Projectile Motion

Equipment

Qty	Item	Part Number
1	Mini Launcher	ME-6800
1	Metal Sphere Projectile	
	1 and 2 Meter Sticks	
1	Large Metal Rod	ME-8741
1	Small Metal Rod	ME-8736
1	Support Base	ME-9355
1	Plumb Bob	SE-8728
1	Double Rod Clamp	ME-9873
1	Carbon Paper	
	White Paper	

Purpose

The purpose of this activity is to examine some of the basic behaviors and properties of simple projectile motion. Among those properties and behaviors that will be examined are, how does the initial angle at launch affect the range of the projectile?

Theory

Projectile motion is a form of motion in which an object (called the projectile) is launched at an initial angle ϑ, with an initial velocity v_i. While the projectile is in flight, only the force of gravity (we are ignoring any air resistance) is acting on the projectile. Since, near the Earth's surface, the force of gravity causes masses to be accelerated downwards at a constant rate of $g = 9.81\ {}^{m}/_{s^2}$, we can use the simple Kinematic equations to describe projectile motion. Using the standard coordinate system where the x-direction is purely horizontal and the y-direction is purely vertical, we obtain the following equations of projectile motion for the y-direction:

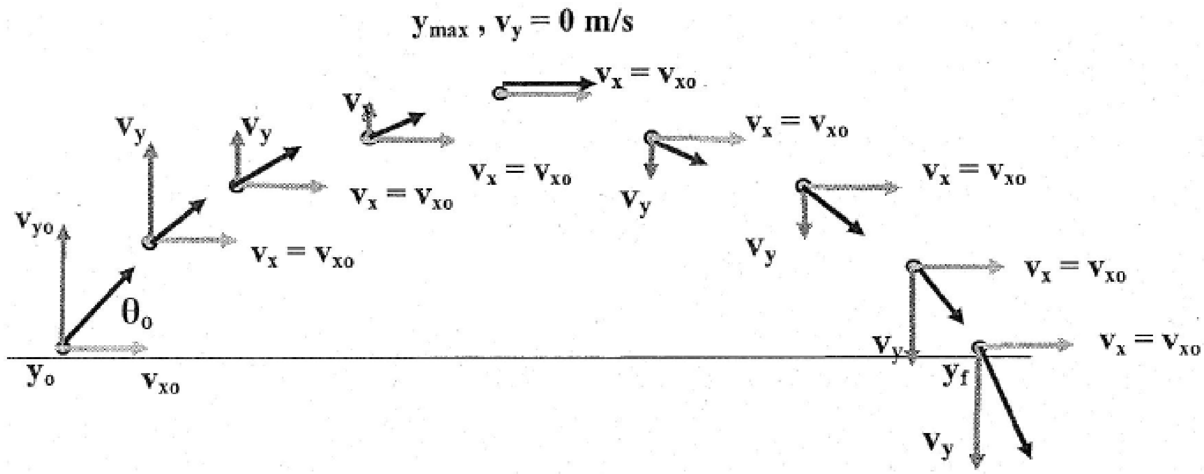
$$y = y_i + v_{iy}t - \frac{1}{2}gt^2 \qquad y = \frac{1}{2}\left(v_y - v_{iy}\right)t \qquad v_y = v_{iy} - gt \qquad v_y^2 = v_{iy}^2 - 2g\Delta y$$

Since gravity acts purely in the vertical direction, and we have no other forces acting on the projectile during flight, the acceleration in the x-direction is zero: $a_x = 0$. This results in our kinematic equations in the x-direction reducing to the following;

$$\Delta x = v_x t \qquad v_x = constant$$

Assuming that the initial angle ϑ is measured from the horizontal, then the projectile's velocity components are given by;

$$v_x = v_i \cos(\vartheta) \qquad v_y = v_i \sin(\vartheta)$$



From the above diagram we can see the behaviors of the velocity vector, and its components, of a projectile while it is in flight. The x-component is constant through the entire flight while the y-component is constantly changing. The y-component is equal to zero when the projectile is at its maximum height, and therefore the velocity vector is at its minimum value when the projectile is at its maximum height.

The x-displacement, $\Delta x = x - x_i$, the projectile goes through during its flight is called 'the range' of the projectile. One of the things we will look at in this activity is how changing the initial launch angles affects the range of the projectile.

Procedure: Determining Initial Velocity

1. Attach the Large Metal Rod to the Support Base, and then put the support base on the ground.
2. Then use the Double Rod Clamp, and the Small Metal Rod to attach the Mini-Launcher to the Large Metal Rod.
3. Use a meter stick to make sure that the bottom of the barrel opening of the Mini-Launcher is 1.00 meter above the floor. Record this as y_i for **TABLE 1**.
4. Using the protractor on the side of the Mini-Launcher set the initial launch angle to 0^o. This will result in the initial velocity being purely in the in x-direction, and therefore the initial y-component of the velocity will be zero.

