



Centripetal Force Apparatus

Model No. ME-8088

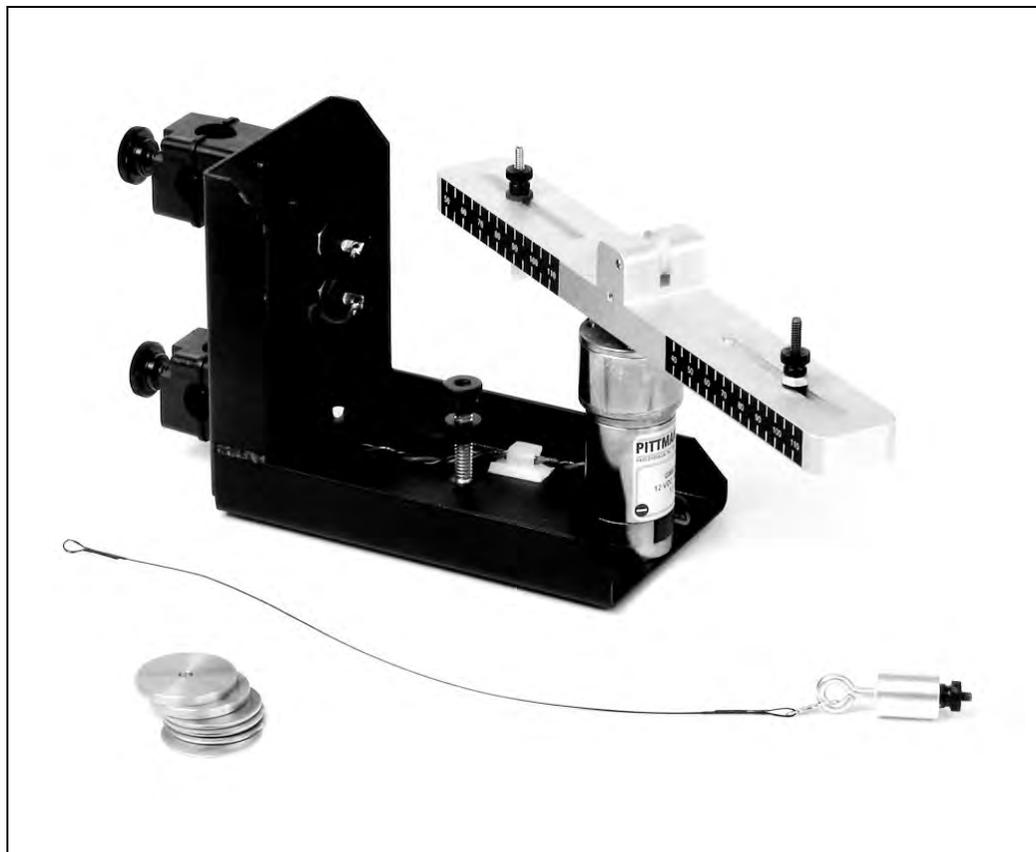


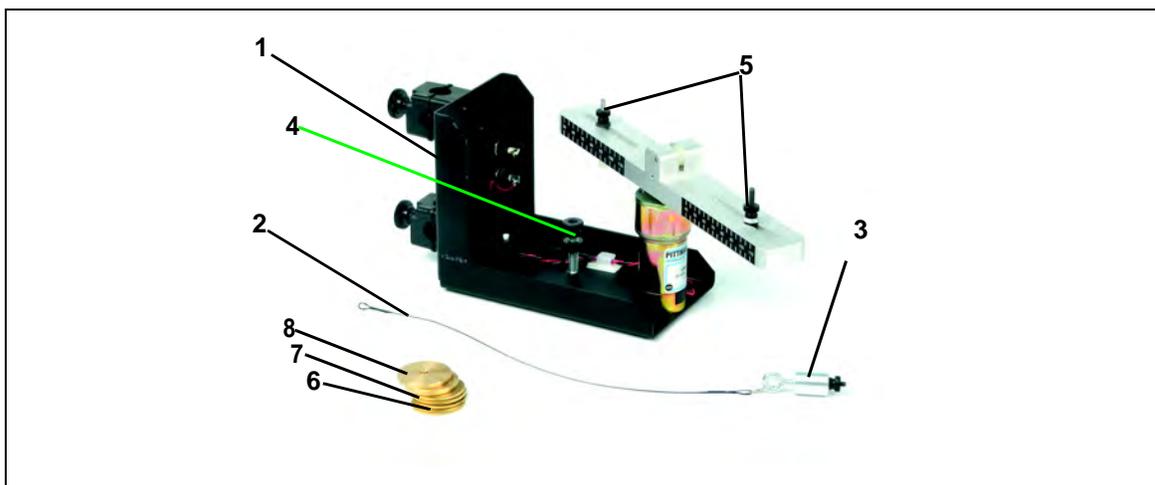
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Centripetal Force Apparatus

