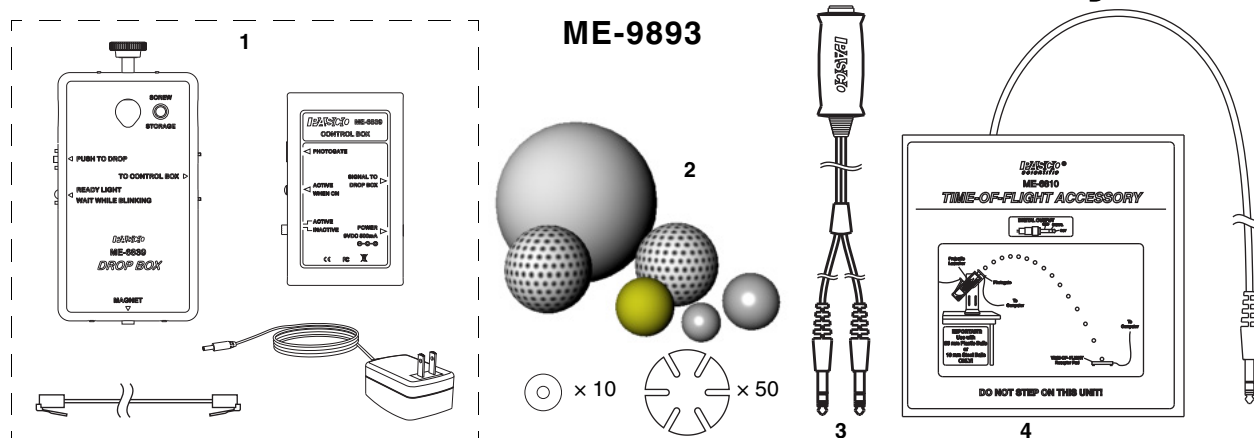




Discover Free Fall System

ME-9889

Discover Free Fall Accessory



Included Equipment ME-9889

Part Number

1. Drop Box assembly:

ME-6839

Drop Box, main unit

Control Box

AC Adapter

Cable

2. Free Fall Ball Accessory:

ME-9890

Release Washers (qty. 10)

Release Stickers (qty. 50)

Yellow Nylon Ball (2.5 cm diameter, 10 g)

Larger Stainless Steel Ball (2.5 cm diameter, 70 g)

Smaller Stainless Steel Ball (1.6 cm diameter, 16 g)

Regular Golf Ball (4.4 cm diameter, 50 g)

Practice Golf Ball (4.2 cm diameter, 6 g)

Large Hollow Plastic Ball (10 cm diameter, 40g)

ME-9893

3. Timer Switch

ME-9819

4. Time-of-Flight Accessory

ME-6810

Required Equipment

Timing device (see page 3)

See PASCO catalog

Mounting rods and base (see page 3)

See PASCO catalog

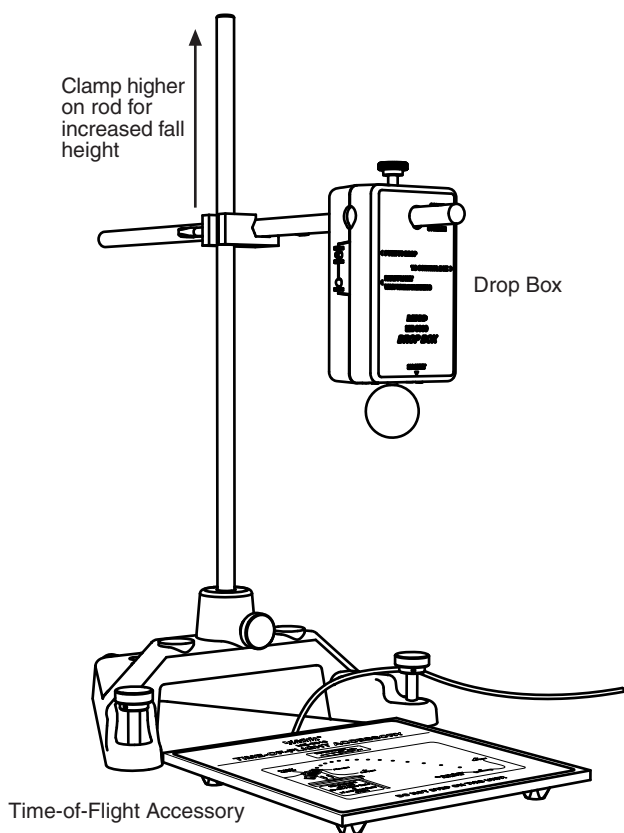


Figure 1: Drop box mounted on a rod stand

Introduction

The PASCO Discover Free Fall System consists of the ME-6839 Drop Box plus the ME-9893 Discover Free Fall Accessory. The Discover Free Fall Accessory consists of the Free Fall Ball Accessory (ME-9890), the Timer Switch (ME-9819) and the Time-of-Flight Accessory (ME-6810).

The PASCO Discover Free Fall System allows students to precisely time falling objects. The system includes several balls of various sizes and masses (ranging from about 6 g to 70 g). Other objects of similar mass can also be used.

The object to be dropped is suspended from a magnet. When the timer switch is pushed, the object is released and the timing starts. Timing stops when the object hits the time-of-flight pad. The system includes steel washers and adhesive stickers to allow non-steel objects to be suspended from the magnet.

The timer switch is a push-button device that simultaneously causes the drop box to release the object and triggers the timing device to start timing.

The time-of-flight accessory is a pad that triggers the timing device to stop timing when an object hits it.

Mounting Options

Mount the drop box on a horizontal rod attached with a right angle clamp to a tall rod. Figure 1 shows a typical setup using a rod stand (ME-8735), a 120 cm vertical rod (ME-8741), a 45 cm horizontal rod (ME-8736), and a right angle clamp (SE-9444). Any similar configuration will work just as well. For a greater fall height, place the rod stand on a table and the time-of-flight pad on the floor.

The drop box can also be attached magnetically to a steel part of the ceiling (see Figure 2). This mounting method works well for maximizing the height from which objects will be dropped.

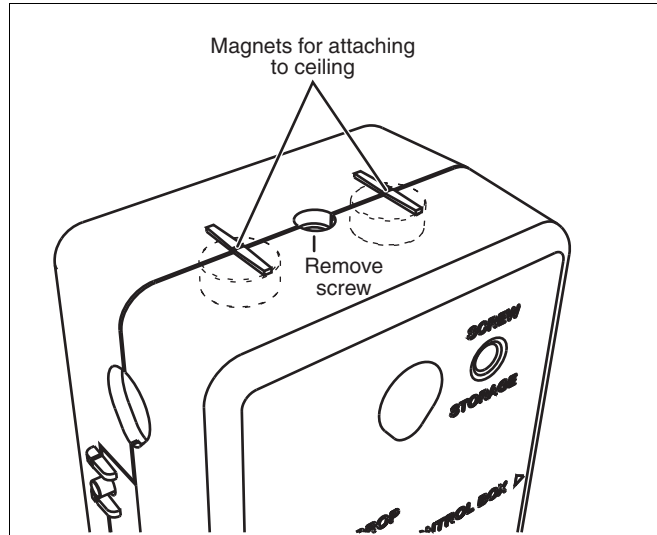


Figure 2: Magnets for attaching to ceiling

Timing Device Options

In order to time the object, the system must be connected to one of the following timing devices:

- Smart Timer (ME-9830)
- *ScienceWorkshop* 500 or 750 interface connected to a computer running DataStudio.
- PASPORT interface with a Digital Adapter (PS-2159). Any PASPORT interface can be used connected to a computer running DataStudio. The Xplorer GLX (PS-2002) can also be used in standalone mode without a computer.

For more information about these devices, see the PASCO catalog, visit www.pasco.com, or contact PASCO Technical Support (see page 10).

Equipment Set-up

1. Connect the included AC Adapter to the **POWER** jack on the control box.
2. Connect one plug of the timer switch to the **PHOTO-GATE** port on the control box.
3. Use the included cable to connect the **SIGNAL TO DROP BOX** jack on the control box to the **TO CONTROL BOX** jack on the drop box.
4. Mount the drop box as shown in Figure 1.
5. Place the time-of-flight pad directly below the drop box.
6. If the object to be dropped is not steel, attach one of the included washers to it using one of the included stickers (see Figure 3). The sticker is pressure activated; press hard to make it stick permanently.
7. Hang the object from the drop box magnet.
8. Set the **ACTIVE/INACTIVE** switch on the control box to **ACTIVE**.
9. Select one of the timing options (Smart Timer, *ScienceWorkshop*, or PASPORT) and follow the instructions on pages 5–8 to configure the timing device and take data.



