexural Elastic Modulus for the material.

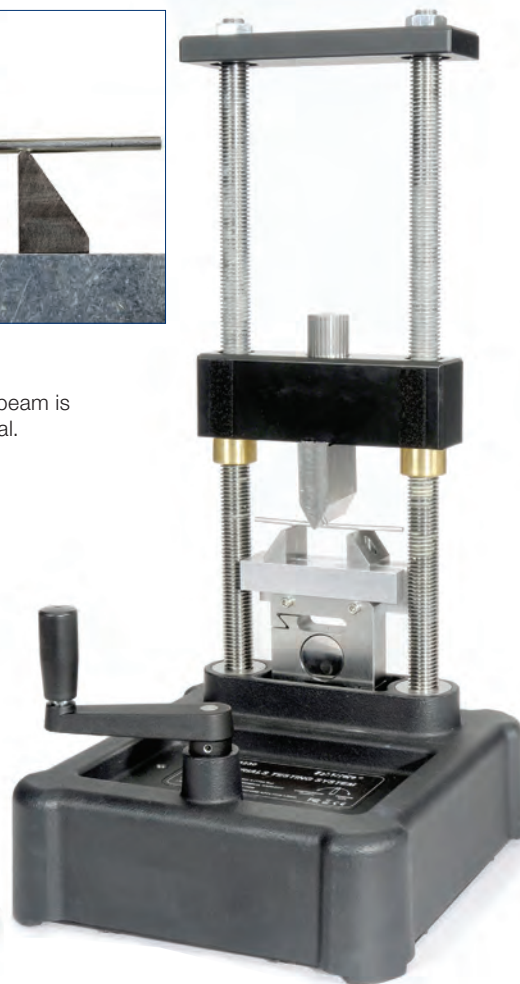


4-Point Bending

A Four-Point Bend Test is performed on the ABS plastic beams from the PASCO Structures System. As a downward force (F) is applied in the middle of the beam, the flex (Δx) is recorded. The ratio ($F/\Delta x$) is the effective stiffness of the length of beam being tested, and is measured directly from the slope of the F vs. Δx graph. The Flexural Elastic Modulus for the material is then calculated.

Includes:

- Materials Testing Machine ME-8236
- Bending Accessory ME-8237
- Shear Samples ME-8240
- Flat Structures Members ME-6987
- Four-Point Load Anvil ME-8249
- Digital Calipers SE-8710



Order Information

Bending: 3-point and 4-point	EX-5559
Required:	
850 Universal Interface	pp. 14-15
PASCO Capstone Software	pp. 68-71

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Thermodynamics

Specific Heat Experiment

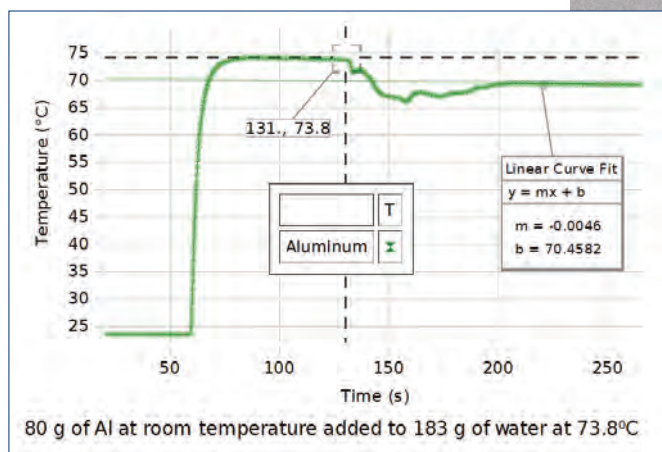
EX-5524A

Topics Covered:

- ▶ Thermal Energy
- ▶ Equilibrium Temperature
- ▶ Specific Heat

In this experiment designed for use with PASCO Capstone software, students learn that materials can be identified using specific heat as a measurable characteristic. A known mass of water is used and the unknown material is placed in the water. The initial temperature of the water and the unknown material are measured. The equilibrium temperature is found and from this the specific heat of the unknown material is derived.

By performing this experiment in two ways (water warming, water cooling) students explore how experiment design may alter results. Finally students explore sources of error and magnitude of error.



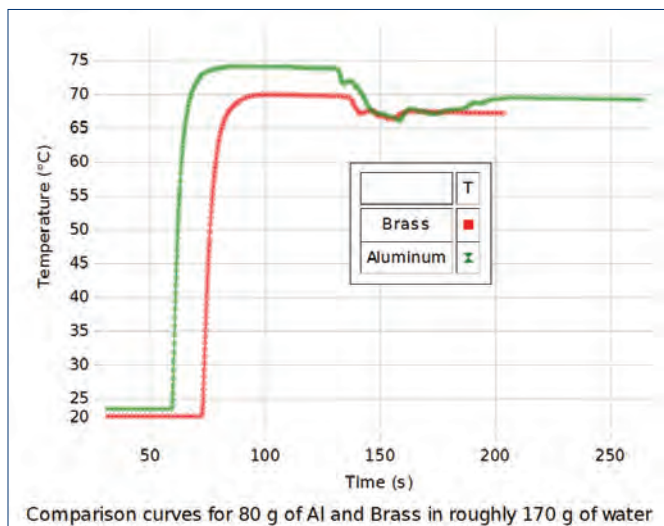
Room temperature A1 is added to hot water. After 210 s, the system has come to equilibrium and is slowly cooling. A linear fit to the cooling curve allows extrapolation back to find the equilibrium temperature that would have occurred at 131 s when the A1 was added, if the system had come to equilibrium instantaneously. This allows measurement of the specific heat within approximately 10%.

Includes:

- PASPORT Temperature Sensor PS-2125
- Calorimetry Cup with Lid
- Heater Stirrer PS-3401
- Ohaus Triple-Beam Balance (without Tare) SE-8723
- Graduated Cylinder, 50 mL
- 1000-mL Beaker
- Braided Physics String SE-8050

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.



Comparison of a similar system shows that A1 causes about twice the drop in water temperature as does brass. The cooling slopes before and after support Newton's Law of Cooling.

Order Information

Specific Heat Experiment..... EX-5524A

Required:

550 or 850 Universal Interface* pp. 14-17

PASCO Capstone Software pp. 68-71

* This experiment can be performed using the 550 or 850 Universal Interface or AirLink.

Electrical Equivalent of Heat Experiment

EX-5525

Concepts:

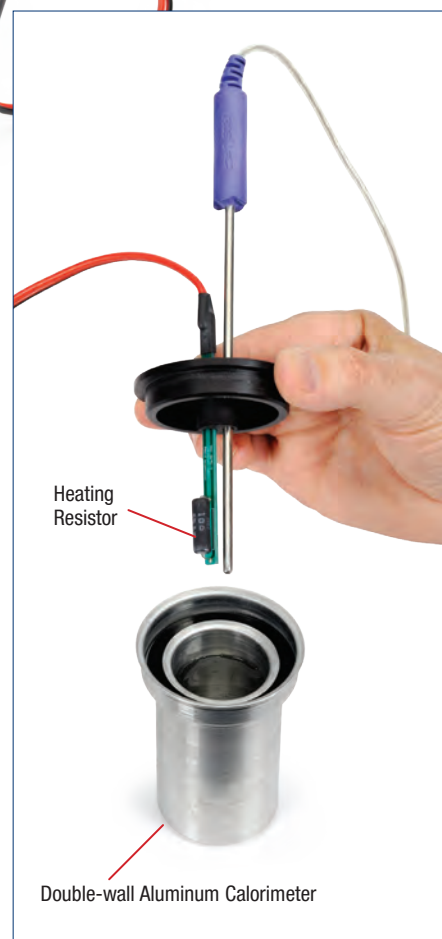
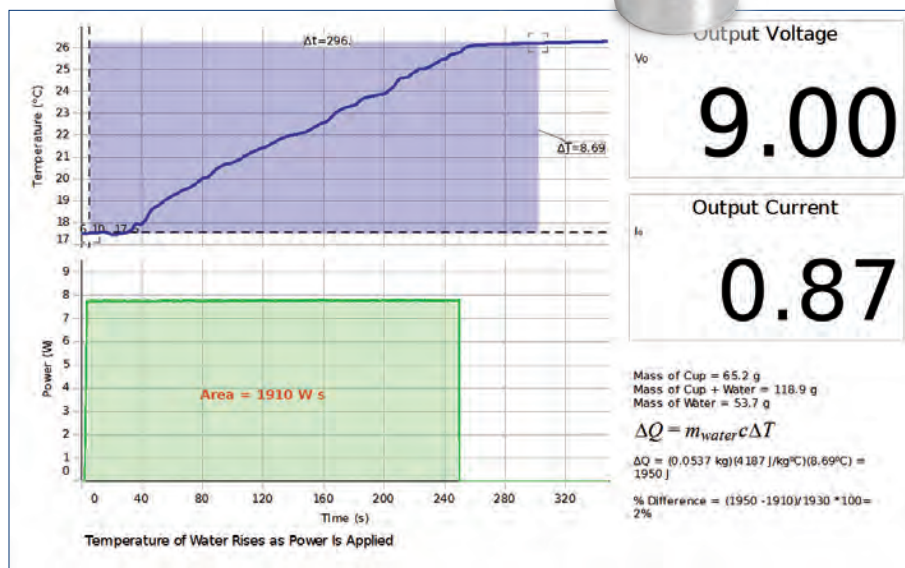
- ▶ Compare electrical energy input to changes in internal energy

In this experiment designed for use with PASCO Capstone software, nothing reinforces the relationship between mechanical work and heat better than hand cranking a generator to produce electricity and electrically heated water.

With the Energy Transfer Calorimeter and the interface to measure temperature and voltage, the student role turns a qualitative demonstration into a quantitative experiment.

The amount of electrical energy used to heat the water is equal to the area under the power versus time curve. The amount of heat delivered to the water can be calculated using the increase in temperature and the mass of the water.

The comparison of the electrical energy to the heat results in a value for the number of Joules in a calorie.



The bottom graph displays the power output from the generator and the top graph shows the increase in temperature. The amount of electrical energy used to heat the water is determined by finding the area under the Power vs. Time curve.

Includes:

- Energy Transfer – Calorimeter ET-8499
- PASPORT Temperature Sensor PS-2125
- Ohaus Triple-Beam Balance (with Tare) SE-8707

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Electrical Equivalent of Heat Experiment	EX-5525
Required:	
850 Universal Interface	pp. 14-15
PASCO Capstone Software	pp. 68-71

Thermodynamics

Ideal Gas Law Experiment

EX-5527

Concepts:

- ▶ Ideal Gas Law
- ▶ Boyle's Law
- ▶ Gay-Lussac's Law

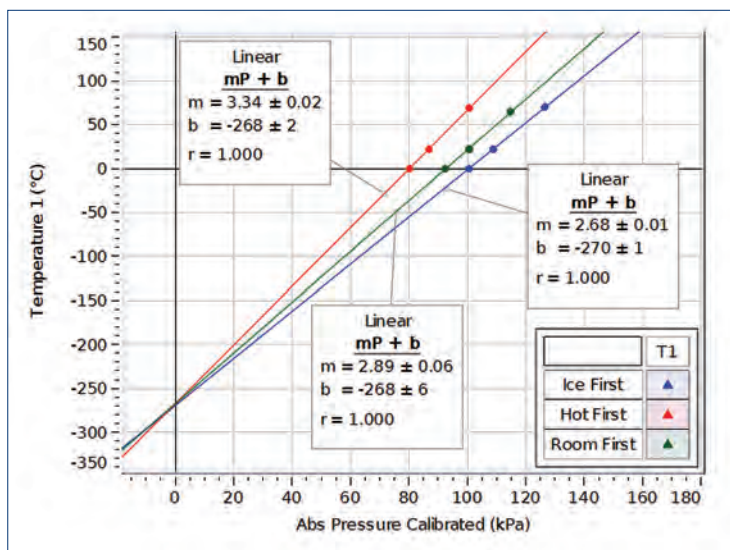
In this experiment designed for use with PASCO Capstone software, the temperature, volume, and pressure of a gas are measured simultaneously to show that they change according to the Ideal Gas Law. Two special cases of the Ideal Gas Law are also examined: constant volume (Gay-Lussac's Law) and constant temperature (Boyle's Law). A syringe is used to vary the volume at constant temperature. A sphere of constant volume is immersed in different temperature water baths to show the change in pressure.

PASCO Advantage:

The Ideal Gas Syringe and Absolute Zero Sphere have a thermistor with small mass that responds quickly to temperature changes.



For the Ideal Gas Syringe (shown above) the Slope of the Volume vs. $\frac{1}{P}$ graph equals nR .



For the Absolute Zero Apparatus (shown at right), which has constant volume, the Pressure vs. Temperature graphs have different slopes corresponding to the different number of moles in the container.



Includes:

- Ideal Gas Law Apparatus TD-8596A
- PASPORT Absolute Pressure/Temperature Sensor PS-2146
- Absolute Zero Sphere TD-8595
- 3-Liter Plastic Tub (2-Pack) ME-7559

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Ideal Gas Law Experiment..... EX-5527
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 Digital Calipers SE-8710 p. 192
 * This experiment can be performed using the 550 or 850 Universal Interface or AirLink.

Blackbody Radiation Experiment

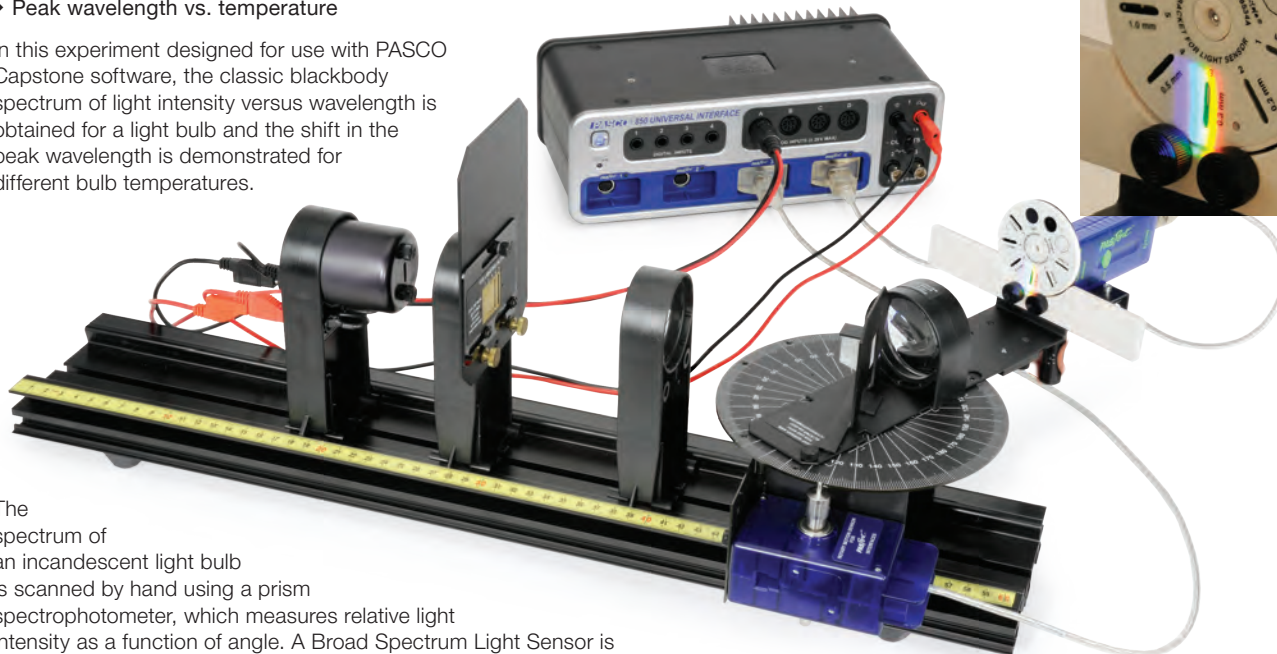
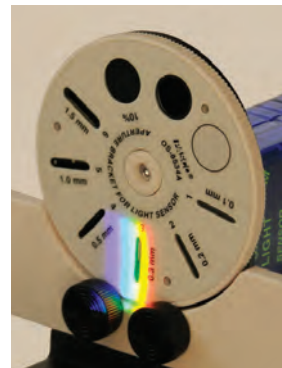
EX-5529A

Concepts:

- ▶ Blackbody spectrum
- ▶ Peak wavelength vs. temperature

In this experiment designed for use with PASCO Capstone software, the classic blackbody spectrum of light intensity versus wavelength is obtained for a light bulb and the shift in the peak wavelength is demonstrated for different bulb temperatures.

The continuous blackbody spectrum is scanned using a prism spectrophotometer.



The spectrum of an incandescent light bulb is scanned by hand using a prism spectrophotometer, which measures relative light intensity as a function of angle. A Broad Spectrum Light Sensor is used with a prism so the entire spectrum from approximately 400 nm to 2500 nm can be scanned without the overlapping orders caused by a grating. The wavelengths corresponding to the angles are calculated using the equations for a prism spectrophotometer. The relative light intensity can then be plotted as a function of wavelength as the spectrum is scanned, resulting in the characteristic blackbody curve. The intensity of the light bulb is reduced, reducing the temperature, and the scan is repeated to show how the curves nest with a shift in the peak wavelength.

The temperature of the bulb's filament can then be measured indirectly by determining the resistance of the bulb from the measured voltage and current. From the temperature, the theoretical peak wavelength can be calculated and compared to the measured peak wavelength.

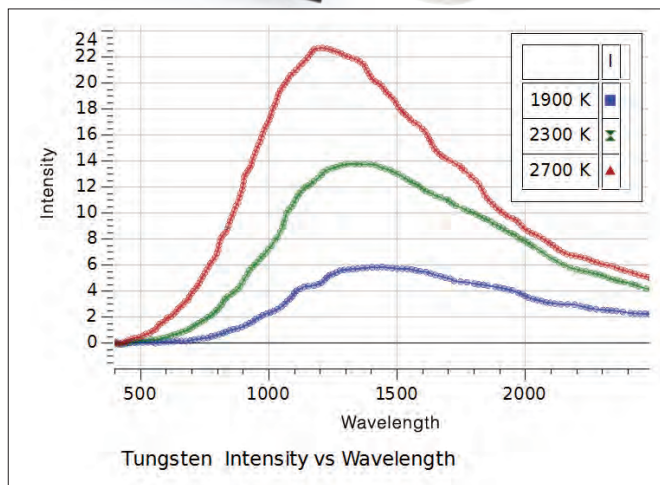
Note: The results are qualitative, and suitable for introductory classes only.

PASCO Advantage:

The light bulb is powered by the interface, making it easy to change its temperature by changing the voltage across the bulb. All the complex calculations for the angle-to-wavelength conversion are stored in the setup file for PASCO Capstone.

Includes:

- Prism Spectrophotometer Kit OS-8544
- Optics Benches (60 cm) OS-8541
- Educational Spectrophotometer Accessory Kit OS-8537
- Aperture Bracket OS-8534A
- PASPORT Broad Spectrum Light Sensor PS-2150
- PASPORT Rotary Motion Sensor PS-2120A
- Voltage Sensor (unshrouded) UI-5100
- Replacement Light Bulbs (10) SE-8509
- Banana Plug Cord-Black (5 Pack) SE-9751



Classic textbook diagram of the intensity vs. wavelength blackbody curves can be produced with real data. In this graph, the peak wavelength in the blackbody curve shifts as the source temperature is decreased.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Blackbody Radiation Experiment..... EX-5529A
 Required:
 850 Universal Interface pp. 14-15
 PASCO Capstone Software pp. 68-71

Thermodynamics

Heat Engine Cycles Experiment

EX-5530B

Concepts:

- ▶ Heat engine efficiency
- ▶ Isothermal processes
- ▶ Isobaric processes
- ▶ Ideal Gas Law

A P-V diagram is generated as a heat engine is taken through a cycle. From this diagram, the heat added to the gas and the work done by the engine are measured to determine the efficiency of the engine. This actual efficiency is compared to the theoretical maximum efficiency.

