Work and Energy

INTRODUCTION

The concept of energy is one of the most fundamental topics in physics. The famous equation $E = mc^2$ deals with energy, and most of physics involves energy in one form or another. In this experiment, you will compare the energy of a system during different phases and examine the validity of the *work-kinetic energy theorem*:

$$\Sigma W = \Delta K. \tag{1}$$

Here the work done on an object is

$$W = F \cdot d = Fd \ \cos \ \theta, \tag{2}$$

and the kinetic energy is given by

$$K = \frac{1}{2}mv^2. \tag{3}$$

The work done by gravity is equal to the change in gravitational potential energy:

$$W_g = -\Delta U_g = -mgh. \tag{4}$$

A spring that exhibits a linear restoring force ($F = -kx$) when it is stretched or compressed some distance x will have elastic potential energy

$$U_s = \frac{1}{2}kx^2. \tag{5}$$

All of these forms of energy will be used to analyze the motion of a ball that is launched vertically by a compressed spring.

PROCEDURE

General Operation of the Projectile Launcher

<u>CAUTION</u>: Safety glasses must be worn during this experiment.

> **<u>CAUTION</u>:** When the projectile launcher is loaded, a yellow indicator is visible in one of the range slots in the side of the barrel and the ball is visible in another one of the slots in the side of the barrel. As with all projectile launching mechanisms, **NEVER LOOK DOWN THE BARREL WHEN IT IS LOADED**. To check to see if the launcher is loaded, always check the side of the barrel.

Before shooting the ball, make certain no one is in its flight path. To shoot the ball, pull straight up on the string that is attached to the trigger. It is only necessary to pull it about a centimeter.

Elastic potential energy

Before calculating the potential energy stored in the projectile launcher for each of the three launch positions, you will first need to determine the spring constant for the projectile launcher. This value can be found by measuring the force required to compress the spring a given distance from its relaxed length, and plotting F versus x. If the spring obeys Hooke's law ($F = -kx$), then the graph should have a constant slope. These PASCO projectile launchers generally have spring constants of 600 to 700 N/m. The following procedure should be followed to determine the spring constant for the launcher you will be using.

1 **Clamp the projectile launcher to the edge of the table**, and align the barrel so that it is pointing straight up. Note the position of the piston when it is not compressed.

2 Place the plunger inside the barrel and add masses on top of the plunger until the piston begins to move. Record the total weight applied to the spring and the distance the spring is compressed from its relaxed position. Repeat this procedure several more times with additional weights to obtain a total of at least five data points spanning the operating range of the spring. **Be sure to also measure and record the distance that the spring is compressed for each of the three launch positions (short, medium, and long range).**

3 Plot a graph of force versus displacement to find k and its uncertainty from the slope.

4 Use your value of k and its uncertainty to calculate the elastic potential energy stored in the launcher for each of the three launch positions.

Gravitational potential energy

1 Find a space in the room near a wall where you can safely fire the projectile launcher without interfering with any other lab groups and where you can hang a tape measure to determine the maximum height of the ball for each launch. Place the launcher on the ground with the barrel pointing straight up and place several large weights on the base to help hold it in place.

2 Put on your safety glasses.

3 Place a yellow plastic ball into the launcher and push it down with the black ramrod until the latch catches for the shortest range. Pull the cord to release the ball and note the approximate height that the ball reached for this practice trial.

4 Assign one member of your lab group to be the observer who will read the maximum height of the ball from the tape measure the next time it is released. This observer should look straight across the peak of the ball's path to the measuring tape to avoid parallax error.

5 Once the observer is ready, launch the ball and record the maximum height. Use this procedure to obtain at least five measurements for each launch position (short and medium range). Calculate the average height and its uncertainty based on the variation in height measurements. With practice, you should be able to obtain height measurements with less than 5% variation.

Kinetic energy

As in the previous lab on Projectile Motion[1], use the dual photogates to measure the speed of the ball as it leaves the launcher. Find the mass of the ball and calculate its maximum kinetic energy for each of the three launch positions.

ANALYSIS

Calculate and compare the elastic potential energy with the kinetic energy of the ball and all the moving parts of the launcher. According to the manufacturer, the piston mass = 55.6 ± 0.5 g, and the mass of the spring = 58 ± 1 g (but as can be shown using calculus, you should use 1/3 of this value as the effective mass of the spring that is moving for computing its kinetic energy). Also compare the maximum kinetic energy of the ball with its maximum gravitational potential energy.

DISCUSSION

Is energy conserved throughout this experiment? If not, what forms of work are not accounted for in your analysis? Is the work-kinetic energy theorem ever violated? Be sure to include uncertainty estimates when deciding whether there is or is not a significant difference between values.

[1] ..\lab_3\manual.html