Figure 3: Attaching a washer to a non-steel object

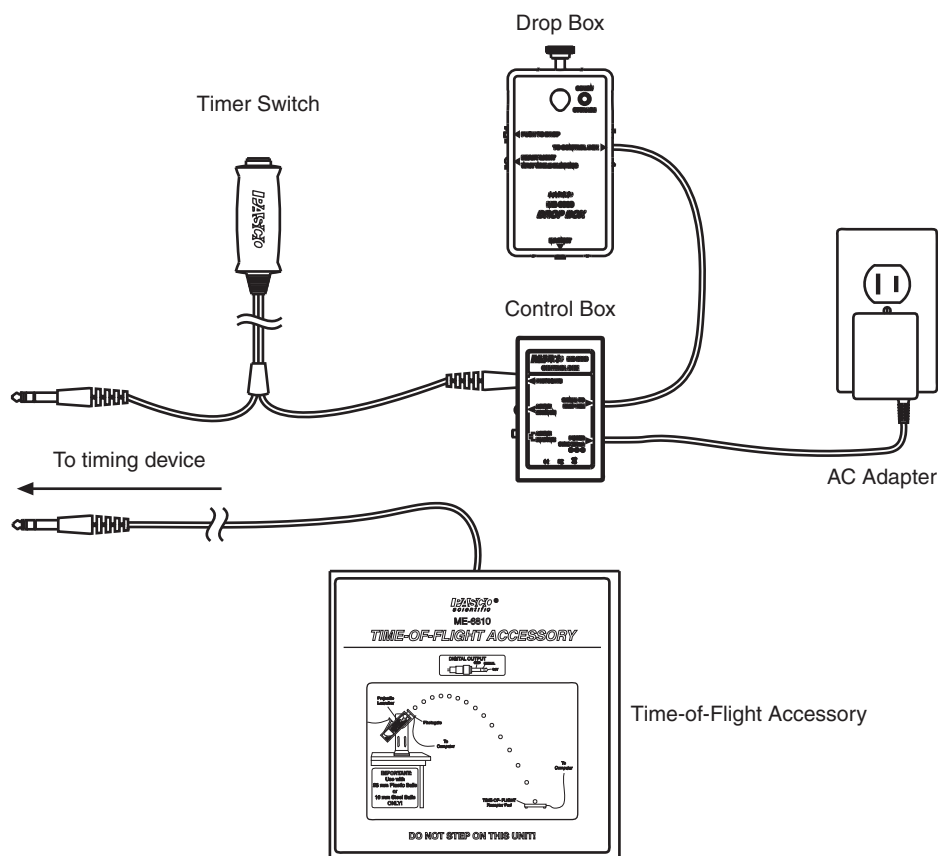


Figure 4: Equipment Set-up

Test Drop

1. Press the **PUSH TO DROP** button on the drop box.
 - If the object drops immediately, no adjustment is necessary.
 - If the object does not drop or drops after a delay, add a sticker to the object to increase the space between the steel part of the object and the drop box magnet.
2. Hang the object from the drop box and retest if necessary.

Timing Option 1: Smart Timer

Set-up

1. Connect the Smart Timer's AC adapter to its power port.
2. Turn on the Smart Timer.
3. Connect the remaining plug of the timer switch to channel **1** of the Smart Timer.
4. Connect the time-of-flight pad to channel **2** of the Smart Timer.
5. On the Smart Timer, press the **1 Select Measurement** button once to select **Time**.
6. Press the **2 Select Mode** button several times to select **Two Gates** mode.

Data Collection

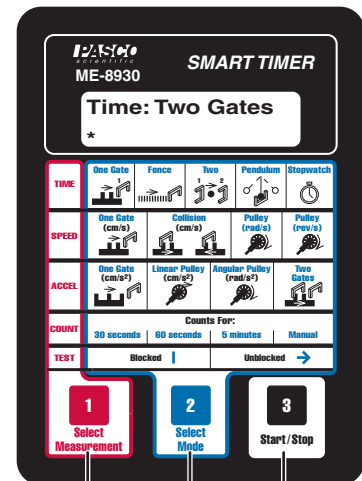
1. On the Smart Timer, press the **3 Start/Stop** button.

Result: The Smart Timer beeps and an asterisk (*) appears on the display to indicate that it is ready to start timing.

2. Press the timer switch button.

Result: The object is released from the drop box. When the object hits the time-of-flight pad, the Smart Timer displays the fall time.

To time another object: hang the object from the drop box, wait until the LED on the drop box stops blinking, and repeat steps 1 and 2.



Select
Time

Select
Two Gates

Press before
releasing ball

Timing Option 2: *ScienceWorkshop* Interface

Set-up

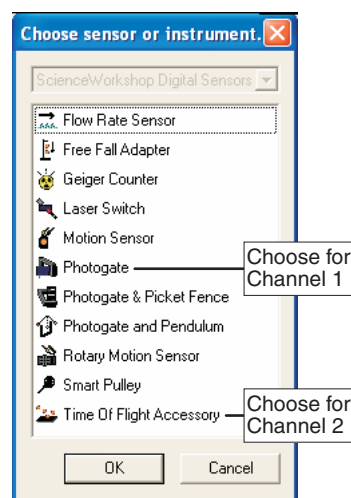
1. Connect your ScienceWorkshop interface to your computer (refer to the instructions that came with the interface).
2. Start DataStudio. If you see the **Welcome to DataStudio** window, select **Create Experiment**.
3. Connect the remaining plug of the timer switch to Channel 1 of the interface.
4. Connect the time-of-flight pad to Channel 2 of the interface.
5. In the **Experiment Setup** window, click Channel 1 on the picture of the interface.

Result: The **Choose Sensor or Instrument** window appears.

Note: If you do not see the **Experiment Setup** window, click the **Setup** button. If you do not see a picture of your interface in the window, click the **Choose Interface** button and select your interface.

6. In the **Choose Sensor or Instrument** window, double-click **Photogate**.
7. In the **Experiment Setup** window, deselect the **Velocity In Gate** measurement.
8. In the **Experiment Setup** window, click Channel 2 on the picture of the interface.

Result: The **Choose Sensor or Instrument** window appears.



9. In the **Choose Sensor or Instrument** window, double-click **Time Of Flight Accessory**.
10. In the Summary Bar (on the left side of the screen), double-click **Table**.

Result: A table appears configured to display Elapsed Time.

Note: If you do not see the Summary Bar, click the **Summary** button.

Data Collection

1. In DataStudio, click the **Start** button.

Result: DataStudio's experiment clock starts running, indicating that it is ready to collect data.

2. Press the timer switch button.

Result: The object is released from the drop box. When the object hits the time-of-flight pad, the table in DataStudio displays the fall time.

To time another object: hang the object from the drop box, wait until the LED on the drop box stops blinking, and repeat steps 1 and 2.

When you have finished timing all objects, click the **Stop** button.

Timing Option 3: PASPORT Interface with Computer

Set-up

1. Connect your PASPORT interface to your computer (refer to the instructions that came with the interface).
2. Connect the remaining plug of the timer switch to channel **1** of your Digital Adapter (PS-2159).
3. Connect the time-of-flight pad to channel **2** of the Digital Adapter.
4. Connect the Digital Adapter to the PASPORT interface.

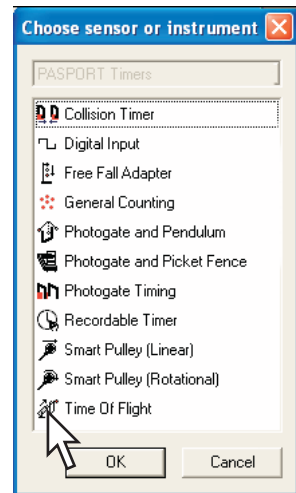
Result: DataStudio starts automatically and the **Choose Sensor or Instrument** window appears.

5. In the **Choose Sensor or Instrument** window, double-click **Time Of Flight**.

Result: A table appears configured to display Elapsed Time.

Note: This table is also configured to show Initial Velocity, which is not relevant in this case. Follow the next step to remove Initial Velocity.

6. Click once on the blank cells of the Initial Velocity column. Click the Remove button (✖) to delete the column.



Data Collection

1. In DataStudio, click the **Start** button.

Result: DataStudio's experiment clock starts running, indicating that it is ready to collect data.

2. Press the timer switch button.

Result: The object is released from the drop box. When the object hits the time-of-flight pad, the table in DataStudio displays the fall time.

To time another object: hang the object from the drop box, wait until the LED on the drop box stops blinking, and repeat steps 1 and 2.

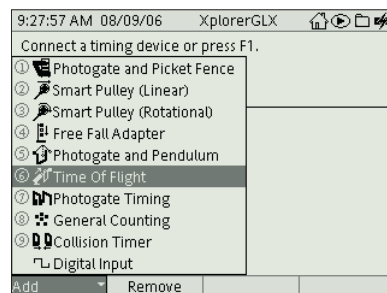
When you have finished timing all objects, click the **Stop** button.

