Kinematics in Two Dimensions

Mechanics

Unit 2

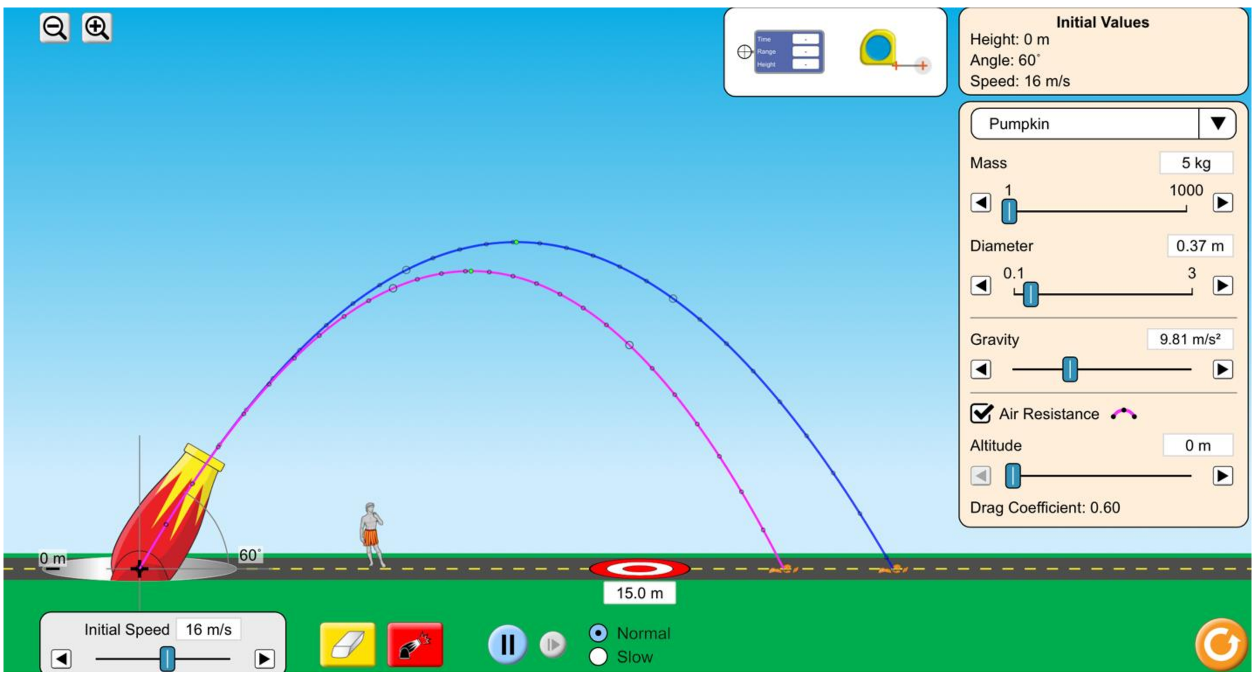
TA name: Due Date:

Student Name:

Student ID:

Simulation Activity #2: *Projectile Motion*

Simulation created by the Physics Education Technology Project (PhET)
c/o The University of Colorado at Boulder https://phet.colorado.edu/en/simulation/projectile-motion



Investigating 2D Motion: Objects under the Influence of Gravity

Objective:

This activity is intended to enhance your physics education. We offer it as a virtual lab online. We think it will help you make connections between predictions and conclusions, concepts and actions, equations and practical activities. We also think that if you give this activity a chance, it will be fun! This is an opportunity to learn a great deal. Answer all questions as you follow the procedure in running the simulation.

Blast a Buick out of cannon! Learn about projectile motion by firing various objects. Use simulation controls from the bottom right controls. Click “Fire” to launch the projectile or click “Erase” to clear the projectile. You can pick different objects to shoot out of the canon by using the object selector from the top right. You can manually adjust the settings of the projectile from the middle right projectile controls. Using projectile controls, you can set the angle, initial speed, mass, and diameter. If you resemble the projectile with the reality, check the air resistance box. You can also add sound to the simulation by checking the sound box. As the projectile travels along its path, the three boxes at the top left display results at the point in time. Range and heights can be verified by using the “Tape measure”. To move the tape measure, click and drag it to the location of your choice. Elongate the tape by clicking and dragging on the end of the tape. Make a game out of this simulation by trying to hit a target. In general familiarize yourself with control features and displayed results.

Introduction:

The basic kinematics equations in one dimensional motion are also used for two dimensional motions. Because, the two dimensional motion is described using two components, x and y independently. Here are the basic two-dimensional kinematics formulas:

$x = x_0 + \bar{v}_x t$	$y = y_0 + \bar{v}_y t$
$v_x = v_{0_x}$	$v_y = v_{0_y} + a_y t$
$v_x^2 = v_{0_x}^2 + 2a_x x$	$v_y^2 = v_{0_y}^2 + 2a_y y$
$x - x_0 = v_{0_x} t + \frac{1}{2} a_x t^2$	$y - y_0 = v_{0_y} t + \frac{1}{2} a_y t^2$

When working with projectiles, we apply these kinematics equations with the following settings:

- An initial velocity, v_0 and initial (launch) angle, θ_0
  - Horizontal component for the initial velocity is $v_0\cos\theta_0$
  - Vertical component for the initial velocity is $v_0\sin\theta_0$
- There is no acceleration in the horizontal direction: $a_x = 0$
- Gravitational acceleration is directed downwards: $a_y = -g$

The velocity at any point on the projectile results by applying the Pythagorean Theorem:

$$v = \sqrt{v_x^2 + v_y^2}$$

The angle θ the velocity vector makes with the horizontal can be found using the following formula:

$$\theta = tan^{-1}\left(\frac{v_y}{v_x}\right)$$

When the kinematics equations are applied with the given specifications, the following useful equations can be derived.

