Part 1: Projectile Motion

Introduction:
Projectiles travel with two components of motion, X any Y. The acceleration and velocity in the Y direction is independent of the acceleration (if any) and velocity in the X direction. In this module, you will investigate the motion of a simple projectile. Realize that while gravity (acceleration) acts on the projectile in the __________ direction, it does not affect the velocity of the projectile in the __________ direction.

Procedure: (we will be ignoring air resistance during this lab)
- Run the PhET Simulations ➔ Play ➔ Motion ➔ Projectile Motion
- The cannon can be moved to add or remove initial Y position and X position.
- The cannon can be pivoted to change the firing angle, θ.
- The tape measure can be moved and dragged to measure range to target.
- To fire the cannon, Fire.
- To erase the projectile’s path, Erase.

Be sure air resistance is off and spend some time firing various projectiles.
- Set the initial speed to a value between 10-15m/s. Choose your favorite projectile.
- Find the range of the projectile at various angles.

θ = _30__ Range (dx) = _______ m  θ = _70__ Range (dx) = _______ m
θ = _40__ Range (dx) = _______ m  θ = _80__ Range (dx) = _______ m
θ = _50__ Range (dx) = _______ m  θ = _____ Range (dx) = _______ m
θ = _60__ Range (dx) = _______ m  θ = _____ Range (dx) = _______ m

- Measure the distance from the cannon to the target using the tape measure.
- Move the target to 21.0 m from the cannon. Attempt to hit the target with three different angles by changing the firing angle and initial velocity.

Range (d_x) = 21.0m  θ = __________  Vi = __________
Range (d_x) = 21.0m  θ = __________  Vi = __________
Range (d_x) = 21.0m  θ = __________  Vi = __________

Very Important

- A projectile’s velocity (v) has an X component (v_x) and a Y component (v_y). The X component (v_x) is found by multiplying the magnitude of the velocity by the cosine of the angle, θ.
- Similarly, the Y component of velocity is found by multiplying the magnitude of the velocity by the sine of the angle, θ.
So, a projectile fired at 20 m/s at 65° has an X-velocity of \(v_x = 20 \cos 65°\) or 8.5 m/s.

The projectile would have a Y-velocity of \(v_y = 20 \sin 65°\) or 18 m/s. So, the projectile would fire as far as one fired horizontally at 8.5 m/s and as high as one fired straight up at 18 m/s.

A projectile fired at 30 degrees with a velocity of 15 m/s would have an x-velocity component of ________ m/s and a y-velocity component of ________ m/s.

Calculate the components of the following projectile’s velocities:

1. \(v = 35 \text{ m/s } \theta = 15°\) \(v_x = ____\) \(v_y = ____\)
2. \(v = 35 \text{ m/s } \theta = 30°\) \(v_x = ____\) \(v_y = ____\)
3. \(v = 35 \text{ m/s } \theta = 45°\) \(v_x = ____\) \(v_y = ____\)
4. \(v = 35 \text{ m/s } \theta = 60°\) \(v_x = ____\) \(v_y = ____\)
5. \(v = 35 \text{ m/s } \theta = 75°\) \(v_x = ____\) \(v_y = ____\)
6. \(v = 35 \text{ m/s } \theta = 90°\) \(v_x = ____\) \(v_y = ____\)

We can reverse the process and combine the two components of velocity back into one velocity fired at an angle.

The magnitude of velocity is found using the Pythagorean Theorem with \(v_x\) and \(v_y\) as the legs of a right triangle. For instance, the velocity of a projectile with an x-component of 7.2 and a y-component of 4.8 is \(\sqrt{7.2^2 + 4.8^2} = 8.7\) m/s.

The angle above the horizontal is found using the inverse tangent \((\tan^{-1})\) of the legs \(v_y/v_x\). For instance, the angle of the projectile described above would be \(\tan^{-1}(\frac{4.8}{7.2}) = 34°\).

Calculate the velocity magnitude and angle of the projectiles listed below:

7. \(v_x = 5.6\) \(v_y = 6.4\) \(v = ____\) \(\theta = ____\)
8. \(v_x = 2.8\) \(v_y = 4.9\) \(v = ____\) \(\theta = ____\)
9. \(v_x = 8.1\) \(v_y = -7.2\) \(v = ____\) \(\theta = ____\)
10. \(v_x = -1.3\) \(v_y = -5.2\) \(v = ____\) \(\theta = ____\)
Part 2: My Solar System

Find the simulation "My Solar System” and run it. You should see this:

Virtual Lab Simulation:

1. **Start**  What shape is the orbit of the planet? ______________________________________

   Why does the “sun” wobble? ___________________________________________________

   What is this principle called in Physics (Chap 6) _________________________________

2. **Stop Reset**  Complete the table at the right

   The SUN is **body ____**, the Planet is **body ____**

   Which variable is the planet’s initial radius? __________

   Which variable is the planet’s initial velocity? __________

3. Change the **mass** of the planet to 5

   **Start**  Explain what is different.

4. **Stop Reset**  Change planet mass to 2

   **Start** Does the mass of the **planet** affects it’s **own** orbit? __________

5. **Stop Reset** Still with planet mass 2

   change **velocity** and describe each orbit shape in the table.