Timing Option 4: Xplorer GLX in Standalone Mode

Set-up

1. Connect the remaining plug of the timer switch to channel **1** of the Digital Adapter.
2. Connect the time-of-flight pad to channel **2** of your Digital Adapter (PS-2159).
3. Turn on the GLX
4. Connect the Digital Adapter to the GLX.

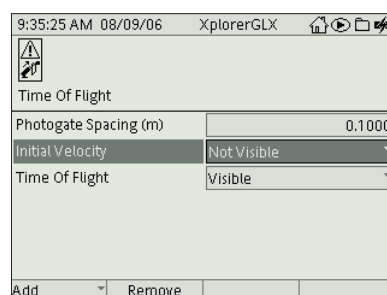
Result: The Timers list appears.



Timers List

5. Press the down arrow several times to highlight **Time Of Flight**. Press .

Result: The Timing screen appears.



Timing Screen

6. Press the down arrow to highlight **Initial Velocity**. Press to set it to **Not Visible**.
7. Press , **F2** to open the Table display.

Data Collection

1. Press .

Result: The clock icon () appears at the top of the screen to indicate that the GLX is ready to collect data.

2. Press the timer switch button.

Result: The object is released from the drop box. When the object hits the time-of-flight pad, the GLX displays the elapsed time.

No Data	
Time Of Flight (s)	
1	----
2	
3	
4	
5	
6	
7	
8	

Table Display

To time another object: hang the object from the drop box, wait until the LED on the drop box stops blinking, and repeat steps 1 and 2.

When you have finished timing all objects, click .

Suggested Experiments

Fall Time of Different Objects

Keeping the drop-height constant, measure the free-fall time of different objects. Measure the drop height from the time-of-flight pad to the *bottom* of the object when it is hanging from the drop box. (You will need to adjust the drop box position slightly for different sized balls.) Time each ball several times to make sure you get an accurate measurement.

Compare objects of various size, mass, and density.

If the *only* force acting on the balls is gravitational force, you would expect the fall time to be the same for every ball. Do you find this to be the case?

Fall Time Versus Height

Time a stainless steel ball dropping from several different heights. Use as wide a range of heights as possible.

Plot fall time (t) versus height (h). Is the relationship linear?

Plot t^2 versus h . Is that relationship linear?

For an object falling with constant acceleration, a , the relationship between t and h is given by

$$t^2 = \frac{2}{a}h$$

Use your data to find a .

Repeat the procedure with the large hollow ball. Does it accelerate at a constant rate? How can you tell?

Technical Support

For assistance with any PASCO product, contact PASCO at:

Address: PASCO scientific
10101 Foothills Blvd.
Roseville, CA 95747-7100

Phone: 916-786-3800 (worldwide)
800-772-8700 (U.S.)

Fax: (916) 786-7565

Web: www.pasco.com

Email: support@pasco.com

Limited Warranty

For a description of the product warranty, see the PASCO catalog.

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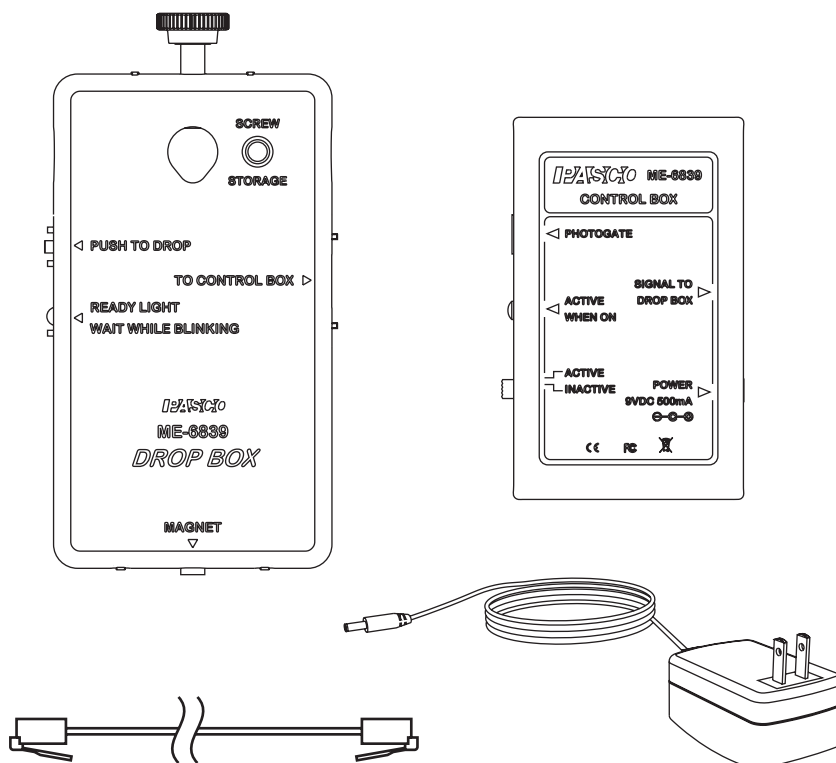
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Drop Box

ME-6839



Included Equipment	Part Number
Drop Box, main unit	003-09468
Control Box	003-09471
AC Adapter	540-007 (120 VAC) 540-027 (230 VAC)
Cable (7.6 m length, 6P4C RJ-11 connectors)	516-011

Introduction

The PASCO Drop Box magnetically suspends a metal object and drops it when externally triggered. The triggering device can be a photogate (such as PASCO part ME-9498A) or a push-button timer switch (PASCO part ME-9819). You can also trigger it without an external device by pressing a built-in button. The Drop Box is designed for use with PASCO sys-

tems such as the ME-6853 Shoot-the-Target Accessory and the ME-9889 Discover Free Fall System.

The Drop Box holds the object with a permanent magnet. To cause the object to drop, current flows through a coil canceling the magnetic field.

Equipment Set-up

For set-up instructions specific to the Discover Free Fall System or Shoot-the-Target Accessory, refer to the manuals included with those systems.

1. Connect the included AC Adapter to the **POWER** jack on the control box.
2. Connect a photogate or timer switch to the **PHOTO-GATE** port on the control box. (You can skip this step if you plan to use only the **PUSH TO DROP** button on the drop box.)
3. Use the included cable to connect the **SIGNAL TO DROP BOX** jack on the control box to the **TO CONTROL BOX** jack on the drop box.
4. Mount the drop box on a horizontal support rod (see Figure 1), or remove the thumbscrew and attach the drop box magnetically to a steel part of the ceiling (see Figure 2).

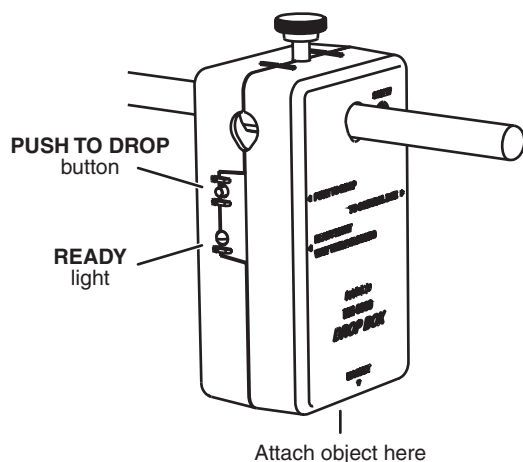


Figure 1: Drop box mounted on horizontal rod

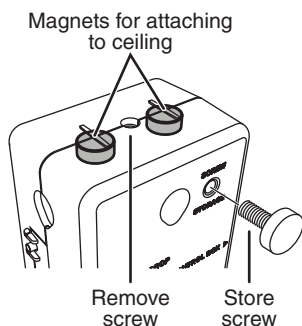


Figure 2: Location of magnets for attaching to ceiling

5. Stick a ball (from the ME-9889 Discover Free Fall System), target (from the ME-6853 Accessory), or similar object to the magnet on the underside of the drop box.
6. To make the object drop, block the photogate or push the timer switch *or* press the **PUSH TO DROP** button on the drop box.

Note the **READY LIGHT** on the drop box. After the drop box is triggered, the light blinks for a few seconds to indicate that the drop box is recharging. Wait until the light glows steadily before triggering the drop box again.

If you are using a photogate, you may want to disable it to prevent unwanted triggering. Set the **ACTIVE/INACTIVE** switch on the control box to **INACTIVE** to disable the trigger.

Technical Support

For assistance with any PASCO product, contact PASCO at:

Address: PASCO scientific
10101 Foothills Blvd.
Roseville, CA 95747-7100

Phone: 916-786-3800 (worldwide)
800-772-8700 (U.S.)

Fax: (916) 786-7565

Web: www.pasco.com

Email: support@pasco.com

Limited Warranty

For a description of the product warranty, see the PASCO catalog.