The heat engine consists of air inside a cylinder that expands when an attached can is immersed in hot water. The expanding air pushes on a piston and does work by lifting a weight. The heat engine cycle is completed by immersing the can in cold water, which returns the air pressure and volume to the starting values.

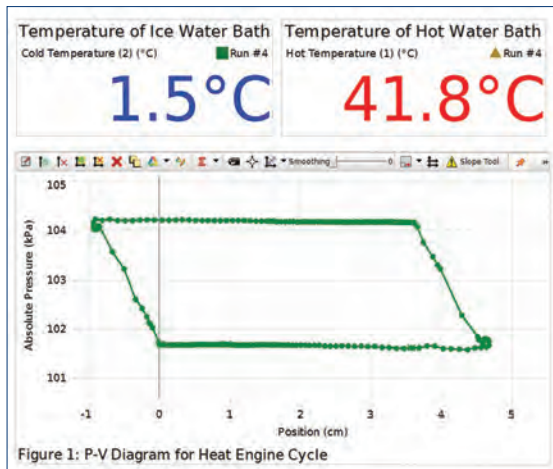


Figure 1: P-V Diagram for Heat Engine Cycle
The PASCO Capstone™ graph shows an isobaric/isothermal heat engine cycle operating between a cold water bath at 1.5°C and a hot water bath at 41.8°C.

The actual efficiency is determined for a heat engine that lifts a weight as heat is added to the gas.

PASCO Advantage:

This operating heat engine shows how a difference in temperature can be used to do work. Each part of the cycle is easily identifiable, and the actual efficiency as well as the maximum possible efficiency can be easily determined.

The cycle is performed as follows:

- With the can in the cold bath, the 200 g mass is placed on the platform.
- The can is moved from the cold bath to the hot bath.
- The 200 g mass is removed from the platform.
- The can is moved from the hot bath to the cold bath.

The change in pressure is measured with a Low Pressure Sensor. The change in piston height is measured by the attached string over the Rotary Motion Sensor pulley. The change in volume is calculated by multiplying the change in piston height by the piston cross-sectional area.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Includes:

- Heat Engine and Gas Law Apparatus TD-8572A
- Large Rod Base ME-8735
- Mass and Hanger Set ME-8979
- 3-Liter Plastic Tub (2-Pack) ME-7559
- Thread
- 90 cm Stainless Steel Rod ME-8738
- PASPORT Rotary Motion Sensor PS-2120A
- PASPORT Quad Temperature Sensor PS-2143
- PASPORT Dual Pressure Sensor PS-2181

Order Information

Heat Engine Cycles Experiment.....EX-5530B

Required:

550 or 850 Universal Interface* pp. 14-17

PASCO Capstone Software pp. 68-71

* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with three ports.

Ratio of Specific Heat Experiment

EX-5531A

Concepts:

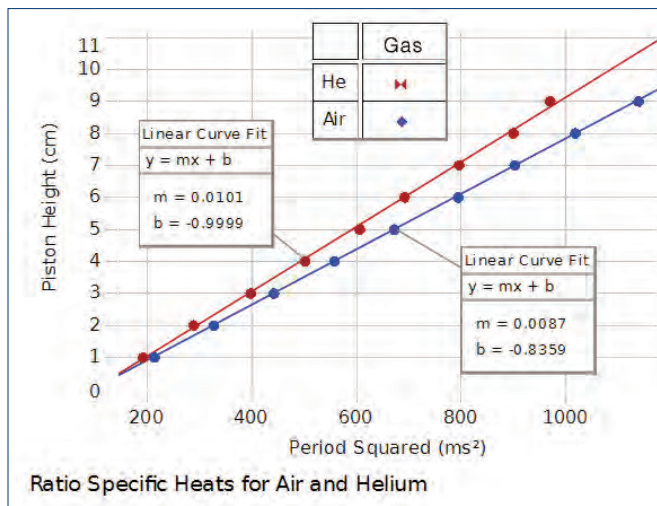
- ▶ C_p/C_v for a gas
- ▶ Ruchardt's method of measuring the ratio of specific heats
- ▶ Adiabatic process

In this experiment, the ratio of specific heat capacities for air is determined using Ruchardt's method of measuring the period of oscillation of the piston in a cylinder filled with air.

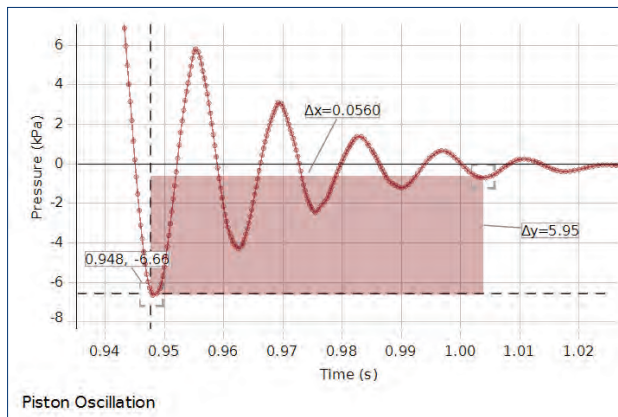
A cylinder is filled with air and a Pressure Sensor is attached. The piston is plucked by hand and allowed to oscillate. The oscillating pressure is recorded as a function of time and the period is determined. The ratio of specific heat capacities is calculated using the period of oscillation, according to Ruchardt's method.

PASCO Advantage:

Since the oscillations are plotted, it is easy to accurately measure the period of oscillation.



A plot of the Piston Height vs. the Period Squared shows that the period increases as the gas volume increases. The slope of the line is related to the ratio of specific heats (C_p/C_v) and is different for the two gases.



The pressure oscillates after the piston is plucked by hand.



Includes:

- Heat Engine and Gas Law Apparatus TD-8572A
- Large Rod Base ME-8735
- 45 cm Stainless Steel Rod ME-8736
- PASPORT Dual Pressure Sensor PS-2181

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Ratio of Specific Heat Experiment EX-5531A
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or AirLink.

Electromagnetism

Electrostatic Charge Experiment

EX-5532

Topics Covered:

- ▶ Methods of Charging
- ▶ Charge Distribution
- ▶ Conservation of Charge

Using classic equipment (a Faraday Ice Pail and Conductive Spheres), students learn to charge objects by direct contact and by induction. The charge is measured using a high impedance electrometer.

Students explore the distribution of charge on different shaped conductive shapes. A sphere with a hole in it is provided to show that no charge resides on the inner surface of the conductor when it is charged.



Use the ball end to sample inside the hollow sphere.



New Digital Readout



Includes:

- Basic Electrometer ES-9078A
- Charge Producers and Proof Plane ES-9057C
- Faraday Ice Pail ES-9042A
- Conductive Spheres ES-9059C
- Conductive Shapes ES-9061
- Electrostatics Voltage Source ES-9077

Order Information

Electrostatic Charge Experiment EX-5532
 Required:
 PASCO Capstone Software pp. 68-71
 (No interface required.)

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

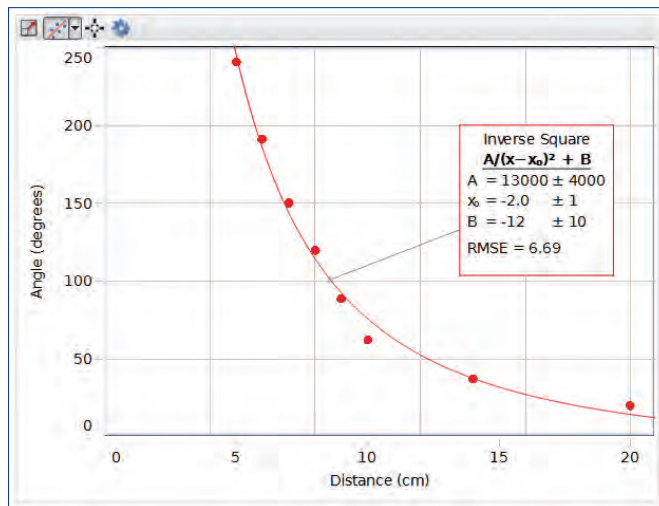
Coulomb's Law Experiment

EX-9930B

Concepts:

- ▶ Verify the Inverse Square Law: $F \sim 1/R^2$
- ▶ Verify the Force/Charge Relationship: $F \sim q_1q_2$
- ▶ Determine Coulomb's Constant: $k = 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2$

A conductive sphere is mounted on the end of an insulating counterbalanced rod and suspended from a very thin torsion wire. An identical sphere is mounted on a calibrated linear track and can be positioned at various distances from the first sphere. When the conductive spheres are charged, the force between them is proportional to the twist of the torsion wire that is required to bring the balance back to its equilibrium position. Introductory physics students can determine the Inverse Square Law in a simple experiment, while advanced students can perform investigations into all the variables involved in electrostatic repulsion.



Electrostatic force is directly proportional to the angle of twist, and the angle of twist is proportional to the inverse square of the separation of the balls.



When an electrostatic force is applied, the torsion wire is twisted to return the balance to equilibrium. The twist of the wire is proportional to the electrostatic repulsion force.

Includes:

- Coulomb's Law Apparatus ES-9070
- Kilovolt Power Supply SF-9586B
- Basic Electrometer ES-9078A
- Faraday Ice Pail ES-9042A
- Charge Producers and Proof Plane ES-9057C
- Coulomb's Law Experiment Manual

Download This Experiment

Search for EX-9930B at www.pasco.com

Order Information

Coulomb's Law Experiment EX-9930B
(No interface required.)

Electromagnetism

Charge of an Electron Experiment

EX-9929A

Concepts:

- ▶ Accurately measure the charge of a single electron
- ▶ Recreate Robert Millikan's historical experiment

Small droplets of oil are introduced into a chamber where an electric field of known strength is present. Using the viewing scope and a stopwatch, the velocity of a falling oil droplet is measured and recorded. Next, the electric field in the chamber is increased, causing the oil droplet to move upward. This allows the measurement of the force on the droplet and, ultimately, the charge of the droplet. By measuring the charge of several different oil droplets, the smallest difference in charge between them can be equated to the charge of an electron.



PASCO Advantage:

PASCO's Charge of an Electron Experiment features a 30x, bright-field, erect-image microscope for clear viewing of the oil droplets. The droplet viewing chamber utilizes a special condenser to minimize droplet drift typically caused by droplet illumination and outside air currents. An ionization source allows the droplet charge to be changed.

Includes:

- Millikan Oil Drop Apparatus AP-8210A
- Basic Digital Multimeter SE-9786A
- High Voltage Power Supply SF-9585A
- Large Rod Base ME-8735
- 45 cm Stainless Steel Rod (2) ME-8736
- Banana Plug Cord-Red (5 Pack) SE-9750
- Banana Plug Cord-Black (5 Pack) SE-9751
- Charge of an Electron Experiment Manual

Easy Cleaning

The condenser system easily disassembles for cleaning and inspection.

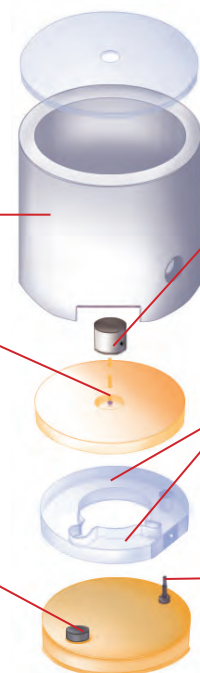
Condenser Housing

Minimum Electric Field Distortion

A 0.5 mm diameter droplet entry hole in the top capacitor plate has a negligible effect on the electric field.

Ionization Source

The thorium-232 alpha source can be activated by the switch on the side of the chamber. The source allows the charge on the oil droplets to be changed.



Droplet Hole Cover

Prevents additional droplets from entering the chamber once the experiment has started.

Polished Surfaces

Polished surfaces on the plate spacer minimize absorption of light (and heat) through the chamber walls.

Electrical Connection

Electrical connection to the top plate.

Condenser Assembly

Download This Experiment

Search for EX-9929A at www.pasco.com

Order Information

Charge of an Electron Experiment..... EX-9929A
(No interface required.)

Capacitance Experiment

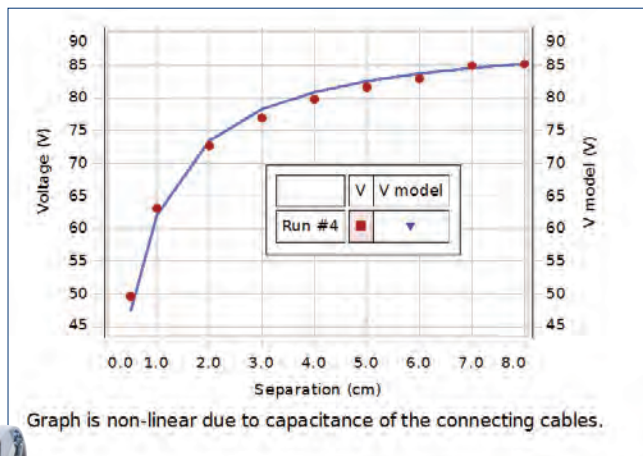
EX-5533

Topics Covered:

- ▶ Capacitance
- ▶ Parallel Plate Capacitor
- ▶ Factors Affecting Capacitance

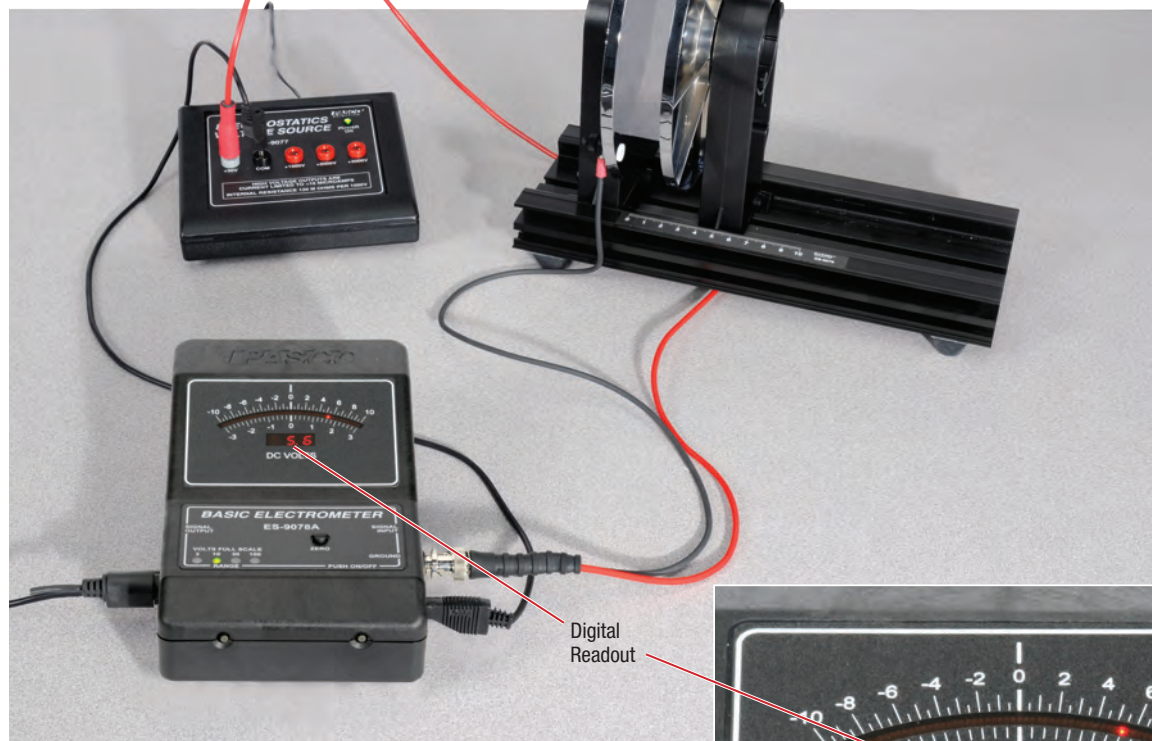
This lab explores the effect of varying plate distances and insulating dielectric materials in a variable flat plate capacitor.

The electrometer used in this experiment allows you to measure the voltage across the capacitor plates, without discharging the capacitor, since it has an internal resistance of 1014 ohms.

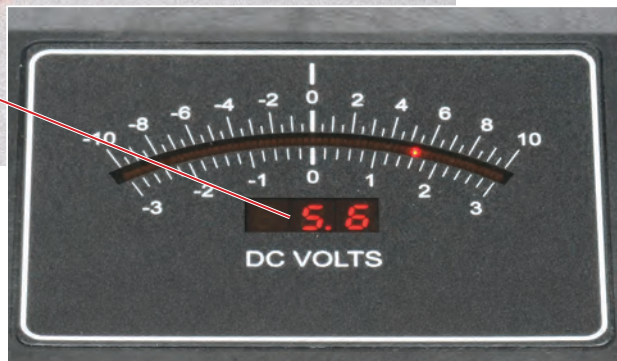


Graph is non-linear due to capacitance of the connecting cables.

Manipulation of the computer model allows measurement of the capacitance of the connecting cables and the charge on the system.



Digital Readout



Includes:

- Basic Electrometer ES-9078A
- Basic Variable Capacitor ES-9079
- Electrostatics Voltage Source ES-9077

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Capacitance Experiment EX-5533

Required:

550 or 850 Universal Interface pp. 14-17
 PASCO Capstone Software pp. 68-71

Electromagnetism

Resistivity Experiment

EX-5534

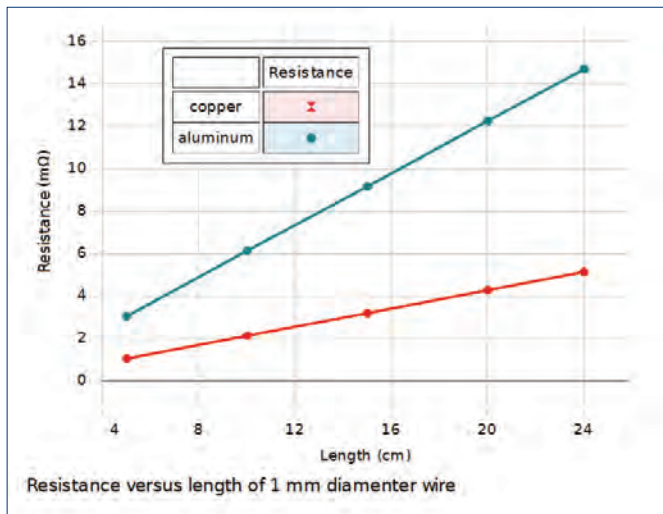
Concepts:

- ▶ Relate resistance to wire length
- ▶ Determine resistivity of different materials

Discover the relationship between the resistance of a wire and its length, diameter, and the resistivity of the metal.

The current is measured directly by the 850 Universal Interface, and the voltage drop over the selected section of wire is measured by the Voltage Sensor. This allows easy calculation of the resistance of the length of wire. The resistance is plotted vs. the length of the wire, and the slope of the resulting straight line is used to determine the resistivity.

