**A. Title**

The Effect of the Mass of an Object on the Distance the Projectile is Launched From a Catapult

**B. Introduction/Purpose**

 Catapults are ancient mechanisms that were used in the military for launching missiles (Merriam Webster, 9/18/2014.) Catapults were used by ancient civilizations, including the Greeks, Romans, and the Ancient Chinese. If an enemy civilization had defensive walls, catapults were often used to knock down these fortifications. Catapults were also used to bombard enemies. Throughout history, many different variations of the catapult were made by many different civilizations. However, most catapults used tension or gravity in order to accumulate the force and energy needed to launch the object. Many different types of objects were launched from catapults, including stones, sharp wood poles, darts, burning tar, burning sand, and human bodies. These objects had various amounts of mass, each used for different reasons (Physics of Catapults, 9/18/2014.) In the late 1600s, a scientist named Isaac Newton discovered that the mass of an object has an effect on its acceleration, which affects how far it travels. He discovered that two objects, when given the same amount of force, will accelerate at different speeds, and will travel different distances (Synonym, 9/18/2014.) Also, objects with different masses can fly in different directions. This is because objects with different weights have different amounts of inertia, and are affected differently by unbalanced forces, such as wind (The Physics Classroom, 9/18/2014.) This causes the objects to curve in different directions.

 This experiment is being done to find out how an object’s mass affects the distance and direction the object travels when a certain amount of force is applied. The force will be applied by launching objects from catapults. This experiment will also determine the effect of an object’s mass on its acceleration. This experiment may interest football and baseball players, who may want to know if the weight of a football or baseball affects how far, as well as where, it travels. This experiment may also interest firearms enthusiasts, who may want to know how the mass of their ammunition affects what distance and direction the bullet will travel. This experiment is important because it will determine the correlation between an object’s mass and how far, as well as what direction, it can travel under a certain force. This is important in determining the mass of several things, including ammunition and sports equipment, such as footballs, shot puts, and discuses.

 I predict that the lightest object that is launched in the catapult will travel the farthest. However, I believe that the lightest object will curve the most while in flight. I think that the lightest object will travel the farthest because the lightest object will feel the least amount of gravity, and will travel the farthest before hitting the ground. By feeling the effect of gravity the least, the force of the catapult will be able to launch the object in a more vertical path, allowing it to travel farther before curving downwards. However, because the lightest object has less inertia, it is affected more by unbalanced forces, such as wind. These two hypothesis are supported by examining the manufacturing of certain vehicles. For example, NASA tries to make rockets from strong but lightweight materials, such as titanium and aluminum (NASA, 9/18/2014.) NASA scientists also must account for wind speeds during launching. This implies that lighter materials can travel further with the same amount of force, but are significantly affected by unbalanced forces. Also, a 2005 study show that heavier SUVs use about $2806 worth of gas annually, while lighter compact cars only use $1459. However, SUVs were found to withstand impacts better than compact cars, and were safer than compact cars (How Stuff Works, 9/18/2014). This suggests that lighter cars can move farther and more efficiently than heavier cars, using the same force (gas powered). However, because of their smaller mass, they are more affected by unbalanced forces, such as impacts.

**C.) Hypothesis**

If we catapult an object with the lowest mass, then that object will travel the farthest average distance. If we catapult an object with the highest mass, then that object will most often travel straight.

**D.) Materials and Procedures**

Materials:

* Plastic Spoon
* Rubber Bands
* Staple Remover
* Tape
* Stable surface to place Catapult
* Pencils
* Paper

• Scale to measure mass of Objects

• Penny

• Pencil Cap Eraser

 • Pinto Bean

• Calculator

 • Meter Sticks

• Ruler

Experimental Set-Up Procedure:

1.)  Gather necessary materials for the experiment.

2.)  Once materials are gathered, begin making the catapult.

3.)  To make the catapult successfully, place the staple remover on a stable surface.

4.)  Place the neck and handle of the spoon on one the arms of the staple remover, so that the concave surface is facing and extending upwards.

5.)  Secure the spoon to the staple remover by wrapping the rubber bands around the neck of the spoon and the arm of the staple remover it is connected to.

6.)  After the catapult is constructed, apply tape to the other arm of the staple remover, so that it is taped to the stable surface. The catapult must be fastened to the stable surface securely.

7.)  Set up two Data Tables for your qualitative and quantitative data. Make sure to also include a control (No Object) in both Data Tables.

8.)  Set up a graph for the quantitative data.

Data Collection Procedure:

1.) Set up scale, so that it is in position to weigh all the objects.

2.) Carefully weigh each of the objects that will be launched (penny, pencil cap eraser, and pinto bean). Make sure that the objects are weighed in grams.

3.)  Record the weight of all the objects in the Data Table.

4.)  Have someone launch each of the objects from the catapult individually.

5.)  Using the meter sticks, have a second person measure the distance that each of the objects travels in centimeters, and record the results in the Data Table.

6.)  Have someone record which direction the object travels compared to the catapult (left, middle, or right of the catapult) in the Date Table.

7.)  For each of the objects, repeat Steps 4-6 for five trials.

8.)  Using your calculator, calculate the average distance that each object traveled. Record in Data Table.

9.)  Calculate the mode direction that each object traveled. Record in Data Table.

10.) Return your materials and clean up station.