Model No. ME-8088

Equipment List



Included Equipment	Replacement Model Number*
1. Frame with Mounted Electric Motor (1)	NA
2. Connecting Cable (1)	623-038
3. Ball Bearing Swivel (1)	003-08383
4. Thumbscrew for Photogate (1)	614-034
5. Nuts for Free and Fixed Mass Holders (2)	614-029
6. 5 g Mass (2)	648-06507
7. 10 g Mass (2)	648-06508
8. 20 g Mass (2)	648-06509
9. Centripetal Force Apparatus Setup disk (3.5" floppy) (not shown above)	013-08478

*Use Replacement Model Numbers to expedite replacement orders.

NA = not available as individual replacement item. To replace product, use ME-8088.

(continued on next page)

Additional Equipment Recommended for Experiments (with ScienceWorkshop)	Replacement Model Number*
A computer (Windows or Macintosh)	NA
DataStudio® Software	various (see catalog)
ScienceWorkshop® 500 or 750 Interface	CI-6400 or CI-6450 or CI-7650
Economy Force Sensor	CI-6746
Photogate Head	ME-9498A
Steel Rod (45 or 120 cm)	ME-8736 and ME-8741
Multi-Clamp	SE-9442
Large Rod Base	ME-8735
Banana plugs (1 red, 1 black)	SE-9750 or SE-9751
Triple Output Power Supply (12 V, 3 A) (1)	SE-8587

Additional Equipment Recommended for Experiments (with PASPORT™)	Replacement Model Number*
A USB-compatible computer (Windows or Macintosh)	NA
DataStudio Software (version 1.5 or later)	various (see catalog)
PASPORT™ Force Sensor	PS-2104
Photogate Port	PS-2123
Photogate Head	ME-9498A
USB Link (2) or Xplorer (2) or PowerLink	PS-2100 or PS-2000 or PS-2001
Steel Rod (45 or 120 cm)	ME-8736 and ME-8741
Multi-Clamp	SE-9442
Large Rod Base	ME-8735
Banana plugs (1 red, 1 black)	SE-9750 or SE-9751
Triple Output Power Supply	SE-8587

Introduction

PASCO's Centripetal Force Apparatus (ME-8088) allows students to investigate the relationships between centripetal force, radius, mass, and velocity for an object undergoing uniform circular motion. Traditional experiments in this area involve the swinging of masses above the head. The traditional approach is difficult to execute and data is rarely sufficient for an understanding of the relationships. The Centripetal Force Apparatus removes these difficulties by using sensors to measure the force and velocity of the mass as it rotates.

Velocity is varied by changing the voltage supplied to the included electric motor.

Drilled masses are included to facilitate a range of mass trials. The radius is changed by sliding the captured masses along the grooves in the rotating arm. A convenient measuring scale is included on both sides of the arm.

The sturdy base includes rod clamps for connection to a standard rod stand or the unit can be clamped to a table using a common "C" clamp.



Figure 1: Setup with Force Sensor on stand

Equipment Setup

1. Mount a stainless steel rod into a base support stand.
2. Use the rod clamps to attach the Centripetal Force Accessory to the rod (See Figure 2).
3. Remove the free mass holder (Figure 3) and measure its mass. To remove the free mass holder, loosen the screw below the rotating arm.

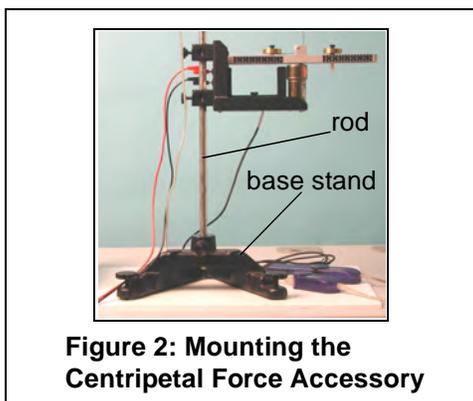


Figure 2: Mounting the Centripetal Force Accessory

(**Note:** The free mass holder includes the screw, two plastic washers, nut, and two thumbscrews. If a scale is not available, use the mass provided in Appendix A: Specifications.)