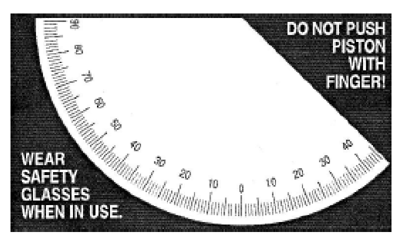


Illustration 2: The mini launcher is equipped with a built-in protractor and plumb bob so as to launch from specific angles.

5. Now dangle the Plumb Bob right next to the Mini-Launcher such that its string crosses the little sign at the center of the white circle on its side, and the mass just barely touches the floor. With a pencil put a little mark on the floor where the Plumb Bob is touching it. This is the initial x-coordinate of the center of mass of the projectile at the moment it will leave the Mini-Launcher.
6. Place a large object about 2 to 3 meters in front of the Mini-Launcher. (One of your book bags, or something similar will do fine) This will serve as a barrier to stop the projectile.

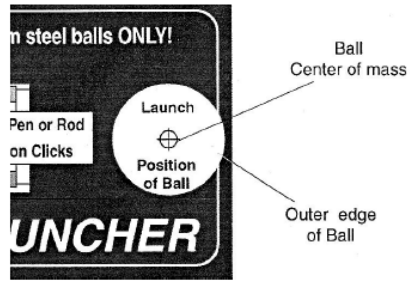


Illustration 1: When performing measurements such as range and launch height, always measure from the crosshatch, ie, the 'Ball Center of Mass' as shown in this picture.

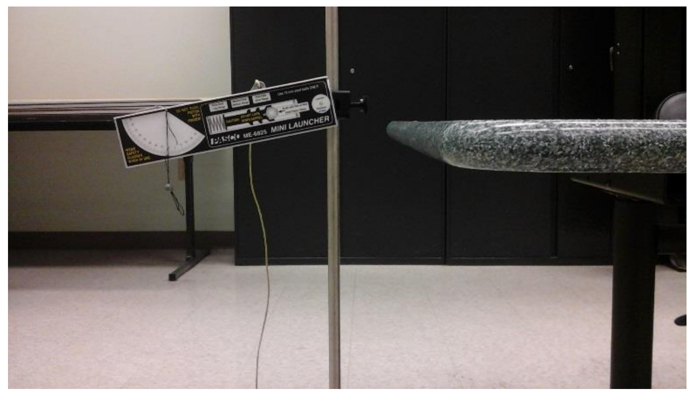
7. Insert the Metal Sphere Projectile into the barrel of the Mini-Launcher, then using a pencil or pen push it back into the barrel until you hear a click. The Mini-Launcher is now at setting 1. (There are 3 settings)
8. Pull on the little rope attached to the Mini-Launcher's trigger to fire the projectile.
9. Note about where the projectile hit the floor, and tape a white piece of paper at that location.
10. Now on top of the white piece of paper, place a piece of carbon paper with the carbon side (the dark/black side) facing downward. **DO NOT TAPE DOWN THE CARBON PAPER.**
11. Now shoot the projectile 5 times onto the carbon paper, then remove the carbon paper. There should now be 5 black marks on the white piece of paper signifying the locations that the projectile hit the floor. (These 5 marks should be closely packed together. If they are not, you need to make sure everything is still aligned correctly, and then try again.)
12. Using a meter stick(s), measure the displacements from the projectile's initial x-coordinate, and the 5 marks on the white paper. Record these x-displacements in **Table 1**, for setting 1.

Projectile Motions on an Uneven Surface

1. Place a large object about 2 to 3 meters in front of the Mini-Launcher. (One of your book bags, or something similar will do fine) This will serve as a barrier to stop the projectile.
2. Using the protractor on the side of the Mini-Launcher set the initial launch angle to 10^o, and make sure the bottom of the barrel opening of the Mini-Launcher is 1.00 meter above the floor. Record this as y_i for **TABLE 2**.
3. Insert the Metal Sphere Projectile into the barrel of the Mini-Launcher, then using a pencil or pen push it back into the barrel until you hear a click. The Mini-Launcher is now at setting 1.
4. Pull on the little rope attached to the Mini-Launcher's trigger to fire the projectile.
5. Note about where the projectile hits the floor and tape a white piece of paper at that location.

6. Now on top of the white piece of paper place a piece of carbon paper with the carbon side (the dark/black side) facing downward. **DO NOT TAPE DOWN THE CARBON PAPER.**
7. Now shoot the projectile 3 times onto the carbon paper, then remove the carbon paper. There should now be 3 black marks on the white piece of paper signifying the locations that the projectile hit the floor. (These 3 marks should be closely packed together. If they are not, you need to make sure everything is still aligned correctly, and then try again.)
8. Using a meter stick(s), measure the displacements from the projectile's initial x-coordinate, and the 3 marks on the white paper. Record these x-displacements in **Table 2**.
9. Using the protractor on the side, reset the initial launch angle to 20^o, and repeat procedure, making sure of the height of the Mini-Launcher, such that the bottom of the barrel opening stays at 1 meter.
10. Then repeat again for all the angles listed in **Table 2**.

