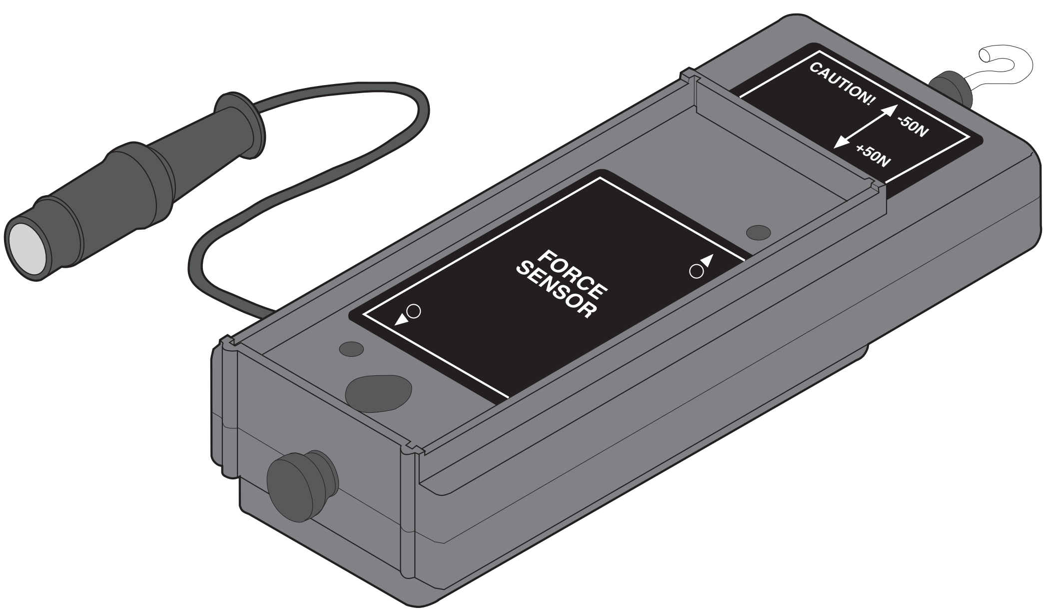
Instruction Manual
Manual No. 012-05804C

Force Sensor

Model No. CI-6537



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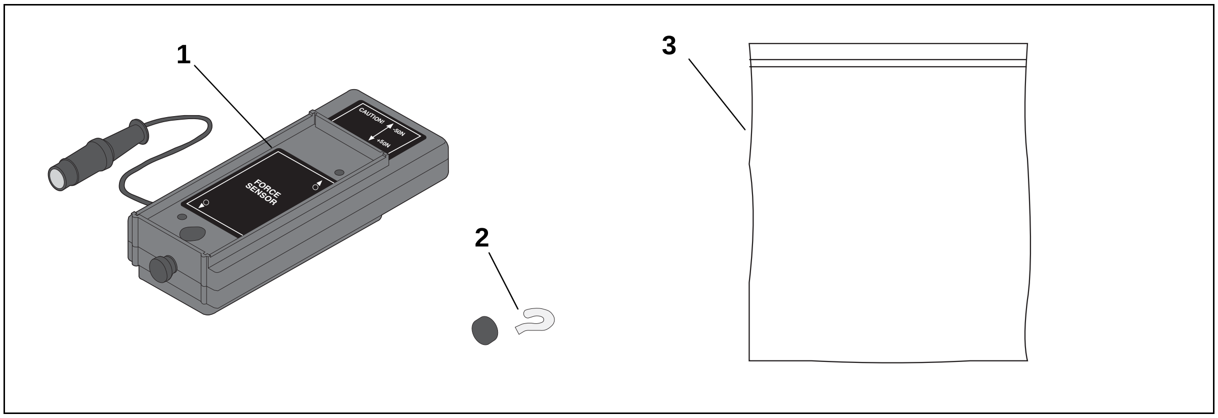
Equipment List



Included Equipment	Replacement Model Number*
1. Force Sensor (1)	CI-6537
2. Hook and bumper (2)	003-05798
3. Ziplock bag (1)	NA

*Use Replacement Model Numbers to expedite replacement orders.

