Student Launcher

Congratulations on your purchase of the Science First® student launcher. You will find Science First® products in almost every school in the world. We have been making high quality, high value apparatus since 1960. Our products are available from many science education dealers in the U.S.A.

Warranty and Parts:
We replace all defective or missing parts free of charge. Order replacement parts by referring to part numbers above. We accept Master Card, American Express, Visa, School P.O's, checks and money orders. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse, or normal wear and tear.

Introduction:
The Projectile Launcher can be used for experiments and demonstrations involving trajectories. It is optimized for safer operation. A heavy aluminum body and sturdy base give the launcher the stability it needs. An attached protractor and plumb bob permit an accurate determination of angle of inclination. The range of the projectile is determined by three firing positions, which are set using a cocking lever. Three positions allows for three different data sets, which can then be compared. The Launcher was designed so that no matter what angle is chosen, the height of the ball at its release point from the table is constant.

Description:
The Launcher includes the base unit, a 16mm ball, and instructions. A special bracket allows attachment of photogate timers. (We recommend 25-195 from Science First®.) The attached protractor and plumb bob permit easy measurement of angle of inclination. Use the Launcher at any angle from -40° to 90°.

Always Wear Safety Glasses When Launching Balls!

Additional Materials Needed:
Meter Stick
A meter stick or tape is required for distance measurements (along with a target, discussed below.) To measure the horizontal distance from launcher to target, determine the points at which projectile flight begins and ends. If the launcher is on a table and the target on the floor you must locate the point on the floor directly under the launch position of the ball.

Target
Old magazines work well for a target. By placing a piece of carbon paper inside the magazine, you can locate the point of impact caused by the ball striking the magazine cover.
The impact will show through many pages. If the target is placed in a shallow box, it is easier to retrieve the ball.

Photogate Timer (Optional)
Photogate Accessory
We recommend 25-195 Smart Timer manufactured by Science First®. This will work with 40-456 photogates, which are specifically desgined for the student launcher.

Safety Factors:
There is potential for injury from any moving object. We recommend these safety precautions:
• All people in the vicinity should be called to observe demonstration launches. This highlights the need to stay out of the way and shows how to avoid problems.
• Avoid sudden, unannounced movements. Before pursuing a rolling ball, notify those in your path. This prevents you from interfering with their experiment and keeps you out of the path of a launch.
• All people in the lab should always wear safety glasses when watching or experimenting.
• The unit has a trigger cable that fires the unit. Always extend this cable and stand fully behind the launcher.

Operation Setting Up:
1. Use a clamp to fix the base to a table edge with gun pointing at desired angle.When shooting onto the floor, use the plumb bob to position the launcher in relation to the floor.
Help align launcher with a target by using a straight edge or meter stick.
2. Set angle by loosening wing nut on bracket. Rotate launcher to desired angle and tighten nut when angle is reached. Any angle from -40° to + 90° may be selected above or below the horizontal. Use the plumb bob and protractor attachment to select angle.
3. Place ball in the barrel.
4. Cock trigger mechanism. Slide the cocking lever to the desired position. There are three possible firing positions, as indicated by the label on the launcher.
5. Check vicinity for safety. Once the launcher is set up, check out your intended course before performing any experiments. Examine the direction the projectile is aimed and whatever

may be within range, including people, breakable material and items that may be marred by the projectile. People in the area should be fully informed and provided with safety glasses. The teacher should perform one demonstrationfirst.

6. **Release trigger** by pressing the mechanism on the end of the firing cable. This will shoot the ball. Make sure you are behind the unit when firing!
7. When shooting onto the floor, protect the floor surface from damage. Use old magazines or similar placed at the point of impact.
8. Adjust range by adjusting latch and angle.

Experiment 1
Range vs Angle of Inclination

Equipment Needed:

Projectile Launcher
Paper
Carbon Paper
Meter Stick
Target
Photogate Timing System
(Optional)

Purpose:

The purpose of this experiment is to demonstrate the relationship between range and angle of launch. The elevation of the impact point is important.

Theory:

The range of a projectile depends upon the horizontal component of its velocity and its time of flight. The time of flight depends upon the vertical component of its velocity.

Maximum range is obtained when the product of these two components is a maximum horizontal velocity is constant.

If the projectile is launched at an angle θ from the horizontal, it will have two components of velocity, vertical - $v_0 \sin\theta$ and horizontal - $v_o \cos\theta$. The projectile when launched will rise to its acme and then fall to the floor. See *Diagram 2.*

We can get the acme y_{max} by first calculating the time of rise, t_r.

$$t_r = \frac{v_o \sin\theta}{g}$$

We obtain the muzzle velocity v_o by any of the three methods described later. You can then use the kinematic equation:

$$y_{max} = v_o \sin\theta\, t_r - 1/2\, g\, t_r^2$$

to obtain the acme.

Then the total distance, y, that the projectile falls is:

$$y = y_{max} + y_0$$

Where y_0 is the height of the launch point above the floor.