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Freefall Picket Fence

Introduction

A Picket Fence is a clear plastic strip with uniformly spaced opaque bands. Each opaque band blocks the photogate beam, and the time from one blockage to the next becomes shorter as the velocity of the falling Picket Fence increases. Using the known distance between the leading edge of each band, and the time interval between photogate blocks, the student calculates the average velocity of the Picket Fence for each interval. The slope of the graph of average velocity versus time gives the acceleration of the falling object.

Equipment

Qty	Items	Part Number
1	Photogate	ME-9498A
1	Picket Fence	ME-9377A
1	Mounting Rod	SA-9242
1	Table Clamp	ME-9472
1	Multi-Clamp	ME-9507
1	90-cm Rod	ME-8783
1	No Bounce Pad	SE-7347



Figure 1. Dropping a Picket Fence

Set-up

1. Fasten the Table Clamp and the 90 cm Rod to the edge of the table as shown in Figure 1.
2. Use the Multi-Clamp to fasten the Photogate to the vertical rod. The Mounting Rod (see Fig. 2) screws directly into the side of the Photogate. Make sure that the Photogate is high enough so that the Picket Fence can pass completely through before it reaches the table.
3. Plug the Photogate cord into Digital Input #1.
4. Position the yellow No-Bounce Pad (see Fig. 1) below the Photogate to protect the falling Picket Fence when it reaches the table.

5. Practice dropping the Picket Fence through the Photogate. Hold the Picket Fence at one end between thumb and forefinger, as shown in Figure 3. The Picket Fence must hang vertical, so that when it is released, it will fall straight without rotating. Make sure the bottom edge of the Picket Fence is just above the Photogate beam when you let go.

Note: The procedure is easier if one person handles the Picket Fence and another operates the computer.

6. There is a built-in timer that will record the times that each opaque band blocks the photogate beam. Click on Timer Set-up in the palette at the left of the screen to view the set-up.

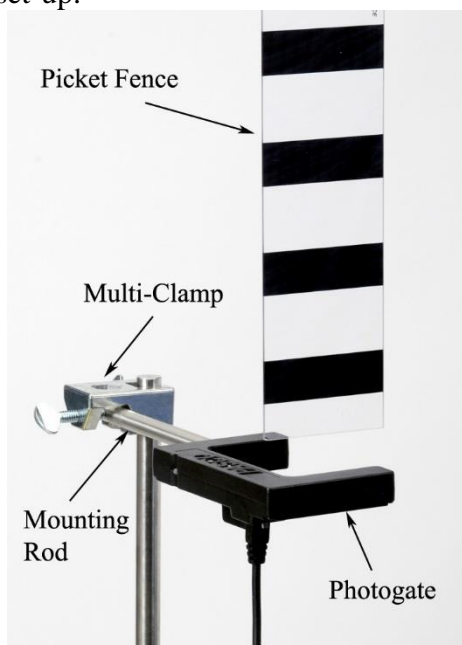


Figure 2. Picket Fence Initial Position

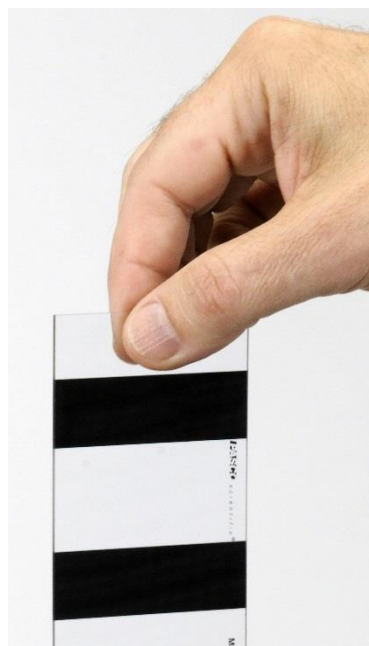


Figure 3. Hold in Center

Hold the Picket Fence at one end between thumb and forefinger, as shown. The Picket Fence must hang vertical, so that when it is released, it will fall straight without rotating. Make sure the bottom edge of the Picket Fence is just above the Photogate beam when you let go.

Procedure

1. Taking Data
 - a. Make a table and put the Block Times in the first column. Then create a user-entered data set named " Δt " with units of seconds. (Remember that you can get a Δ in Capstone by right-clicking where you are typing.) Create a new column and create another user-entered data set called "Average Time" with units of seconds. Create another column with another user-entered data set called " $v = \Delta x / \Delta t$ " with units of m/s.
 - b. Start recording data, then drop the Picket Fence through the Photogate. Stop recording data.

- c. If the Picket Fence hits the Photogate, or if it rotates too much, you should take another run. You should have seven entries in the data table. These are the times that each of the seven bands on the Picket Fence broke the Photogate beam.
2. Calculations
 - a. Calculate the difference (Δt) between block times and enter them into the column in the table. Note that you may have to increase the number of decimal places in each column to see the difference between the numbers. You can do this using the tool at the top of the graph.
 - b. Calculate the average speed of the Picket Fence during the time between the first and second block.

$$v = \frac{\Delta x}{\Delta t} = \frac{\Delta x}{t_2 - t_1}$$
 where t is the time each block occurred. Δx is the spacing between the bands on the Picket Fence, and is measured from the beginning of one band to the beginning of the next. You can measure over several bands to get a more accurate value of Δx . Enter your calculated average speeds into the table. You will end up with only six average speeds in your table.
 - c. To calculate the time that the average velocity actually occurred, calculate the average time between the Block Times. Add adjacent Block Times and divide by two. Enter these times into the table under Average Time.
3. Slope
 - a. Create a graph of the user-entered v vs. Average Time. You may want to turn off the connected lines in the graph and perhaps make the data points bigger.
 - b. Select a Linear Curve Fit from the graph toolbar.
 - c. What is the physical meaning of the slope? Does it have units? What is the uncertainty in your value?
 - d. Compare to the accepted value using the % error calculation.

$$\% \text{ difference} = \frac{\text{Measured} - \text{Accepted}}{\text{Accepted}} \times 100\%$$
 - e. Was your value too high or too low? What might account for that?