NA= not sold separately from PASCO

Additional Equipment Recommended	
A PASCO *ScienceWorkshop*® 500 or 750 interface	CI-6400 or CI-6450 or CI-7599
A computer	NA
Introductory Dynamics System (cart, track, track accessories)	ME-9429A or ME-9452
Force Sensor Bracket and Collision Bumpers	CI-6545
Phillips head screwdriver (size #0) for mounting the Force Sensor on a PASCO Dynamics Cart (included with the Force Sensor bracket)	NA
DataStudio® software	CI-6870C

Introduction

The CI-6537 ± 50 newton Force Sensor is designed to be used with a PASCO Computer interface [*ScienceWorkshop* 500 or 750]. This version of the Force Sensor has an output between -8 volts and +8 volts and a range between -50 newtons and +50 newtons. In other words, it produces -8 volts for -50 newtons, 0 volts for “zero” force, and +8 volts for +50 newtons. (A push is considered to be positive, and a pull is considered to be negative.) The sensor has strain gauges mounted on a specially designed “binocular beam.” The beam deflects less than 1 millimeter, and has built-in over-limit protection so it will not be damaged if a force greater than 50 newtons is applied.

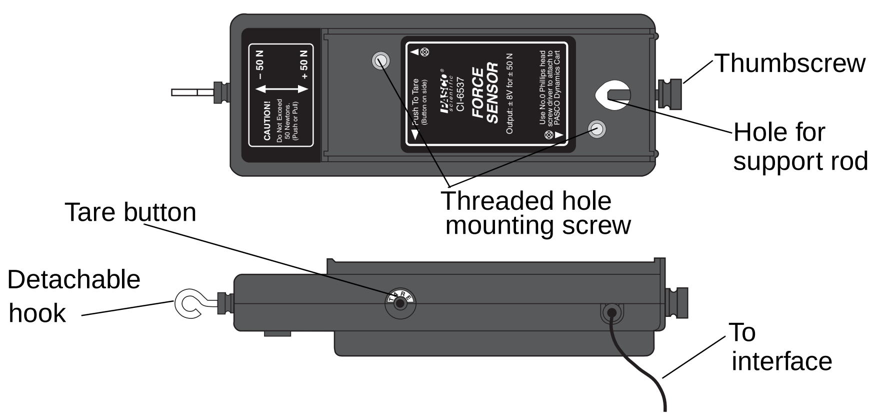


Figure 1: Force Sensor Components

The Force Sensor consists of the housing for the beam and electronics, a cable with a 8-pin DIN plug for connecting to the computer interface, and a detachable hook. The housing has a **Tare** button (for zeroing the sensor) on the same side of the housing as the cable and a thumbscrew (for mounting on a support rod up to 1/2” diameter) on the end opposite to the detachable hook.

The bottom of the housing fits into the accessory tray of a PASCO Dynamics Cart. The top of the housing has the same dimensions as the Dynamics Cart accessory tray, and includes notches at each end for mounting the IDS “picket fence.” The top of the housing has two threaded holes (M5 metric threads). You can mount any accessory that fits on top of the Dynamics Cart into the tray on top of the Force Sensor. For more information, see the PASCO catalog.

Equipment Setup

Mounting the Force Sensor on a PASCO Dynamics Cart

The Force Sensor has two built-in mounting screws that align with the threaded holes in the accessory tray of a PASCO Dynamics Cart (such as the ME-9430 Plunger Cart or ME-9454 Collision Cart). The screws are spring loaded so they remain in a retracted position when not in use.

1. Position the sensor lengthwise it in the accessory tray of the Dynamics Cart.

2. Insert a size #0 Phillips head screwdriver into the threaded hole in the accessory tray of the Force Sensor, and align the screwdriver with the Phillips head screw.

