**Projectile Motion**

**I. Introduction**

 Projectiles are objects that are shot through the air. Examples of projectiles include simple objects such as baseballs, arrows, or bullets. Projectiles follow a path through space called a trajectory. The parabolic path of the trajectory is the result of a combination of horizontal and vertical forces and the angle of release. Precise measurements of trajectories are needed for military and space missions. For example, missiles need to be accurately calibrated in order to strike the correct target (and not civilians), whereas NASA needs to precisely measure trajectories of rockets to place objects in proper orbit.

**II. Objectives**

 Students will be able to :

 - Determine angles of projectiles needed to strike targets.

 - Determine initial speed of projectiles with constant angles needed to strike targets.

 - Determine how air drag affects projectile motion.

**III. Procedure**

 1. Go to the PhET simulation entitled Projectile Motion at the website : <https://phet.colorado.edu/sims/projectile-motion/projectile-motion_en.html>.

 2. Starting with the pumpkin as your projectile, gather data and answer the following questions :

 a. With an initial speed of 18 m/s and no air resistance, what angle must the

 cannon be at to hit the bull’s eye? Click on FIRE.

 Cannon Angle = \_\_\_\_\_\_\_\_\_\_\_\_\_˚

 b. Clear your results from Part a. Now add air resistance and answer the same

 question.

 Cannon Angle = \_\_\_\_\_\_\_\_\_\_\_\_\_˚

 c. Clear your results from Part b and remove air resistance. Collect data to figure

 out how the angle must be changed to hit the bull’s eye as the initial speed

 increases.

|  |  |
| --- | --- |
|  **Initial Speed** |  **Angle** |
|  **14 m/s** |  |
|  **18 m/s** |  **75˚** |
|  **22 m/s** |  |
|  **26 m/s** |  |

 3. Now using different projectiles, collect data to figure out how the angle must be

 changed as the mass of the projectile changes. Use 18 m/s as your speed.

|  |  |  |
| --- | --- | --- |
|  **Projectile** |  **Mass** |  **Angle** |
|  **Football** |  |  |
|  **Bowling Ball** |  |  |
|  **Adult Human** |  |  |
|  **Piano** |  |  |
|  **Buick** |  |  |

 a. As the mass of the object increases, the angle \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 as long as the speed is constant.

 4. Now, repeat the last experiment, only keep the angle constant at 65˚, and determine

 what happens to the initial speed needed to hit the bull’s eye as the mass of the

 projectile changes.

|  |  |  |
| --- | --- | --- |
|  **Projectile** |  **Mass** |  **Initial Speed** |
|  **Football** |  |  |
|  **Bowling Ball** |  |  |
|  **Adult Human** |  |  |
|  **Piano** |  |  |
|  **Buick** |  |  |

 a. As the mass of the object increases, the initial speed \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 as long as the angle is constant.

 5. Repeat the last experiment, except set the speed based on your results in Step 4. Add

 air resistance and record the drag coefficient and whether the object hits the bull’s eye

 or not.

|  |  |  |  |
| --- | --- | --- | --- |
|  **Projectile** |  **Initial Speed** **(From Step 4)** | **Drag Coefficient** |  **Hit Bull’s Eye?** |
|  **Football** |  |  |  |
|  **Bowling Ball** |  |  |  |
|  **Adult Human** |  |  |  |
|  **Piano** |  |  |  |
|  **Buick** |  |  |  |

 6. Finally, choose an object and analyze its motion without air resistance. Fill in the data

 table below by first choosing an initial speed and angle. As the object is in motion,

 record the remaining data.

|  |  |
| --- | --- |
|  **Object** |  |
|  **Angle** |  |
|  **Initial Speed** |  |
|  **Maximum Height** |  |
|  **Range** |  |
|  **Time** |  |