# Two-Dimensional Motion: Projectiles

Guided Inquiry

Driving Question | Objective

What is the range of a projectile launched horizontally? Develop a plan to measure the variables that affect the two-dimensional motion of a projectile launched horizontally, and then use those variables to accurately predict and test the projectile's horizontal range.

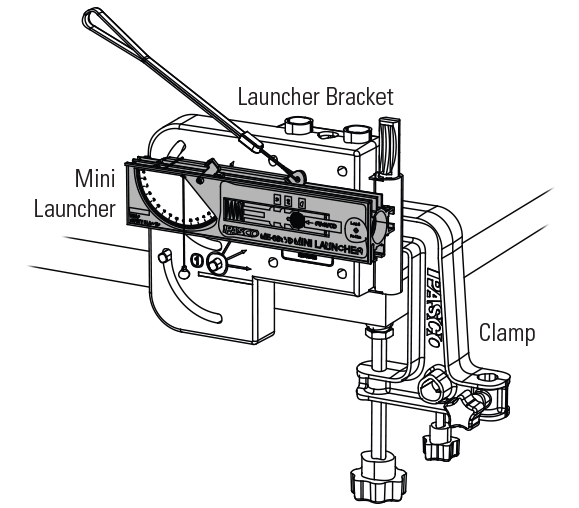
Design and Conduct Your Investigation

It is your group’s responsibility to design and conduct an investigation whose data will support your answer to the driving question above. Use the answers to the guiding questions below to help guide your experiment design. After you have answered the guiding questions, write an outline of the equipment setup and procedure you will use to collect data, identifying the steps in sequence and the points at which each piece of equipment will be used.

DO NOT fully launch your projectile until you are ready to test your range prediction. You may fire the projectile from the launcher to make any measurements that will be part of your investigation; however, you must not allow the projectile to travel fully down the range until you are ready to test your range prediction.

Required Materials and Equipment

|  |  |
| --- | --- |
| * PASCO Mini Launcher2 | * Launcher loading rod2 |
| * Mini launcher bracket2 | * Steel ball, 1.6-cm diameter2 |
| * Table clamp |  |

Required Setup

Each group is required to assemble their projectile launcher as described below.

1. Choose one corner of a table to mount the projectile launcher. Make sure a distance of about 3 m is clear on the floor around the table in the direction you plan to launch the projectile when testing your prediction.

2. Clamp the launcher to the corner of the table using the mini launcher table clamp, and then adjust the angle of the mini launcher to zero degrees (horizontal launch).

Suggested Materials and Equipment

Although you have the freedom to design your procedure using any reasonable equipment at your disposal, the following equipment is recommended for your investigation.

|  |  |
| --- | --- |
| * Data collection system | * White paper, 1 sheet |
| * PASCO Wireless Smart Gate photogate1 | * Carbon paper, 1 sheet |
| * PASCO Photogate Mounting Bracket2 | * Cardboard, square piece, 10 × 10 inch |
|  | * Meter stick |

|  |  |
| --- | --- |
| 1[www.pasco.com/ap38](http://www.pasco.com/ap38) | 2[www.pasco.com/ap05](http://www.pasco.com/ap05) |
|  |  |
| PASCO Wireless  Smart Gate | PASCO Mini Launcher |

Guiding Questions

* 1. For a projectile launched horizontally, neglecting air drag, what horizontal and vertical forces are acting on it while it is in motion?

* 2. Assuming air resistance is negligible, is a projectile that is launched horizontally accelerating in both the horizontal and vertical directions after it is launched? How do you know?

* 3. Kinematic equations are used to describe the motion of an object undergoing constant acceleration. Can kinematic equations be used to describe the motion of a projectile? Justify your answer.

* 4. What kinematic equation(s) would you use to help calculate the range of a projectile launched horizontally, and what variables from these equations must you know to accurately calculate range?

* 5. What equipment and techniques could you use to determine the variables listed in the response to the previous question?

Experimental Design

Your goal is to perform an investigation in which you identify the variables that affect the two‑dimensional motion of a projectile launched horizontally, and then accurately predict the projectile's horizontal range. Use the responses to the Guiding Questions to help finalize your procedure and your method of calculating the range of your projectile.

Record your investigation setup, procedure, and any data that will be collected in the following sections.

Once you are convinced that your investigation has identified the variables needed to predict the range of your projectile, calculate the projectile’s range, recording any calculations used to make your prediction in the Calculate the Range section below.

After you have made your prediction, follow the steps in the Test the Range section to test it.

Setup

Draw and/or describe your investigation setup such that a third party could recreate the same setup in an attempt to reproduce your investigation.

Procedure

Outline the procedure you will use in your investigation, listing all of the steps below. Your outline should be written such that a third party could follow the same procedure in an attempt to reproduce your investigation.

Collect Data

Perform your investigation and record all relevant data. Present your data below (or in an attached document) in a form that best suits the experiment format, such that a third party can understand your experimental results in an attempt to reproduce them.

Calculate the Range

Use the results of your investigation and any relevant calculations to determine a predicted value for the range of your projectile. Record your calculations and work in the Collect Data space above.

Test the Range

Use the following steps to test your predicted range value:

1. Draw a circle with a radius of 8 cm in the center of a piece of white paper, and then tape the paper to the floor in front of the projectile launcher with the center of the circle at a distance equal to your predicted range.

2. Place carbon paper over the white paper, and then align the projectile launcher with the center of the paper.

5. Place the steel ball into the launcher and then use the push rod or plunger to load the ball as far into the launcher as possible (three clicks).

6. Launch the ball toward the paper. Place the steel ball back into the launcher and repeat the test four more times.

7. Remove the carbon paper. Observe the locations where the ball struck the paper.

Analysis Questions

* 1. Assuming air resistance is negligible, what other variables affect the range of a projectile?

* 2 Qualitatively describe how close your predicted range is to your actual range in terms of accuracy (the relative distance between each test shot and the actual target) and precision (the grouping of the test shots). Use the tables below to help.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Accuracy | Accuracy Definition |  | Precision | Precision Definition |
| Very high | All shots in 8 cm target |  | Very high | All shots within 3 cm radius |
| High | Four shots in 8 cm target |  | High | Four shots within 5 cm radius |
| Moderate | Three shots in 8 cm target |  | Moderate | Two shots within 8 cm radius |
| Low | Two shots in 8 cm target |  | Low | Two shots within 20 cm radius |
| Very low | One or no shots in 8 cm target |  | Very low | No shots within 30 cm radius |

* 3. What are factors that may have caused your range prediction to be incorrect, and what could you have done differently to avoid them?

* 4. Sketch the complete trajectory of your projectile. Draw your projectile at five locations on its trajectory (evenly spaced). At each of these locations, draw the net force vector acting on the projectile at that location. Make sure the lengths of the vectors represent the relative magnitudes.
* 5. Sketch the complete trajectory of your projectile. Redraw the projectile at the same five locations used in the previous question. At each of these locations, draw the projectile’s horizontal and vertical component velocity vectors. Make sure the lengths of the vectors represent the relative magnitudes of the velocities.
* 6. How did the kinetic energy of the projectile change in its trajectory? Use your sketches from the previous questions to explain how the kinetic energy of the projectile changed in its trajectory.

Synthesis Questions

* 1. A ball player throws a ball horizontally. What variables affect the horizontal range of the ball?

* 2. For the same ball player, how would doubling the initial velocity affect the range, if at all?

* 3. For the same ball player, how would quadrupling the height affect the range, if at all?

* 4. For the same ball player, how would doubling the mass of the ball affect the range, if at all?