

# Two Dimensional Motion Activity

## Projectile Motion

### Purpose

A projectile launched into the air either horizontally or at an angle represents Two Dimensional Motion. Using a launcher and two photogates, you will determine the initial velocity of a projectile (a 25mm steel ball). By launching the ball to the floor from a known height, your group will also determine the initial velocity of the projectile by measuring the range of the projectile. Your group should confirm the initial velocity of the projectile by comparing the values of the initial velocities obtained by the different methods. After you have determined and confirmed a valid initial velocity, your group will be required to hit a target that is positioned vertically above the floor at a known height. Your grade will depend largely on where the ball strikes the target.

Note that there is no step by step procedure written for this activity. In order to obtain all of the information to successfully complete this activity, the entire document should be read prior to beginning the activity. This includes reviewing the data sheet.

### Pre-Lab (10 Points)

### Part I (30pts total)

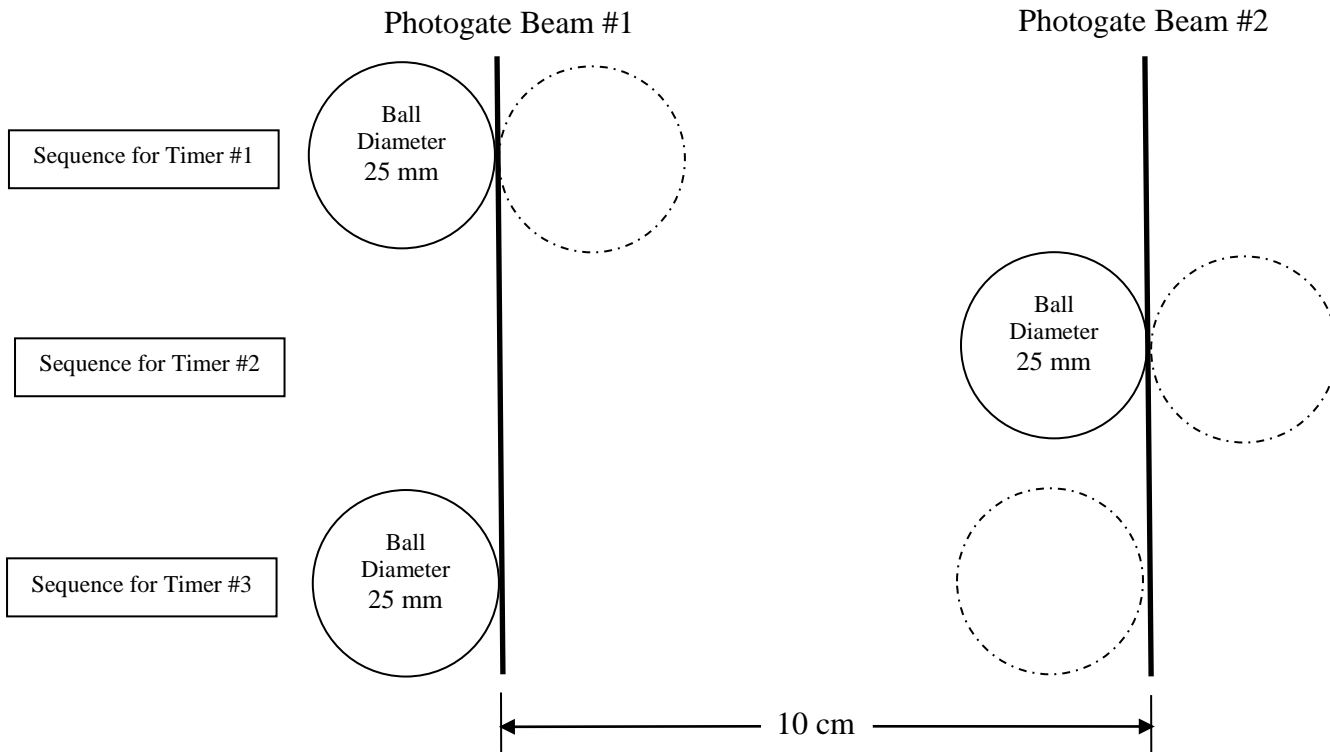
A photogate is a device that uses a beam of light and a detector to act as a switch. When the beam of light is broken, the detector can send a signal to a controller that could activate a multitude of devices. In this case, we will use two photogates to start and stop a set of three timers.

Physically connect the photogates to the PASCO interface, and make sure the interface is turned on. It is important that the photogate nearest the launcher be connected to port #1 and the second photogate be connected to port #2.

After selecting the Data Studio 1.8.5 icon, choose "Open Activity". Within the "Lab-Docs" folder, you should find a file labeled "2D Motion.ds". This file contains a pre-set version of Data Studio. When selected, this version will allow you to determine the time it takes the projectile (a 25mm Steel Ball) to pass through the photogates. Upon collecting data, the first column will contain the time it takes the projectile to pass through Photogate #1. The first timer begins when the ball blocks the photogate beam and the timer stops when the photogate beam is no longer blocked. Similarly, the second column will contain the time it takes the projectile to pass through Photogate #2. The third column will contain the time it takes the projectile to travel from Photogate #1 to Photogate #2. The third timer begins when the beam of the first photogate is blocked, and the timer stops when the beam of the second photogate is blocked. At the bottom of each column the max, min, and mean will be calculated.

