PhyzExperiment: Catch the Pop-Up

an investigation of mechanical energy

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• Pre-Lab •

1. When a ball is tossed upward, a force must act through a distance. In other words, _______________ must be done.

2. As the ball rises, what happens to its
 a. speed?

 b. kinetic energy?

 c. elevation?

 d. gravitational potential energy?

3. a. At what point in its flight is the kinetic energy of the ball
 i. at a maximum value?

 ii. at a minimum value?

 b. At what point is the potential energy of the ball
 i. at a maximum value?

 ii. at a minimum value?

4. a. What would you need to know to determine the kinetic energy of the ball when it was launched?

 b. How would you use that information to calculate the kinetic energy? Make a sample calculation with your choice of values. (A sample calculation includes an equation written with symbols, rewritten with values, and a solution.)

5. a. What would you need to know to determine the potential energy of the ball when it reached its apex?

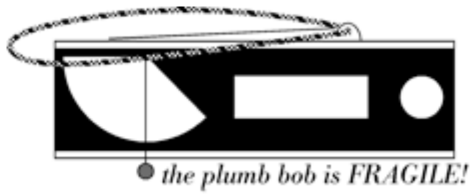
 b. How would you use that information to calculate the potential energy? Make a sample calculation with your choice of values. (A sample calculation includes an equation written with symbols, rewritten with values, and a solution.)

• Purpose •

In this investigation, we will compare the kinetic energy given to a ball launched vertically and the potential energy of that ball at the apex of its flight. We will also extend the findings to determine the launching force and acceleration. For best results, two different launch speeds should be used.

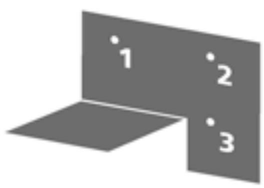
• Apparatus • (Diagrams not to scale)

___ PASCO mini launcher



___ safety glasses/goggles

___ table mounting bracket



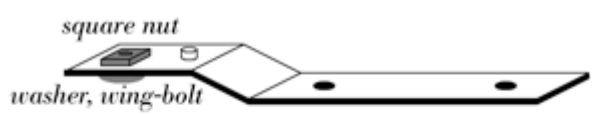
___ table clamp or equivalent

___ attachment wing-bolt with small washer

___ 16 mm steel ball (m = 16.0 g)

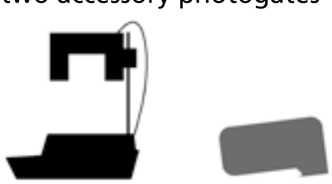
___ photogate attachment thumbscrews (short)
these screws are plastic; their threads can easily be stripped
DO NOT OVER-TIGHTEN!

___ photogate mounting bracket
includes wing-bolt, large washer, and square nut
DO NOT DETACH NUT OR WASHER FROM BRACKET!



___ plastic push rod

___ photogate timer or Smart Timer
or two accessory photogates



___ auxiliary photogate head

___ meterstick

___ small C-clamp or equivalent

• Experimental Design •

THIS ACTIVITY CAN ONLY BE ATTEMPTED BY STUDENTS MATURE AND RESPONSIBLE ENOUGH TO WORK WITH THE PROJECTILE LAUNCHER. THE PROJECTILE LAUNCHER IS SAFE WHEN OPERATED IN ACCORDANCE WITH INSTRUCTIONS AND COMMON SENSE. THE PROJECTILE LAUNCHER IS DANGEROUS IF OPERATED INCORRECTLY. IF YOU FEEL YOU DON'T POSSESS THE MATURITY AND RESPONSIBILITY TO WORK WITH THE PROJECTILE LAUNCHER, YOU MAY OPT TO COMPLETE THE "FIRE IT UP" PHET-BASED ACTIVITY INSTEAD.

BY PROCEEDING BEYOND THIS POINT, YOU ARE AGREEING TO BE MATURE AND RESPONSIBLE ENOUGH TO USE THE MATERIALS FOR THIS ACTIVITY. VIOLATIONS WILL RESULT IN NEGATIVE CLASSROOM AND SCHOOL CONSEQUENCES.

1. **Launcher.** Without loading a ball into the barrel, carefully use the push-rod and the corded trigger to determine the number of launch force/speeds available from the launcher. **Be careful to not launch the push rod.** How many launch force/speeds are available? Answer using words and diagram/s.

2. **Speed.** How can the available apparatus be used to accurately determine the speed of a projectile launched from the projectile launcher? Recall the method we used to measure the speed of the projectile in the "Blowout!" demonstration. Answer using words and diagram/s. Make a test launch vertically upward (hand-held). Show the complete calculation: symbols, numbers, units, and answer. If your speed is less than 1 m/s or greater than 10 m/s, you have made a mistake.

3. **Secure Vertical.** How can the available apparatus be used to reliably and repeatedly launch the projectile vertically upward? The table mounting bracket and the table clamp will come into play here. But how can you attach the bracket to the table (using the table clamp) so that the launcher can be attached to launch vertically upward? Answer using words and diagram/s.