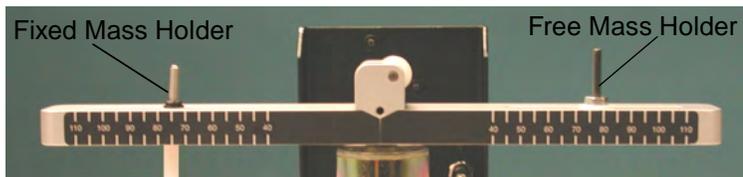


Figure 3: Free and Fixed Mass Holders

- Use a thumbscrew to mount a Photogate Head (ME-9498A) to the bottom base of the Centripetal Force Accessory (See Figure 4).

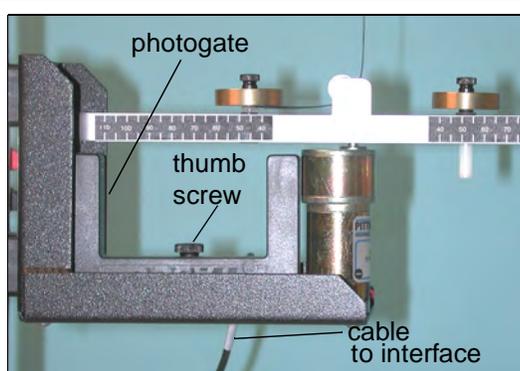


Figure 4: Photogate on base of Centripetal Apparatus

- Attach a Multi-Clamp to the upper end of the stainless steel rod. (Figure 5a).

- Insert another stainless steel rod horizontally into the Multi-Clamp.

- Slide a Force Sensor through the stainless steel rod and adjust the top screw to anchor it to the rod (Figure 5a). (Note: Be sure to keep the cords from the sensor out of the path of the rotating arm.)

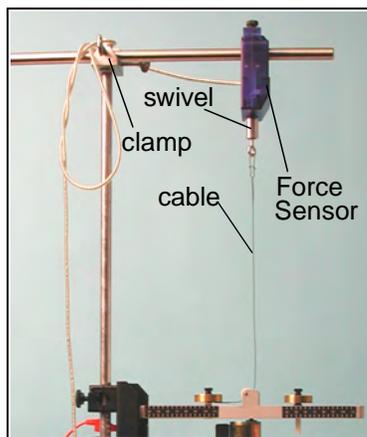


Figure 5a: Mounting the Force Sensor

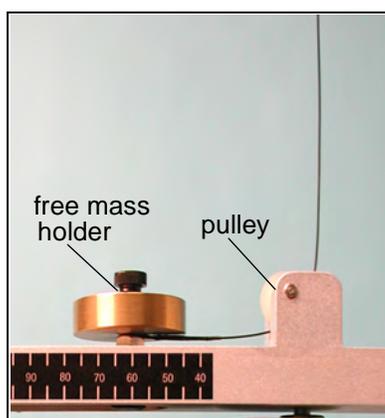


Figure 5b: Threading the cable through the free mass holder



Note: To calibrate the ScienceWorkshop Force Sensor, follow the instructions provided in the documentation included with your Force Sensor or in the DataStudio online help. Calibration of the PASPORT Force Sensor is not required. However, you can tare the PASPORT Force Sensor by pressing the **Zero** button without any weight attached.

8. Attach the ball bearing swivel to the bottom of the Force Sensor
9. Thread the cable from the swivel hook through the pulley and over the free mass holder (Figure 5b).

Note: Always lay down the cable *before* adding the mass.

10. Add a mass to the free mass holder; then screw on the thumbscrew to hold the mass in place.
11. Add a mass to the fixed mass holder and use a thumbscrew to hold the mass in place.
12. Plug the Force Sensor into either a PASPORT or *ScienceWorkshop* interface.

13. Use banana plugs to connect the Centripetal Force Accessory to a Power Supply.

14. To turn on the motor to the Centripetal Force Accessory, turn on the Power Supply.

(CAUTION: To avoid damaging the equipment, keep all cords away from the motor and rotating arm.)