The diagram on the next page should provide some insight on each timer's sequence. The solid circle indicates the position of the ball when a timer begins, and the dotted circle indicates the position of the ball when the timer will stop.

Prior to launching, make sure that the path of launch is clear and that no one will be struck by the projectile while it is in flight. Also take care of keeping track of your projectile. **Lost projectiles will result in a 10 percent grade deduction.** Make sure someone is ready to catch the projectile after it impacts the floor. Use the Medium Range setting on the launcher for all of the launches

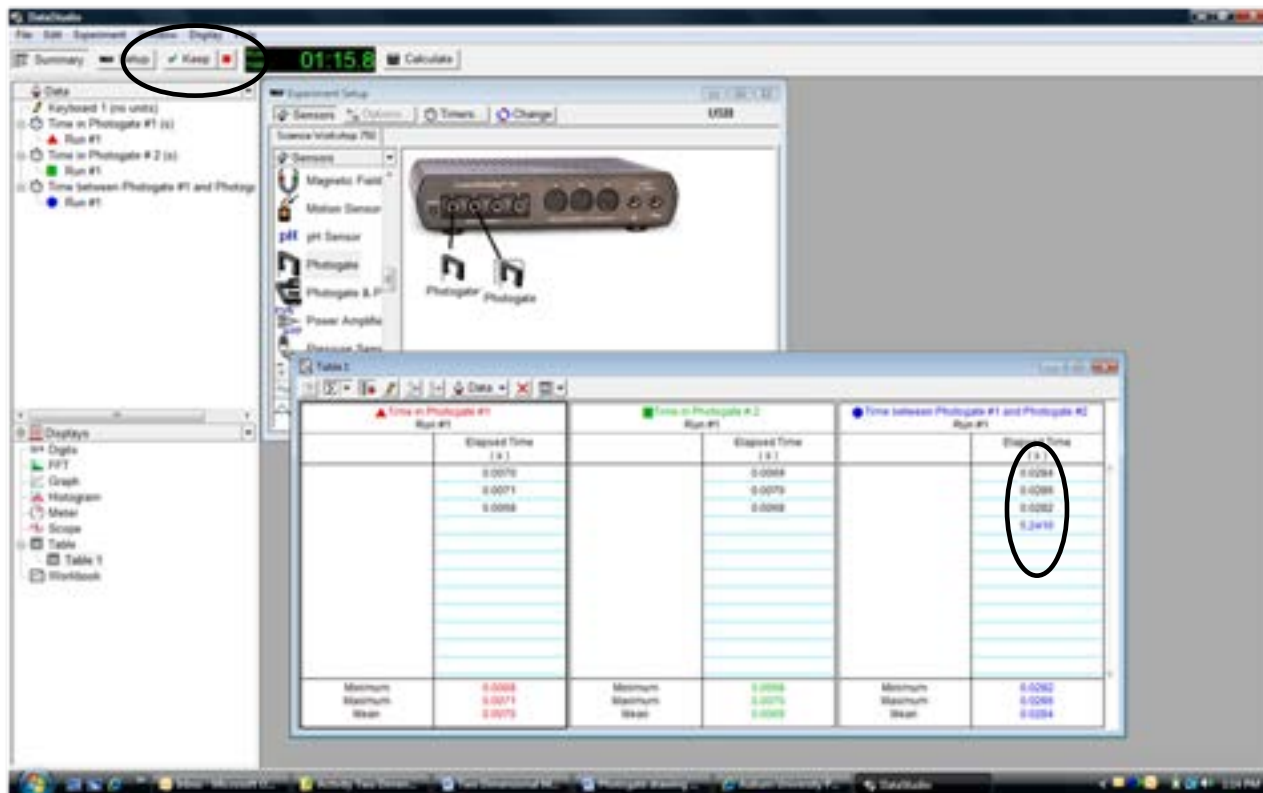


Perform a test launch, and witness where the projectile impacts the floor. Center a piece of blank paper over the point of impact, and tape the paper in place with masking tape. Perform one more test launch to make sure the paper has been located properly, and make adjustments if necessary. After the blank page is in the correct position, lay a piece of carbon paper on top of the blank paper. **Do not tape the carbon paper in place.** The carbon paper should just lie on top of the blank piece of paper that has been taped to the floor. Now, the exact point of impact will be recorded on the blank piece of paper by the carbon paper.

When the **Start** button is pressed, you will have an option to keep data by pressing the **Keep** button or to stop collecting data by pressing the button with the red square (stop button). The stop button should only be pressed after data from five (5) launches have been successfully recorded. Check the data in the table prior to pressing the **Keep** button to determine if it is valid. If you determine the current data point to be invalid, do not press the **Keep** button. Instead, rerun the trial, and the invalid data point will be automatically replaced with the new data point. In order to prevent losing the last data point collected, the **Keep** button must be pressed prior to the stop button. After collecting data for five (5) launches, press the stop button.