6. **Exploring Universal Gravitation**  The program was developed in Elbonia which is not on the metric system but it

   does follow Newton's Law of Universal Gravitation - G comes out a little different.

   *a. Write the equation for universal gravitation for a planet

   mass **mp** orbiting a sun **ms** at dist **r**
Write the circular motion equation for the planet

c. Combine 1,2 and cancel to make an expression for $G$
d. Use your values from Step 5 above for a PERFECT Circle to solve for $G$ in this simulation.

7a) **Stop Reset** Click **Number of bodies** 3 to add a planet
    WE will put planet 2 at TWICE the radius of planet 1
    **EDIT** to match the **first 3 lines** in the table.
    This time describe the orbit of planet 2 (body 3)
    as TOO FAST or TOO SLOW for a perfect circle

7b) Find the **exact** velocity for a **perfectly circular orbit**
    use measuring tape !!

7c) The outer planet is going at ( faster ) (slower) velocity
    = ( faster ) (slower) tangential speed

7d) Find how many times the planet 1 orbits for just one orbit of planet 2 ________________
    Planet 2 has a ________ ________ year

* 7e) Rearrange your equation 6c to solve for $v$
    $v^2 =$
    $v =$

7f) Solve this for radius $r = 284$
    Compare the calculated value with your data table

7g) Calculate the ratio vel body3/ vel body2
    for circular obits = ___________ =
    When the radius is doubled the velocity for circular orbit is approx. ( 1/2 ) (same) ( 1/sqrt2)

8. Find **select preset** and pull down to
    **Sun Planet moon** Start
    **Draw** the sun and one complete orbit of each

9a) Find **select preset** and pull down to
Sun Planet comet Start

**Draw** the sun and one complete orbit of each

9b) Observe the comet

Where is it moving fastest? ______________________________________________________________________

Slowest ______________________________________________________________________

Where does the comet have greatest PE? _________________________________________

<table>
<thead>
<tr>
<th>Planet</th>
<th>Orbital Radius A.U.</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>1.0</td>
</tr>
<tr>
<td>Jupiter</td>
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<tr>
<td>Uranus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neptune</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. **Research Our Solar System**

to see how it follows the same pattern

The unit A.U is convenient 1 A.U = earths orbital radius

Complete the table INCLUDING THE BLANKS

- EVERY ROW IS A PLANET !! list the sites you use

-- ( try "stardate" or "nineplanets")

**Pre-Lab Questions – Projectile Motion:**

1. Without air resistance, the piano travels further / the same distance as the football. (circle)
2. This is due to the fact that velocity in the X-direction increases / is constant / decreases as projectiles travel.
3. The Y-component of velocity increases / is constant / decreases as projectiles travel.
4. The answers to #2 and #3 are due to the fact that gravity acts only in the Y / both the X any Y direction.
5. The path of a projectile is a linear curve / round curve / parabolic curve.
6. This is due to the fact that the time component in the free fall equation (dy) is ____________.
7. Without air resistance, maximum range of a projectile is obtained with an angle of ________.
8. The same range can be obtained with angles of ________ and ________.
9. Firing a projectile at 25 m/s at an angle of 35° is similar to firing a projectile with a speed of __________ straight up and __________ horizontally.
10. A projectile with a horizontal component of 13 m/s and a vertical component of 18 m/s would have an overall velocity of __________ m/s at an angle of __________ above the horizontal.

**Pre-Lab Questions – Solar System:**

0) Play with this simulation and “mouse” around with it. Try to figure out what all the controls do.

1) Using **Select Preset**, select “Sun and Planet”. Then select, **System Centered, Show Traces**, and **Show Grid**. Describe the shape of the orbit. How does the distance and planet tangential speed affect the shape of the orbit?

2) Move the planet outward, and observe (and record) the orbit period. Make a graph of distance (from the star) vs. period of orbit. (Use the graph paper on next page).
3) What happens to the period as the star-planet distance increases? Why do you think there is a relationship?