

## Projectile Lab – Angled Launch

### Link for online lab:

<https://phet.colorado.edu/en/simulation/projectile-motion>

### OBJECTIVES:

- Draw motion diagrams for a projectile launched at an angle
- Investigate how range, maximum height and flight time of a projectile changes with the launch angle
- Determine gravitational field strength at a location by using a projectile and performing curve fitting on linearized data

### PROCEDURE:

Click on the Vectors window. Deselect **Air Resistance**. Air resistance will remain zero for this experiment. Mass and diameter of the cannonball will also remain fixed at default values.

#### Part 1 – Motion Diagrams

1. Select the **Velocity Vectors** in the vectors box and choose “Components” from the radio buttons. Keeping rest of the settings on default, fire the projectile and observe how the vectors change as the projectile falls to the ground.
  - a) Draw a motion diagram showing velocity components at different locations.
  - b) What happens to the velocity y-component at the peak of the projectile? Explain why?
  - c) Compare initial velocity y-component (at the moment of launch from the cannon) to final velocity y-component (at the moment when the projectile hits the ground)? Discuss any similarity and/or difference.
2. Now keeping the **Velocity Vectors** selected, choose “Total” from the radio buttons. Fire the projectile and observe how the velocity vector changes as the projectile falls to the ground.
  - a) Draw a motion diagram showing the velocity vector at different locations.
  - b) How do the magnitude and direction of the velocity vector change as the projectile moves?
  - c) What can you say about the velocity vector at the peak of the projectile?
  - d) How is the velocity vector related to the path of the projectile (i.e. how is this vector drawn in relation to the path)?

- e) Compare initial velocity vector (at the moment of launch from the cannon) to final velocity vector (at the moment when the projectile hits the ground)? Discuss any similarity and/or difference.
3. Now choose the **Acceleration Vectors** and **Force Vectors** in the vectors box and keep “Total” selected from the radio buttons. Fire the projectile and observe how the acceleration and force vectors change as the projectile falls to the ground.
- a) Draw a motion diagram showing the acceleration vector at different locations.
- b) Are the acceleration and force vectors related? Does the simulation show this relation?

### Part 2 – Effects of launch angle on the motion of projectile

4. Reset the simulation and deselect **Air Resistance**. Air resistance will remain zero for this experiment. Set initial speed to 15 m/s. For constant values of initial speed (15 m/s), fire the projectile for 8 different angles (25, 35, 45, 55, 65, 75, 85, 90 degrees). Using the Time, Height and Range tool, collect data in the following data table. Time, Height and Range tool is accessible in the top right corner of the simulation and looks like this:



Measure the following quantities:

- **R** - Range (at the location where projectile hits the ground)
- **T<sub>f</sub>** - Flight Time (at the location where projectile hits the ground)
- **H** - Maximum Height (at the peak of the projectile)
- **T<sub>h</sub>** - Time at Max Height (at the peak of the projectile)

Launch Speed $v_x$ (m/s)	Launch Angle $\theta$ (degree s)	Range R (m)	Flight Time $T_f$ (s)	Max. Height H (m)	Time to Max. Height $T_h$ (s)	$\sin \theta$	$\sin^2 \theta$	$\sin 2\theta$
15	25							
15	35							
15	45							
15	55							
15	65							

15	75							
15	85							
15	90							

5. Using the data table, answer the following questions:

- For which angle is the maximum height **H** of the projectile greatest? Explain why?
- For which angle is the flight time **T<sub>f</sub>** of the projectile greatest? Explain why?
- For which angle is the range **R** of the projectile greatest? Explain why?
- How is the flight time **T<sub>f</sub>** of the projectile related to the time to maximum height **T<sub>h</sub>**? What does it tell us about the projectile motion?

(**HINT** for parts a, b & c above: For constant value of magnitude of initial velocity i.e. 15 m/s, the components of initial velocity change with launch angle.)

- Flight time a projectile launched at an angle is given by:  $T_f = \frac{2v_i \sin \theta}{g}$   
 Explain how you can graphically obtain gravitational field strength  $g$ , by plotting  $T_f$  vs.  $\sin \theta$ .  
 Use this graph to calculate  $g$  and compare it with known value of  $9.81 \text{ m/s}^2$ .  
 (Paste the graph with linear fit here.)
- Maximum height of a projectile launched at an angle is given by:  $H = \frac{v_i^2 \sin^2 \theta}{2g}$   
 Explain how you can graphically obtain gravitational field strength  $g$ , by plotting  $H$  vs.  $\sin^2 \theta$ .  
 Use this graph to calculate  $g$  and compare it with known value of  $9.81 \text{ m/s}^2$ .  
 (Paste the graph with linear fit here.)
- Range of a projectile launched at an angle is given by:  $R = \frac{v_i^2 \sin 2\theta}{g}$   
 Explain how you can graphically obtain gravitational field strength  $g$ , by plotting  $R$  vs.  $\sin 2\theta$ .  
 Use this graph to calculate  $g$  and compare it with known value of  $9.81 \text{ m/s}^2$ .  
 (Paste the graph with linear fit here.)