WARNING: Do not stand next to the motor or rotating arm or look at the rotating arm at eye level. To avoid possible injury from the rotating arm hitting the body, keep at least 1 foot distance from the motor and rotating arm when running the motor.

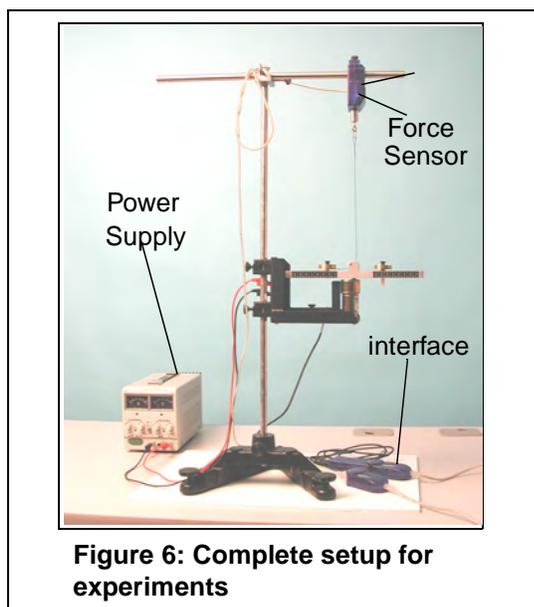


Figure 6: Complete setup for experiments



Note: If you do not have a setup disk available, follow the DataStudio setup instructions in Appendix B (for PASPORT sensors) or C (for ScienceWorkshop sensors).

Suggested Experiments

Experiment 1: Centripetal Force vs. Velocity

Equipment Required (for use with ScienceWorkshop sensors):	Equipment Required (for use with PASPORT sensors):
ScienceWorkshop Force Sensor (CI-6746)	PASPORT Force Sensor (PS-2104)
Photogate Head (ME-9498A)	Photogate Head (ME-9498A)
ScienceWorkshop interface (500, 700, or 750) (CI-6400 or CI-6450)	Photogate Port (PS-2123)
Power Supply (12 v, 3A) (SE-8587)	USB Link (2) (PS-2100) or Xplorer (2) (PS-2000) or Power Link (PS-2001)
DataStudio Software (ver. 1.5 or higher)	Power Supply (12 V, 3AA) (SE-8587)
Base support, clamps, and mounting rods	DataStudio Software (ver. 1.5 or higher)
	Base support, clamps, and mounting rods

Introduction

In this experiment, you will *vary the velocity* by changing the voltage to the electric motor as the centripetal force is continuously measured by the Force Sensor. The radius and mass are held constant as the velocity is increased.

Setup

Follow the equipment setup instructions on pages 5-7 of this manual and the Experiment Tips that follow. When you are ready to begin the experiment, open the appropriate DataStudio file on the setup disk.



Note: If you do not have a setup disk available, follow the DataStudio setup instructions in Appendix B (for PASPORT sensors) or C (for ScienceWorkshop sensors).