Range of the projectile: $R = \dfrac{v_0^2}{g} \sin\ 2\theta$

Physics Lab 2 (Online Simulation)

Maximum height: $$y_{max} - y_0 = \frac{v_0^2}{2g} sin^2 \theta$$

Total time of flight: $$t_{total} = \frac{2v_0 sin\theta}{g}$$

Procedure: *Open Projectile Motion*

http://phet.colorado.edu/simulations/sims.php?sim=Projectile_Motion

Part I

1. Settings: Maximize the screen, select the pumpkin, set the angle to 60 degrees, the initial speed to 16 m/s, keep launch height at 0 m, and mass and diameter remain in the default setting. Turn off air resistance.
2. Launch the pumpkin.
3. Use the tape measure to find the maximum height and the range of the projectile. Record your measurement.
   Maximum height (y_{max}) = <u>9.94m</u>   Range (x) = <u>22.66m</u>

4. Calculate the maximum height and the range using the angle and initial speeds set at step 1. Record your result.
   Calculated Maximum height (y_{max}) = <u>9.795m</u>   calculated Range (x) = <u>22.616m</u>

5. Is there a difference between your measurement, the display, and your calculated result?
   a. Compare your calculated result with your measurement. Explain the reason if there are differences
      Measured Maximum height (y_{max}) = <u>9.94m</u>   Measured Range (x) = <u>22.66m</u>
      <u>The two answers are extremely close but slightly different. The most likely reason for this difference is slight inaccuracies while measuring while the calculated results are probably the true answer.</u>
   b. Compare your measurement with the displayed results. Explain any differences
      Displayed Maximum height (y_{max}) = <u>9.79m</u>   Displayed Range (x) = <u>22.6m</u>
      <u>The measured result and the displayed result are slightly different. The displayed result lines up more with the calculated result. This promotes the idea that my manual measurements were slightly off.</u>
6. Do not click Erase button

Part II

7. Keep the settings in part I of step 1 except change the angle to 30 degrees.
8. Use the tape measure to find the maximum height and the ranges. Record your measurement.
   Measured Maximum height (y_{max}) = <u>3.33m</u>   Measured Range (x) = <u>22.66m</u>

9. Explain similarity and differences with the 60 degree setting.

While the maximum range is the same, the maximum height has been reduced by about the same. The maximum range is the same probably because there is more horizonal motion but less time.

10. Which setting has longer time of flight?
    Total time (t) with 60 degree setting = 2.82s
    Total time (t) with 30 degree setting = 1.62s

Part III

11. Clear the projectiles by clicking the "Erase" button
12. Go back to part I / step 1 settings and launch the pumpkin
13. Do not click Erase button
14. Now, check the air resistance box (drag coefficient to 0.6) and launch the pumpkin.
15. Measure the maximum height and the range
    Measured Maximum height (y_{max}) = 8.93m Measured Range (x) = 19.33m

16. Did you see the change in height and range due to the air resistance? If so how the air resistance is affects the height and ranges of the projectile?
    Yes. The air resistance slowed down the projectile over time and caused the pumpkin to reach a lower height and reach a shorter distance.

17. What effect do you see on the range and height if (keeping the drag coefficient constant)
    a. Mass increased or decreased
       If the mass in increased the affects of air resistance are lessened and if the mass is decreased the affects are amplified. The more mass the further and higher the pumpkin will go. This effect levels off.
    b. Diameter increased or decreased
       If the diameter is increased there is more drag and if it is decreased there is less drag. The larger the diameter the lower and shorter the pumpkin will go.

Follow-up questions:

1. Did you see any differences in ranges for different objects with the air resistance box checked off?
   Yes. Air resistance slows down the object which causes it to have a lower max height and go a shorter distance.
2. With the air resistance on, the pumpkin travels shorter than the football
3. What angle do you need to set the cannon to get
   a. The maximum range 45 degrees
   b. The maximum height 90 degrees
4. The same range can be obtained with angles of 25 degrees and 65 degrees
5. The Y-component of velocity decreases as projectiles travel
   a. Increases b. is constant c. decreases
6. A projectile is fired with an initial angle of 60 degrees at 10 m/s. calculate the following quantities as the angle decreased to 30 degrees
   a. The y component of velocity
      -9.8t + 5*3^1/2

b. The time it takes to this y component.
   .5891s
c. The velocity of the projectile
   5.774m/s
d. The height
   3.401m