4. **Height.** How can the available apparatus be used to reliably and repeatedly determine the height attained by a projectile launched vertically upward? (This is the distance from the launch point to the apex.) This needs to be secure and reliable, and involves a vertical meterstick. Answer using words and diagram/s. Pay particular attention to where "zero" is and where the height will be measured to.

5. **Depth.** How can the available apparatus be used to measure the distance to which the plunger is pushed into the barrel for a particular launch?. Answer using words and diagram/s.

6. **Logistics**. a. The launcher operator must wear the safety glasses.

b. What's the best combination to get distinct low-speed and high-speed launches that can be measured using the apparatus provided? ___1-click and 2-click, __1-click and 3-click __2-click and 3-click

What's "wrong" with the setting you chose not to use?

• Analysis •

Secure a PhyzBlessing for your arrangement. While waiting, answer these questions. The figures below show the load and launch sequence. The figure **descriptions** below have been scrambled. Describe each figure (in the space below or between the figure's numbers) using the correct description. Some figures may require more than one description. Some figures may be left without a description. Some descriptions may indicate a process (from one figure to another). Two have been done for you.

- **Work done on ball**
- **Work done on piston**
- **Timing stops**
- **Timing starts**
- **Maximum Potential Energy**
- **Maximum Kinetic Energy**

Label the following with double-ended span arrows (in whichever figure is appropriate):

d: distance through which the ball was pushed by the piston
y: distance through which the the ball moved while being timed
h: distance the ball traveled from launch to apex

In the space below the diagrams, describe what's going on, physics /experiment-wise. For example, when does the ball have maximum potential energy? Maximum kinetic energy? When does the timer start; when does it stop? When is work done on the launcher spring? When does the launcher spring do work on the ball?

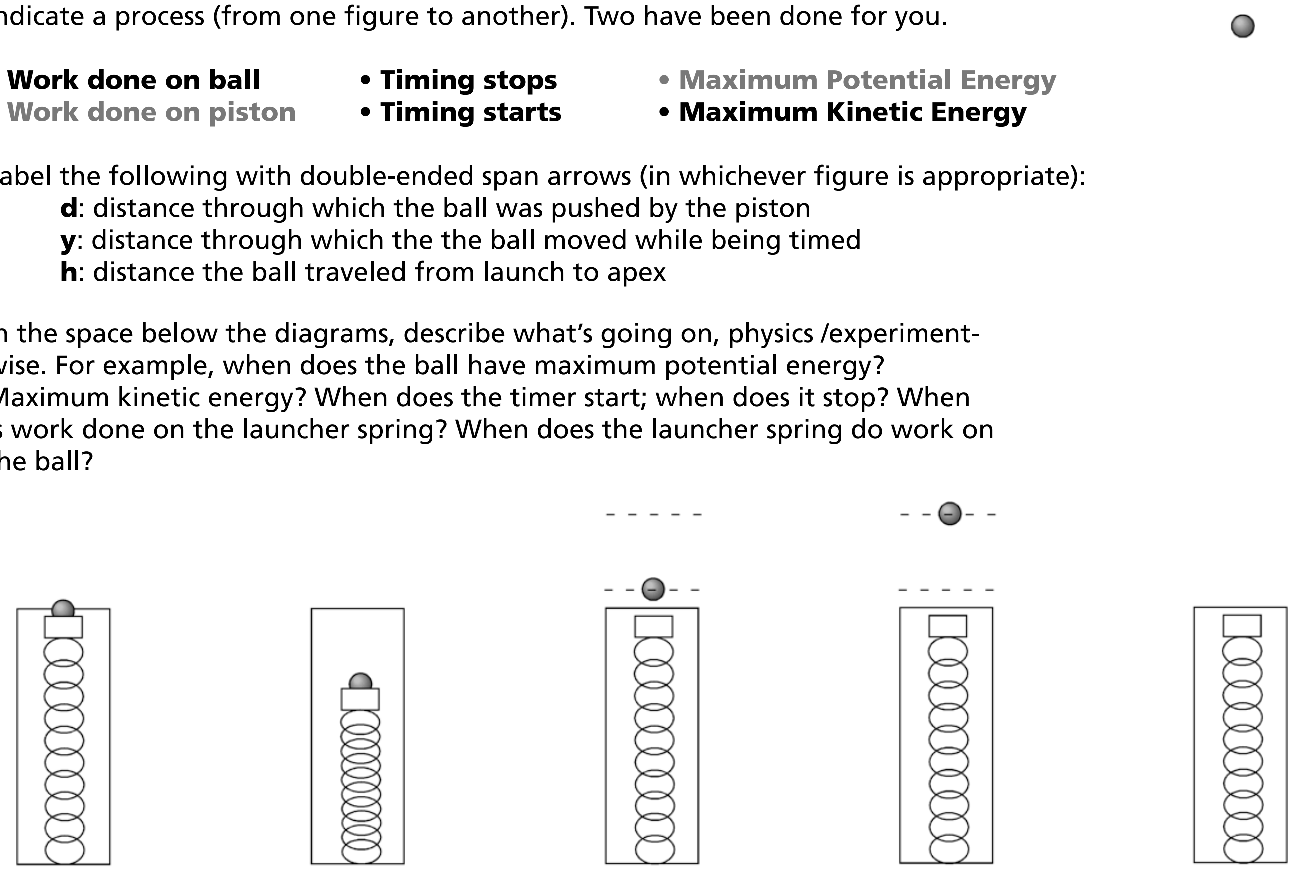


Figure 1. Figure 2. Figure 3. Figure 4. Figure 5.