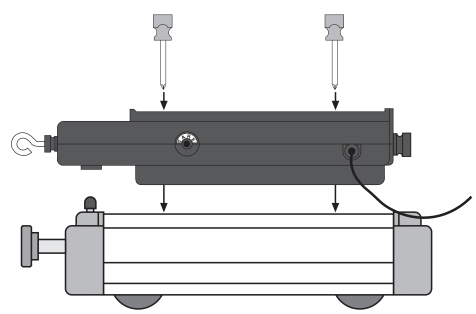


Figure 2: Mounting the sensor on the Dynamics Cart

3. Press down with the screwdriver until the screw extends into the threaded hole on the dynamics car or cart.

4. Turn the screwdriver clockwise until the screw is tight. Repeat the process with the other screw.

To mount other accessories (e.g. ME-9481 Bernoulli Cart Accessory) on top of the Force Sensor, attach the accessory in the Force Sensor accessory tray in the same way you would attach the accessory to a Dynamics Cart.

Mounting the Force Sensor on a Support Rod

The Force Sensor has a hole and thumbscrew at one end that allows you to mount the sensor on a support rod from 3/8” to 1/2” diameter.

Mounting the Force Sensor on the IDS Force Sensor Bracket

The Force Sensor can be mounted on the CI-6545 Force Sensor Bracket.

1. Place the bracket on top of the sensor so the thumbscrews align with the threaded holes in the top of the sensor accessory tray.

2. Turn each thumbscrew clockwise until it is tight.

3. Mount the Force Sensor Bracket on the T-slot on the side of the IDS Track.

For more information, see the Force Sensor Bracket instruction sheet.

Taring the Force Sensor

To tare (zero) the sensor, press the **Tare** button on the side of the sensor and then release it.

When the Tare button is pressed, the voltage from the sensor will be set to approximately zero volts. You can also tare the sensor while a force is applied to the sensor. For example, if you want to measure the ***change*** in force during an experiment, set up the experimental equipment as needed, and tare the sensor at the beginning of the experiment before taking data. The sensor can maintain its "zeroed" condition for over thirty minutes.

You can verify the tare procedure by monitoring the force using DataStudio.

Calibration (Optional)

Calibrating the Force Sensor is not required; the CI-6537 Force Sensor is factory calibrated. *However, you must tare the Force Sensor before taking measurements*. Always zero (tare) the Force Sensor in the exact orientation in which it will be used.

The sensor is designed to produce approximately zero volts when it is "zeroed." A change in force of one newton causes a change in output voltage of 160 millivolts (0.160 V). **Therefore, the sensor does not need to be calibrated.** Instead, the voltage can be converted directly into force. For example, after the sensor is "zeroed," an output voltage of 0.160 volts equals a force of one newton, a voltage of 1.60 volts equals a force of 10 newtons, and so on. In the same way, a voltage of

-1.60 volts equals a force of -10 newtons (in other words, a pull of 10 newtons).

If you want to calibrate for greater accuracy, follow the instructions in Appendix C.

Using the Force Sensor with PASCO Interfaces

The instructions in this manual are intended for those using the Force Sensor with the PASCO 500 or 750 *ScienceWorkshop* interfaces. Using the Force Sensor with older PASCO interfaces may require additional instructions. If you have any questions, please contact Technical Support (See Appendix D of this manual).

Suggested Experiments

Component of Force on an Incline Plane

When a cart is at rest on an inclined plane, the component of force acting on the cart that is parallel to the plane is mgsinθ, where mg is the weight of the cart and θ is the angle of the plane. Use the sensor to measure the weight of a dynamics cart. Mount the sensor at the high end of the inclined IDS track and connect it with a string to the dynamics cart on the track. Measure the angle of the track. Measure the tension in the string, and compare this to the theoretical value mgsinθ.

