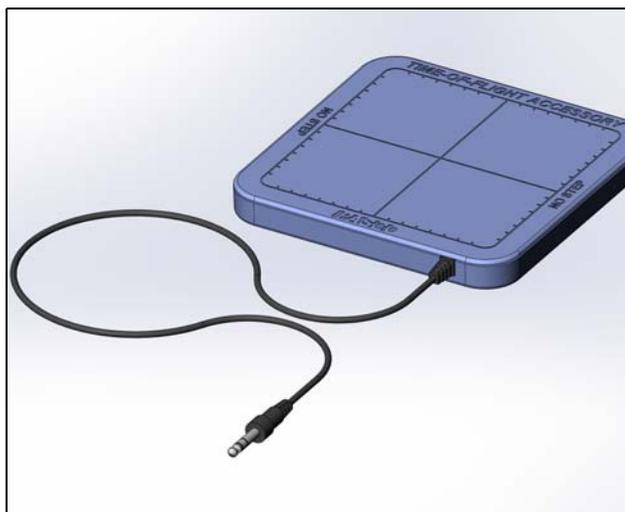


Time of Flight Accessory

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.

What Is Needed	Time of Flight Experiments		Initial Speed Experiments	
	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

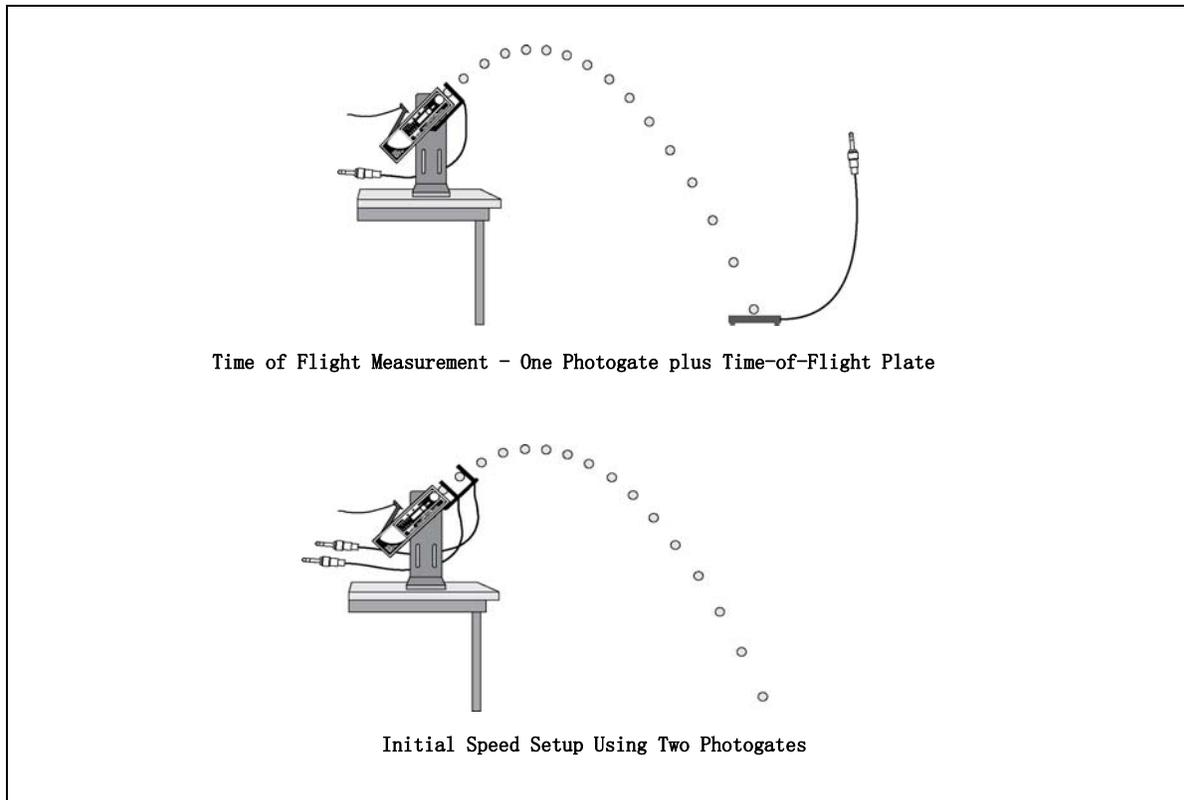
Introduction

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).

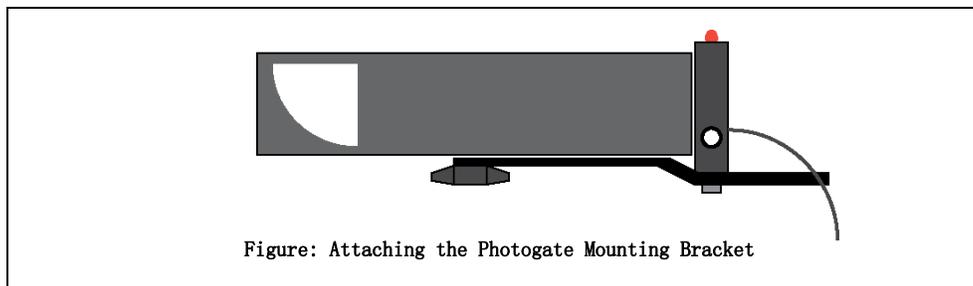


Setup with a Timer

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.