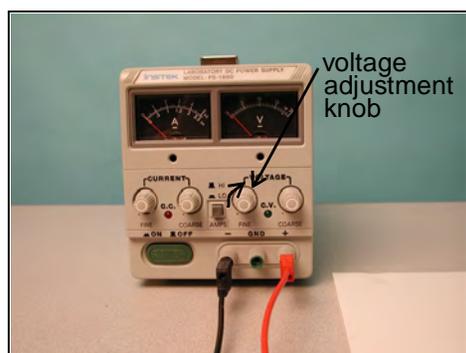


Figure 1a: Adjusting the voltage on the Power Supply



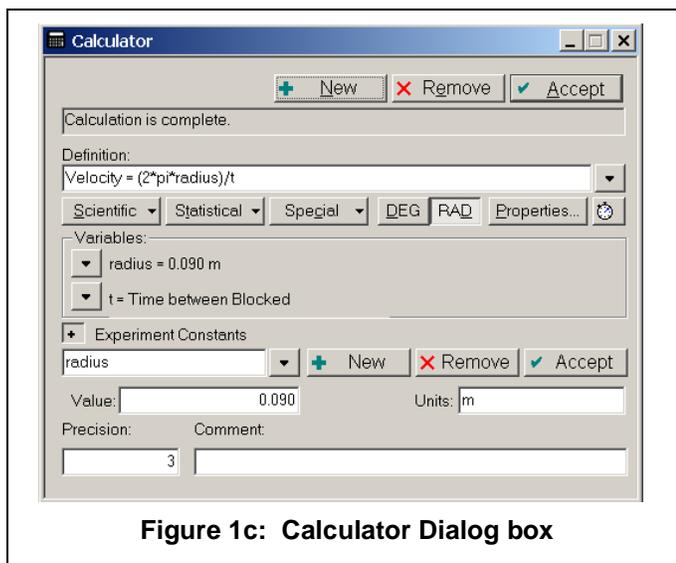
Figure 1b: Complete setup

Experiment Tips

- a) To add the free mass, lay the components over the attachment screw in the following order: a) cable b) mass and c) thumbscrew to tighten.
(Note: Place the cable over the washer and nut on the screw. For more details, see “Equipment Setup” on pages 5-7.)

Note: Do not place the mass underneath the cable, as this will interfere with a proper measurement.

- b) Allow the “free mass” plenty of length along its holder within the slot. If the mass is not free to slide along the groove, significant frictional losses can be present.
- c) Place an equal amount of mass on the “fixed mass” and “free mass” holders.
- d) Be sure to place the “fixed mass” at the same radius as the “free mass” to ensure balancing of the unit as it rotates.
- e) The velocity of the free mass can be measured as an angular or linear velocity. DataStudio files for both of these variations are included on the floppy disk.
- f) Be sure to enter the correct value for the radius in the experimental constants area of the calculator (when using the linear velocity DataStudio file).



Experiment 2: Centripetal Force vs. Mass

Equipment Required (for use with <i>ScienceWorkshop</i> sensors):	Equipment Required (for use with PASPORT sensors):
<i>ScienceWorkshop</i> Force Sensor (CI-6746)	PASPORT Force Sensor (PS-2104)
Photogate Head (ME-9498A)	Photogate Head (ME-9498A)
<i>ScienceWorkshop</i> interface (500, 700, or 750) (CI-6400 or CI-6450)	Photogate Port (PS-2123)
Power Supply (12 v, 3A) (SE-8587)	USB Link (2) (PS-2100) or Xplorer (2) (PS-2000) or Power Link (PS-2001)
DataStudio Software (ver. 1.5 or higher)	Power Supply (12 V, 3AA) (SE-8587)
Base support, clamps, and mounting rods	DataStudio Software (ver. 1.5 or higher)
	Base support, clamps, and mounting rods

Introduction

In this experiment, the radius and velocity are held constant as the *mass is varied*. By adding additional drilled masses to the holder, the mass of the system is increased. Equal amounts of mass must also be added to the “fixed mass” to balance the arm as it rotates. Centripetal force is directly measured by the Force Sensor.

Setup

Follow the equipment setup instructions on pages 5-7 of this manual and the Experiment Tips below. When you are ready to begin the experiment, open the appropriate DataStudio file on the setup disk.

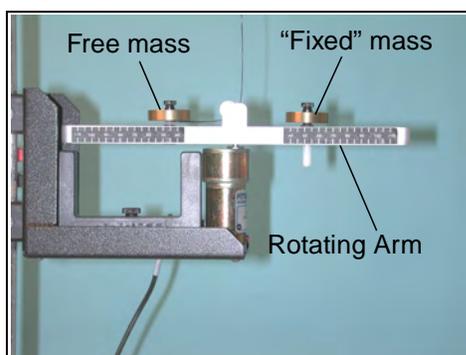


Figure 2a: Free and fixed Mass Holders



Figure 2b: Complete setup



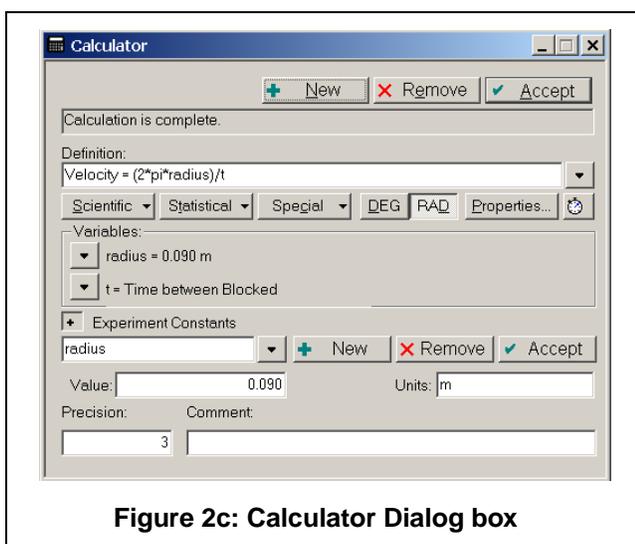
Note: If you do not have a setup disk available, follow the DataStudio setup instructions in Appendix B (for PASPORT sensors) or C (for *ScienceWorkshop* sensors).