Using wires of the same diameter made of different materials allows examination of the effect of resistivity. Using brass wires with various diameters allows examination of the effect diameter has on resistance.



Since both wires have the same diameter, the resistivity is directly proportional to the slope. The graph shows that the resistivity of copper is about one-third that of aluminum.

The Resistance Apparatus has a slide wire probe to easily change the measured length of the wire, and it utilizes a four wire hook-up to accurately measure the voltage drop. It comes with four different brass wire diameters and four other wire materials.



PASCO Advantage:

The Resistance Apparatus has a slide-wire probe to easily change the measured length of the wire. It utilizes a four-wire hook-up to accurately measure the voltage drop. The 850 Universal Interface Power Amplifier makes it possible to scan the voltages, allowing more time to examine wires made of different metals and with different diameters.

Includes:

- Resistivity Apparatus EM-8812
- Voltage Sensor (unshrouded) UI-5100
- Banana Plug Cord-Red (5 Pack) SE-9750

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Resistivity Experiment.....	EX-5534
Required:	
550 or 850 Universal Interface.....	pp. 14-17
PASCO Capstone Software.....	pp. 68-71
Micrometer.....	p. 192

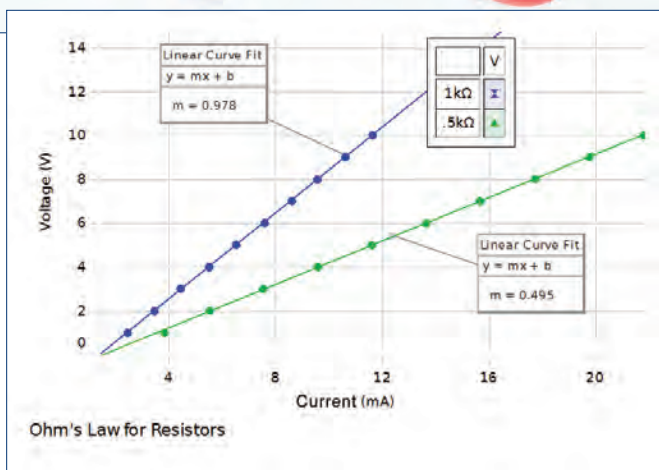
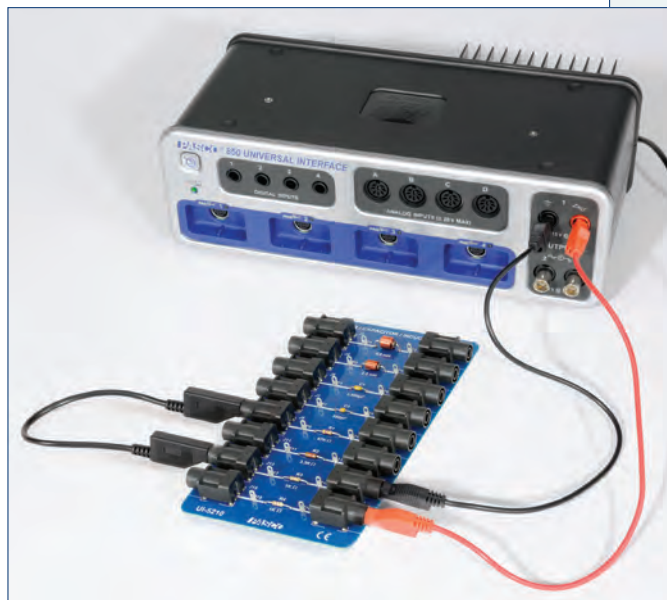
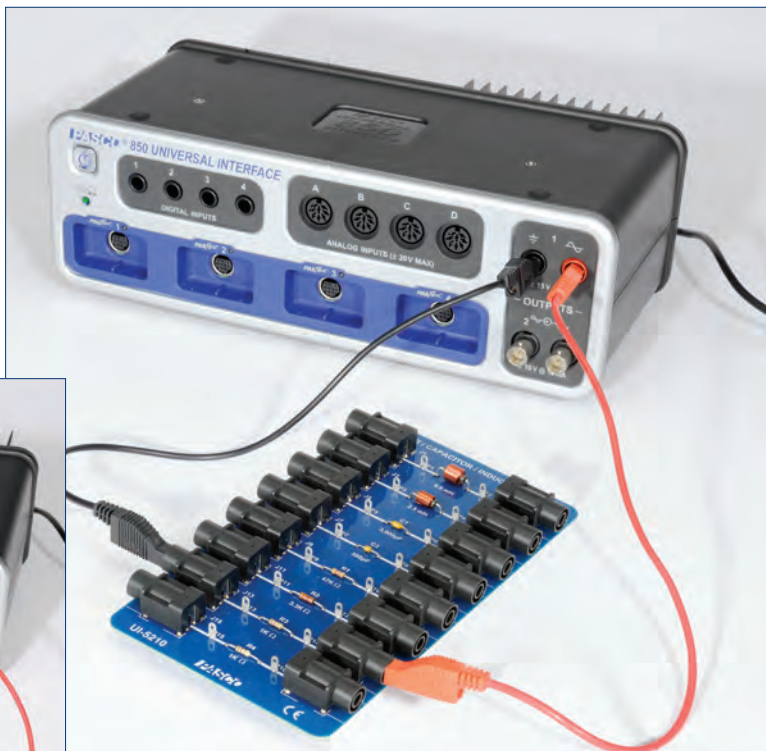
Ohm's Law Experiment

EX-5535

Concepts:

- Relationship between voltage and current

In this experiment, students simultaneously measure both current and voltage for a simple DC circuit. The relationship between current and voltage is explored for different resistors in parallel. Voltage is graphed vs. current to verify Ohm's Law and recognize the physical meaning of slope.



The relationship between voltage and current varies for different circuit resistance.

Signal Generator

▼ 850 Output 1

Waveform: DC

DC Voltage: 6 V

▼ Offset and Limits

Voltage Limit: 15 V

Current Limit: 0.55 A

On Off Auto

► 850 Output 2

► 850 Output 3

Students control output from the 850 signal generators directly from the user interface in PASCO Capstone.

Includes:

- Resistor Capacitor Inductor Network UI-5210
- Banana Plug Cord Sets, 30 cm Length (set of 8) SE-7123

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Ohm's Law Experiment.....	EX-5535
Required:	
550 or 850 Universal Interface.....	pp. 14-17
PASCO Capstone Software.....	pp. 68-71

Electromagnetism

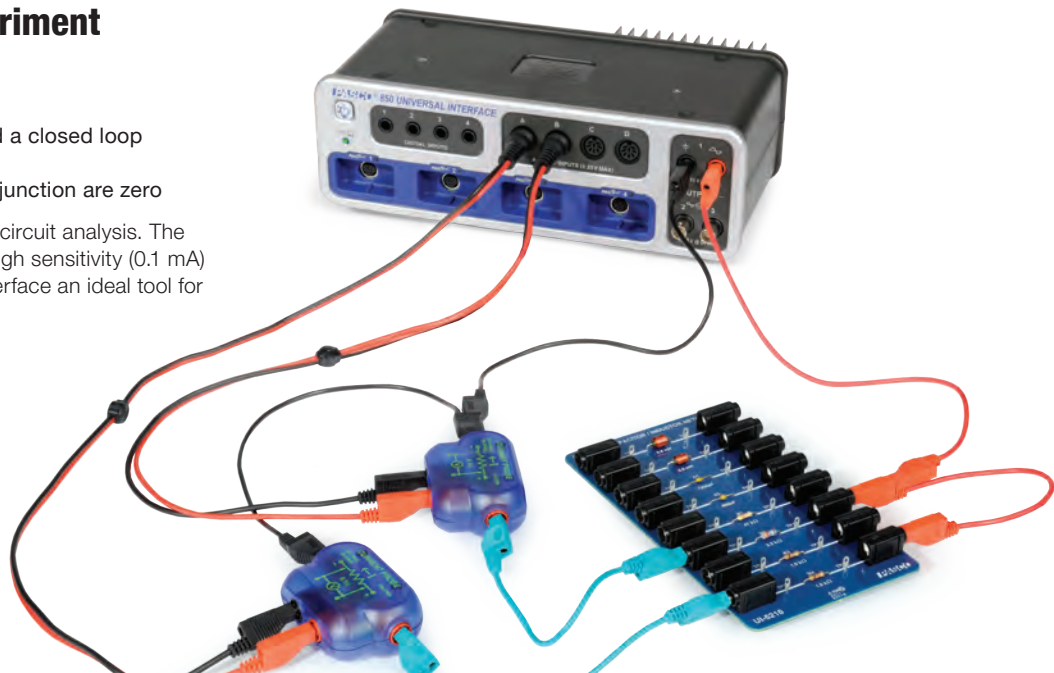
Kirchhoff's Rules Experiment

EX-5538

Concepts:

- ▶ Summation of the voltages around a closed loop are zero at any instant
- ▶ Summation of the currents at any junction are zero

Kirchhoff's Laws form the basis of all circuit analysis. The high speed for AC applications and high sensitivity (0.1 mA) for DC applications make the 850 Interface an ideal tool for investigating AC and DC circuits.



Signal Generator

▼ 850 Output 1

Waveform DC

DC Voltage 15 V

▼ Offset and Limits

Voltage Limit 15 V

Current Limit 0.55 A

On Off Auto

▶ 850 Output 2

▶ 850 Output 3

Total Current

19.7mA

Current 1

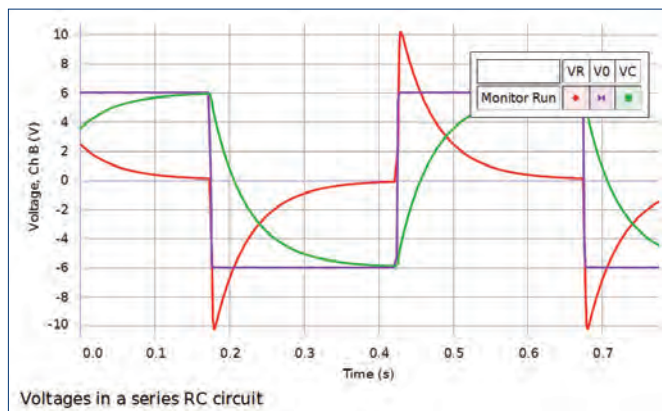
15.2mA

Current 2

4.5mA

Measurement of voltages and currents in series-parallel DC circuits demonstrates the validity of Kirchhoff's Laws. The use of multiple current probes avoids student confusion that can arise when rearranging the circuit to measure currents at different points.

Students control output from the 850 signal generators directly from the user interface in PASCO Capstone. Students compare the current flow through each resistor to the total current output from the 850.



The high speed of the 850 Universal Interface, in scope mode, allows the examination of time varying voltages in an RC circuit to verify that Kirchhoff's loop theorem holds even when voltage is not constant.

Includes:

- Resistor Capacitor Inductor Network UI-5210
- Voltage Sensors (unshrouded) (3) UI-5100
- PASPORT Current Probes (2) PS-2184
- Banana Plug Cord Sets, 30 cm Length (8) SE-7123

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Kirchhoff's Rules Experiment EX-5538

Required:

550 or 850 Universal Interface pp. 14-17
 PASCO Capstone Software pp. 68-71

RC Circuit Experiment

EX-5536

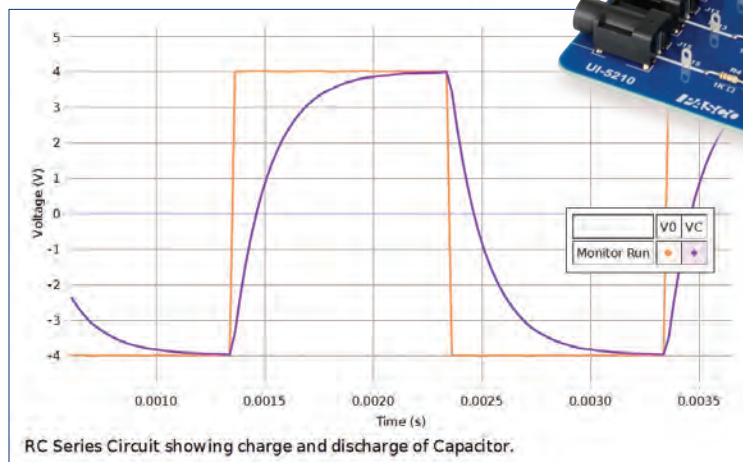
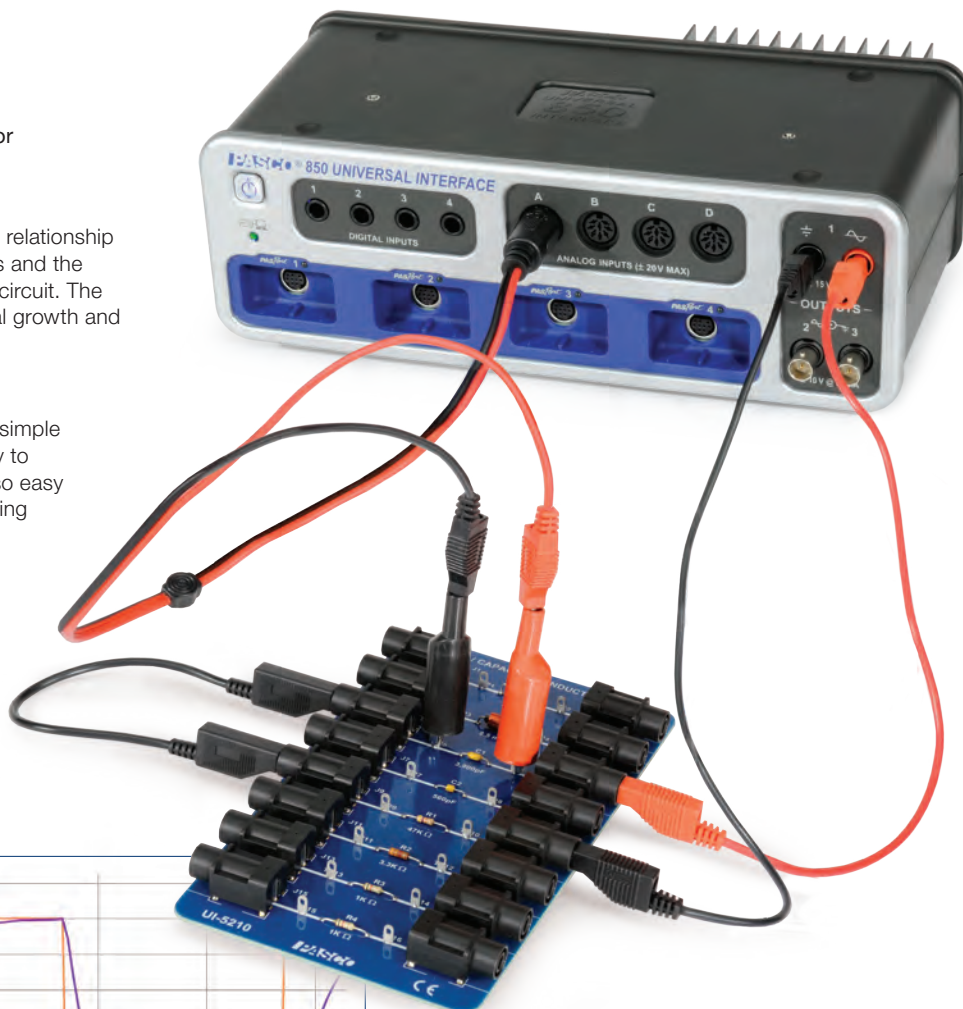
Concepts:

- ▶ Charging and discharging a capacitor
- ▶ Exponential growth and decay
- ▶ Time constants

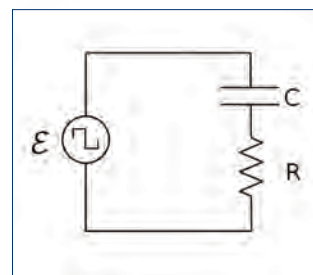
Students collect data to understand the relationship between charging and discharging rates and the capacitance and resistance in a simple circuit. The time constant is derived and exponential growth and decay are explored.

PASCO Advantage:

The RC Circuit experiment is extremely simple and transparent to set up. It is very easy to measure the time to half charge. It is also easy to verify that the curve is exponential using the curve-fitting capability of PASCO Capstone software.



The actual capacitance is determined from the charge/discharge curve.



The 850 Universal Interface provides a very clean square wave to the series RC circuit.

Includes:

- Resistor Capacitor Inductor Network UI-5210
- Voltage Sensor (unshrouded) UI-5100
- Banana Plug Cord Sets, 30 cm Length (8) SE-7123

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

RC Circuit Experiment.....	EX-5536
Required:	
550 or 850 Universal Interface.....	pp. 14-17
PASCO Capstone Software.....	pp. 68-71

Electromagnetism

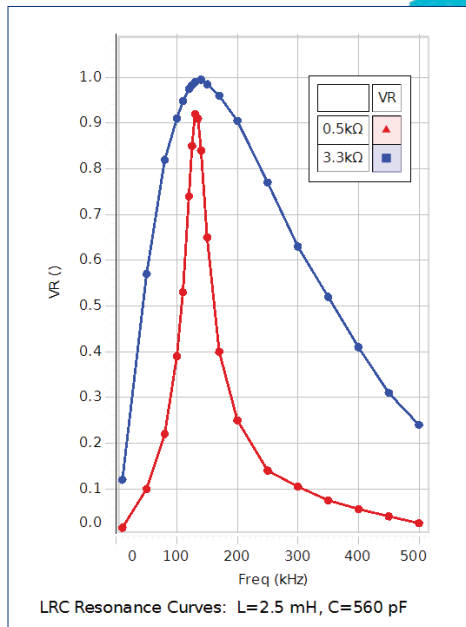
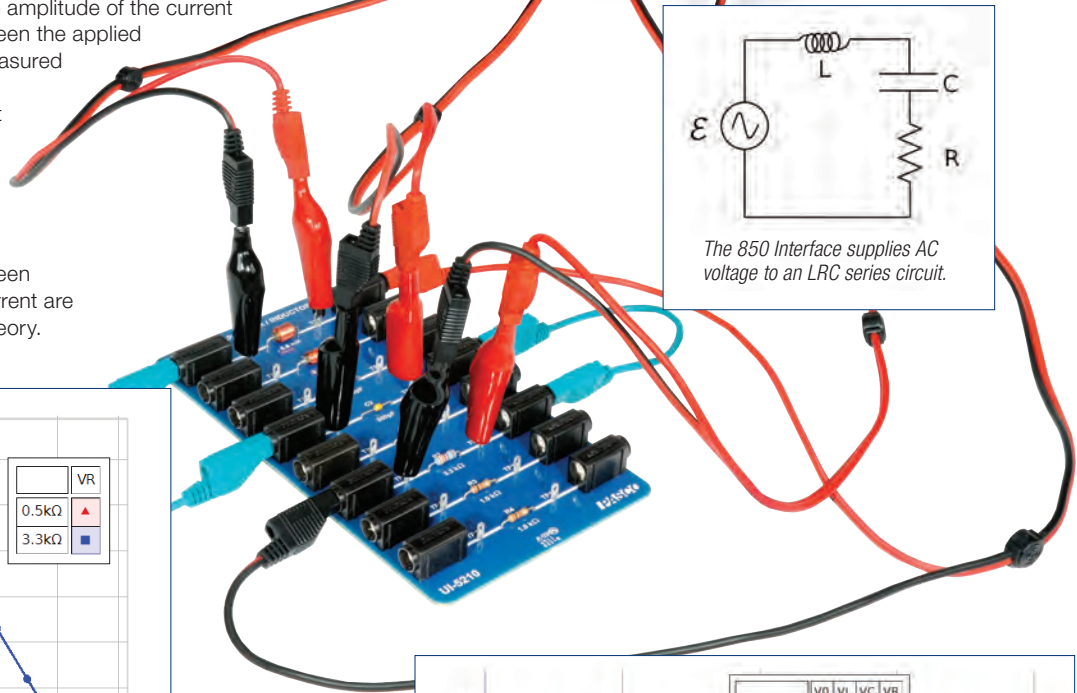
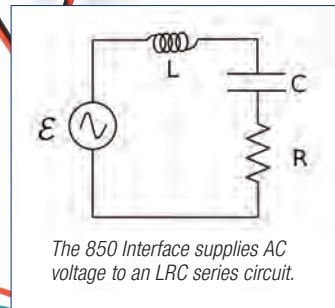
LRC Circuit Experiment

EX-5537

Concepts:

- ▶ LC oscillations
- ▶ Inductive, capacitive, and resistive AC circuits
- ▶ LRC resonant frequency

The response of a series LRC circuit is examined at driving frequencies above, below, and at the resonant frequency. A sinusoidal voltage is applied individually to a resistor, a capacitor, and an inductor. The amplitude of the current and the phase difference between the applied voltage and the current are measured in each of the three circuits to see the effect each component has on the current. Finally, a sinusoidal voltage is applied to an inductor, resistor, and capacitor in series. The amplitude of the current and the phase difference between the applied voltage and the current are measured and compared to theory.