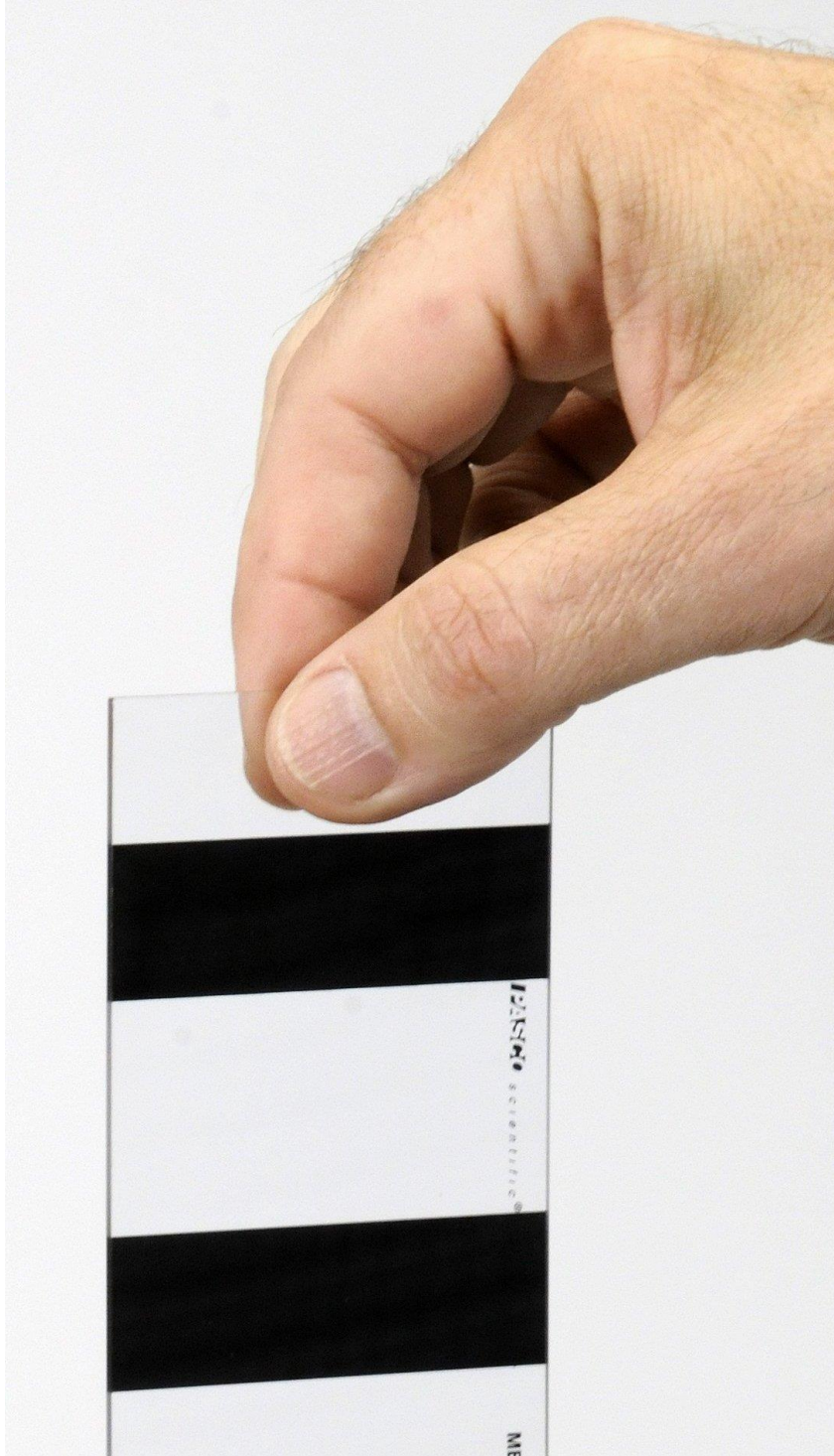
Analysis

In the previous sections, you used the Photogate only to measure the time of block, and then calculated the speeds by hand. The computer can also be configured to calculate these speeds automatically, allowing you to take multiple runs in a short period of time. This is set up in the Timer Setup, which you can open at the left of the screen to view.

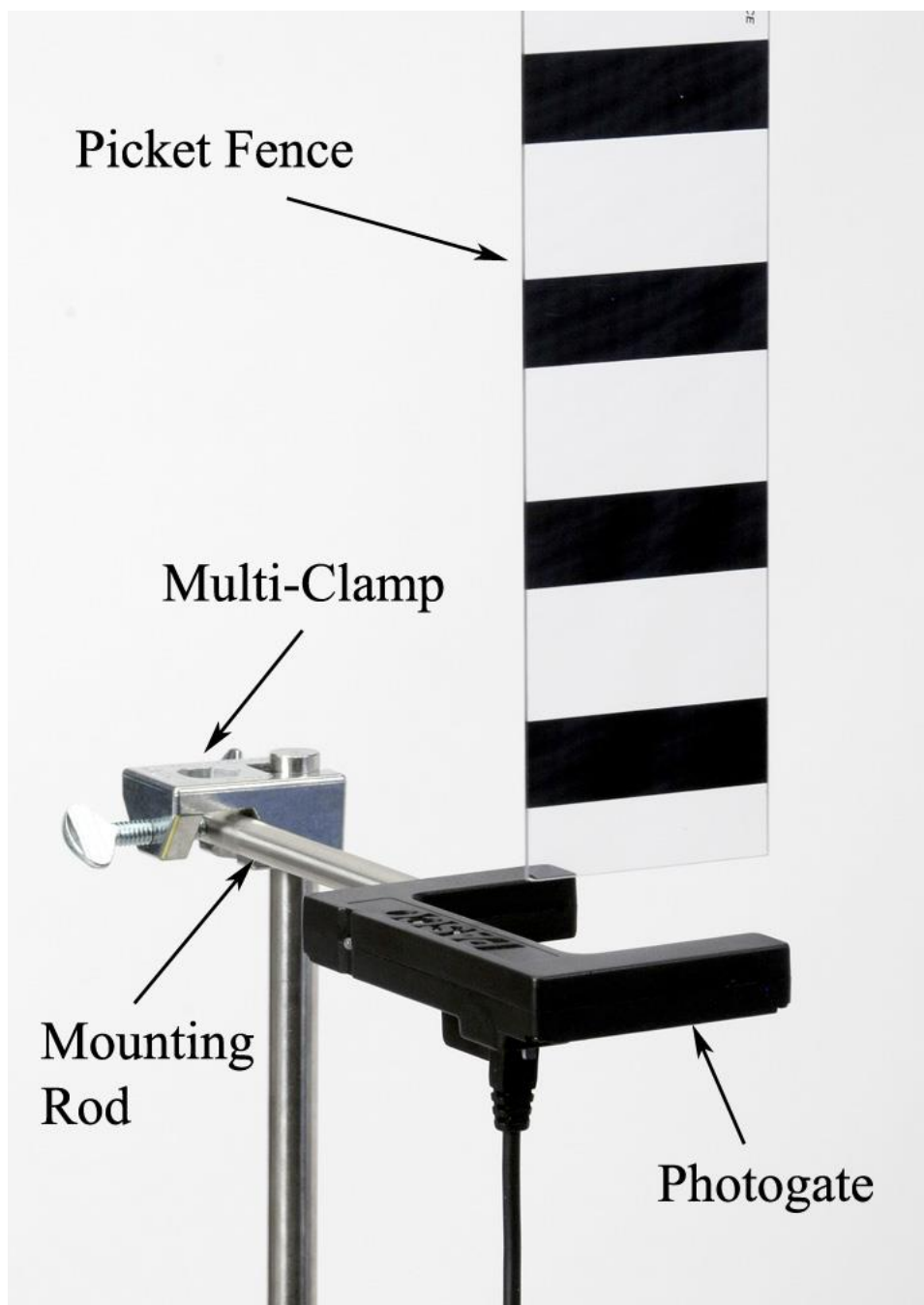
1. Create a graph Speed (from the Picket Fence) vs. Time (listed under time in the drop-down list).
2. Start recording data, then drop the Picket Fence through the Photogate as before. Stop recording data.

3. The speed vs. time data for this run will be graphed at right. Select a Linear Curve Fit to find the acceleration as before.
4. Repeat several times to get an average value. Also record your highest value.
5. In the set-up procedure, you were instructed to start the Picket Fence as low as possible. This decreases the speed and lowers the amount of air drag. Try letting go of the Picket Fence higher up to see if you can affect the measured acceleration. Do you get a lower value?

Holding_Picket_Fence.jpg



Photogate.jpg

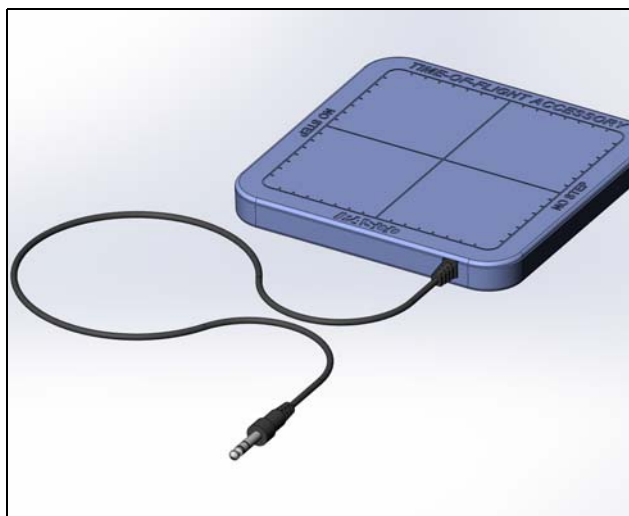


Accel_due_to_gravity_w_Picket_Fence.jpg



Time of Flight Accessory

ME-6810A



Equipment List

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

Equipment Required	
Projectile Launcher, Short Range or Long Range	see www.pasco.com
Photogate Mounting Bracket	see www.pasco.com
Smart Gate (1) or Photogate (2)	see www.pasco.com
PASCO Interface and Data Collection Software	see www.pasco.com
OR	
Smart Timer or Photogate Timer	see www.pasco.com

Equipment Recommended	
Phone Jack Extender Cable*	PI-8117
Ruler, Meter Stick, or Tape Measure	see www.pasco.com

*The Phone Jack Extender Cable can be used to connect the Time-of-Flight Accessory to a Timer or Interface if you are using a Long Range Projectile Launcher (ME-6801).

Equipment needs may vary, depending on whether you will do the Time-of-Flight experiment or the Initial Speed experiment. Use the following table as a guide for determining what equipment you need.

	Time of Flight Experiments		Initial Speed Experiments	
What Is Needed	Timer	Interface	Timer	Interface
Time-of-Flight Accessory	x	x	x	x
Projectile Launcher	x	x	x	x
Photogate Mounting Bracket	x	x	x	x
Smart Gate (see A)	x	x	x	x
OR				
Photogate(s) (see B)	x (1)	x (1)	x (2)	x (2)
Smart Timer or Photogate Timer*	x		x	
Interface		x		x
Extender Cable (see C)	x	x		x

* If an interface and/or data collection software are not available, you can use a Photogate Timer (ME-9215B) or a Smart Timer (ME-8930) instead.

A. One Smart Gate (PS-2180) can be used to perform all of the experiments. Two Photogate Heads are required for measuring the initial speed.

B. One Smart Gate or two Photogate Heads are required for measuring both initial speed and time of flight in the same experiment.