Experiment Tips

- a) To add the free mass, lay the components over the attachment screw in the following order: a) cable b) mass and c) thumbscrew to tighten. (Note: Place the cable over the washer and nut on the screw. For more details, see “Equipment Setup” on pages 5-7.)

Note: Do not place the mass underneath the cable, as this will interfere with a proper measurement.

- b) Allow the “free mass” plenty of length along its holder within the slot. If the mass is not free to slide along the groove, significant frictional losses can be present.
- c) Place an equal amount of mass on the “fixed mass” and “free mass” holders.
- d) Be sure to place the “fixed mass” at the same radius as the “free mass” to ensure balancing of the unit as it rotates.
- e) Perform several different data runs, each time varying the mass on the free and fixed mass holders. (**Note:** Be sure to include the mass of the holders in your calculations.)
- f) In the DataStudio file for this experiment, a graph display is available for monitoring the velocity of the rotating mass.
- g) Be sure to enter the correct value for the radius in the experimental constants area of the calculator.



Experiment 3: Centripetal Force vs. Radius

Equipment Required (for use with <i>ScienceWorkshop</i> sensors):	Equipment Required (for use with PASPORT sensors):
<i>ScienceWorkshop</i> Force Sensor (CI-6746)	PASPORT Force Sensor (PS-2104)
Photogate Head (ME-9498A)	Photogate Head (ME-9498A)
<i>ScienceWorkshop</i> interface (500, 700, or 750) (CI-6400 or CI-6450)	Photogate Port (PS-2123)
Power Supply (12 v, 3A) (SE-8587)	USB Link (2) (PS-2100) or Xplorer (2) (PS-2000) or Power Link (PS-2001)
Base support, clamps, and mounting rods	Power Supply (12 V, 3AA) (SE-8587)
DataStudio Software (ver. 1.5 or higher)	Base support, clamps, and mounting rods
	DataStudio Software (ver. 1.5 or higher)

Introduction

In this experiment, the velocity and mass are held constant as the *radius is varied*. By lowering the Force Sensor, the radius increases. As the radius increases, the “fixed mass” must be moved to a matching radius to balance the rotating arm. Again, centripetal force is measured by the Force Sensor.

Setup

Follow the equipment setup instructions on pages 5-7 of this manual and the Experiment Tips that follow. When you are ready to begin the experiment, open the appropriate DataStudio file on the setup disk.

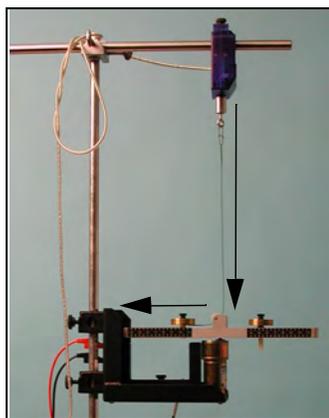


Figure 3a: Changing the radius

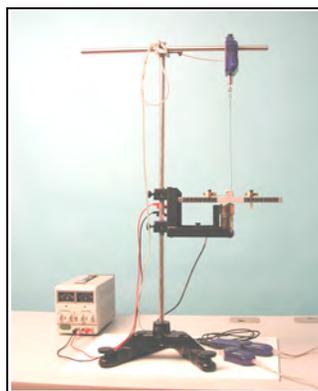


Figure 3b: Complete setup



Note: If you do not have a setup disk available, follow the DataStudio setup instructions in Appendix B (for PASPORT sensors) or C (for *ScienceWorkshop* sensors).

Experiment Tips

- a) Allow the “free mass” plenty of length along its holder within the slot. If the mass is not free to slide along the groove, significant frictional losses can be present.
- b) To add the free mass, lay the components over the attachment screw in the following order: a) cable b) mass and c) thumbscrew to tighten. (Note: Place the cable over the washer and nut on the screw. For more details, see “Equipment Setup” on pages 5-7.)

Note: Do not place the mass underneath the cable, as this will interfere with a proper measurement.