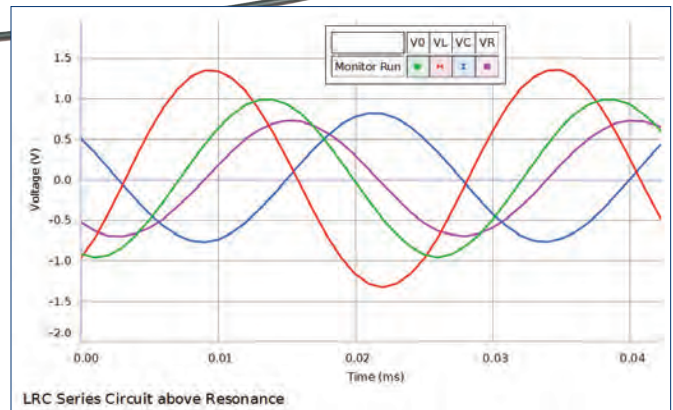
The effect of circuit resistance on peak width is clear and leads to an understanding of how to design a filter for a circuit.

Includes:

- Resistor Capacitor Inductor Network UI-5210
- Voltage Sensors (unshrouded) (3) UI-5100
- Banana Plug Cord Sets, 30 cm Length (8) SE-7123
- BNC Function Generator Output Cable (unshrouded) UI-5119

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.



The oscilloscope display in PASCO Capstone is used to simultaneously display the voltages across the inductor, capacitor, and resistor, as well as the source voltage.

Order Information

LRC Circuit Experiment.....	EX-5537
Required:	
550 or 850 Universal Interface.....	pp. 14-17
PASCO Capstone Software.....	pp. 68-71

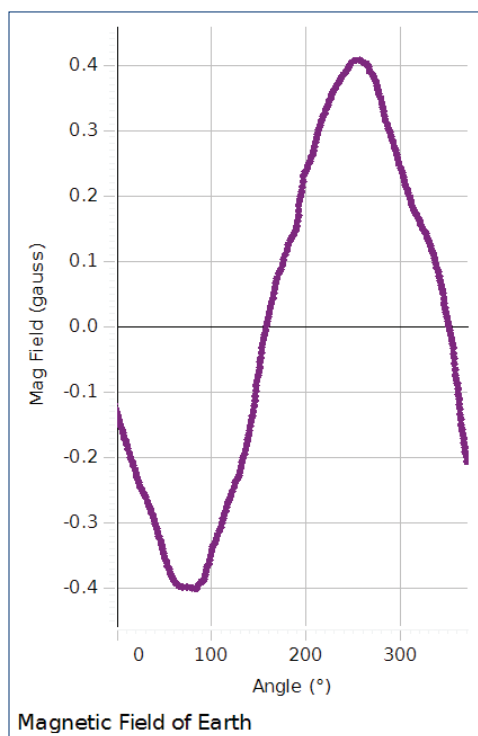
Earth's Magnetic Field Experiment

EX-5539A

Concepts:

- ▶ Magnitude of the earth's magnetic field
- ▶ Direction of earth's magnetic field
- ▶ Dip angle

The magnitude and direction of the Earth's magnetic field are measured using a Magnetic Field Sensor mounted on a Rotary Motion Sensor. The Magnetic Field Sensor is rotated through 360 degrees by rotating the Rotary Motion Sensor pulley by hand. The Magnetic Field Sensor is zeroed using the Zero Gauss Chamber, the walls of which are made of a highly permeable material that redirects the magnetic field around the chamber.



The Earth's magnetic field is measured as the Magnetic Field Sensor is rotated 360 degrees in the Earth's field.



The Magnetic Field Sensor is mounted on a Rotary Motion Sensor to measure the magnitude and direction of the Earth's magnetic field.

PASCO Advantage:

The sensitive Magnetic Field Sensor combined with the Rotary Motion Sensor enables the measurement of the magnetic field strength as a function of angle from North. It is essentially a computerized compass that can measure both the direction and the magnitude of the field.

Includes:

- PASPORT 2-Axis Magnetic Field Sensor PS-2162
- Zero Gauss Chamber EM-8652
- PASPORT Rotary Motion Sensor PS-2120A
- Dip Needle SF-8619
- Aluminum Table Clamp ME-8995
- Stainless Steel Rod, 25 cm Threaded ME-8988
- Adjustable Angle Clamp ME-8744
- Angle Indicator ME-9495A

Order Information

Earth's Magnetic Field Experiment..... EX-5539A

Required:

550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71

* This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

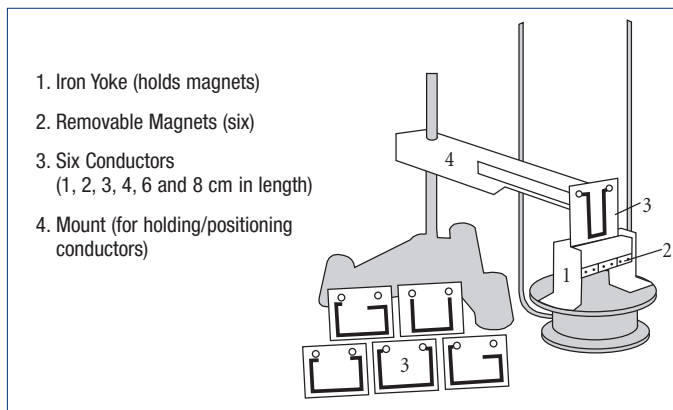
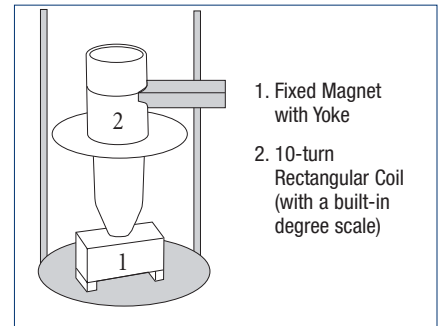
Electromagnetism

Magnetic Forces on Wires Experiment

EX-9933

Concepts:

- ▶ Examine the relationships between: force and current, force and length of wire, force and magnetic field strength, and force and angle

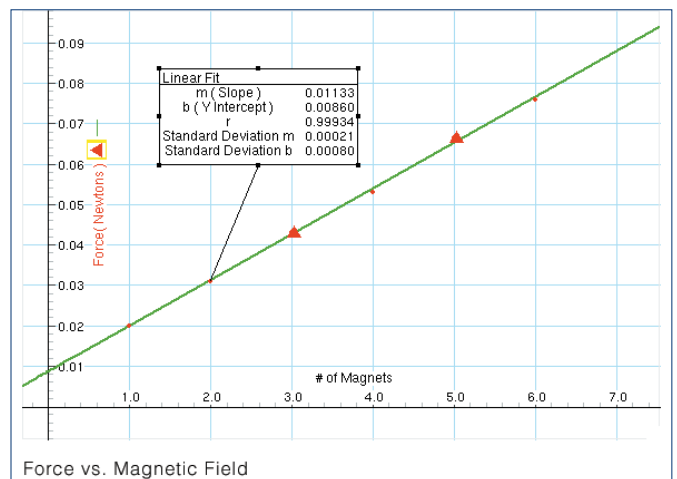


Magnets are mounted on an iron yoke and placed on a balance (resolution of at least 0.01 g). One of the conducting paths is suspended between the magnets. The balance is used to measure the mass of the magnets and yoke prior to any current passing through the conducting path. Current is then passed through the conducting path, producing a force. The change in reading on the balance can be converted to find the magnetic force between the conductor and magnetic field.

Conductors of different lengths are included to measure the effect of length on magnetic force. Magnetic field can be varied by changing the number of magnets in the yoke. The power source is used to change the current supplied to the conductor. The Current Balance Accessory includes all the components needed to test the effect of angle on magnetic force.

PASCO Advantage:

PASCO's Magnetic Forces on Wires Experiment allows students to study the key variables (conductor length, current, magnetic field strength, and angle) that affect magnetic force.



Graph illustrates the direct relationship between magnetic field and magnetic force.

Includes:

- Basic Current Balance SF-8607
- The Current Balance Accessory Kit SF-8608
- Ohaus Cent-O-Gram Balance SE-8725
- Low Voltage AC/DC Power Supply SF-9584B
- Base and Support Rod ME-9355
- Banana Plug Cord-Red (5 Pack) SE-9750
- Banana Plug Cord-Black (5 Pack) SE-9751
- Magnetic Forces on Wires Experiment Manual

Download This Experiment

Search for EX-9933 at www.pasco.com

Order Information

Magnetic Forces on Wires Experiment..... EX-9933
(No interface required.)

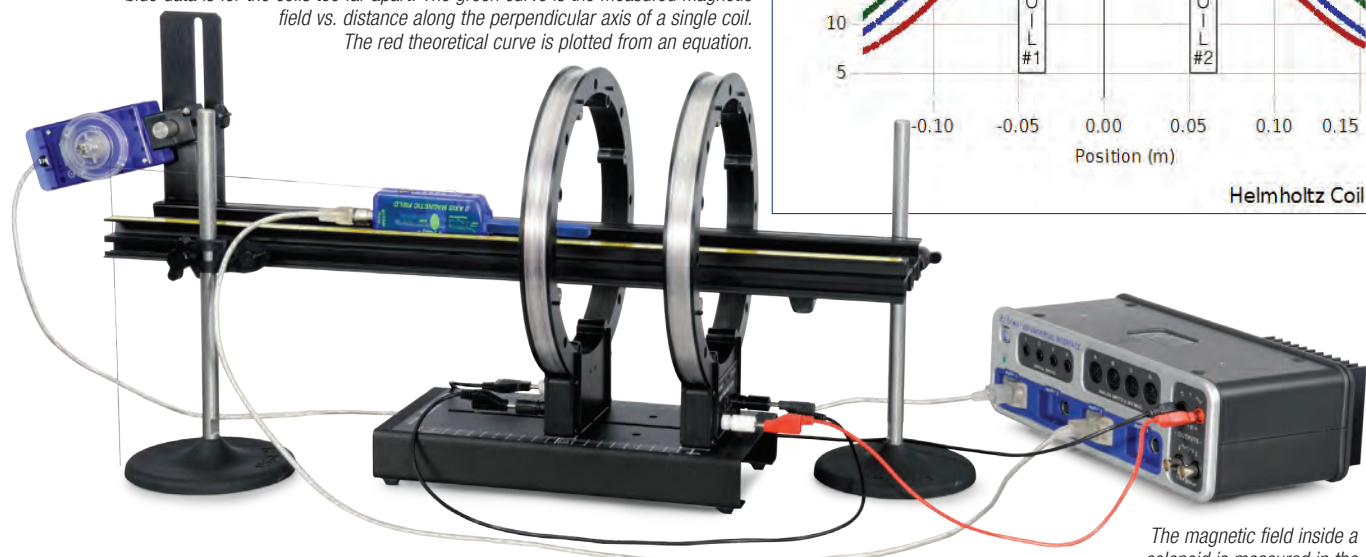
Magnetic Fields of Coils Experiment

EX-5540A

Concepts:

- ▶ Magnetic fields of single coil Helmholtz coils inside a solenoid

This plot shows the magnetic field strength along the axis of Helmholtz coils for three different coil separations. The green data is for coils with the proper separation (the coil radius); the red data is for the coils too close together; and the blue data is for the coils too far apart. The green curve is the measured magnetic field vs. distance along the perpendicular axis. The red theoretical curve is plotted from an equation.



The magnetic field inside a solenoid is measured in the radial and axial directions.

The magnetic field of Helmholtz coils is measured as a function of distance along the perpendicular axis.

The dependence of the magnetic field strength of current-carrying coils on the distance from the coil along the perpendicular axis is determined and compared to the theoretical curve. In addition, the effect of varying the coil separation on the shape of the magnetic field between the Helmholtz coils is examined.

The magnetic fields of various coils are plotted vs. position as the Magnetic Field Sensor is passed through the coils, guided by a track. The position is recorded by a string attached to the Magnetic Field Sensor that passes over the Rotary Motion Sensor pulley to a hanging mass.

It is particularly interesting to compare the field from Helmholtz coils at the proper separation of the coil radius to the field from coils separated at less than or more than the coil radius.

The magnetic field inside a solenoid can be examined in both the radial and axial directions.



PASCO Advantage:

Using the PASCO Capstone™ curve fit, the theoretical equation for the magnetic field can be plotted on the same graph.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Includes:

- Helmholtz Coil Base EM-6715
- 500-Turn Field Coils (2) EM-6723A
- Primary and Secondary Coils SE-8653A
- Banana Plug Cord-Red (5 Pack) SE-9750
- Banana Plug Cord-Black (5 Pack) SE-9751
- Optics Benches (60 cm) OS-8541
- Dynamics Track Mount CI-6692
- Hooked Mass Set SE-8759
- Round Base with Rod (2 of each) ME-8270
- Optics Bench Rod Clamp (set of 2) OS-8479
- PASPORT 2-Axis Magnetic Field Sensor PS-2162
- PASPORT Rotary Motion Sensor PS-2120A

Order Information

Magnetic Fields of Coils Experiment.....	EX-5540A
Required:	
550 or 850 Universal Interface.....	pp. 14-17
PASCO Capstone Software.....	pp. 68-71

Electromagnetism

Ampere's Law

EX-5552

Concepts:

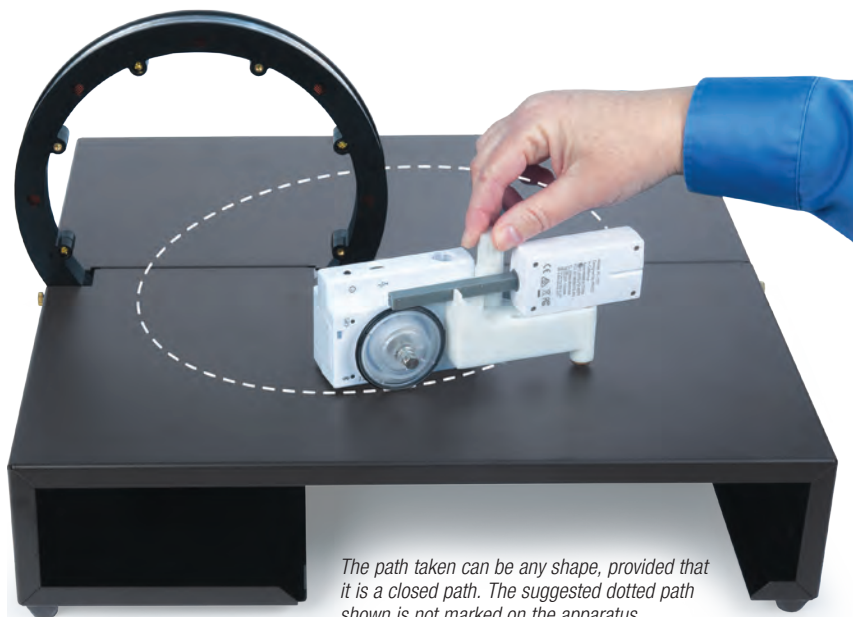
- ▶ Verify Ampere's Law
- ▶ Plot magnetic field tangent to path
- ▶ Closed integral is area under B vs. Distance plot
- ▶ Choose to enclose current in path or not

Students can verify Ampere's Law experimentally by graphing the magnetic field strength that is tangent to the path taken along a closed path that encloses a current source.

The magnetic field strength is measured with a Wireless Magnetic Field Sensor which rides on a Rotary Motion Sensor. The student pushes the Rotary Motion Sensor, which rolls on its wheel, along a closed path.

PASCO Advantage:

The Wireless 3-Axis Magnetic Field and Rotary Motion sensors allow the students to move in any shaped path without wires getting wrapped around the coil. Students can choose any path they want; you don't have to follow a circular path because the sensors are recording the field tangent to any path.



The path taken can be any shape, provided that it is a closed path. The suggested dotted path shown is not marked on the apparatus.

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 NI$$

Ampere's Law

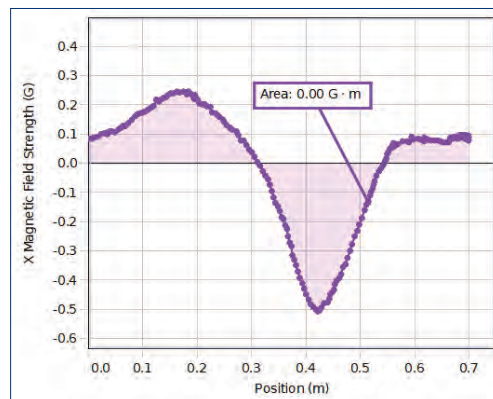
Area under B vs. Distance curve = μ_0 (# of coil turns enclosed in path) (Current)

The key to making this work is that the Magnetic Field Sensor element is positioned tangent to the Rotary Motion Sensor's wheel. This accomplishes the dot product in Ampere's Law because only the component of the magnetic field that is tangent to the path is recorded.

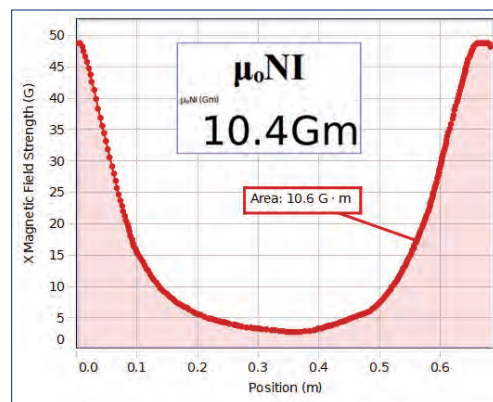
If you traverse a path that does not enclose any current source, the area under the curve is zero. The magnetic field of the Earth or any nearby source is measured but they will cancel out in a closed loop that encloses no current.

