Online Lab: Projectile Motion

Name: Date:

Instructor: Section:

Theory:

The horizontal range, Δx, for a projectile can be found using the equation:

$$\Delta x = v_x t \tag{1}$$

where v_x is the horizontal velocity (= the initial horizontal velocity) and t is the time of flight. To find the time of flight, t, the following kinematic equation is needed:

$$\Delta y = \frac{1}{2} a_y t^2 + v_{y0} t \tag{2}$$

where Δy is the height, $a_y = -g$ is the acceleration due to gravity and v_{y0} is the vertical component of the initial velocity.

When a projectile is fired horizontally (from a height Δy), the time of flight can be found by rearranging Equation 2. Since the initial vertical velocity is zero, the last term drops out of the equation yielding:

$$t = (2\Delta y/a_y)^{1/2} = (-2\Delta y/g)^{1/2} \tag{3}$$

When a projectile is fired at an angle and it lands at the same elevation from which it was launched, Δy = 0, and we may solve Equation (2) for t:

$$t = 2v_{yo}/g \tag{4}$$

Substituting this into Equation (1) yields

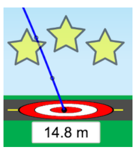
$$\Delta x = 2v_x v_{yo}/g = (2\ v^2\ cos\theta\ sin\theta)/g \tag{5}$$

where v is the initial speed of the projectile.When a projectile is fired from a height, none of the terms drop out and Equation 2 may be rearranged as follows:

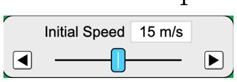
$$\frac{1}{2} a_y t^2 + v_{yo} t - \Delta y = 0 \tag{6}$$

Equation 6 may be solved using the quadratic formula to find the time of flight, t. Equation 1 then yields the horizontal range.

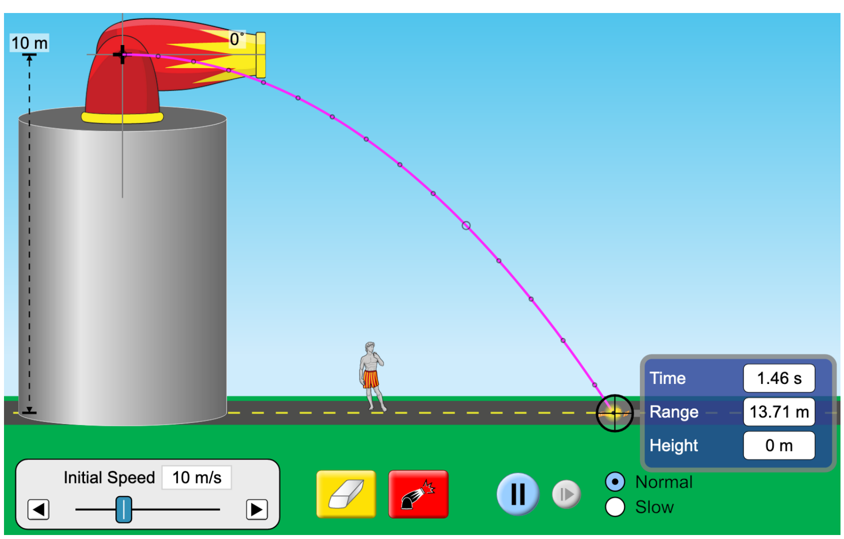
Online Experiment Setup Instructions:

1. Go to the following website: **https://phet.colorado.edu/sims/html/projectile-motion/latest/projectile-motion_en.html**
2. Click **Intro** on the PHeT simulation.
3. The cannon can be moved up or down to increase or decrease the initial height, h.
4. The cannon can be pivoted to change the firing angle, θ.
5. CLICK  to fire the cannon.
6. CLICK  to erase the path of the projectile.
7. DRAG  to place the target at an estimated range. If the target is hit directly, 3 Yellow stars will explode above. If not, adjust the position of the target accordingly.


8. DRAG the measurement tool (shown below) to the point where the object lands to measure the time of flight, range and final height. An example measurement is shown in the Figure at the bottom of the page.


9. This control panel allows you adjust the initial velocity from (0 - 30) m/s.


10. Example of how to measure the time of flight and range after the projectile hits the ground.



Vertical Speed and Time of Flight

For this procedure we are going to launch a pumpkin horizontally from a height in the air at different speeds and check to see how the range and time spent in the air are affected.

1. CLICK and DRAG the wheel of the cannon to raise it to a height of 10.0m in the air.
2. Select Pumpkin from the drop down menu in the upper right control panel.

   Record the mass of the pumpkin (**including units**) here:
3. **SET** the Angle, θ to $0°$.
4. **SET** the Initial Speed to 5 m/s. Record this value in Row 1 of the Table below.
5. CLICK  to launch the pumpkin.
6. Measure and Record the Range and Time by placing the cross hairs of the measurement tool at the bottom most point the pumpkin landed in the table below.
7. Repeat Steps 4 - 6 for Initial Speeds of 10, 15, 20, 25 and 30 m/s.

Table 1: Time of Flight vs Initial Speed

Firing (#)	**Initial Speed (m/s)**	**Range (m)**	**Time-of-Flight (s)**
1			
2			
3			
4			
5			
6			

Launching at an Angle on a Plane

1. Click the "Lab" tab at the top of the window.
2. Select the Cannonball from the drop down menu in the upper right control panel.

   Record the mass of the cannonball (**including units**) here:
3. Calculate the predicted range, $\Delta x_{predicted}$ for each set of Angles, θ and initial speed, V_0 in Table 2 using the Equation below.

$$\Delta x_{predicted} = \frac{2\ V_0^2\ cos\theta\ sin\theta}{g}$$

4. **SET** the Angle, θ to 25° and **SET** the Initial Speed to 15 m/s.
5. **Place** the target  at the predicted range you calculated for this angle in Step 4.
6. CLICK  to launch the cannonball.
7. Measure the Range, $\Delta x_{measured}$ and **Time**. Record them in the table below.
8. Repeat Steps 4 - 7 for Angles of 35°, 45°, 55°, 65°, 75°, 85° and 90°.
9. **Create a graph of $\Delta x_{measured}$ versus angle, θ and upload it with this Lab Report in D2L.**

Table 2: Horizontal Range as a Function of Angle

Angle θ (∘)	**V**∘ **m/s**	$\Delta x_{predicted}$ **(m)**	$\Delta x_{measured}$ **(m)**	$Time$ **(s)**
25°	15 m/s			
35°	15 m/s			
45°	15 m/s			
55°	15 m/s			
65°	15 m/s			
75°	15 m/s			
85°	15 m/s			
90°	15 m/s			

Conclusions

1. Did the time of flight depend on the initial horizontal speed? What does this imply about the dependence of the vertical motion on the horizontal motion?

2. How does the initial speed of a projectile launched horizontally affect the range of the projectile?

3. How would the horizontal range change if the height from the ground was doubled? Explain how you know.

4. How would the horizontal range change if the mass of the ball was doubled? Explain how you know.

5. Compare your measure range values $\Delta x_{measured}$ to the predicted range values $\Delta x_{predicted}$ using the equation below. Do they agree? Try to explain any differences.

$$\%_{Error} = \left(\frac{x_{measured} - x_{predicted}}{x_{predicted}} \right) \times 100 \tag{7}$$

6. **Take a photo or scan a copy showing all of your calculations and upload it with this Lab Report in D2L.**