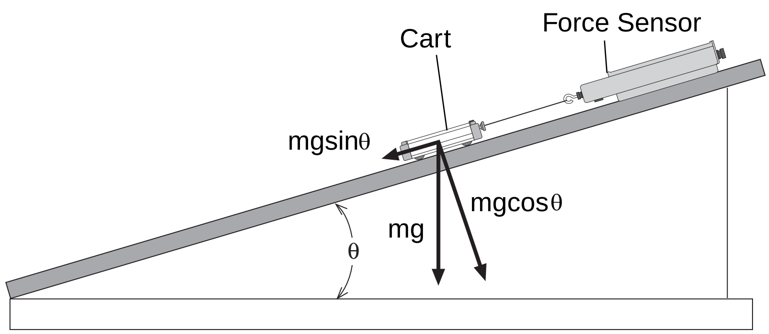


Figure 3: Setup for Force on Incline Experiment

Newton's Second Law: Pushing and Pulling a Cart

When an object is accelerated by a net force, the acceleration is directly proportional to the net force and inversely proportional to the object's mass. Mount the Force Sensor onto a Dynamics Cart. Use a CI-6742 Motion Sensor to measure the velocity and acceleration of the cart. Zero the Force Sensor. Hold the hook on the front of the Force Sensor, and move the cart gently but irregularly back and forth in front of the motion sensor. Use the computer program to compare the measured force to the measured velocity and acceleration.

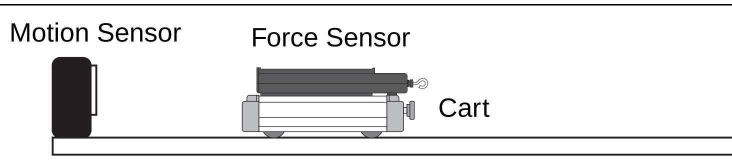


Figure 4: Setup for Push/Pull Experiment

Newton's Second Law: Constant Force

What happens if the cart is pulled by a constant force? Arrange the CI-6742 Motion Sensor, CI-6537 Force Sensor, and cart on the track as in the previous suggested experiment. Set up a pulley, string, and hanging mass so that the cart/Force Sensor will be pulled by the string attached to the hanging mass. Use the Motion Sensor to measure the velocity and acceleration of the cart as it is pulled by the string. Use the computer program to compare the measured force to the measured velocity and acceleration. Change the hanging mass and repeat the experiment.

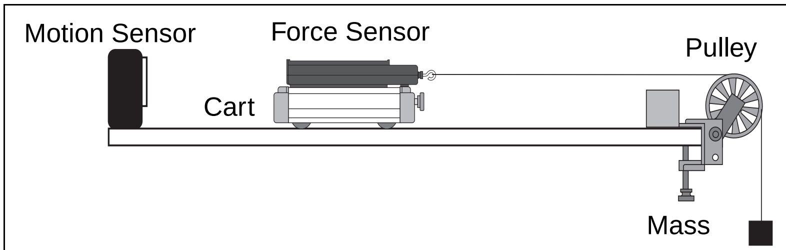


Figure 5: Setup for Constant Force Experiment

Work Energy Theorem: W = ΔKE

What happens to the kinetic energy of the cart as it is pulled by a constant force? Arrange the CI-6742 Motion Sensor, CI-6537 Force Sensor, and cart on the track as in the previous suggested experiment. Set up a pulley, string, and hanging mass so that the cart/Force Sensor will be pulled by the string attached to the hanging mass. Use the Motion Sensor to measure the change in position and the velocity of the cart as it is pulled by the string. Use the computer program to find the integration under the curve of a force versus distance graph. Use the program to calculate the amount of kinetic energy gained by the cart. Compare the calculated value of the work to the calculated value of the final kinetic energy.