Includes:

- Ampere's Law Accessory EM-6720
- Wireless Magnetic Field Sensor PS-3221
- Wireless Rotary Motion Sensor PS-3220
- 500-Turn Field Coil EM-6723A
- Zero Gauss Chamber EM-8652



No current enclosed: Area is zero.



Current enclosed: Area is $\mu_0 NI$.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Ampere's Law EX-5552
 Required:
 PASCO Capstone Software pp. 68-71
 (No interface required.)

Faraday's Law of Induction Experiment

EX-5541A

Concepts:

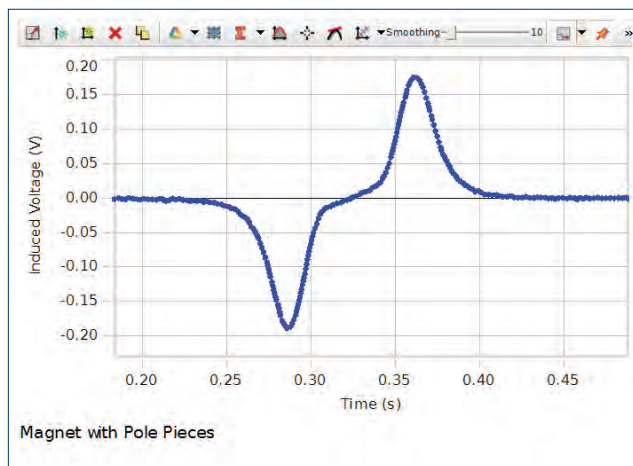
- ▶ Magnetic flux
- ▶ Faraday's Law of Induction
- ▶ Lenz's Law
- ▶ Conservation of energy
- ▶ Electrical power

A voltage is induced in a coil swinging through a magnetic field. Faraday's Law and Lenz's Law are examined and the energy dissipated in a load resistor is compared to the loss of energy of the coil pendulum.

A rigid pendulum with a coil at its end swings through a horseshoe magnet. A resistive load is connected across the coil and the induced voltage is recorded using a Voltage Sensor. The angle is measured with a Rotary Motion Sensor, which also acts as a pivot for the pendulum. The induced voltage is plotted vs. time and angle. The power dissipated in the resistor is calculated from the voltage and the energy converted to thermal energy is determined by finding the area under the Power vs. Time curve. This energy is compared to the loss of energy determined from the amplitude and speed of the pendulum.

Faraday's Law is used to estimate the magnetic field of the magnet from the maximum induced voltage. Also, the direction of the induced voltage as the coil enters and leaves the magnetic field is examined and analyzed using Lenz's Law.

A voltage is induced in a coil swinging through a magnetic field.



Plot of induced voltage as coil swings through the magnet



PASCO Advantage:

PASCO Capstone™ calculates energy and power using the voltage and angle data. The induced voltage and the calculations are plotted in real time as the coil swings through the magnet.

Includes:

- | | |
|--|----------|
| • Induction Wand | EM-8099 |
| • Large Rod Base | ME-8735 |
| • 45 cm Stainless Steel Rods (2) | ME-8736 |
| • Multi-Clamp | ME-9507 |
| • Voltage Sensor (unshrouded) | UI-5100 |
| • PASPORT 2-Axis Magnetic Field Sensor | PS-2162 |
| • PASPORT Rotary Motion Sensor | PS-2120A |
| • Variable Gap Magnet | EM-8618 |

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Faraday's Law of Induction Experiment.....	EX-5541A
Required:	
550 or 850 Universal Interface.....	pp. 14-17
PASCO Capstone Software.....	pp. 68-71

Waves and Optics

Vibrating Strings Experiment

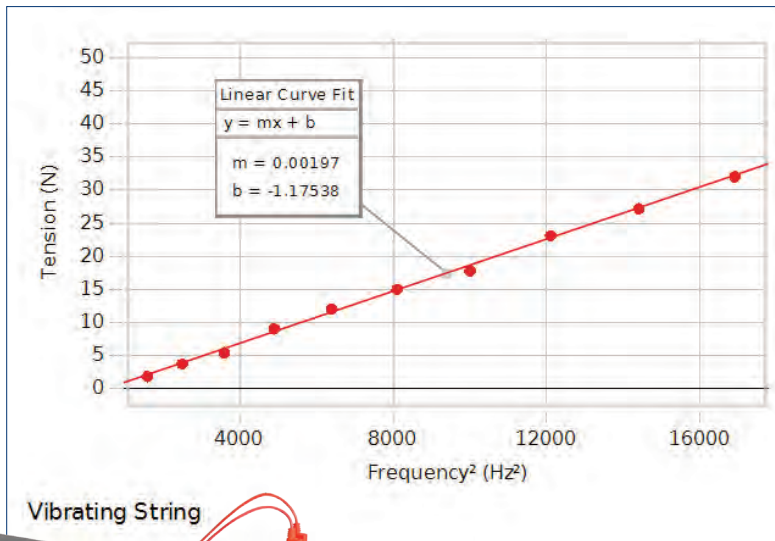
EX-5542

Concepts:

- ▶ Investigate standing waves
- ▶ Pull string to adjust number of segments
- ▶ Vary frequency of vibration

Study standing waves in a string by varying the driver frequency and keeping the number of segments constant. The String Vibrator is powered by the 850 Universal Interface. Students vary both the frequency and amplitude.

The string tension is measured directly with a Force Sensor, enabling students to feel the force required to obtain a certain number of segments.



A graph of force vs. the square of the frequency shows a linear relationship. The slope of this line is related to the length and density of the string.

PASCO Advantage:

The unusual approach in this version of the experiment is that the students actually provide the tension in the string by pulling directly on the force sensor. This is particularly instructive because the students get a feel for how the tension must change to vary the number of segments. Rather than hanging more weight over a pulley, the students must pull harder to achieve a smaller number of segments. This helps them remember the relationship between tension and wavelength.

The 850 Universal Interface controls the frequency and amplitude of the sine waves applied to the String Vibrator. As the frequency is gradually increased (in 10 Hz increments), the student pulls on the Force Sensor to adjust the tension for resonance with the string vibrating in two segments.

Includes:

- | | |
|--|----------|
| • String Vibrator | WA-9857A |
| • Braided Physics String | SE-8050 |
| • PASPORT High Resolution Force Sensor | PS-2189 |
| • Large "C" Clamp | |
| • Banana Plug Cord-Red (5 Pack) | SE-9750 |
| • 30 Meter Measuring Tape | SE-8712A |

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Vibrating Strings Experiment.....	EX-5542
Required:	
550 or 850 Universal Interface.....	pp. 14-17
PASCO Capstone Software.....	pp. 68-71

Mechanical Waves Experiment

EX-9952

Concepts:

- ▶ Speed of waves in a string
- ▶ Resonance in strings and air columns
- ▶ Speed of sound in air
- ▶ Harmonics



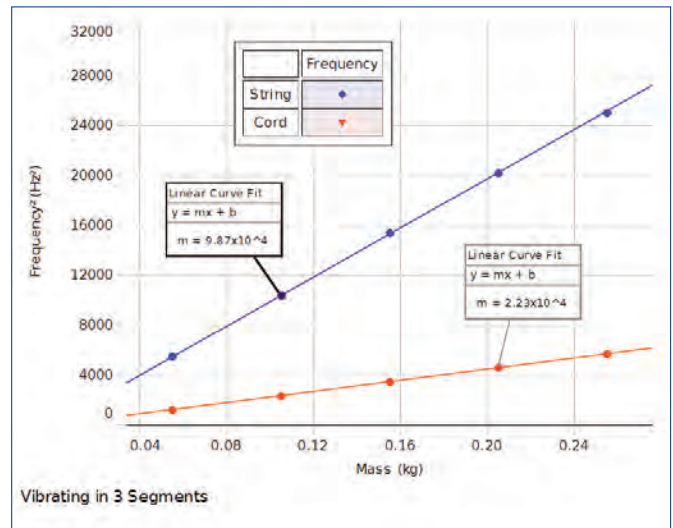
Standing waves in strings and air columns are studied. Using a sine wave generator to drive a string vibrator, the driving frequency, length, density, and tension of the string are varied to explore standing waves in strings and to determine the speed of the wave. For the sound waves in the air column, a speaker is used to drive a resonance tube. The driving frequency and the length of the tube are varied for both open and closed tubes. The relationship between resonant frequency modes and tube length is determined for closed vs. open tubes.

PASCO Advantage:

The frequency of the vibration of the string is not limited to the line frequency, so the frequency can be varied as well as the length and the tension.

Includes:

- String Vibrator WA-9857A
- Sine Wave Generator WA-9867
- Open Speaker WA-9900
- Economy Resonance Tube WA-9495
- Elastic Wave Cord SE-9409
- Braided Physics String SE-8050
- Mass and Hanger Set ME-8979
- Universal Table Clamp (2) ME-9376B
- Adjustable Angle Clamp ME-8744
- Super Pulley ME-9450A
- Pulley Mounting Rods SA-9242
- 45 cm Stainless Steel Rod (2) ME-8736
- Banana Plug Cord-Red (5 Pack) SE-9750
- Waves Experiment Manual



Graphs of the square of the frequency vs. the hanging mass for two different types of strings have different slopes corresponding to different string densities.

Download This Experiment

Search for EX-9952 at www.pasco.com

Order Information

Mechanical Waves Experiment..... EX-9952
(No interface required.)

Waves and Optics

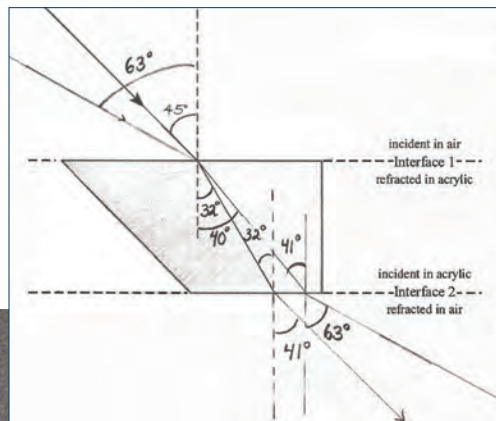
Reflection and Refraction

EX-9987

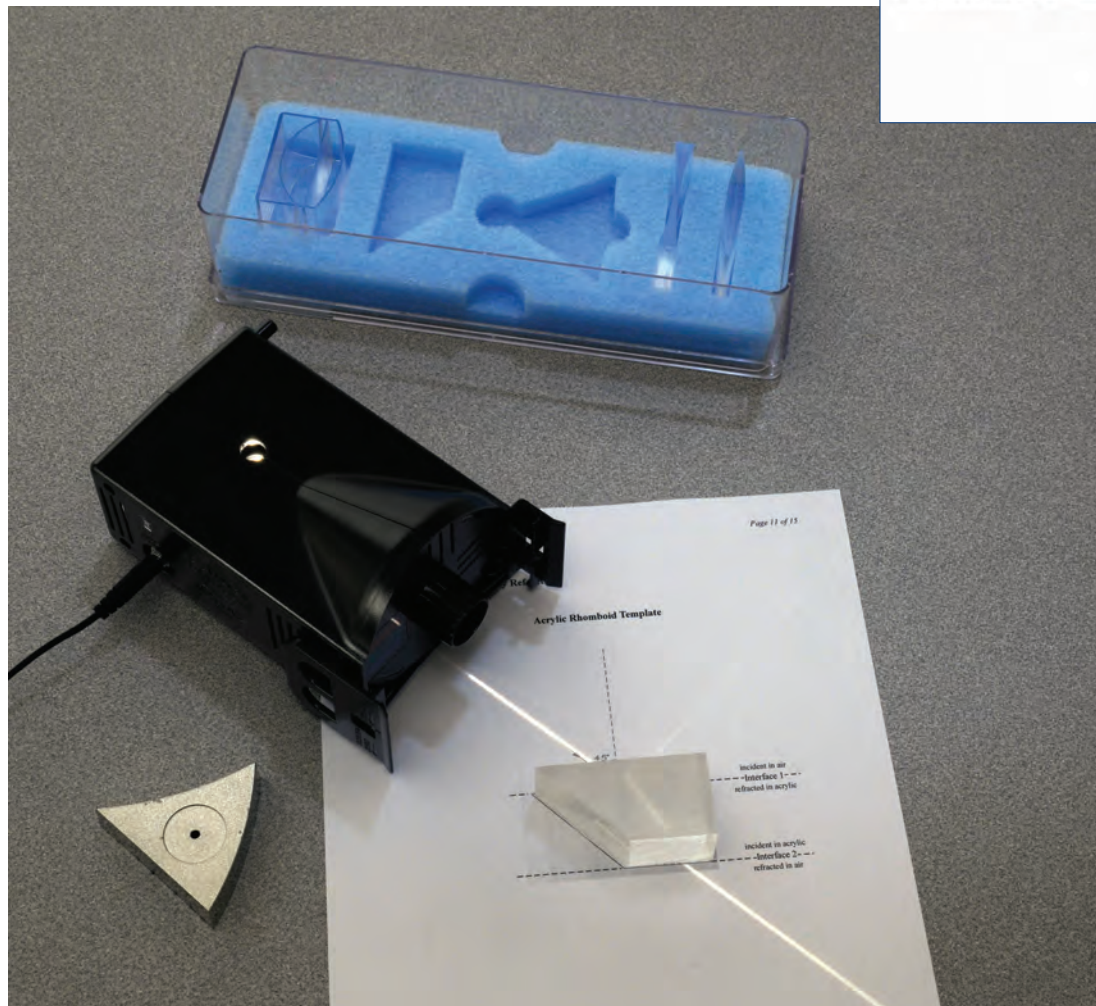
Concepts:

- ▶ Reflection and Refraction
- ▶ Index of Refraction

Students experimentally derive the Law of Reflection for curved and flat mirrors. Snell's Law is explored and the index of refraction for a piece of acrylic material is found.



Sample of student work, showing the path of two different rays passing through the acrylic rhomboid.



PASCO Advantage:

Students trace the rays on the provided templates and make angle measurements directly from their drawing. This reinforces the connection between the real rays they can see in the lab and the type of ray diagrams seen in the classroom.

Includes:

- Ray Optics Kit OS-8516A
- Basic Optics Light Source OS-8470
- Reflection and Refraction Experiment Manual

Download This Experiment
 Search for EX-9987 at www.pasco.com

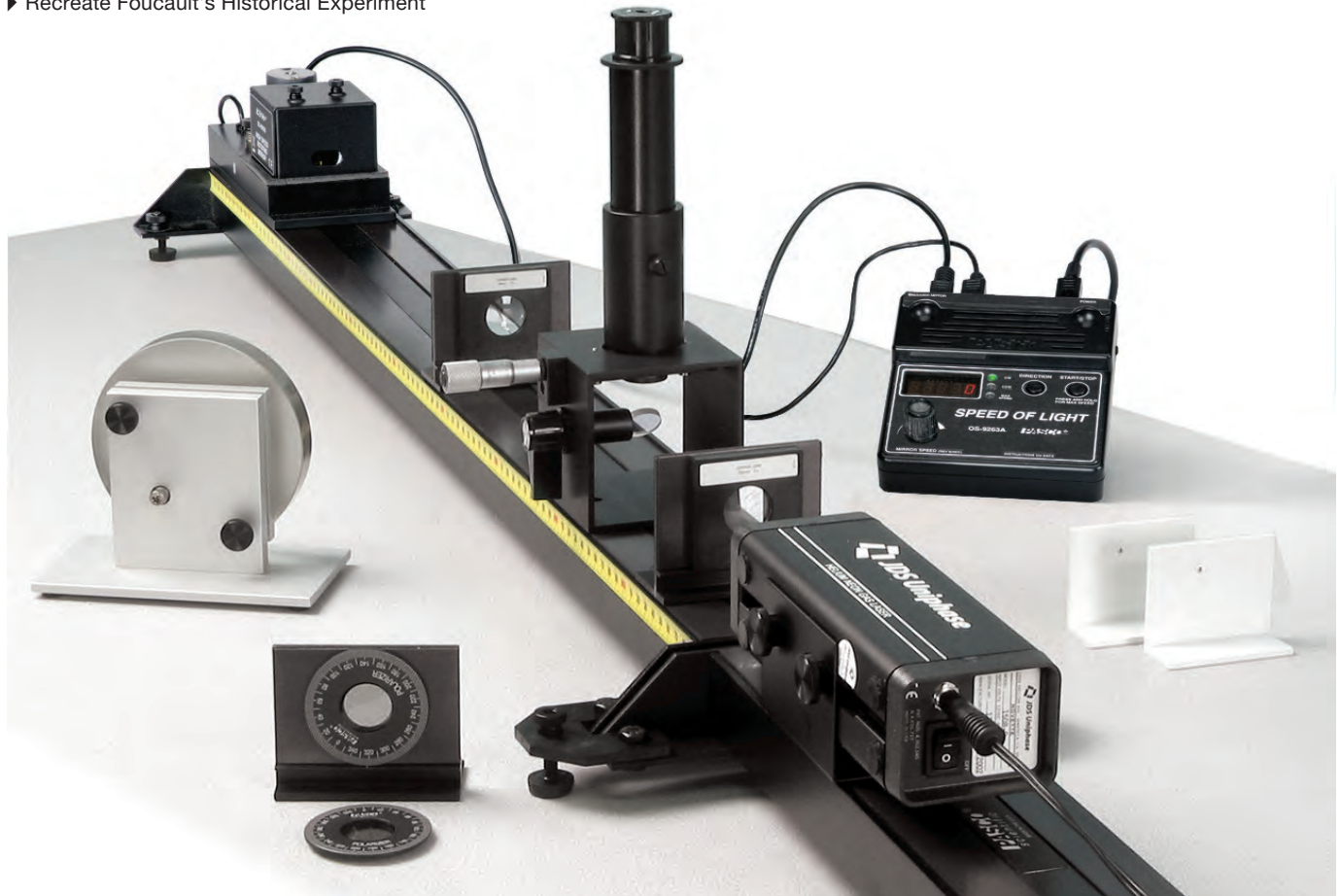
Order Information
 Reflection and Refraction.....EX-9987
 Required:
 Protractor and Ruler

Speed of Light Experiment

EX-9932A

Concepts:

- ▶ Determine the Speed of Light in Air
- ▶ Recreate Foucault's Historical Experiment



The Speed of Light Experiment uses laser light and a high speed rotating mirror to determine this fundamental constant using the Foucault method.

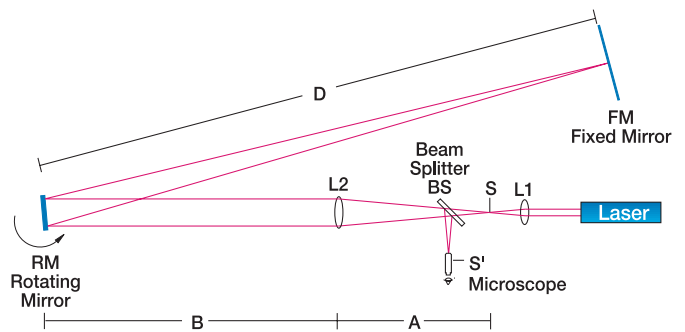
Laser light passes through a series of lenses to produce an image of the light source at a measured position. The light is then directed to a rotating mirror, which reflects the light to a fixed mirror at a known distance from the rotating mirror. The laser light is reflected back through its original path and a new image is formed at a slightly different position. The difference between final/initial positions, angular velocity of the rotating mirror, and distance traveled by the light are then used to calculate the speed of light in air.

PASCO Advantage:

PASCO's Speed of Light Experiment allows students to experimentally measure the speed of light within 5% of the accepted value. In addition, the experiment can be performed on a desktop or in a hallway.