C. The Extender Cable may be needed to connect the Time-of-Flight Accessory to the Timer or Interface if you are using a Long Range Projectile Launcher

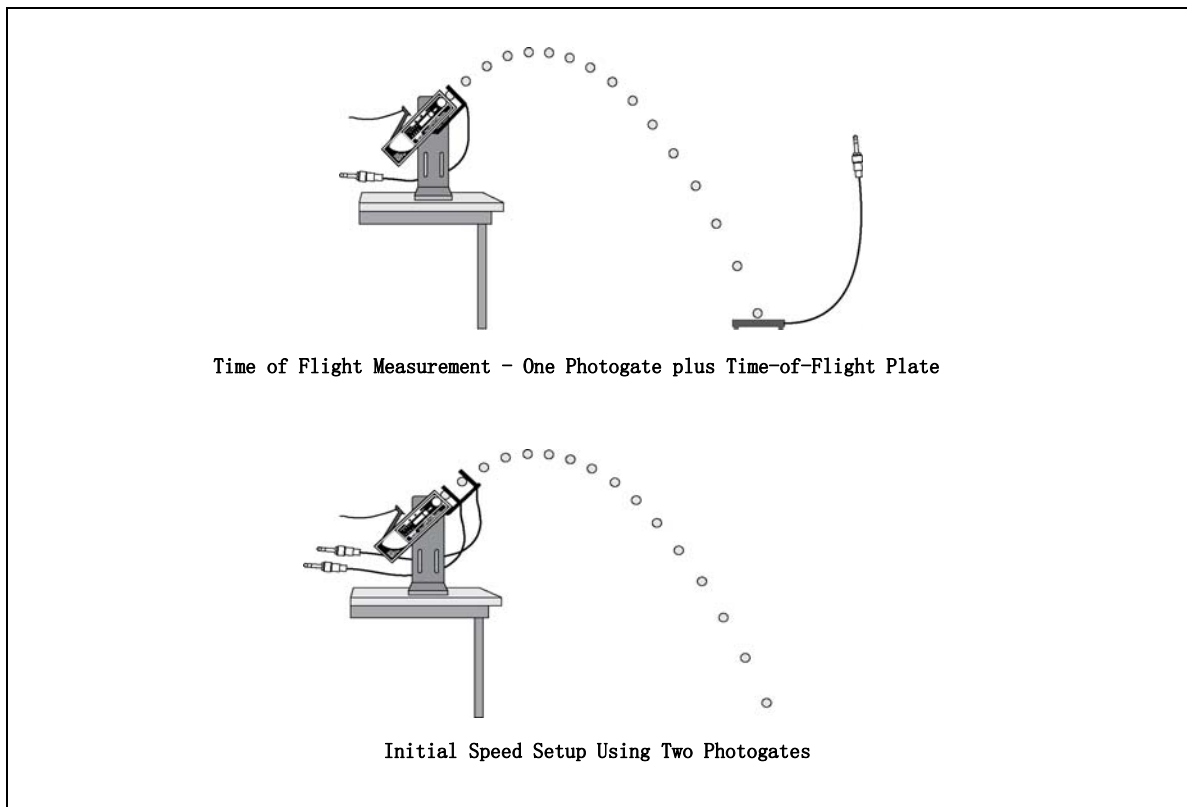
Introduction

The PASCO ME-6810A Time-of-Flight Accessory is built for use with PASCO Projectile Launchers. It consists of a piezo-electric speaker circuit mounted on a 20 by 20 centimeter plastic plate. The plate has a signal cable with a 6 mm (1/4") stereo phone plug. When a solid object hits the plate, the speaker circuit generates a Photogate-like signal. The cable sends the signal to a timer or to an interface. When a ball is fired from a Projectile Launcher, a Photogate mounted on the front of the launcher sends a signal to start the timing, and when the ball hits it, the Time-of-Flight Accessory plate sends a signal to stop the timing. The Time-of-Flight Accessory is designed for use with PASCO Photogates.

Setup Options

The Time-of-Flight Accessory can be used with a Smart Gate or Photogates with a PASCO Timer or a PASCO Interface for time of flight measurements. For a PASCO interface, you will need PASCO Software.

See www.pasco.com/software. If you plan to measure initial speed and time of flight in the same experiment, you will need one Smart Gate and any PASCO Interface, or two Photogates, one or two Digital Adapters, and a PASCO multi-port interface (with PASPORT and Digital ports or two PASPORT ports).

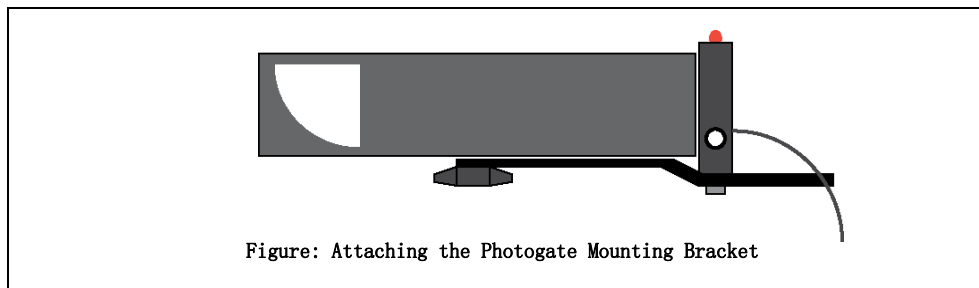


Setup with a Timer

a) Setup for Time of Flight with a Timer

Equipment Required: Time-of-Flight Accessory, Projectile Launcher, Photogate Mounting Bracket, Photogate Head, PASCO Timer.

1. Put the Photogate Mounting Bracket onto the Projectile Launcher. Mount a Photogate Head at the front of the Launcher.



2. Connect the Photogate Head and the Time-of-Flight Accessory to the Timer.
3. Set the Timer to measure the time of flight of the projectile from the launcher to the plate.

b) Setup for Initial Speed with a Timer

Equipment Required: Projectile Launcher, Photogate Mounting Bracket, Two Photogate Heads, PASCO Timer

1. Put the Photogate Mounting Bracket onto the Projectile Launcher. Mount two Photogate Heads on the Photogate Mounting Bracket.
2. Measure the distance between the Photogate Heads. You will use this distance and the measured time between the photogates to calculate the initial speed of the projectile (ball).
 - The distance between the Photogate Heads on the Photogate Mounting Bracket should be close to 10 centimeters.
3. Connect the the two Photogate Heads to the Timer. Set the Timer to measure the time of the projectile from the first photogate to the second photogate.

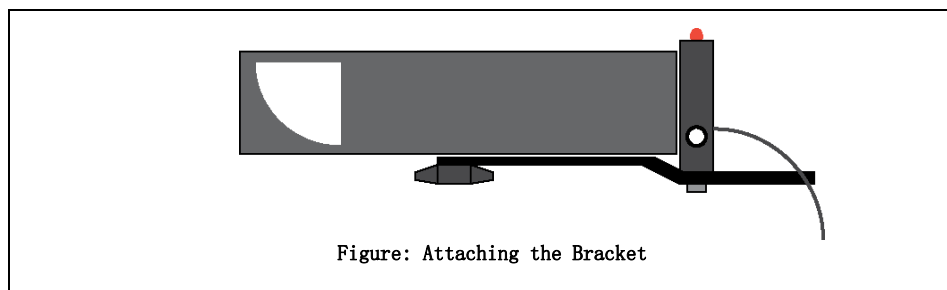
Set up with an Interface

You can setup the Time-of-Flight Accessory for use with a PASCO Interface and PASCO data collection software. NOTE: If the PASCO Interface is PASPORT-compatible only, you will need a PS-2159 Digital Adapter in order to connect phone plugs to the interface.

a) Set up for Time of Flight with an Interface

Equipment Required: Time-of-Flight Accessory, Projectile Launcher, Photogate Mounting Bracket, Smart Gate or Photogate Head, PASCO Interface and Data Collection Software

1. Put the Photogate Mounting Bracket on to the Projectile Launcher and mount a Smart Gate or a Photogate Head in front of the launcher.

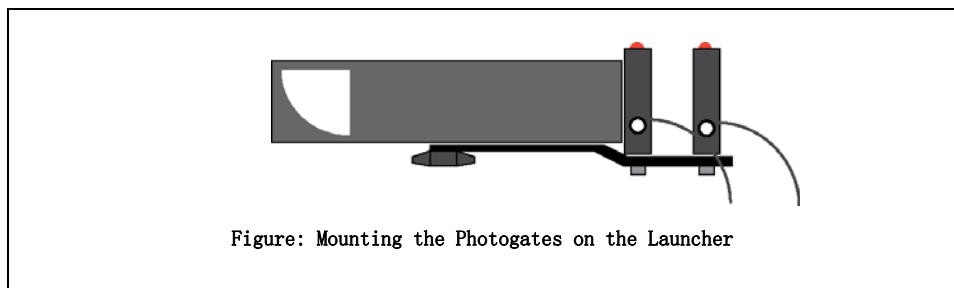


2. Connect the Smart Gate or Photogate and the Time-of-Flight Accessory to the interface.
 3. Set up the data collection software to measure the time of flight of the projectile from the launcher to the plate.
- For information about the data collection software, see the Online Help System or the User's Guides.

b) Set up for Initial Speed with an Interface

Equipment Required: Projectile Launcher, Photogate Mounting Bracket, Smart Gate or two Photogate Heads, PASCO Interface and Data Collection Software.