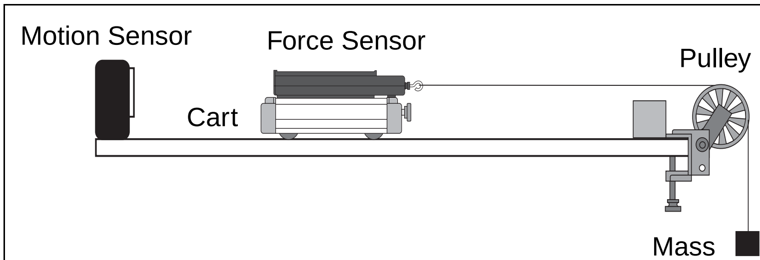


Figure 6: Setup for Work/Energy Experiment

Tension

What is the tension in the string in the previous suggested experiment? Arrange the Force Sensor and cart on the track as in the previous suggested experiment. Set up a pulley, string, and hanging mass so that the cart/Force Sensor will be pulled by the string attached to the hanging mass. First, hold the cart at rest so the tension in the string is "mg" (the hanging mass times the acceleration due to gravity). Then, let go of the cart so it accelerates toward the pulley. Use the DataStudio program to measure the amount of force in the string. The tension should be constant, but less than "mg."

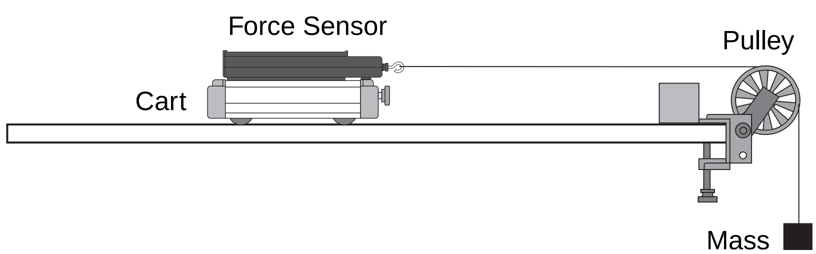


Figure 7: Setup for Tension Experiment

Newton's Second Law: Friction

Make observations when a force is applied to the cart/force sensor and compare its acceleration when no friction is present to the acceleration when friction is added. You will need to add the Friction Cart Accessory to the Dynamics Cart. Arrange the CI-6742 Motion Sensor, CI-6537 Force Sensor, and "friction" cart on the track as in the previous suggested experiment. Set up a pulley, string, and hanging mass so that the cart/force sensor will be pulled by the string attached to the hanging mass. Adjust the Friction Cart Accessory so the friction pad is not in contact with the track. Accelerate the cart with a 50 gram mass. Use the Motion Sensor to measure the velocity and acceleration of the cart as it is pulled by the string. Use the computer program to compare the measured force to the measured velocity and acceleration. Adjust the friction pad on the bottom of the cart until it is rubbing against the track just enough to cause the cart to move with a constant velocity as the 50 gram mass falls. Use the Motion Sensor and the computer program to analyze the force, velocity, and acceleration. Finally, raise the friction pad so it rubs the track slightly less than before and repeat the measurements.

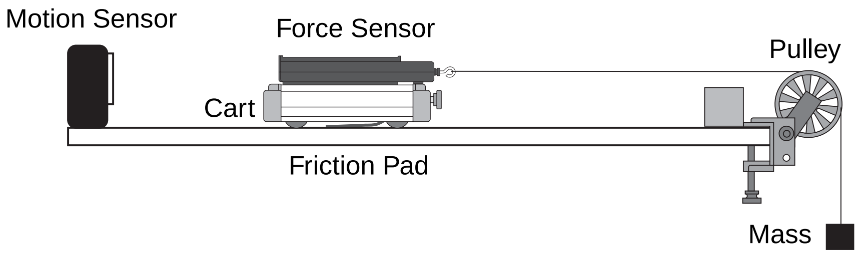


Figure 8: Setup for Friction Experiment

Newton's Third Law

"For every action, there is an opposite but equal reaction." Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first. Use two force sensors. Set up the computer program so that a push will be negative for one of the sensors. Hook the two sensors together, and use the computer program to measure the force from both force sensors as you pull one force sensor with the second force sensor.