Includes:

- Complete Speed of Light Apparatus OS-9261B
- Speed of Light Experiment Manual



Download This Experiment

Search for EX-9932A at www.pasco.com

Order Information

Speed of Light Experiment..... EX-9932A
(No interface required.)

Waves and Optics

Telescope/Microscope

EX-9988

Topics Covered:

- ▶ Multiple Lens Systems
- ▶ Parallax
- ▶ Magnification
- ▶ Description of Images

Students construct an astronomical telescope, a Galilean telescope, and a compound microscope on the optical bench. Using a viewing screen with grid, they find and describe the ways in which images are changed by the multiple lens systems.

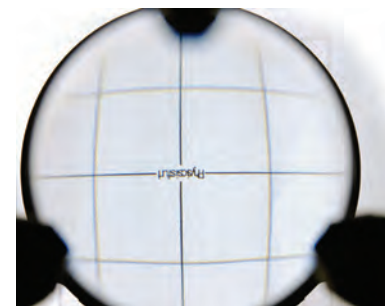
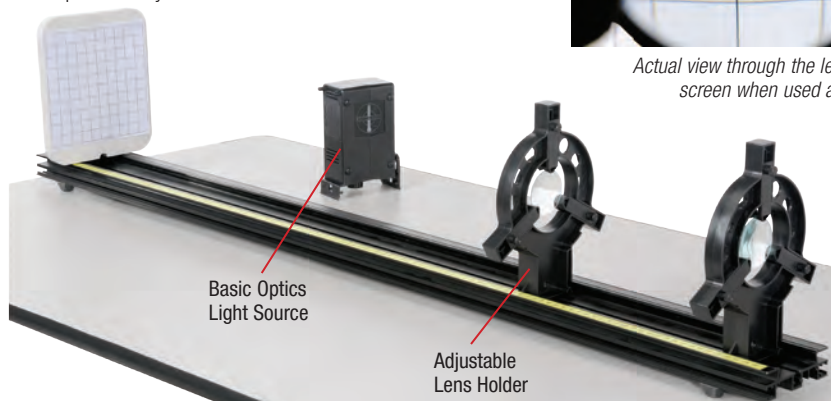
The parallax method is used to locate virtual images. Students draw ray diagrams and measure the magnification of the instruments.

PASCO Advantage:

Using the Basic Optics Track and Adjustable Lens Holders makes it easy for students to quickly build each of the instruments. Open construction means that all students can see the location and types of lenses used.

Includes:

- Basic Optics Light Source OS-8470
- Adjustable Lens Holder (2) OS-8474
- Geometric Lens Set OS-8466A
- Basic Optics Viewing Screen OS-8460
- 1.2 m Optics Track OS-8508



Actual view through the lens of magnified screen when used as a microscope

Download This Experiment

Search for EX-9988 at www.pasco.com

Order Information

Telescope/Microscope EX-9988
 Required:
 Rubber Bands and Ruler

Light Intensity vs. Distance Experiment

EX-5547A

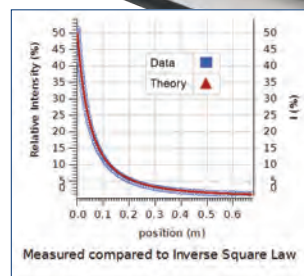
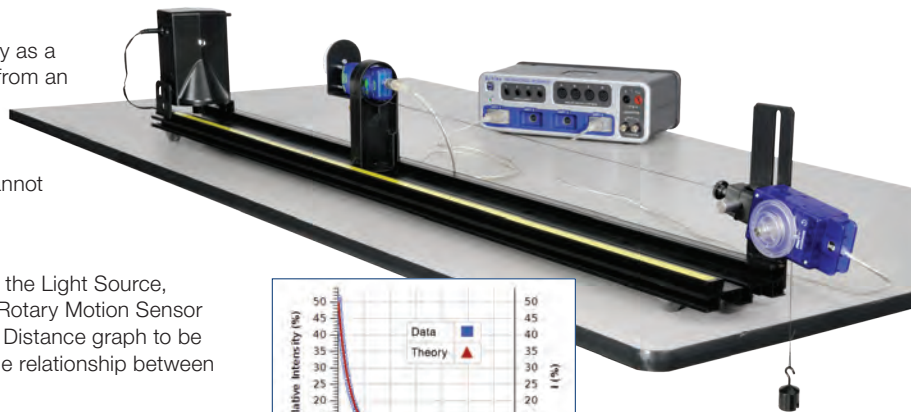
In this experiment the student measures intensity as a function of distance from a point of source and from an extended (5 cm x 5 cm) source. Manipulation of a computer model verifies that for the point source, the intensity drops off like an inverse square. But for the extended source the data cannot be fit by an inverse square relationship.

PASCO Advantage:

As the student slides the light sensor away from the Light Source, the Optics Track keeps everything aligned. The Rotary Motion Sensor measures the position, allowing the Intensity vs. Distance graph to be plotted in real time. Students immediately see the relationship between distance and intensity of light.

Includes:

- 1.2 m Optics Track OS-8508
- Basic Optics Light Source OS-8470
- Aperture Bracket OS-8534A
- Hooked Mass Set SE-8759
- PASPORT High Sensitivity Light Sensor PS-2176
- PASPORT Rotary Motion Sensor PS-2120A
- Dynamics Track Mount CI-6692



Order Information

Light Intensity vs. Distance Experiment EX-5547A
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Interference and Diffraction of Light Experiment

EX-5545A

Concepts:

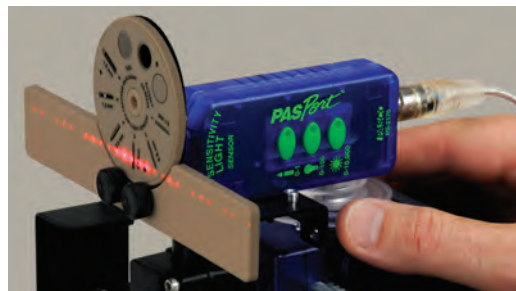
- ▶ Two-slit interference
- ▶ Multiple-slit minor maxima
- ▶ Single-slit diffraction
- ▶ Slit vs. line diffraction

Interference and diffraction patterns from laser light passing through various single-slits and multiple-slits are scanned and plotted in real time. These patterns are then examined for similarities and differences.

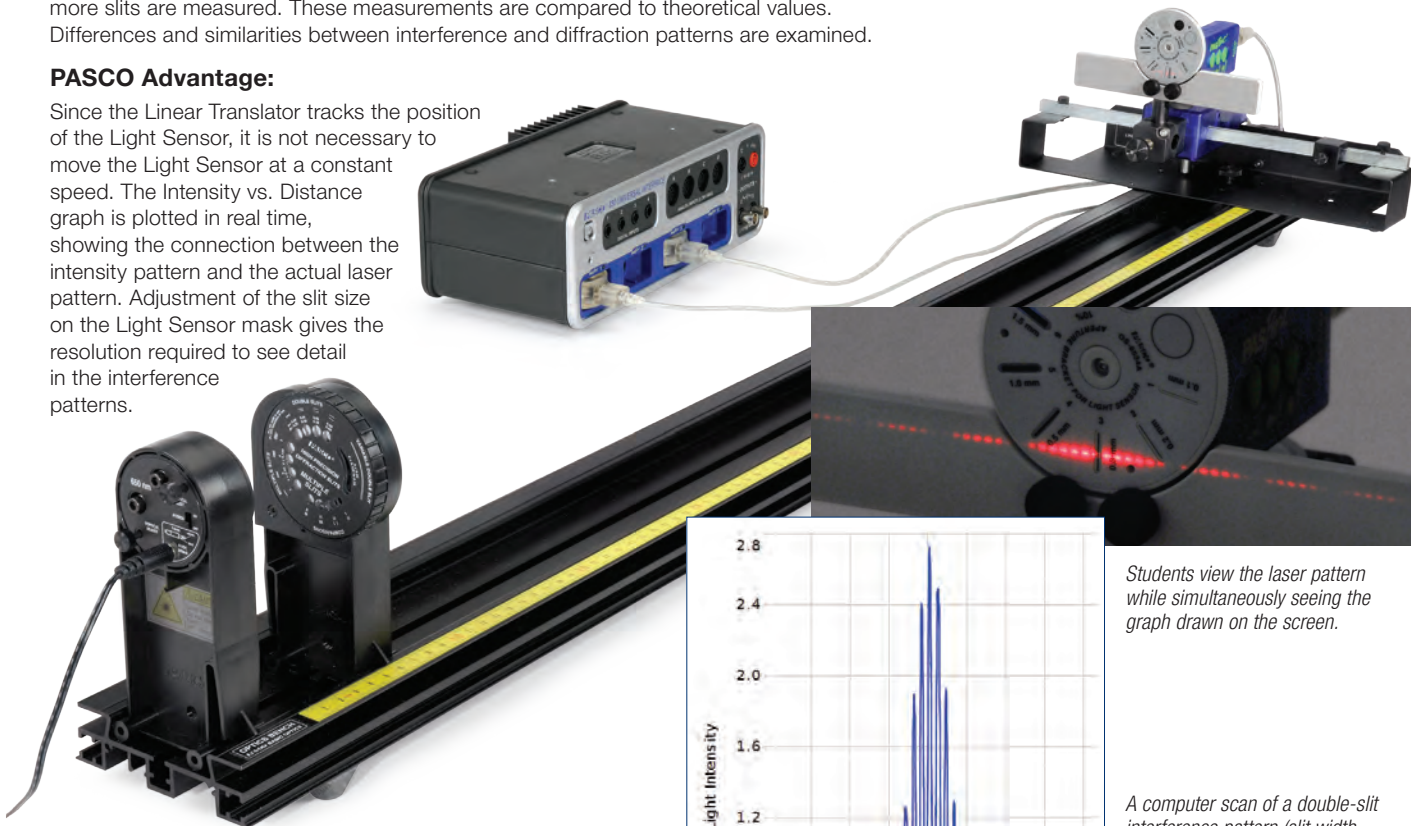
The distances between the central maximum and the diffraction minima for a single slit are measured by scanning the laser pattern with a Light Sensor and plotting light intensity vs. distance. Also, the distances between interference maxima for two or more slits are measured. These measurements are compared to theoretical values. Differences and similarities between interference and diffraction patterns are examined.

PASCO Advantage:

Since the Linear Translator tracks the position of the Light Sensor, it is not necessary to move the Light Sensor at a constant speed. The Intensity vs. Distance graph is plotted in real time, showing the connection between the intensity pattern and the actual laser pattern. Adjustment of the slit size on the Light Sensor mask gives the resolution required to see detail in the interference patterns.

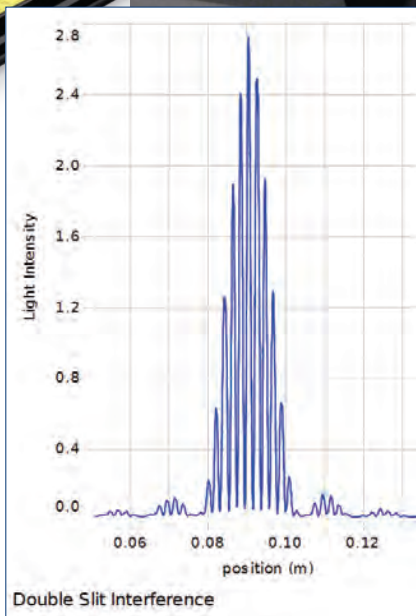


The laser interference pattern is scanned by hand with a Light Sensor on a Linear Translator.



Includes:

- 1.2 m Optics Track OS-8508
- Precision Diffraction Slits OS-8453
- Red Diode Laser OS-8525A
- Aperture Bracket OS-8534A
- Linear Translator OS-8535A
- PASPORT High Sensitivity Light Sensor PS-2176
- PASPORT Rotary Motion Sensor PS-2120A



Students view the laser pattern while simultaneously seeing the graph drawn on the screen.

A computer scan of a double-slit interference pattern (slit width 0.08 mm and slit separation 0.50 mm) is shown at left. A photograph of the actual laser pattern is shown above.

Order Information

Interference and Diffraction of Light Experiment..... EX-5545A
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Waves and Optics

Polarization Experiment

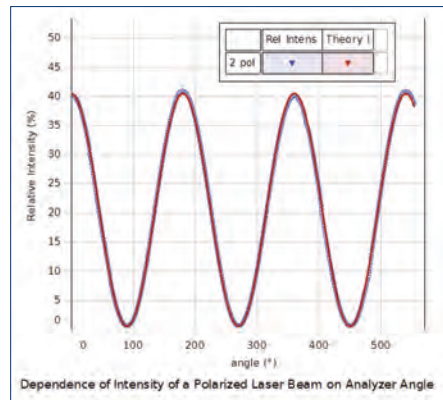
EX-5543A

Concepts:

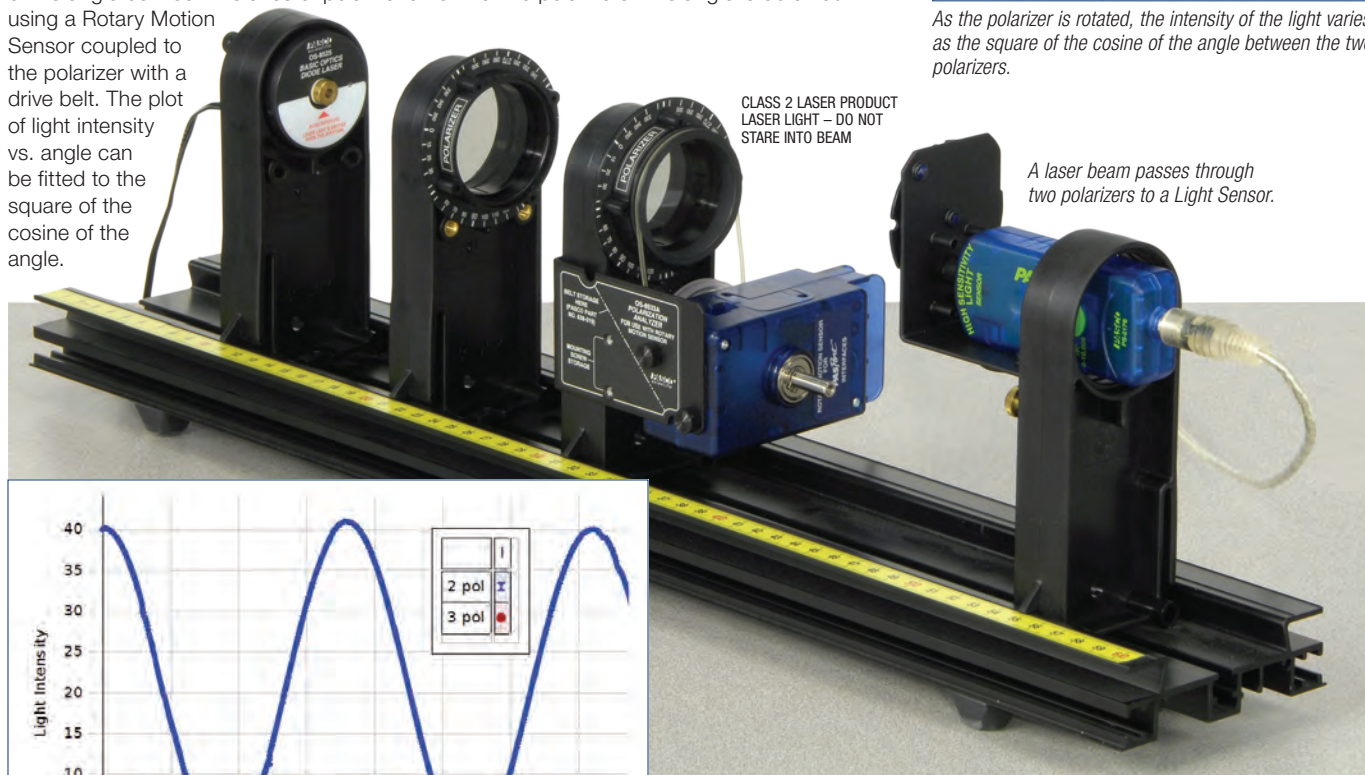
- ▶ Measure the Zeeman Effect with polarization perpendicular and parallel to the field
- ▶ Observe the light along the magnet axis
- ▶ Calculate the value of the Bohr magneton
- ▶ Malus' Law of Polarization

In this experiment, Malus' Law of Polarization is verified by showing that the intensity of light passed through two polarizers depends on the square of the cosine of the angle between the two polarization axes.

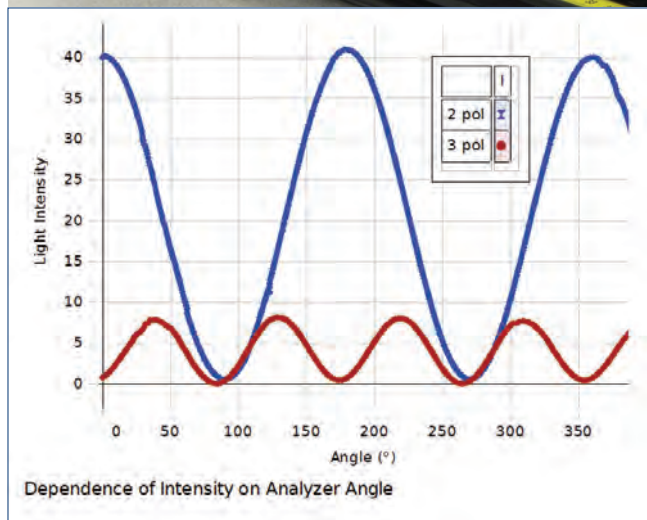
Laser light (peak wavelength = 650 nm) is passed through two polarizers. As the second polarizer (the analyzer) is rotated by hand, the relative light intensity is recorded as a function of the angle between the axes of polarization of the two polarizers. The angle is obtained using a Rotary Motion Sensor coupled to the polarizer with a drive belt. The plot of light intensity vs. angle can be fitted to the square of the cosine of the angle.



As the polarizer is rotated, the intensity of the light varies as the square of the cosine of the angle between the two polarizers.



A laser beam passes through two polarizers to a Light Sensor.



A three-polarizer system can be produced using the fact that the laser is polarized. The data (red trace) at left shows that there are four oscillations per full rotation for a three-polarizer system.

PASCO Advantage:

Laser light is used in this experiment because its wavelength is more completely extinguished by the crossed polarizers.

