Lab 7: Trebuchet vs. Potato Cannon – A Physics Experiment

The scientific goal of this activity is to explore ways of transferring energy from gravitational potential energy to kinetic energy, and from chemical energy to kinetic energy. From the earliest days of human history, people have strived to find better ways to throw projectiles at other things. Often times, the survival and health of a tribe, city, or society depended specifically on its ability to throw things; faster, bigger, heavier, and/or with more accuracy.

The trebuchet was the ultimate muscle-powered thrower of heavy things. Large, well-designed trebuchets could hurl large blocks at things from well beyond effective arrow range. It was the last device designed to launch large projectiles from which the energy was solely derived from the work of human muscles. The work is done during the launch by a falling weight, but the weight must be lifted into place with muscle power.

Once the Chinese figured out how to harness the power of chemical propellants, muscle-powered throwers quickly supplanted by rockets and cannons. This caused a complete re-thinking and re-designing of city walls, forts, and the entire methods of warfare.

We are going to compare these methods of throwing things using a fairly large (for a home built version) of the trebuchet, and a potato cannon constructed from PVC pipe and charged with a small amount of hairspray (less dangerous than gun powder or a sugar-potassium nitrate mixture).

The specific goals are:

- **To determine the average total kinetic energy imparted to projectiles with each device, and**
- **To determine the efficiency with energy is imparted with each device.**

To do these things, we are going to need to measure

1. The (gravitational) potential energy of the trebuchet counterweight
2. The (chemical) potential energy of the exploding hairspray in the potato cannon.
3. The kinetic energy of the pumpkins
4. The kinetic energy of the potatoes

To measure these things, we need to know, the **mass of each projectile**, the **distance over which the trebuchet counterweight falls**, the **mass of the trebuchet counterweight**, the **amount of hairspray (and chemical potential energy)**, and the **exit velocities of the pumpkins and the potatoes**.
Most of these are relatively straightforward, but measuring the exit velocities is hard. We will try both a direct and indirect way.

For both the trebuchet and the potato cannon, we will use a high-speed video camera and the "Video Analysis" component of Logger Pro to measure the exit velocities. In addition to this direct method, we will *also* use an indirect method to measure exit velocities: the range the projectile travels along with the launch angle of the projectile (along with 2D motion equations).

We will split into teams:

Team A: Pumpkin Video Analysis
Equipment: Sony Camera, GoPro Camera
Use a video camera (or two) to carefully film the launch of the pumpkin. This filming **must** take place from roughly the launch height of the pumpkin. You will use this video to measure:

- The launch velocity of the pumpkin (note that you need to have a "scale" when you get to video physics. The arm of the trebuchet is useful for this – **make sure the full length is clearly visible in your frame and you carefully measure its length**)
- The launch angle of the pumpkin

Team B: Potato Video Analysis
Equipment: Sony Video Camera, GoPro Camera
Use a video camera (or two) to carefully film the launch of the potatoes. You will use this to measure:

- The launch velocity of the pumpkin (note that you need to have a "scale" when you get to video physics. The tube of the potato cannon is good for this – make sure the full length is clearly visible in your frame and you carefully measure its length)

Note: Before we got the Sony camera (frame rate of ~1000 FPS), we had never successfully measured the launch velocity of the potatoes; it is probably your primary tool for this job.

Team C: Pumpkin Range Team
Equipment: Tape Measure
Measure the distance the pumpkins travel using a tape measure. Also, estimate the approximate angle of elevation change from the launch location to the landing location.

Team D: Potato Range Team
Equipment: GPS, Walkie Talkies (or cell phones?)
Mark and measure the distance that the potatoes travel using a GPS.

Launch Team
We will split up the pumpkin and potato launch into two different phases. If you aren't currently measuring speeds/distances, you are responsible for *safely* launching the pumpkins/potatoes. Part of this will involve **using the force plate to measure the weight** of the pumpkins and/or potatoes before launching.

Other General Things We Need to Measure:

- The length of the trebuchet arm (or whatever we're going to use for scaling in the trebuchet video analysis)
- The length of the potato cannon (or whatever we're going to use for scaling in the potato cannon video analysis)
- The volume of the potato cannon explosion chamber

Prior to heading outside, we need to develop a plan for measuring these things. After going outside and collecting data, we'll then need to calculate the quantities we care about. I'm expecting everyone to contribute, rotate through measuring different things, and **keep a record** of whatever data they collect.

There are fewer step-by-step instructions for this lab than the typical lab (by design), but everyone should have a short (~1-2 page) write-up in your lab notebooks summarizing the calculations and results.