Newton's Third Law: Impulse/Collision

The impulse during a collision equals the change in momentum during the collision:

$F\Delta t = \Delta mv$

Mount the Force Sensor at one end of the track. Arrange the cart and Motion Sensor so the Motion Sensor can measure the motion of the cart as it is pushed toward the Force Sensor, collides with it, and rebounds. Use the computer program to determine the impulse and the change in momentum during the collision.

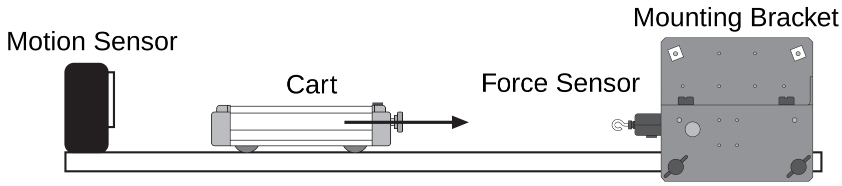


Figure 9: Setup for Impulse/Collision Experiment

Other Suggested Experiments

- Measure the force of a fan cart.
- Measure the centripetal force of a swinging pendulum, and compare the force to the speed, length, and mass of the pendulum.
- Measure the change in mass of liquid nitrogen as it vaporizes versus the energy input to vaporize the liquid nitrogen.
- Measure fluid drag forces on objects of various shapes in a wind tunnel.
- Measure the net force acting on a pair of harmonic oscillators.
- Study damped and undamped harmonic motion using a mass and spring system.

Appendix A: Specifications

Force Sensor:

Output voltage	+8 V for +50 newtons (pushing) + 8 V for -50 newtons (pulling)
Output noise	+/- 2 millivolts
Slew Rate	25 newtons/millisecond
Range*	+/- 50 newtons
Resolution**	0.0305 newtons (or 3.1 grams)
Bandwidth limit	2 kilohertz (internal low pass filter)
Output drive	8 meters of cable without instability

* The range of the sensor is +/- 50 newtons with an output between -8 to +8 volts, or 160 millivolts per newton.

** The resolution of the sensor refers to the smallest change in force that the sensor can measure. For example, an interface with a 12-bit analog-to-digital converter and an input range of +/- 10 volts gives a resolution of 0.0305 newtons (or 3.1 grams).

Appendix B: Calibration using DataStudio Software

All calibrations assume that the sensor produces an output voltage that is linear with respect to the input signal. Calibration is done by setting up two calibration situations (such as “no force” and a known force), measuring the input signal in each situation in comparison to a known standard, and entering the readings.

Whenever possible, calibrate the Force Sensor in the orientation in which it will be used.

Calibration Procedure (for Short-Term Measurements):

You will need a known mass, such as 1 kilogram, and a support rod for mounting the sensor.

1. Connect the Force Sensor to an analog channel on the interface.

2. In DataStudio, click on the **Setup** button to open the Experiment Setup window.

3. In the Sensors list of the Experiment Setup window, double click the Force Sensor icon to associate it with the *same analog channel* on the picture of the interface.

4. Mount the Force Sensor vertically on a support rod. (Attach the hook to the sensor and rotate to tighten).

5. Double-click on the Force Sensor icon to open the Sensor Properties dialog. In the Calibration tab, the dialog box shows the default settings for the calibration (i.e., 50.000 newtons at 8.000 volts and -50.000 newtons at -8.000 volts).

6. Press the **Tare** button to “zero” the sensor. Without mass on the hook, enter “0” in the value box under the Low Point. When the voltage under “Current Reading” stabilizes, click the “Take Reading” button for the low point.

7. Hang the known mass from the hook. Enter the mass value (in newtons, e.g. -9.8 newtons if you used a 1 kilogram mass) in the value box under the High Point. When the voltage under “Current Reading” stabilizes, click the “Take Reading” button for the high point. Click OK.

Calibration Procedure (for Long-Term Measurements)

When you plan to measure force over long periods, you must allow time for the aluminum beam to relax in your calibration; otherwise your experimental results may contain error. The mass of the beam is approximately 37 g.