Includes:

- Polarization Analyzer OS-8533A
- Optics Benches (60 cm) OS-8541
- Red Diode Laser OS-8525A
- PASPORT High Sensitivity Light Sensor PS-2176
- PASPORT Rotary Motion Sensor PS-2120A

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

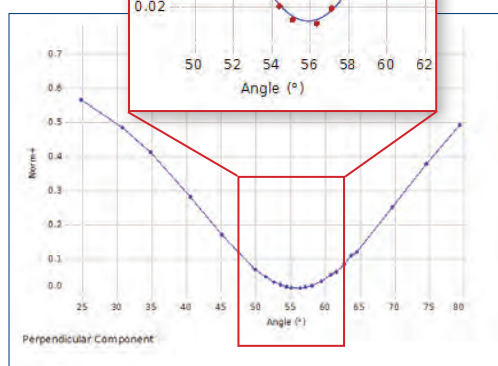
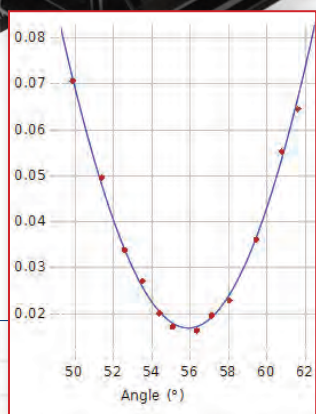
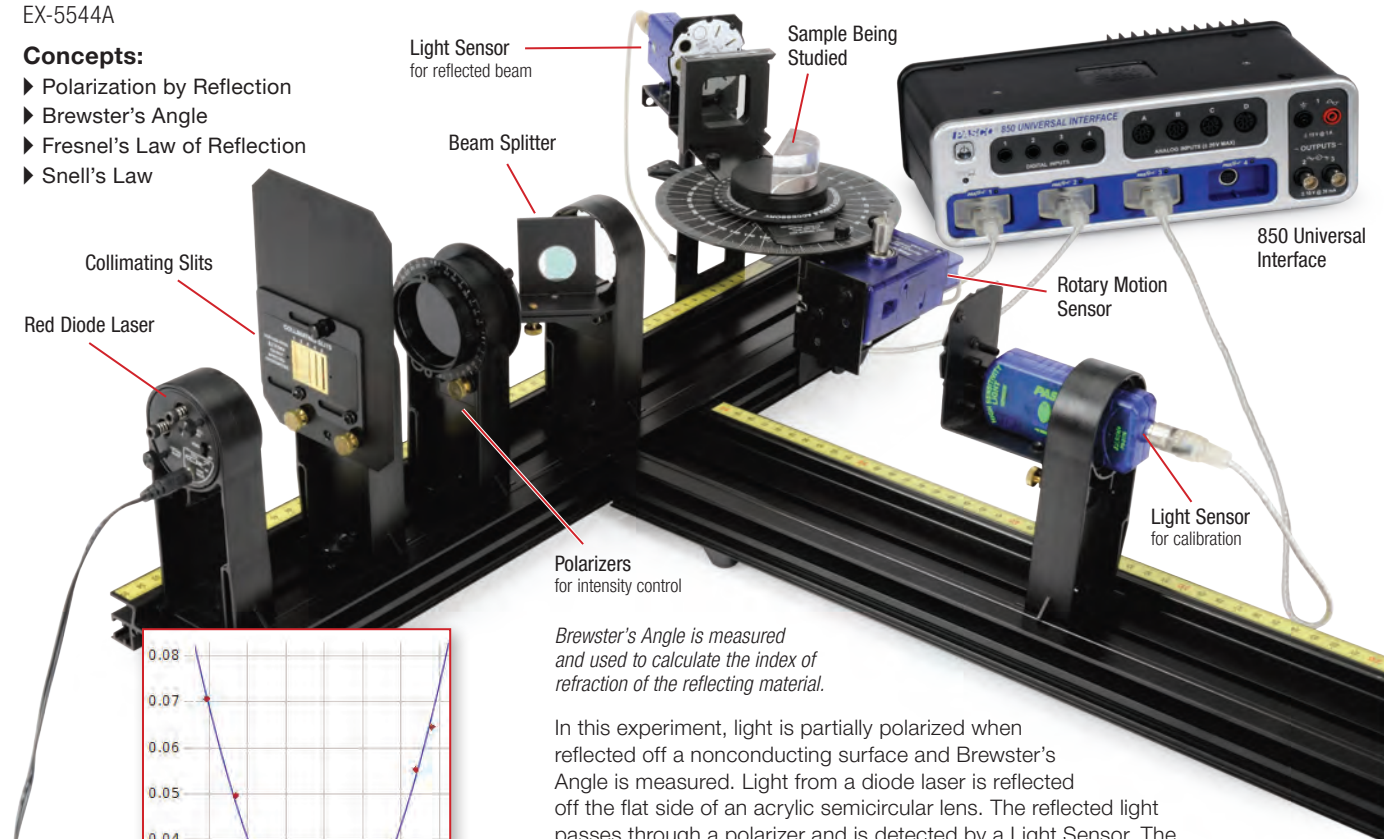
Polarization Experiment EX-5543A
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Brewster's Angle Experiment

EX-5544A

Concepts:

- ▶ Polarization by Reflection
- ▶ Brewster's Angle
- ▶ Fresnel's Law of Reflection
- ▶ Snell's Law



Brewster's Angle is measured and used to calculate the index of refraction of the reflecting material.

In this experiment, light is partially polarized when reflected off a nonconducting surface and Brewster's Angle is measured. Light from a diode laser is reflected off the flat side of an acrylic semicircular lens. The reflected light passes through a polarizer and is detected by a Light Sensor. The angle of reflection is measured by a Rotary Motion Sensor mounted on the Spectrophotometer table. The intensity of the reflected polarized light vs. reflected angle is graphed to determine the angle at which the light intensity is a minimum. This is Brewster's Angle, which is used to calculate the index of refraction of acrylic.

PASCO Advantage:

It is possible to determine the difference in index of refraction for different wavelengths of light. This is accomplished by using a beam-splitter and a second light sensor to compensate for the variation of the laser intensity. The reflected beam intensity is normalized by the intensity of the laser. This modification to the experiment was suggested by Cristian Bahrim and Wei-Tai Hsu in the American Journal of Physics article: "Precise Measurement of the Refractive Indices for Dielectrics Using an Improved Brewster Angle Method", Vol. 77, page 337 (2009).

Developed using original ideas from P.J. Ouseph, Professor of Physics at University of Louisville, KY: "Polarization of Light by Reflection and the Brewster Angle" by P.J. Ouseph, Kevin Driver, and John Conklin, Am. J. Phys. 69, 1166 (2001).

Brewster's Angle is determined by finding the angle at which no light is transmitted through the analyzing polarizer.

Includes:

- Brewster's Angle Accessory OS-8170A
- Educational Spectrophotometer Accessory Kit OS-8537
- Optics Benches (60 cm) (2) OS-8541
- PASPORT Rotary Motion Sensor PS-2120A
- PASPORT High Sensitivity Light Sensor (2) PS-2176
- Aperture Bracket (2) OS-8534A
- Red Diode Laser OS-8525A
- Polarizer Set OS-8473

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Brewster's Angle Experiment EX-5544A
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with three ports.

Quantum

Atomic Spectra Experiment

EX-5546B

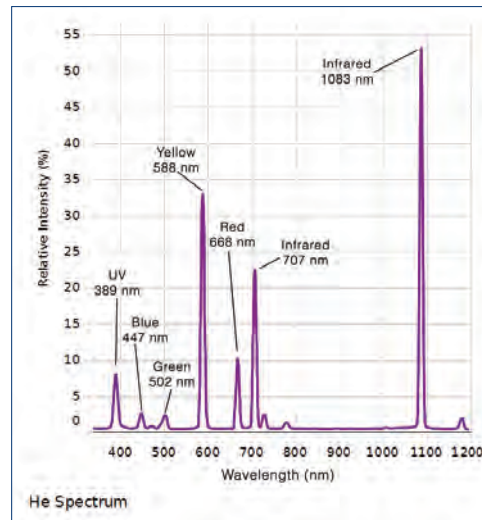
Concepts:

- ▶ Hydrogen balmer series
- ▶ Helium spectrum
- ▶ Mercury doublet

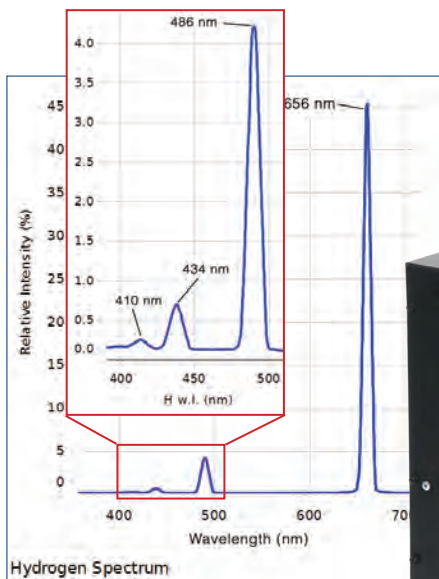
The wavelengths of the discrete lines of the atomic spectra of various gases are measured using a grating spectrophotometer.

The atomic spectra of hydrogen, helium, and mercury are scanned by hand using a grating spectrophotometer, which measures relative light intensity as a function of angle. From the resulting graph, the wavelengths of the spectral lines are determined by measuring the angle from the central maximum to each line. First and second order lines are examined.

The wavelengths of the spectral lines are compared to the accepted values and, in the case of hydrogen, the electron orbit transitions corresponding to the lines are identified.



The spectral lines of helium are scanned.

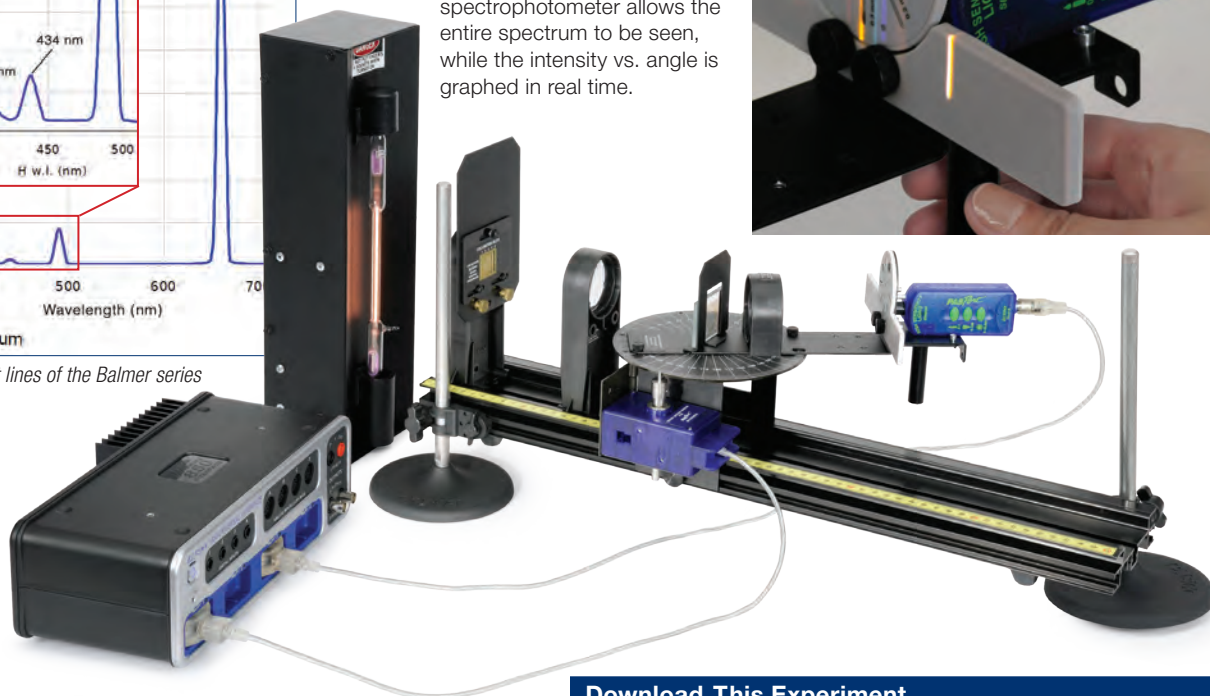
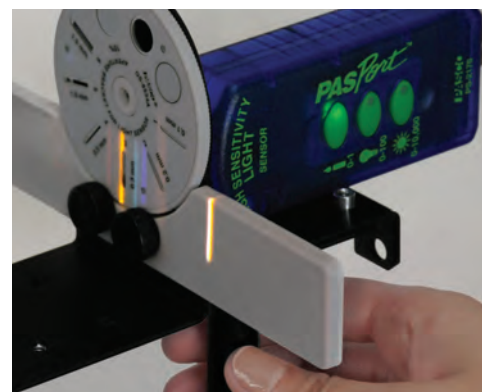


Hydrogen Spectrum

The four brightest lines of the Balmer series for hydrogen

PASCO Advantage:

The open construction of the spectrophotometer allows the entire spectrum to be seen, while the intensity vs. angle is graphed in real time.



Includes:

- Educational Spectrophotometer Accessory Kit OS-8537
- Optics Benches (60 cm) OS-8541
- Aperture Bracket OS-8534A
- PASPORT High Sensitivity Light Sensor PS-2176
- PASPORT Rotary Motion Sensor PS-2120A
- Round Base with Rod (2) ME-8270
- Spectral Tube Power Supply and Mount SE-9460
- Spectral Tube (Hydrogen) SE-9461
- Spectral Tube (Helium) SE-9462
- Spectral Tube (Mercury) SE-9466

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Atomic Spectra Experiment..... EX-5546B
 Required:
 550 or 850 Universal Interface* pp. 14-17
 PASCO Capstone Software pp. 68-71
 * This experiment can be performed using the 550 or 850 Universal Interface or any PASPORT interface with two ports.

Photoelectric Effect Experiment

EX-5549A

Concepts:

- ▶ Connects to the 850 Universal Interface for data collection in PASCO Capstone
- ▶ Find Planck's Constant within 5%
- ▶ Verify that stopping voltage is independent of intensity
- ▶ Find characteristics of the photodiode

The Photoelectric Effect System is used to perform the photoelectric experiment, determining Planck's Constant within 5%. This apparatus uses the conventional method of determining Planck's Constant. The metal plate in the photodiode is illuminated with various frequencies of light, selected from a mercury lamp using filters. The voltage is then adjusted to stop the photoelectric current. The stopping voltage is plotted vs. the frequency, and Planck's Constant is determined from the slope of the graph. The concept that the stopping voltage does not change with light intensity is tested using the various apertures that change the light intensity by partially blocking the light.

Use the 850 Universal Interface and PASCO Capstone to collect and analyze data.

Both the picoammeter and the power supply for the stopping voltage have sensor ports on the front that connect to the analog sensor ports of the 850 Universal Interface. PASCO Capstone automatically recognizes these instruments and can read the current and the voltage. During the experiment, each time a different filter is applied, the user clicks "Keep" in PASCO Capstone and the value of the stopping voltage for that frequency is recorded and automatically graphed vs. frequency.

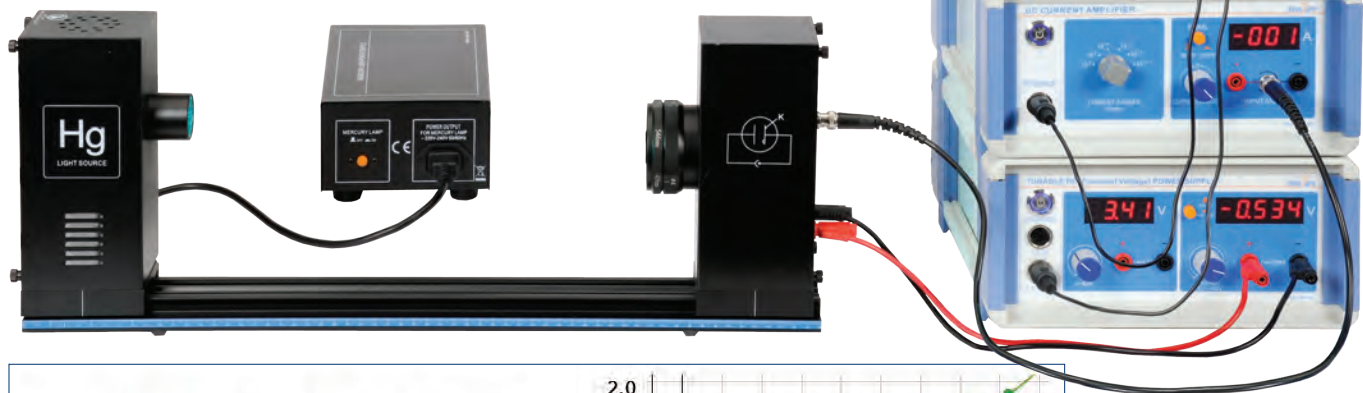
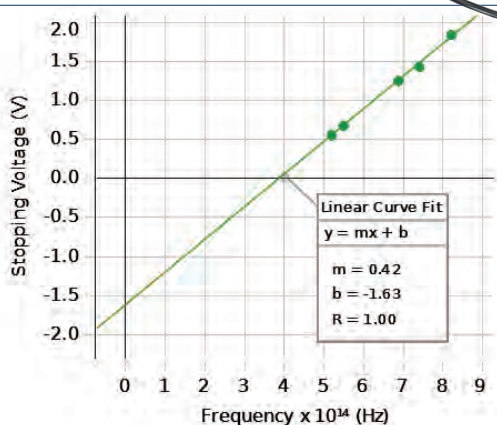


Table I: Photoelectric Effect with 4 mm Aperture

	▲ Run #1	■ Run #1
	Frequency $\times 10^{14}$ (Hz)	Stopping Voltage (V)
1	8.214	1.835
2	7.408	1.428
3	6.879	1.248
4	5.490	0.671
5	5.196	0.551



For the typical sample data shown, the graph of Stopping Voltage vs. Frequency gives a slope of 4.2×10^{-15} V-s. This results in a value for Planck's Constant of 6.7×10^{-34} J-s, which is 1.3% above the accepted value. Graph generated using PASCO Capstone software.

Includes:

- Basic Photoelectric Effect Apparatus SE-6614
- DC Current Amplifier SE-6621
- DC Power Supply I (Constant Voltage) SE-6615
- Cables for 850 Interface

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Photoelectric Effect Experiment EX-5549A
 Required:
 550 or 850 Universal Interface pp. 14-17
 PASCO Capstone Software pp. 68-71

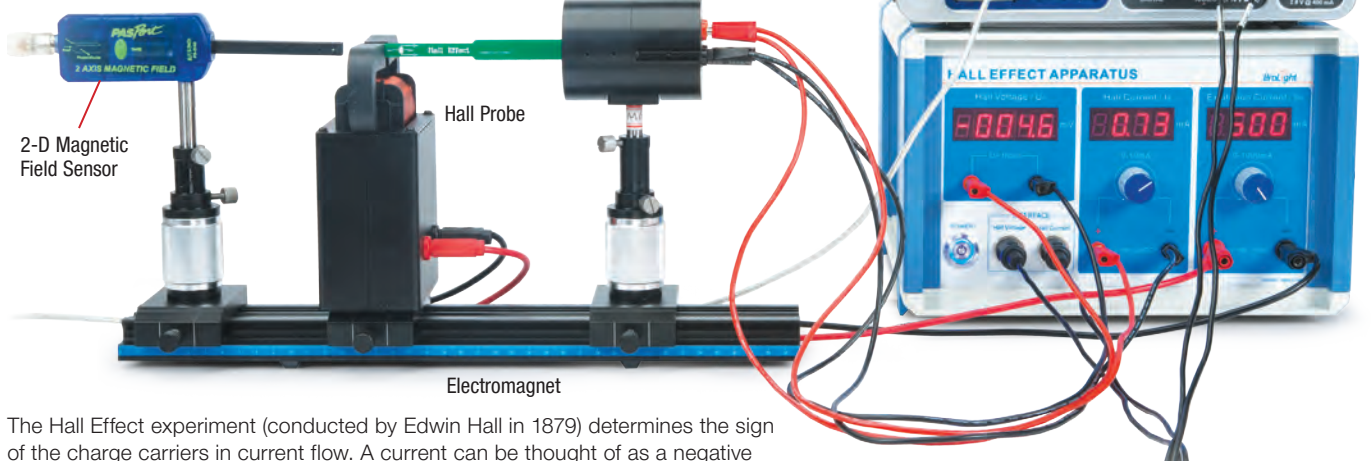
Quantum

Hall Effect Experiment

EX-5560

Concepts:

- ▶ Determine sign of charge carriers
- ▶ Vary magnetic field and current



The Hall Effect experiment (conducted by Edwin Hall in 1879) determines the sign of the charge carriers in current flow. A current can be thought of as a negative charge moving in one direction (Figure 1) or as a positive charge moving in the opposite direction (Figure 2). To determine which it actually is, the semiconductor is immersed in the magnetic field transverse to the direction of flow of current. The moving charge experiences a force, causing a charge buildup on one side of the semiconductor (creating an electric field), which in turn leads to a force. The direction of the electric field will depend on the sign of the charge carriers, and the polarity of the Hall voltage across the semiconductor reveals this sign.