Projectile Motion on an even plane



1. Reposition your Mini-Launcher so that it is now right next to and aimed down the length of your lab table. Adjust the height of the Mini-Launcher such that the bottom of the barrel opening is at the same height as the table top. This means that the initial height and final height of the projectile will be the same, and therefore the y-displacement is zero. Record $\Delta y = 0$ for **Table 3**.
2. Using the protractor on the side of the Mini-Launcher set the initial launch angle to 10^o.
3. Place a large object about 1 to 2 meters in front of the Mini-Launcher. (One of your book bags, or something similar will do fine) This will serve as a barrier to stop the projectile.
4. Insert the Metal Sphere Projectile into the barrel of the Mini-Launcher, then using a pencil or pen push it back into the barrel until you hear a click. The Mini-Launcher is now at setting 1.
5. Pull on the little rope attached to the Mini-Launcher's trigger to fire the projectile.
6. Note about where the projectile hit the table top, and tape a white piece of paper at that location.
7. Now on top of the white piece of paper place a piece of carbon paper with the carbon side (the dark/black side) facing downward. **DO NOT TAPE DOWN THE CARBON PAPER.**
8. Now shoot the projectile 3 times onto the carbon paper, then remove the carbon paper. There should now be 3 black marks on the white piece of paper signifying the locations that the projectile hit the table top. (These 3 marks should be closely packed together. If they are not, you need to make sure everything is still aligned correctly, and then try again.)
9. Using a meter stick measure the displacements from the projectile's initial x-coordinate (which will be the little sign at the center of the white circle on the Mini-Launcher's side) and the 3 marks on the white paper. Record this these x-displacements in **Table 3**.
10. Using the protractor on the side, reset the initial launch angle to 20^o, and repeat procedure, making sure of the height of the Mini-Launcher, such that the bottom of the barrel opening is at the same height as the table top.
11. Then repeat again for all the angles listed in **Table 3.**

Analysis of Projectile Motion Lab

Name____ Group#________

Course/Section_______________________________________

Instructor____

Table 1 $y_i =$ ______

	Setting 1
Δx_1	
Δx_2	
Δx_3	
Δx_{avg}	
t	
v_i	

1. Calculate the average x-displacement, and enter your answers in **Table 1**. (5 points)

2. Using the equation $y = y_i + v_{iy}t - \frac{1}{2}gt^2$ calculate the time of flight, and enter your answers in **Table 1**. (5 points)

3. Using the equation $v_i = \frac{\Delta x_{avg}}{t}$ calculate the projectile's initial velocity, and enter your answers in **Table 1**. (5 points)

Table 2: Uneven surface $y_i =$ ____________

	10°	20°	30°	40°	45°	50°	60°	70°	80°
Δx_1									
Δx_2									
Δx_3									
Δx_{avg}									

4. Calculate the average x-displacement for each setting, and enter your answers in **Table 2**. Which angle gives the longest range? (10 points)

5. Graph Range vs. Initial Launch Angle. (10 points)

6. Using the equation $y = y_i + v_{iy}t - \frac{1}{2}gt^2$ calculate the time of flight for the initial launch angle of 45°. (5 points)

7. Using equation $\Delta x = v_{ix}t$ calculate the theoretical range for your projectile with the initial launch angle of 45°. (5 points)

8. Calculate the % difference between your measured range, and your theoretical range for the initial launch angle of 45°. (5 points)

Table 3: Even Plane $\Delta y = 0$

	10°	20°	30°	40°	45°	50°	60°	70°	80°
Δx_1									
Δx_2									
Δx_3									
Δx_{avg}									

9. Calculate the average x-displacement for each setting, and enter your answers in **Table 2**. Which angle gives the longest range? (10 points)

10. Graph Range vs. Initial Launch Angle. Do you notice a symmetry in the graph? If so, what is that symmetry? Does the same symmetry exist for the graph on the uneven surface? Write your answer on the graph for an even plane. (10 points)

11. Using the equation $y = y_i + v_{iy}t - \frac{1}{2}gt^2$ calculate the time of flight for the initial launch angle of 45°. (5 points)

12. Using equation $\Delta x = v_{ix}t$ calculate the theoretical range for your projectile with the initial launch angle of 45°. (5 points)

13. Calculate the % difference between your measured range, and your theoretical range for the initial launch angle of 45°. (5 points)

14. What would change if we decided to double the initial height in the first part of the experiment? (6 points)

15. We assumed the effect that air resistance had on the projectile was negligible. Was this a good assumption? Explain your answer. (8 points)

16. Do the results of our experiment confirm theoretical predictions? (6 points)