Experimental Design

The independent variable to this experiment is the mass of the object. The levels of the independent variable are the control, which weighs 0 grams, the pinto bean, which weighs 0.48 grams, the pencil eraser, which weighs 1.95 grams, and the penny, which weighs 2.54 grams. There are five trials for each object. The quantitative variable is the distance the object travels when launched by a catapult, and the qualitative variable is the direction it flies. The constants include the same placement of the rubber band on the catapult, the same rubber band, the same windspeed, and the same catapult.

**F. Discussion**

 The data collected produced varied results. The pinto bean was the lightest object launched, weighing 0.48 grams. The pinto bean traveled the farthest average distance, having covered an average distance of 491.0 centimeters when launched. The pencil eraser weighed 1.95 grams, and traveled an average distance of 373.4 centimeters. The penny was the heaviest object, with a weight of 2.54 grams. The penny traveled an average distance of 244.8 centimeters. Both the penny and the pinto bean's mode direction when launched was "left,” meaning that they both curved towards the left while in flight. However, the pencil eraser's mode direction was "middle,” meaning that it usually stayed straight during its launches. During any of the trials, only one of the objects, the penny, traveled "right" during their flight. The experiment presented a few anomalies. While the average distance the pencil eraser traveled was 373.4 centimeters, the pencil eraser only traveled 272 centimeters during its second trial. Also, the penny's average distance traveled was 244.8 centimeters, but traveled only 153 centimeters during its second trial. Also, the pinto bean traveled the farthest, traveling an average distance of 491 centimeter. This was more than 100 centimeters than all of the other objects' average distances. Another anomaly is that the penny, the heaviest object, didn’t travel straight, but had a mode direction of “left.” However, the second heaviest object, the pencil eraser, had a mode direction of “middle.” This means that the middleweight object traveled straighter than the heaviest object. These results were astonishing, and completely unexpected by our group.

 We observed the results we did because gravity, as well as other unbalanced forces, such as air resistance, affected how the objects launched. Gravity and other forces affected each of the objects differently, based on each of their masses and shapes. Objects with greater masses are found to be affected more by gravity, and therefore don’t travel as far when launched. This means that the lightest object, the pinto bean, was affected the least by gravity. This also means that the heaviest object, the penny, was affected the most by gravity. This explains why the pinto bean traveled the farthest, and why the penny traveled the least far. Also, as shown by Newton’s Second Law of Motion, if two objects are given the same force, the lighter object will accelerate more, and therefore cover more distance. This also explains why, the lighter the object, the farther it was launched. Also, if the object has more mass, then it has more inertia, and therefore is less affected by unbalancing forces, such as wind (The Physics Classroom, 9/21/2014). This means that the heaviest object should consistently travel straight when launched. However, the heaviest object, the penny, didn’t have a mode direction of “middle” during its five trials, but a mode direction of “left.” The only object that received a mode direction of “middle” was the pencil eraser, the second heaviest object. This means there is an inconsistency between the lab results we observed and the scientific facts about inertia. However, the lab results can be explained by air resistance. Air resistance is the collision of an object with air molecules, which slow down any object traveling through air (Physics Classroom, 9/21/2014). Objects also have to travel around air molecules, which may make the object shift its direction. If an object is more aerodynamic, then it encounters less air resistance when traveling through the air, and is not as impeded by the air molecules (Seed, 9/21/2014). This also means that objects that are more aerodynamic may have to travel around fewer air molecules, and may not have to shift their direction as much. The pencil eraser, when launched, may have been more aerodynamic than the penny, because it experienced overall less air resistance. This means that the pencil eraser would travel farther and in a straighter direction compared to the penny. This explains why the pencil eraser traveled an overall straighter direction than the penny, despite the penny being heavier.

 To improve and further our experiment, we could’ve controlled more variables in the experiment. The staple remover could’ve been fastened more securely, so that the catapult stayed in the same exact location for all five trials. Also, furniture and objects, such as shelves, chairs, and walls, could’ve been removed from the location of the experiment. This would’ve prevented the objects colliding with anything while in launch, so they could travel their full distance. Also, furniture and objects interfered with how our group measured the distance the objects traveled. To prevent this, our experiments could’ve been conducted in a less cluttered room. Also, to avoid differences in air resistance, we could’ve selected objects of similar shapes, but varying weights. Finally, we could’ve made sure that the catapult was pulled back to the same angle every time. This would’ve allow for a consistent force to be applied to all the objects. Another study that could further the experiment would be throwing Frisbees of different mass, and recording how far each Frisbee travels. This experiment would continue to explore how the mass of the object affects how far it travels, as well as what direction it travels.

**G.) Conclusion**

 The purpose of this experiment was to find how the mass of an object affects how far the object travels when launched, as well as what direction the object travels. Our results showed that the object with the lowest mass travel the farthest distance, which supported our group’s hypothesis. The results to our lab experiment also showed that the heaviest object didn’t travel the straightest. Thus, the direction the object traveled did not completely rely on the object’s mass. This disproved our group’s hypothesis, which was that an object’s mass determines which direction it travels, and that the heaviest object will travel the straightest. The reason that the objects with less mass traveled farther was because it was less affected by gravity. Also, lighter objects accelerate more than heavier objects with the same given force, which causes lighter objects to travel farther. The reason that the heaviest object doesn’t always travel straight is because the direction the object travels is affected by the object’s air resistance, as well as the object’s mass. This means that a heavier object with a lot of air resistance may not travel straight, while a lighter object with little air resistance should travel straight.

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