- c) Place an equal amount of mass on the “fixed mass” and “free mass” holders.
- d) Be sure to place the “fixed mass” at the same radius as the “free mass” to ensure balancing of the unit as it rotates.
- e) To vary the radius, adjust the position of the Force Sensor (See Figure 3a).
- f) In the DataStudio file for this experiment, a graph display is available for monitoring the velocity of the rotating mass.
- g) Be sure to enter the correct value for the radius in the experimental constants area of the calculator. This will need to be changed for each data run of this experiment.

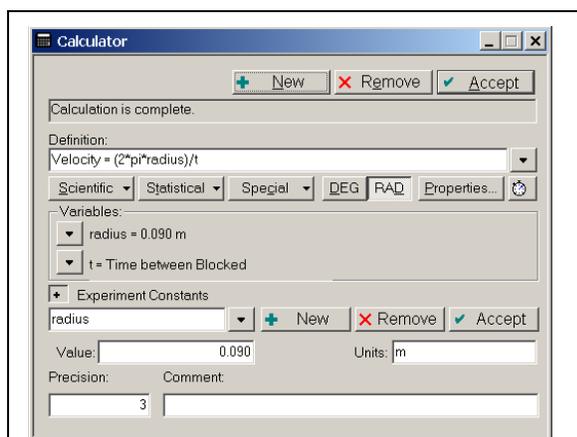
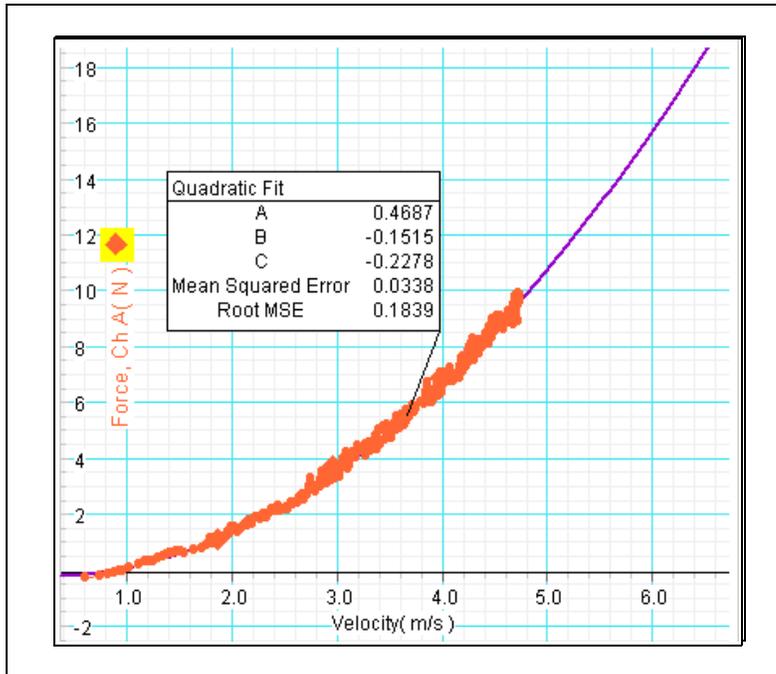


Figure 3c: Calculator Dialog box

Sample Data



Troubleshooting

Problem:	Possible Causes:	Possible Solutions:
Rotating arm does not move.	Too much friction in the cable; power supply is not turned on; motor is defective.	Move Force Sensor down to loosen the cable; connect the power supply to the frame and turn on the power supply; call Technical Support and/or return the product (See Warranty information in Appendix E.)
Force measurement does not display in DataStudio.	Force Sensor is not connected to an interface or associated in the setup window.	If using a PASPORT Force Sensor, plug the Force Sensor into a USB Link connected to a USB-compatible computer. Follow the setup instructions in Appendix B. If using a <i>ScienceWorkshop</i> Force Sensor, connect the Force Sensor to a <i>ScienceWorkshop</i> interface. Follow the setup instructions in Appendix C.
Velocity readings do not appear or are incorrect.	Photogate is not connected to an interface; improper setup in DataStudio.	If using a PASPORT interface, click the Setup button , click the Add Timer button , and select the Smart Pulley option. If using a <i>ScienceWorkshop</i> interface, click the Setup button and select the Smart Pulley option from the Sensors list.