Prior to each launch, make sure that the timer in the third column of the table is not actively running. This condition may occur depending on how the projectile is loaded into the launcher. If the first photogate is blocked without subsequently blocking the second photogate, the third timer will be running prior to launch. If the third timer is running, momentarily block the second photogate by passing your finger through the second photogate.

The snapshot of the Data Studio screen below indicates where the **Keep/Stop** button is located. It also indicates where in the table you must pay attention to make sure the timer is not running prior to launch.



Calculate the average velocity of the projectile while it passes through photogate #1, photogate #2, and while it travels from photogate #1 to photogate #2. Since there is no net force acting on the ball in the horizontal direction, each of these three velocities should be in relative agreement with each other, and they should be the same as the initial velocity of the projectile as it leaves the spring.

For each velocity, calculate the range of the projectile.

## Part II

After you have calculated the velocities and ranges from the data collected from the photogates, carefully measure the range using the provided meter sticks and plumb bob.

Using the height and range of launch, back-calculate the initial velocity of the projectile.

### **Part III (60pts total)**

After you have determined the initial velocity of the projectile, your TA will remove your projectile from your work station, and your TA will provide you with the height of the target that you will try to hit. Your goal will be to determine the distance between the target and the launcher in order to strike the bull's-eye. After you have calculated the distance, you should use the provided meter stick and plumb bob to accurately determine the physical location on the floor that the backstop holding the target will need to be placed in order to hit the bull's-eye. After you have located the position where the backstop will need to be placed, mark the floor with a piece of masking tape. When you are ready, your TA will position the backstop based on the location indicated by the masking tape, and the target will be placed at the appropriate height. Once the target has been positioned, no further adjustments to the launcher or the target will be allowed. Your group will launch the projectile three times, and your score will be based on the average of the two best launches.

Before leaving, any paper that was taped to the floor must be removed, meter sticks should be returned to their proper storage location, and your Work Station should be in proper order.

Name: \_\_\_\_\_

Banner ID: \_\_\_\_\_

Lab Group ID: \_\_\_\_\_

Number of Lab Partners: \_\_\_\_\_

## Data Sheet

# Two Dimensional Motion Activity

Hints:

1. Be mindful of which photogate is plugged into which port.
2. Prior to clamping the launcher to the table, determine the launch height.
3. Use the provided clamp to securely fasten the launcher to the bench. This will help prevent errors from recoil.
4. Make sure the launcher is set to launch horizontally.
5. Use the Medium Range setting on the Launcher for all of the launches.
6. Make sure the ball is in contact with the spring prior to launching.
7. Release the trigger by pulling up on the string using a smooth motion and consistent force from launch to launch.
8. Prior to each launch, make sure the photogates are aligned perpendicular to the photogate support bracket.
9. Make sure the timer in the third column of the table is not actively running prior to launching. If it is running, momentarily block the second photogate by passing your finger through the second photogate.
10. Do not press the stop button until you have collected data from at least five launches.
11. Think about which part of the projectile will strike the floor and which part will strike the vertical target.
12. If you have inadvertently collected invalid data, mathematically adjust for any obvious outlying data points, and explain why you discarded the data.

**Pre Lab (10 Points)** \_\_\_\_\_

### Part I (30pts total)

Launch Height: \_\_\_\_\_

All calculations used to determine the initial velocities and ranges below must be shown. Attach a separate piece of paper if necessary. Also print and attach the table of times from Data Studio.

Initial velocity of the projectile calculated using the times from Column 1: \_\_\_\_\_ (2 points)

Calculated range of the projectile using the above velocity: \_\_\_\_\_ (3 points)

Initial velocity of the projectile calculated using the times from Column 2: \_\_\_\_\_ (2 points)

Calculated range of the projectile using the above velocity: \_\_\_\_\_ (3 points)

Initial velocity of the projectile calculated using the times from Column 3: \_\_\_\_\_ (2 points)

Calculated range of the projectile using the above velocity: \_\_\_\_\_ (3 points)

## **Part II**

Measured Average Range: \_\_\_\_\_

Compare your calculated ranges to the average measured range. (5 points)

Initial velocity of the projectile back-calculated using the height and measured range of launch: You must show your work. \_\_\_\_\_ (10 points)

How does your back-calculated velocity compare to the velocities calculated from the photogate data?

### Part III (60pts total)

Determine which initial velocity your group will use to calculate the distance the target must be placed from the launcher and explain why the value was chosen.

Initial Velocity the group will use: \_\_\_\_\_

The height of the bull's-eye measured from the floor as specified by the TA:

(The TA will circle one): 30cm 35cm 40cm

After the TA indicates the height of the target, the TA will remove the projectile from the workstation and place it in a container that corresponds to the number below.

Ball # \_\_\_\_\_

Distance from the launcher the target must be placed as calculated by the group: \_\_\_\_\_

(All work must be attached)

Once the target has been placed, neither the target nor the launcher can be adjusted. This includes adjustments to the launcher's position or launch angle.

Average of the best two out of three launches: \_\_\_\_\_

(Attach the target to the data sheet)