1. Tare the force sensor where you wish to define zero.

2. Apply the typical force that will be encountered during the experiment.

3. Wait 2-4 minutes for the aluminum beam to relax.

4. Remove the force and retare immediately.

5. Reapply the force.

Note: If you have DataStudio open, you can verify the zero measurement by taking data with no weight attached. If the zero is not achieved, press the Tare button again and enter 0 in the box for the low point. DataStudio assigns a voltage value to the zero point for the position in which you have the Force Sensor. If you change the position of the Force Sensor, you need to retare the sensor.

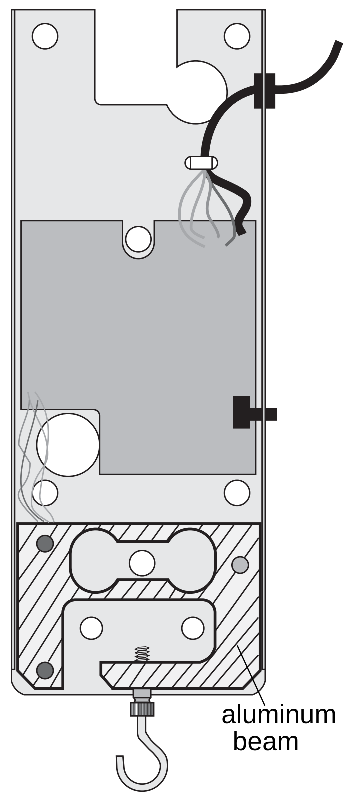


Figure 10: Cut-away view of the Force Sensor beam

In some experiments, the mass of the beam may affect the results; in somes cases, you may need to correct for the mass of the beam in your calculations. For further information, contact Technical Support (See Appendix D in this manual).

Appendix C: Calibration using *ScienceWorkshop*® Software

You will need a known mass, such as 1 kilogram, and a support rod for mounting the sensor.

a) Connect the Force Sensor to the *ScienceWorkshop*® interface. When the *Science Workshop* program begins, click-and-drag the analog sensor plug icon to analog Channel A on the interface.

b) Select “Force Sensor” from the list of analog sensors. The Force Sensor icon will appear below analog Channel A in the Experiment Setup window.

c) Mount the Force Sensor vertically on a support rod so you can hang a known mass from the hook. Don’t put any mass on the hook for this step.

d) Double-click on the Force Sensor icon to open the Sensor Setup dialog box. The dialog box shows the default settings for the calibration (i.e., 50.000 newtons at 8.000 volts and -50.000 newtons at -8.000 volts).

e) Press the **Tare** button to “zero” the sensor. When the reading in the “Cur Value:” row under the “Volts” column settles down, click on the “Read” button in the “Low Value:” row. Enter “0” in the left hand “Low Value:” box.

f) Hang the known mass from the hook. After a few seconds when the reading in the “Cur Value:” row under the “Volts” column settles down, click on the “Read” button in the “High Value:” row. Enter the weight of the mass (e.g.,-9.8 newtons if you used a 1 kilogram mass). Click OK.

Appendix D: Technical Support

For assistance with the CI-6537 Force Sensor or any other PASCO products, contact PASCO as follows:

Address: PASCO scientific

10101 Foothills Blvd.

Roseville, CA 95747-7100

Phone: (916) 786-3800

FAX: (916) 786-3292

Web: www.pasco.com

Email: techsupp@pasco.com

Appendix E: Copyright and Warranty Information

Copyright Notice

Limited Warranty

PASCO scientific warrants the product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. PASCO will repair, or replace, at its option, any part of the product which is deemed to be defective in material or workmanship. The warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is result of a manufacturing defect or improper use by the customer shall be made solely be PASCO scientific. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by the improper packing of the equipment for return shipment will not be covered by the warranty.) Shipping costs for returning the equipment after repair will be paid by PASCO scientific.

Author:

Dave Griffith