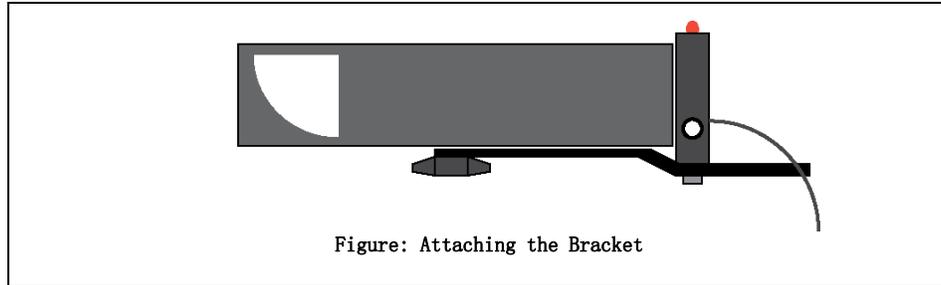


Figure: Attaching the Bracket

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.

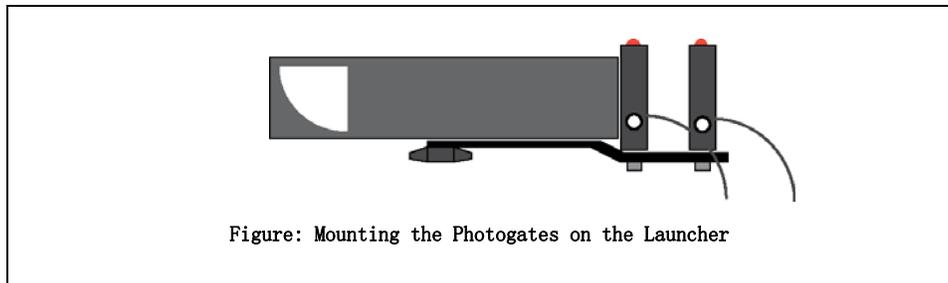


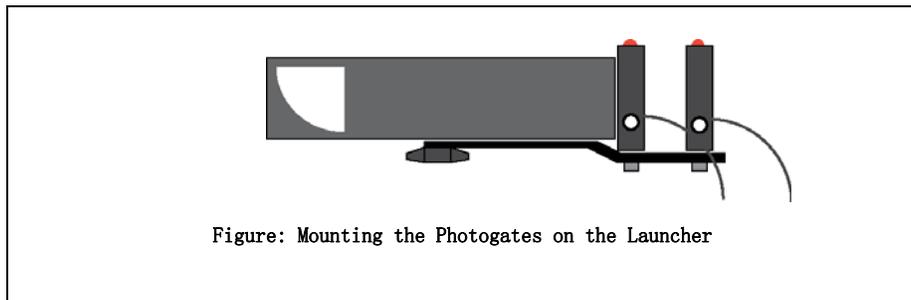
Figure: Mounting the Photogates on the Launcher

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. 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.



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.

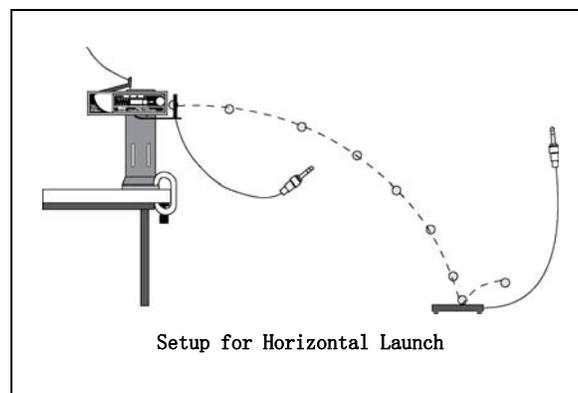
$$h = \frac{1}{2}gt^2$$

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.

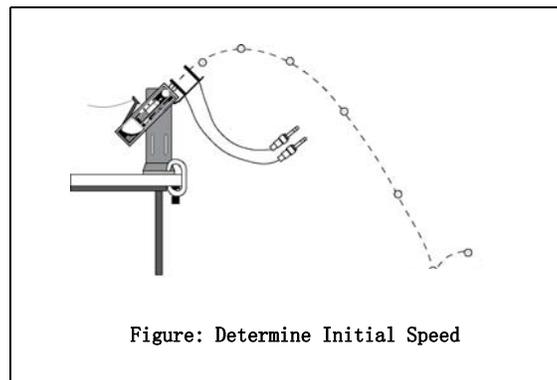
$$x = v_0 \cos \theta t$$

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:

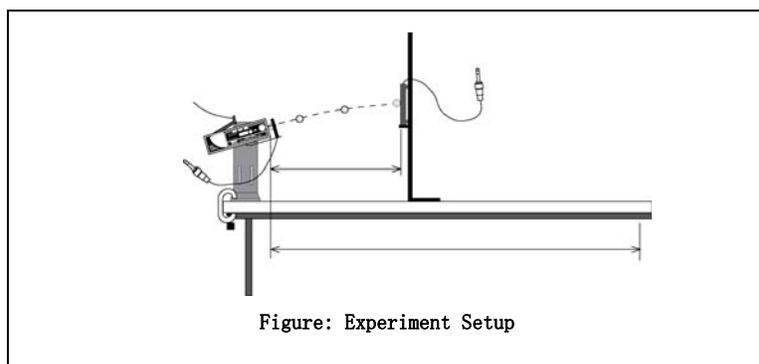
For projectile motion, the horizontal and vertical motions are independent. In the vertical direction, the projectile accelerates downward as gravity pulls on it. But in the horizontal direction, there is no acceleration and the component of the velocity in the horizontal direction is constant (if air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