Appendix A: Specifications

Centripetal Force Apparatus	
Rotating Arm	Length: 24.6 cm
Motor	12 VDC, 0.5 ampere
Frame	Base: 15 x 8.5 cm Back: 11.5 x 8.5 cm Mass (with motor, cable, and rotating arm): 2.10 kg
Free Mass Holder	4.0 g (with screws)
Fixed Mass Holder	2.5 g (with screws)
Thumbscrew	0.5 g
Masses	5 g, 10 g, 20 g
Ball Bearing Swivel	Mass: 12.5 g

Appendix B: DataStudio Setup Instructions (for PASPORT interfaces)

The following instructions are for new users or those unfamiliar with DataStudio software.

PART I: Plug the sensors into the PASPORT interface:

- Plug the Photogate into either channel 1 or 2 on a PASPORT Photogate Port.
- Plug both the Photogate Port and Force Sensor into a PASPORT interface (i.e. USB Link, Xplorer, PowerLink, etc.).

PART II: Set up your experiment in DataStudio

- Open DataStudio and select “Create Experiment.”
- On the main toolbar, click the **Setup** button to open the Experiment Setup window.
- When the Experiment Setup dialog opens, click on the **Add Timer** button, select the Recordable Timer icon, and click OK.

PART III: Create a recordable timing sequence in DataStudio

- Click the **Record Sequence** button in the Experiment Setup window.
- In the Record Timer Sequence box, click the **Start** button.
- Block the beam of the photogate twice with your finger, and click the **Stop** button.
- In the Record Timer Sequence box, highlight “Photogate 1 unblocked,” and click the **Delete** button. (Repeat this task for the second “Photogate 1 unblocked.”)
- Click the **OK** button to accept the timing sequence.

PART IV: Create the mathematical equation in DataStudio

- Click on the **Calculate** button to open the Calculator dialog.
- In the Calculator dialog, click the **New** button to create a new equation.
- In the equation box, type in the equation $velocity = 2 * \pi * radius / t$ and click the **Accept** button.
- Define the variables “radius” and “t.” (Under Variables, click on the arrow and select “constant” to define the variable “radius” and enter the value in the box. Under “Experiment Constants,” click the **Accept** button. Select “Data Measurement” for “t” and select “time between gates.”)
- Click the Accept button. Your equation will appear as an icon in the Data list. To edit the equation, double click on the equation icon in the Data list.

PART V: Collect data

- To collect data in a display, click the **Start** button.

Appendix C: DataStudio Setup Instructions (for *ScienceWorkshop* interfaces)

PART I: Plug the sensors into the interface:

- a) Plug the Photogate into channel 1 on the *ScienceWorkshop* interface.
- b) Plug the Force Sensor into any analog channel (A, B, or C) on the *ScienceWorkshop* interface.

PART II: Set up your experiment in DataStudio

- a) Open DataStudio and select “Create Experiment.”
- b) On the main toolbar, click the **Setup** button to open the Experiment Setup window.
- c) In the Sensors list of the Experiment Setup window, do the following: i) Click on the Smart Pulley icon and drag it to digital channel 1 on the picture of the interface. ii) Click on the Force Sensor icon and drag it to the same analog channel into which the sensor is plugged.

Part III: Create a timing sequence in DataStudio

- a) On the main toolbar, click the **Timers** button. When the Timers dialog opens, click the **New** button.
- b) In the Label box, type the name, “time between blocked.”
- c) In the Timing Sequence menu, select “blocked” and “blocked” and click **OK**.

PART IV: Create the mathematical equation in DataStudio

- a) Click on the **Calculate** button to open the Calculator dialog.
- b) In the Calculator dialog, click the **New** button to create a new equation.
- c) In the equation box, type in the equation $velocity = 2 * \pi * radius / t$ and click the **Accept** button.
- d) Define the variables “radius” and “t.” (Under Variables, click on the arrow and select “constant” to define the variable “radius” and enter the value in the box. Under “Experiment Constants,” click the Accept button. Select “Data Measurement” for “t” and select “time between blocked.”)
- e) Click the Accept button. Your equation will appear as an icon in the Data list. To edit the equation, double click on the equation icon in the Data list.

PART V: Collect data

- a) To collect data in a display, click the **Start** button.

Appendix D: Technical Support

For assistance with the ME-8088 Centripetal Force Apparatus 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

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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 the result of a manufacturing defect or improper use by the customer shall be made solely by 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 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.