Then the fall time, t_f is given by

$$t_f = \frac{2y}{g}$$

The time of flight, **t**, is then:

$$t = t_r + t_f$$

Knowing the flight time, we can then calculate the range, x, by:

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

Use the worksheet at the back of this manual to analyze your data.

You can also use the kinematic equation in the vertical mode to get the time of flight directly by using:

$$y = y_0 + v_0 \sin\theta\, t - 1/2\, g\, t^2$$

where: y = the target height
y_0 = the launch height
v_0 = muzzle velocity

and then solving the quadratic for t by using the quadratic formula:

$$t = \frac{-b +\backslash- \sqrt{b^2 - 4ac}}{2a}$$

Procedure:

Prepare a target consisting of a magazine and carbon paper. Set elevation at 45° and adjust the latch or target as needed. Fire 2 or 3 shots and record range and angle.

Repeat for angles 15°, 25°, 35°, 55°, 65° and 75°.

Results:

Prepare a graph of range vs product of sin θ • cos θ. Repeat this experiment with a target at a different elevation than used before.

Conclusion:

At what angle is the range a maximum? Why?

There are 3 methods of determining muzzle velocity V_0:

- **Time of flight**
- **With 1 photogate**
- **With 2 photogates**

2 photogates yield the most accurate results.

Procedure (Time of Flight):

1 Clamp the launcher to the table in a horizontal position (zero inclination).
2 Adjust the latch as needed to fire the ball a suitable distance.
3 Tighten the lock nut finger tight and place the target at the expected point of impact. When satisfied, tape the target down and insert carbon paper.
4 Place a marker on the latch (for instance, ink, paint, a piece of tape) which would allow you to detect any rotation.

Data:

Measure vertical distance from lower edge of ball to upper edge of target and record on the worksheet on Page 7. Fire a practice shot and if the ball hits the target satisfactorily, fire up to 10 more. It is unlikely that all shots will hit at exactly the same spot. Record distances and calculate average velocity. (See sample worksheet on Page 6.)

Calculating Muzzle Velocity:

The time of flight may be determined by the time required for the ball to fall from launch point to floor. This is obtained from:

$$y = 1/2\ gt^2 \text{ or rewriting:}$$

$$t = \sqrt{\frac{2y}{g}}$$

where **Y** is the vertical distance of fall and **g** is the gravitational acceleration. Horizontal velocity therefore is:

$$V_x = \frac{\text{horizontal distance}}{\text{time}}$$

Procedure

(One Photogate):

1. Clamp Science First® 40-456 photogates to the bracket on the front of the launcher. Use the data cables to connect to the smart timer.
2. Plug in your Photogate Timer.
3. Turn on the Timer and set it to Projectile Motion II (gate) mode.
4. Fire the ball. When the ball is fired, the Timer will measure the time to pass through the photogate.
5. To calculate initial vertical and horizontal velocities:

a. Divide diameter of ball (you will need to measure) by the time **t**.
b. This is velocity of ball in cm/sec.
c. Use this velocity and angle at which the ball was fired to work out the initial vertical and horizontal velocities.

(Two Photogates):

1. Clamp Science First® 40-456 photogates to the bracket on the front of the launcher. Use the data cables to connect to the smart timer.
2. Plug the photogate closest to the drive shaft (Photogate #1) into the phone jack closest to the power jack on the Timer.
3. Plug the other photogate (Photogate #2) to the other phone jack on the Timer. Make sure that no wires are in the path of the ball.
4. Set Timer to **Pulse** mode. When ball is fired, timer will measure the time from the first interrupt on the light beam on Photogate #1 until the first interrupt on light beam of Photogate #2.
5. Divide the time **t** by the distance between the photogates. This gives the initial muzzle velocity of the ball.
6. Resolve the velocity into its x and y components by using the angle at which the ball was fired.

Experiment 2:
Projectile Motion

Equipment Needed:

Projectile Launcher
Vertical Board on Suitable Stand
Carbon Paper
Meter Stick
Target

Purpose:

The purpose of this experiment is to verify that the trajectory of a projectile is a parabola. In order to reduce experimental error, we recommend the release latch be firmly locked in place by the plastic nut. Mark the latch in such a way that it would be noticed if the latch turned.

Sample Procedure:

1. Set the launcher at an angle of about 35°. Make sure it is secured and does not vibrate. Measure angle using the attached protractor. Plumb bob points to angle; read off angle.
2. Set Photogate on the mounting nearest launch point. The projectile should pass through window immediately upon leaving.
3. Set Timer on "Projectile Motion II" mode. In this mode Timer should automatically record five values of time t_{pass} of the projectile (ball) for five runs of one trial. It will also calculate average value of t_{pass}. Each value of time will be measured to one-tenth of a millisecond.
4. Find diameter of ball with vernier caliper. This is value **d.**
5. Set and lock the cocking lever to set the velocity.
6. Tape a small sheet of paper on floor, under the edge of the launcher. Hold plumb bob at edge of launcher such that it almost touches floor and mark point on floor. This point will be the origin of the x-axis and all x-mode distances will be measured from this point. Measure height of edge of launcher using two meter stick held in a strictly vertical position. This value is height $\mathbf{h_0}$.
7. Launch projectile and let it fall on floor below to see where it falls. Tape paper in area where you expect the projectile to hit the floor. Place carbon paper on top.
8. Clear the Timer.
9. Launch projectile. As ithe projectile travels through its trajectory, the Timer will record the value t_{pass}. As projectile hits floor, a black mark will be registered on the paper.