1. Put the Photogate Mounting Bracket onto the Projectile Launcher. Mount a Smart Gate or two Photogates on the Photogate Mounting Bracket.



2. Measure the distance between the Photogate Heads. You will use this distance and the measured time between the photogates to calculate the initial speed of the projectile (ball).
- For the Smart Gate, the distance from Port 1 to Port 2 is 1.5 cm. Connect the Smart Gate or the two Photogates to the interface.
3. Set up the data collection software to measure the time through the Smart Gate or the time between the two Photogates.
- For information about the data collection software, see the Online Help System or the User's Guides.

c) Set up for Time of Flight and Initial Speed with an Interface

Equipment Required: Time-of-Flight Accessory, Projectile Launcher, Photogate Mounting Bracket, Smart Gate or two Photogate Heads, PASCO Interface and Data Collection Software,

1. Put the Photogate Mounting Bracket onto the Projectile Launcher. Mount a Smart Gate or two Photogates on the Photogate Mounting Bracket.

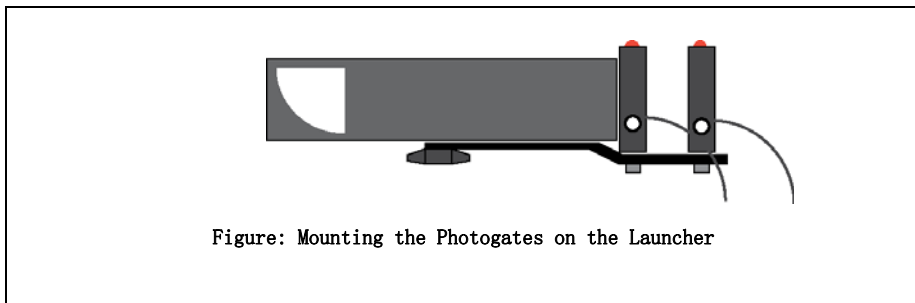


Figure: Mounting the Photogates on the Launcher

2. Measure the distance between the Photogate Heads. You will use this distance and the measured time between the photogates to calculate the initial speed of the projectile (ball).
- For the Smart Gate, the distance from Port 1 to Port 2 is 1.5 cm. Connect the Smart Gate or the two Photogates to the interface.
3. Connect the Time-of-Flight Accessory to the Smart Gate and connect the Smart Gate to the interface, or connect the Time-of-Flight Accessory and the two Photogates to the interface.
- NOTES about Using the Time-of-Flight Accessory and a Smart Gate: The Smart Gate is a “dual-photogate” or two photogates joined together. The Smart Gate has a PASPORT-compatible plug that connects to a PASPORT-compatible interface. (See www.pasco.com.) The Smart Gate also has an auxiliary port that accepts the phone plug from the Time-of-Flight Accessory. This means that the Smart Gate can measure the time of the ball as it goes from Port 1 to Port 2, and also measure the time of the ball from Port 1 to the Time-of-Flight Accessory. The Smart Gate is ideal for measuring initial speed and time of flight.
- NOTE: If the interface is PASPORT-compatible only, you will need two PS-2159 Digital Adapters in order to connect both Photogates and the Time-of-Flight Accessory to the interface.
4. Set up the data collection software to measure the time through the Smart Gate or the time between the two Photogates and also the time of flight from the launcher to the plate.
- For information about the data collection software, see the Online Help System or the User's Guides.

Experiment 1

The Relationship Between Time of Flight and Initial Speed

Equipment required	
PASCO Interface and Software (or PASCO Timer)	Projectile Launcher and ball
Time-of-Flight Accessory	Photogate Mounting Bracket
Phone Jack Extender Cable (PI-8117)	Smart Gate or Photogate Head

Purpose:

The purpose of this experiment is to determine whether time of flight of a ball launched horizontally off a table remains constant as the initial launch speed is changed.

Theory:

A ball is launched horizontally off a table from a height h and has no initial velocity in the vertical direction. Hence, the ball takes the same amount of time to reach the ground as a ball that drops from rest at the same height. The equation gives the time of flight, which is independent of the initial velocity.

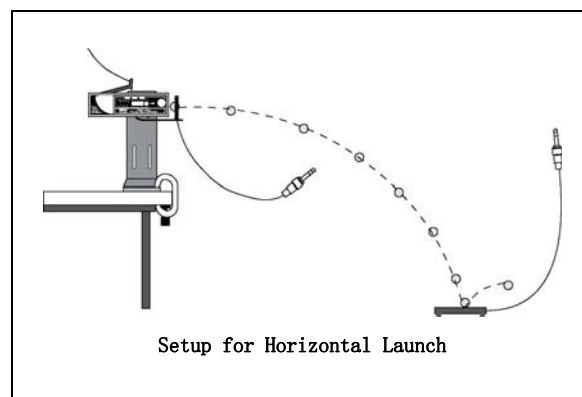
$$h = \frac{1}{2}gt^2$$

Therefore, the time can be calculated by re-arranging the equation:

$$t = \sqrt{2\frac{h}{g}}.$$

Setup:

1. Clamp the Projectile Launcher to one end of a sturdy table with the launcher aimed away from the table.



2. Adjust the angle of the Projectile Launcher to zero degrees so the ball will launch horizontally.

3. Attach the Photogate Mounting Bracket to the Launcher and attach a Smart Gate or a Photogate to the bracket. Connect the Smart Gate or Photogate to the Interface.
4. Connect the Time-of-Flight Accessory to the Interface. If you are using the Smart Gate, you could connect the Time-of-Flight Accessory to the Smart Gate auxiliary port. (Use the Phone Jack Extender Cable if necessary.)
5. Set up the software to measure the time of flight from the launcher to the timer plate. (One Smart Gate or Photogate at the beginning of flight, and the timer plate at the end of the flight).

Procedure:

1. Put the ball into the Projectile Launcher and cock it to the short range (first) position.
2. Test fire the ball to determine where to place the timer plate on the floor. Put the timer plate on the floor where the ball hits.
3. Start data collection. Shoot the ball on the first range position and record the time of flight in Table 1.
4. Repeat steps 1-3 for the Projectile Launcher on medium range and then on long range. Are the times the same?
5. Set the angle of the launcher to 30° and shoot it again on the long range setting. Move the timer plate to the new landing position so the ball will hit the plate. Shoot again and record the time of flight in Table 1. Is this time the same as the times for when the launcher was horizontal?

Table 1: Results

Range	Time
Short	
Medium	
Long	
Long at 30°	

Experiment 2

Predicting the Horizontal Distance Traveled by a Launched Projectile

Equipment required:	
Interface and Software	Time-of-Flight Accessory
Extender Cable (PI-8117)	Plumb bob (SE-8728)
Projectile Launcher and ball	Photogate Mounting Bracket
Smart Gate or Photogate Heads	Measuring tape or meter stick
White paper and carbon paper	

The purpose of this experiment is to use the initial speed and the time of flight to predict the horizontal distance traveled by a ball shot from a table at an angle.

Theory:

A ball is launched off a table from a height h at an angle θ above the horizontal. The horizontal distance, x , traveled by the ball is given by the following equation.

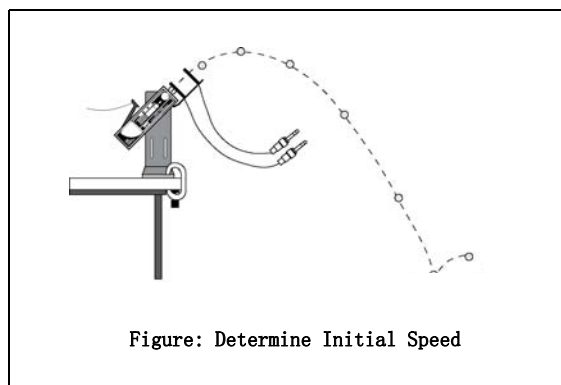
$$x = v_0 \cos \theta t$$

Where in the equation, v_0 is the initial speed of the ball, and t is the time of flight.

Procedure:

Determine the Initial Speed of the Ball

1. Clamp the Projectile Launcher to one end of a sturdy table with the launcher aimed away from the table.



2. Adjust the angle of the Projectile Launcher to any desired angle. Record the angle in Table 2.1.
3. Attach the Photogate Mounting Bracket to the Launcher and attach a Smart Gate or two Photogates to the Bracket.