Work done on piston

Maximum Potenial Energy

Experiment Notepad — Notice that we record distances in meters				
	d (m)	y (m)	h (m)	t (s)
Slower Launch				
Faster Launch				

In the spaces below each question, make calculations for both sets of data: the slower launches *and* the faster launches.

2. Launch speed. Calculate the launch speed of the ball.

a. When did the timer start counting time?

b. When did the timer stop counting time?

c. How far did the ball travel while the timer was counting time? (And which distance is this: d, h, or y?)

d. Show the complete calculation: symbols, numbers, units, and answer. If your speed is less than 1 m/s or greater than 10 m/s, you have made a mistake.

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

3. Kinetic Energy. Calculate the kinetic energy of the ball upon launch. Show the complete calculation: symbols, numbers, units, and answer. If your kinetic energy is less than 0.05 J or greater than 0.5 J, you have made a mistake.

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

4. Potential Energy. Calculate the potential energy of the ball at the apex of its flight. Show the complete calculation: symbols, numbers, units, and answer. If your potential energy is less than 0.05 J or greater than 0.5 J, you have made a mistake.

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

5. Percent Difference: Energy. Calculate the percent difference between the kinetic energy the ball had at launch with the potential energy it had at the top of its flight.

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

6. Motion Mistake. There is a correction for the speed calculated in question 1. Here's why.

a. What kind of motion does the ball execute after being launched?

___Uniform motion (constant velocity) ___Uniform accelerated motion (constant acceleration)

b. Under what conditions does the relation "speed = distance / time" hold true?

___Uniform motion only ___Uniform accelerated motion only ___both UM and UAM

Since "speed = distance / time" was used to determine the speed above, the value it gave was somewhat flawed. Not terribly off, but with room for improvement.

c. Corrected Launch Speed. The correct speed of the ball can be determined by adding $gt/2$ to the speed you determined above, where g is 9.8 m/s^2 and t is the time it takes the ball to travel from one photogate to the other. (The derivation of this correction is beyond the scope of this course but is addressed in AP Physics.) Determine the corrected value of the launch speed.

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

d. Corrected Kinetic Energy. Given the corrected launch speed, what is the corrected value for the kinetic energy of the ball at launch?

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

e. Corrected Percent Difference: Energy. Calculate the percent difference between corrected kinetic energy and the (original) potential energy.

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

• Conclusion •

Which statement best describes your findings regarding the kinetic energy of the ball at launch and the potential energy of the ball at its apex?

___The kinetic energy of a ball at launch is greater than the potential energy of that ball at its apex.

$KE > PE$ (by more than 20%)

___The kinetic energy of a ball at launch is equal to the potential energy of that ball at its apex.

$KE = PE$ (within 20%)

___The kinetic energy of a ball at launch is less than the potential energy of that ball at its apex.

$KE < PE$ (by more than 20%)

• Extensions (Required) •

1. Using only the data you have collected or calculated so far, determine the force acting on the ball during launch. (Hint: the kinetic energy the ball had upon launch came from **work** done by the piston.)

a. Piston Work. The work done by the piston is equal to the kinetic energy of the ball upon launch. How much work did the piston do?

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

b. Piston Force. The work done by the piston is equal to the work on the piston when it was loaded. Given the work and distance that the piston was pushed in during the loading process, how much force does the piston exert? Show the complete calculation: symbols, numbers, units, and answer.

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

2. Ball Acceleration. Determine the acceleration of the ball in the barrel of the mini launcher during the launch. Show the complete calculation: symbols, numbers, units, and answer. (Hint: Newton's second law.)

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

3. G's. While standing at rest on Earth, you are in a "one-g" environment. While in freefall, you are in a "zero-g" environment. While accelerating upward with 9.8 m/s^2 of acceleration, you are in a "two-g" environment. The number of "g's" you experience is $n = 1 + (a/g)$ where a is your upward acceleration and g is acceleration due to gravity. How many "g's" does the ball experience?

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES

4. Apparent Weight. What would your apparent weight be if you were undergoing that much acceleration? Multiply your weight (or your "ideal weight") by the number of g's you found in the previous question to find out. Use units (pounds, kilos, or stones) that you are accustomed to.

SLOWER-LAUNCH VALUES FASTER-LAUNCH VALUES