10 Run through five values of t_{pass} as recorded by the Timer. If there are substantial differences, discard values and repeat. Record average value of t_{pass}.

11Remove carbon paper. You will find five spots on paper, ideally very close to each other. Find center of this "cluster' of points. Draw a line on floor from original of the x-axis to center of cluster. This line is the x-axis. Measure the distance of the "center of cluster" along the x-axis from origin; this is $\mathbf{x_0}$. The corresponding value of height is $\mathbf{-h_0}$. Record the values of x_0 and - h_0 for the first trial.

12 Tape long paper on vertical stand and place stand on x-axis. Tape carbon paper near lower portion of sheet. Position stand so that vertical sheet of paper is about 10 cm closer to the origin from x_0. Measure horizontal distance x_1 of vertical sheet from origin. Record value. See *Diagram 3.*

13 Repeat as above. The projectile will not hit floor; it will hit the vertical paper, leaving black marks close together. Draw a line around these marks and find center of "center" of point. Measure the height of this point above floor. This is $\mathbf{h_1}$, a positive value.

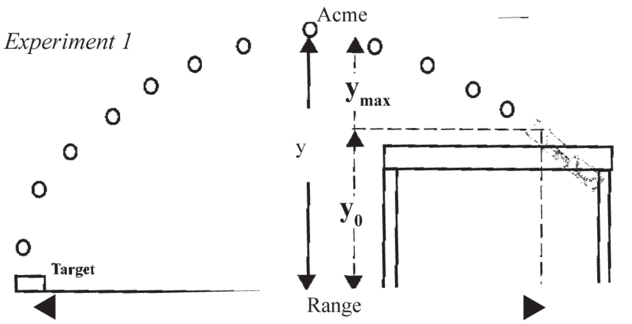
14 Move the vertical board 10 cm

closer to the origin. Repeat. Value of **h** is positive.

Calculations:

1. All values of time are expected to be the same. Find average of all values, divide by diameter of projectile d by t_{av}. This is initial velocity of projectile as it leaves launcher.
2. Add heights h_1 to h_0. All h_1 are positive.
3. Make a table of x_1 and all h_1. Plot x_1 on x-axis and h_1 on y-axis. Perform a least square second order polynomial curve fit using computer or calculator. Get r^2 value.
4. Record values of coefficient of x and x^2. The coefficient of x is tangent of theta0. By taking inverse tangent you get angle at which projectile was launched. Compare to actual angle, as set in first step. Find percentage error.
5. Coefficient of x_2 has a value of $(g/2)/v^2_x$. Solve for V_x. But V_x equals V_0 (cos q). Using value of q from step above, solve for V_0. This value of V_0 should match value of V_0 found in first step of calculations, above. Compare and find the percentage error.

Diagram 2 - Experiment 1



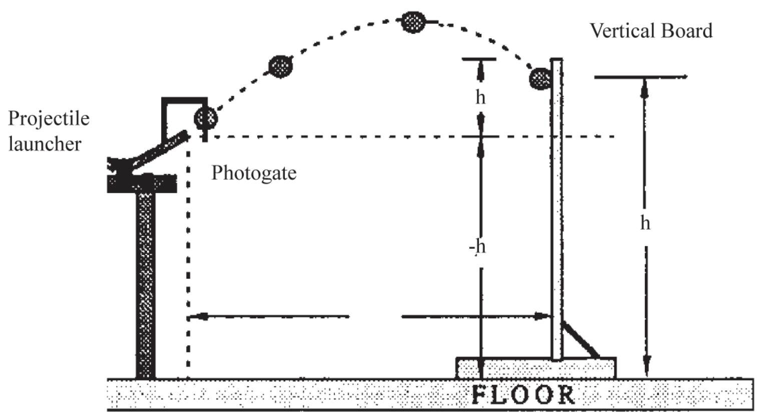


Diagram 3- Measuring trajectory of a projectile

Calculations area:

Data and Data Tables

Name ______________________ Date ______________________

Instructor ______________________ Lab Section ______________________

Partner ______________________ Table # ______________________

Table - Determination of the Value of Muzzle Velocity

Shot number	Distance	Velocity
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
	Average Distance:	Average Velocity:

Data and Data Tables

Name ______________________ Date ______________________

Instructor ______________________ Lab Section ______________________

Partner ______________________ Table # ______________________

Predicting the Range

Shot Number	Muzzle Velocity V_0	Rise Time t_r (*Eqn 1*)	Rise Distance y_{max} (*Eqn 2*)	Fall Distance y (*Eqn 3*)	Time of Fall t_f sec (*Eqn 4*)	Range of Flight $t_r + t_f$ sec (*Eqn 5*)	Range Predicted (*Eqn 6*)	Range Measured
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								