4. Connect the Smart Gate or two Photogates to the interface.
5. Set up the software to measure the time through the Smart Gate or the time between the two Photogates.
6. Put the plastic ball into the Projectile Launcher and cock it.
7. Start data collection. Shoot the ball and record the time through the Smart Gate or between the two Photogates in Table 2.1.
8. Shoot the ball 9 more times to determine the average time through the Smart Gate or between the two Photogates.

Table 2.1: Times For Initial Speed

Trial	Time	Trial	Time
1		6	
2		7	
3		8	
4		9	
5		10	

- Angle of Projectile Launcher = _____
- Initial Speed = _____

Determine the Time of Flight of the Ball

1. Connect the Time-of-Flight Accessory to the Smart Gate auxiliary port, or to the Interface.
2. Put the plastic ball into the Projectile Launcher and cock it.
3. Test fire the ball to determine where to place the Time-of-Flight Accessory plate on the floor. Put the timer plate on the floor where the ball hit.
4. Set up the software to measure the time of flight from the launcher to the plate.
5. Start data collection. Shoot the ball and record the time of flight in Table 2.2.
6. Shoot the ball 9 more times to determine the average time of flight between the launcher and the plate.

Table 2.2: Time of Flight

Trial	Time of Flight	Trial	Time of Flight
1		6	

2	7	
3	8	
4	9	
5	10	

- Average Time of Flight = _____
- Calculated Horizontal Distance = _____

Calculations:

1. Find the average of the times in Table 2.1 and use the average time and the distance through the Smart Gate (1.5 cm) or the distance between the two Photogates to calculate the initial speed of the ball. Record the value for the initial speed
2. Find the average of the values for the time of flight from Table 2.2. Record the value for the average time of flight.
3. Calculate the horizontal distance using the initial speed, the average time of flight, and the angle of the Projectile Launcher and record the calculated distance in Table 2.2.

Check the Prediction:

1. Use a Plumb Bob to find the place on the floor directly below the muzzle of the launcher. Measure from the point directly below the muzzle to the point that is the calculated horizontal distance and tape a piece of white paper on the floor at that point.
 - NOTE: Test fire the Projectile Launcher one time and adjust the piece of white paper so it is along the path of the projectile. Do not move the piece of paper closer to or farther away from the point directly below the muzzle of the launcher.
2. Tape a piece of carbon paper on top of the white paper so that the carbon paper will leave a mark on the white paper when the ball lands. (Put the carbon paper with the carbon side down on top of the white paper.)
3. Shoot the ball a total of 10 times.
4. Use the Plumb Bob to find the place on the floor directly below the muzzle of the launcher. Measure the horizontal distance along the floor to the leading edge of the paper on the floor. Record this distance in Table 2.3.
5. Remove the carbon paper but leave the white paper taped to the floor. Measure from the leading edge of the paper to each of the dots on the white paper. Record in Table 2.3.

Analysis:

1. Find the average of the ten distances from the leading edge of the paper to each dot and record it in Table 2.4. Add the distance from the plumb bob to the leading edge of the paper to the average distance to the dots and record the combined distances in Table 2.4.

2. Calculate the percent difference between the measured distance and the calculated distance. Record in Table 2.4.

Table 2.3: Distance of Dots from Leading Edge of Paper

Dot	Distance	Dot	Distance
1		6	
2		7	
3		8	
4		9	
5		10	

Table 2.4: Results

Distances of Dots (average)	
Distance to Leading Edge of Paper	
Combined Distance	
Calculated Distance	
Percent (%) Difference	

Experiment 3

Horizontal Speed of a Projectile

Equipment required:	
PASCO Interface and Software	Time-of-Flight Accessory
Projectile Launcher and ball	Extender Cable (PI-8117)
Plumb Bob (SE-8728)	Photogate Mounting Bracket
Smart Gate or Photogate Head	Measuring tape or meter stick
White paper and carbon paper	Vertical target board

Purpose:

The purpose is to determine whether the horizontal velocity of a projectile is constant throughout its flight.

Theory:

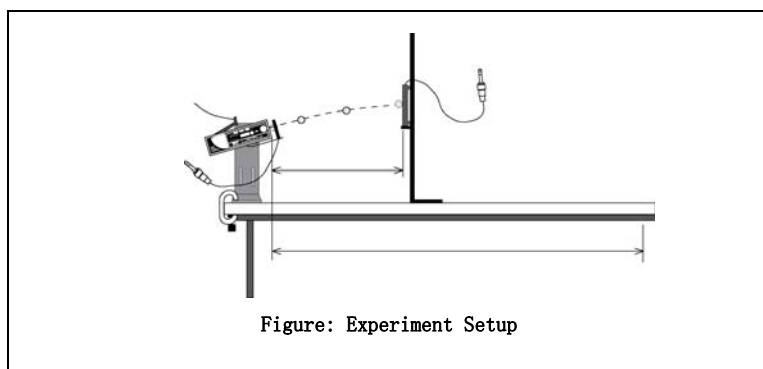
For projectile motion, the horizontal and vertical motions are independent. In the vertical direction, the projectile accelerates downward as gravity pulls on it. But in the horizontal direction, there is no acceleration and the component of the velocity in the horizontal direction is constant (if air resistance is ignored).

The horizontal velocity can be found by measuring the horizontal distance and the time of flight as shown in the equation.

$$v_x = \frac{x}{t}$$

Setup:

1. Clamp the Projectile Launcher to one end of a sturdy table with the launcher aimed along the length of the table.



2. Adjust the angle of the Projectile Launcher to any desired angle.

3. Attach the Photogate Mounting Bracket to the launcher and attach the Smart Gate or Photogate to the bracket. Connect the Smart Gate or Photogate to the Interface.
4. Connect the Time-of-Flight Accessory to the Interface. Use the extender cable if necessary.
5. Set up the data collection software to measure the time of flight of the ball.
6. Set up the vertical target board about 0.5 m in front of the Projectile Launcher. Use the Plumb Bob to aid with the measurement of the exact distance between the muzzle of the launcher and the timer plate. Record the distance in Table 3.1.

Procedure:

1. Load and cock the launcher to the long range position.
2. Fire a test shot to see where the ball hits the vertical target. Hold the timer plate against the vertical board at the place where the ball hit.
3. Shoot the ball again and record the time of flight in Table 3.1.
4. Move the vertical target to 1 m, 1.5 m, and 2 m in succession, finding the time of flight for each position and recording in Table 3.1.

Analysis

1. Calculate the horizontal velocity for each position. Is the velocity constant?

Table 3.1 : Data and Results

Distance	Time	Horizontal Velocity

Teacher' s Guide

Experiment 1: The Relationship Between Time of Flight and Initial Velocity

Notes on Setup:

It is important to keep the launcher exactly horizontal. Use a spirit level for best results.

You may use one of several timing options for this experiment. Consult the software Online Help and then connect things so that the Smart Gate or Photogate starts the timing and the timer plate of the Time-of-Flight Accessory stops it. Alternately, you may use a PASCO Timer such as the ME-8930 Smart Timer.

Notes on Procedure:

The times will be nearly the same, if the launcher is horizontal. You will notice a systematic error if the launcher is not exactly horizontal.

Setting the launcher to some angle other than 0° will significantly affect the time.

Experiment 2: Predicting the Horizontal Distance Traveled by a Launched Projectile

Notes on Setup:

You may use any compatible interface. In any case, you will want to arrange things so that you can record the times through the Smart Gate or between the two Photogates to determine initial speed, and the time between the Smart Gate or a single Photogate and the Time-of-Flight Accessory plate to determine time of flight.

Notes on Analysis:

The initial speed should be close to that measured in other experiments.

The percent difference should be less than 5%.

Experiment 3: Horizontal Velocity of a Projectile

Notes on Setup:

Consult the software Online Help. The system should be set up in such a way that the computer measures the time between the Smart Gate or Photogate and the Time-of-Flight plate.

The "Vertical Target Board" can be any convenient moveable vertical object.

Notes on Analysis:

The velocity is not constant. It is nearly constant, but this equipment is sensitive enough to observe the change in speed due to air resistance. This air resistance will result in your measured speed being slightly lower at longer distances. You may ignore this effect if you wish, or you may want the students to further investigate the air resistance.

More Information

See the PASCO catalog or web site for more information.

www.pasco.com

Technical Support

For assistance with any PASCO product, contact PASCO at:

Address:	PASCO scientific 10101 Foothills Blvd. Roseville, CA 95747-7100
Phone:	916-786-3800 (worldwide) 800-772-8700 (U.S.)
Web:	www.pasco.com
Email:	support@pasco.com

Limited Warranty

For a description of the product warranty, see the PASCO catalog or www.pasco.com/legal.

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