The magnitude of the Hall voltage is dependent on the current, the charge carrier density, and the magnitude of the magnetic field. In modern day electronics, the Hall Effect is used to measure the magnitude and direction of magnetic fields.

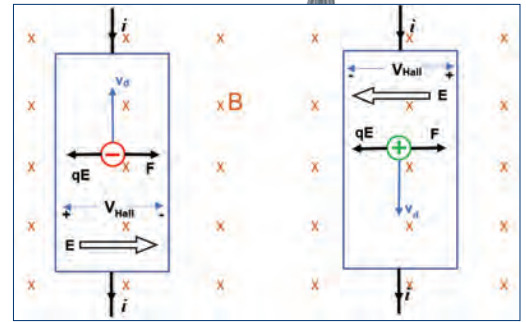
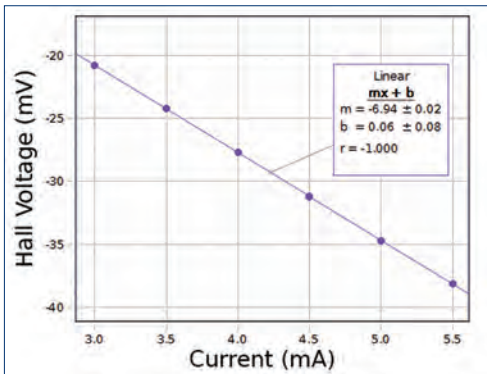


Figure 1

Figure 2



Using the 550 Universal Interface to record data, this plot of the Hall Voltage vs. the Current was made in PASCO Capstone software. In this case, the magnetic field was held constant and the current through the semiconductor was varied.

Includes:

- Hall Probe Unit, n-Semiconductor (GaAs)
- Hall Effect Power Supply
- U-Core Electromagnetic Coil
- Track, Length 40 cm
- Optical Carrier (2)
- PASPORT 2-Axis Magnetic Field Sensor PS-2162
- Adjustable Post Holder with 9 cm Post (2)
- Banana Cords (6)
- Connecting Cables for 550/850 Interface (2)

PASCO Advantage:

The open design of this Hall Effect apparatus makes it possible for students to see the direction of the current and the magnetic field, enabling them to use the sign of the Hall voltage to deduce the sign of the charge carriers.



The directions of the current and the voltage probe are clearly marked on the probe that holds the semiconductor.

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Hall Effect Experiment.....	EX-5560
Required:	
550 or 850 Universal Interface.....	pp. 14-17
PASCO Capstone Software.....	pp. 68-71

Franck-Hertz Experiment

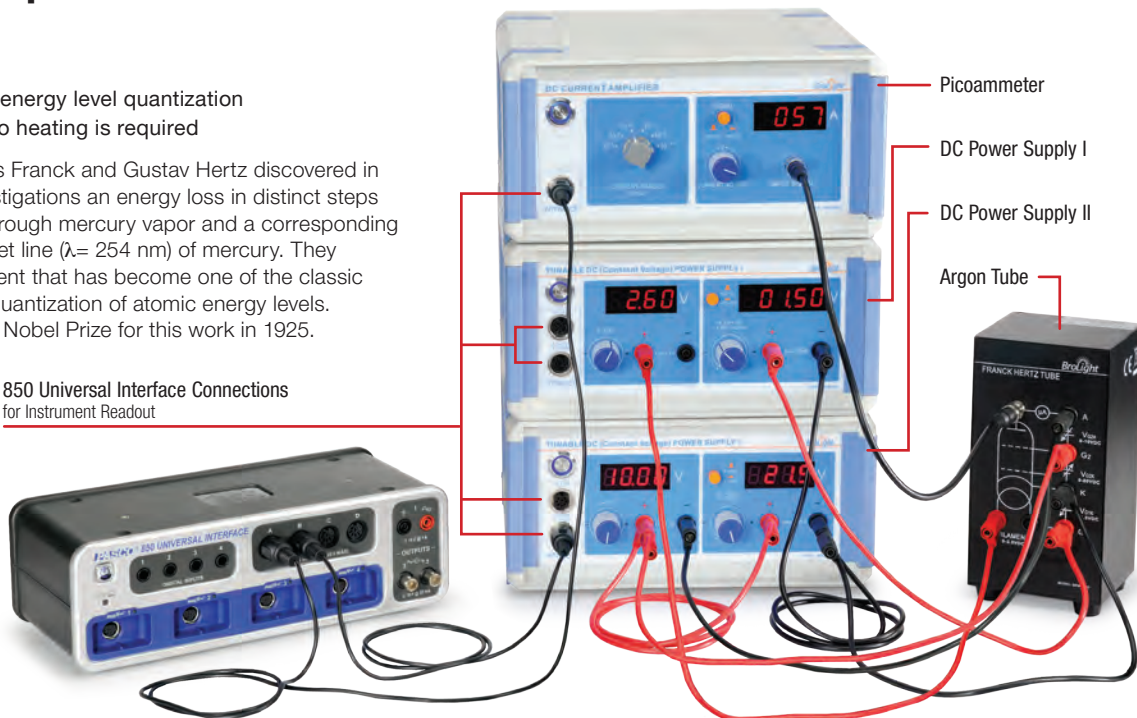
EX-5561

Concepts:

- ▶ Demonstrate atomic energy level quantization
- ▶ Uses argon gas so no heating is required

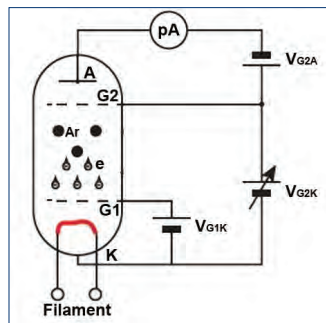
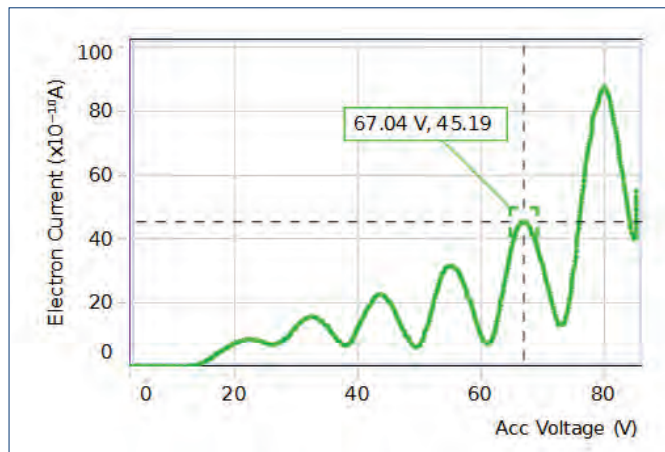
As early as 1914, James Franck and Gustav Hertz discovered in the course of their investigations an energy loss in distinct steps for electrons passing through mercury vapor and a corresponding emission at the ultraviolet line ($\lambda = 254 \text{ nm}$) of mercury. They performed this experiment that has become one of the classic demonstrations of the quantization of atomic energy levels. They were awarded the Nobel Prize for this work in 1925.

850 Universal Interface Connections
for Instrument Readout



PASCO Advantage:

The advantage of using Capstone is that students are able to get many more data points compared to manually taking readings from the digital readouts. The peaks and troughs are easily measured using the coordinate tool.



This diagram shows the internal structure of the Franck-Hertz tube and the wiring diagram.

How It Works:

Electrons are accelerated by applying a known potential between two grids inside the argon tube. When an electron has sufficient kinetic energy to excite one of argon's outer orbital electrons and has an inelastic collision with an argon atom, the electron loses a specific amount of kinetic energy. This loss of electron kinetic energy causes a decrease in the electron current in the argon tube. Within a very short time, the excited argon electron will fall from the excited state back into the ground state level, emitting energy in the form of photons. As the accelerating voltage is increased, the electrons undergo multiple collisions and the excitation energy of the argon atom can be determined by the differences between the accelerating voltages that cause a decrease in the current. Planck's Constant can be determined.

Includes:

- Franck-Hertz Tube Enclosure with Argon Tube SE-9650
- DC Power Supply I (Constant Voltage) SE-6615
- DC Power Supply II (Constant Voltage) SE-9644
- DC Current Amplifier SE-6621
- Red and Black Patch Cords
- Interface Cables (2)

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

Order Information

Franck-Hertz Experiment	EX-5561
Required:	
550 or 850 Universal Interface	pp. 14-17
PASCO Capstone Software	pp. 68-71

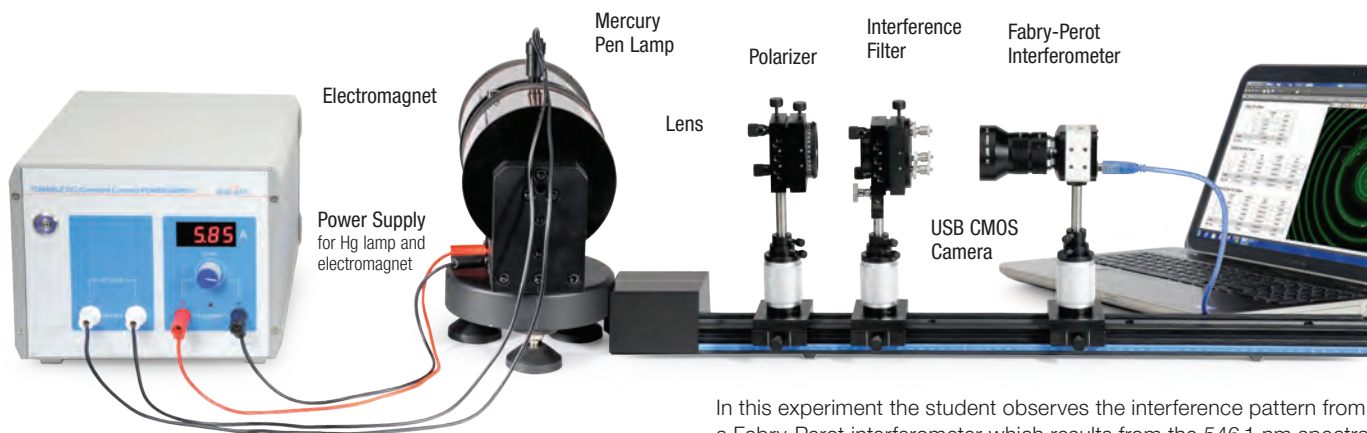
Zeeman Effect Experiment

EX-5562

Concepts:

- ▶ Measure the Zeeman Effect with polarization perpendicular and parallel to the field
- ▶ Observe the light along the magnet axis

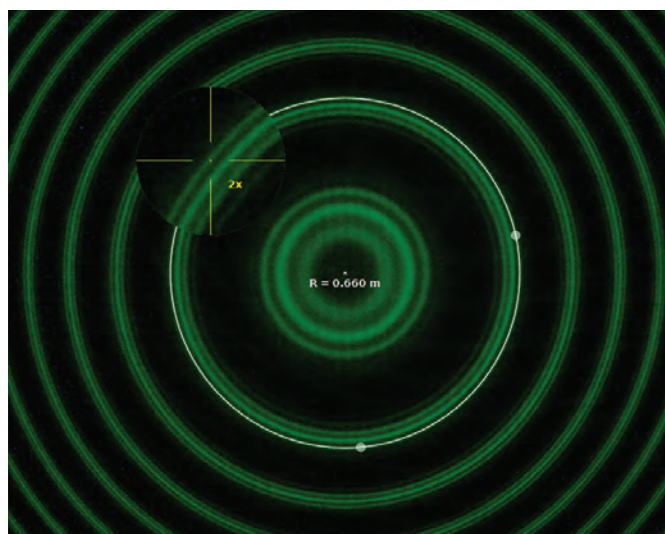
PASCO Capstone™ Software



End view through the axis of the magnet



Electromagnet produces about one Tesla.



In this experiment the student observes the interference pattern from a Fabry-Perot interferometer which results from the 546.1 nm spectral line of a mercury lamp immersed in a uniform magnetic field. The magnetic field is varied from zero to nearly 1 Tesla.

Initially, the light is viewed along an axis perpendicular to the magnetic field axis. A polarizer is used to show the three lines due to light that is polarized parallel to the field axis and to show the six lines that are polarized perpendicular to the field axis. The pattern may also be viewed along the field axis where the light is circularly polarized.

Finally, the pattern that is polarized perpendicular to the field axis is used to calculate the Bohr magneton. All atomic magnetic moments are integral or half-integral multiples of the Bohr magneton.

PASCO Advantage:

In PASCO Capstone software, students can use the video magnifier tool to enlarge the region and observe the line splitting in detail. Also, the radius tool needs only three points to define the circle, so even rings that are partially out of view can be measured.

Includes:

- Electromagnet
- Power Supply
- Optics
- Tesla Meter
- PASCO Capstone Single User License UI-5401

Order Information

Zeeman Effect Experiment EX-5562
 Required:
 PASCO Capstone Software pp. 68-71
 (No interface required.)

Download This Experiment

The FREE experiment files include instructions in Microsoft Word®, PASCO Capstone™ workbook files with sample data, and graphics. Download these experiments at www.pasco.com/CapstoneExperiments.

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Where appropriate, products carry the CE marking, which indicates that they conform to the applicable European standards. This almost exclusively applies to products that are designed to meet the following applicable directives:

2014/30/EU	EMC Directive
2014/35/EU	Low Voltage Directive
2011/65/EU	RoHS Recast/RoHS-2
2014/53/EU	Radio Equipment Directive

Other Regulations May Apply

Local, national, and international regulations may restrict the purchase, storage, transport, use or disposal of certain products such as chemicals, radioactive sources, and specialty products and wireless transmission devices. Please consult your local regulations to ensure compliance.

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- Maximum Altitude (Operational): 10,000 feet
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PASCO scientific Meets the Highest Quality Standards, and our Quality Management System is Registered to ISO 9001.

PASCO and the Environment

PASCO is committed to be in compliance with all laws and requirements in the countries in which our products are sold. PASCO is a responsible steward of the environment and as such, continually seeks to minimize the impact that our manufacturing, distribution, and consumption practices make on the planet's natural resources.

Miscellaneous



RoHS

European Union Restriction of Hazardous Substances. EU Directives 2011/65/EU:

- All applicable electrical products supplied by PASCO to the EU meet the requirements as specified in the RoHS directive either by substance limits or by product exemptions.

EU WEEE

Waste Electrical and Electronic Equipment. EU Directive 2012/19/EC, Effective July 4, 2012:

- All applicable products supplied by PASCO to the EU meet the requirements as specified in the WEEE directive and are marked with the WEEE symbol.

WEEE-Product End of Life Disposal Instructions (Reference):

Electronic products are subject to disposal and recycling regulations that vary by country and region. It is a user's responsibility to recycle electronic equipment per local environmental laws and regulations to ensure that equipment is recycled in a manner that protects human health and the environment. To find equipment recycling drop-off locations, please contact your local waste recycle/disposal service or the product representative.



The European Union (EU) WEEE (Waste Electrical and Electronic Equipment) symbol on our products and packaging indicates that this product must not be disposed of in a standard waste container.

EU REACH

Registration, Evaluation and Authorization of Chemicals, as of: Oct. 28, 2008:

- PASCO has reviewed the REACH SVHC list and, according to our current knowledge, cables supplied with some products may contain certain phthalate plasticizers at greater than 0.1% by weight
- Regarding the other SVHC's, to the best of our knowledge, none are present in PASCO products (articles) at concentrations of greater than 0.1% by weight

Battery Replacement and Disposal Instructions (Reference):

Batteries contain chemicals that, if released, may affect the environment and human health. Batteries should be collected separately for recycling, and recycled at a local hazardous material disposal location adhering to your country and local government regulations. To find a battery recycling drop-off location, please contact local waste disposal service or the product representative.



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EU Battery Directive

EU Directive 2006/66/EC on Waste Batteries:

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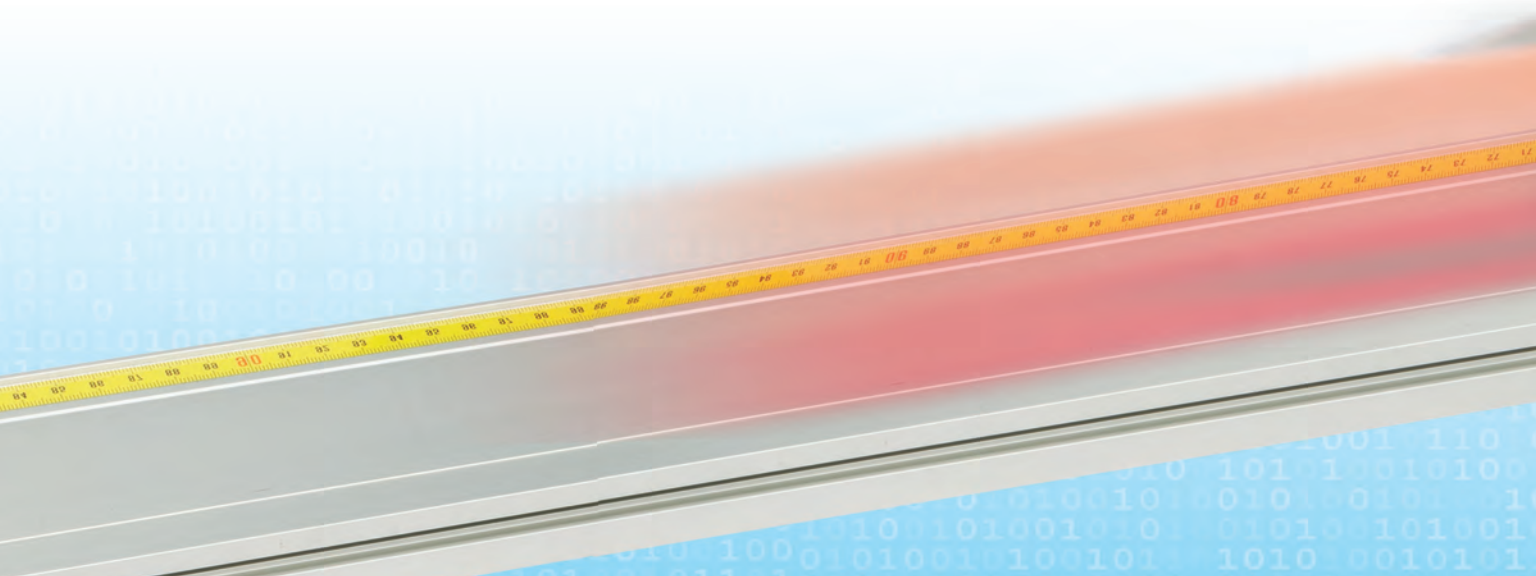
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