Physics 161

# Conservation of Energy

## Introduction

In this lab, you will measure how energy is conserved in a system. This experiment involves measuring the velocity and position of a cart on an inclined track in its path up and back down the track. Potential and kinetic energies will be calculated using the measured velocities.

## Reference

Young & Freedman, University Physics, 13th Edition: Chapter 7, section 7.1-7.5;

## Theory

Conservation principles play a very important role in physics. If the value of a physical quantity is conserved, then the value of that quantity stays constant. The total energy of a system is the sum of its kinetic energy and potential energy. In today's lab, the potential energy is gravitational potential energy expressed by $PE = mgy$. We can write total energy as:

$$Total\ Energy = Kinetic\ Energy + Gravitational\ Potential\ Energy \tag{1}$$

$$E = KE + PE = constant \tag{2}$$

$$E = \frac{1}{2}mv^2 + mgy \tag{3}$$

If the total energy is conserved, a graph of $E$ versus time should be a horizontal line. Gravity is a conservative force, assuming it is the only force involved acting on the system, we expect the total energy of the system to be conserved. For this lab, we will assume that the force of friction is negligible.

You will use a coiled-spring launcher to launch a cart from the bottom of an inclined track. The cart will move up the track, reverse its motion and come back down. If friction is essentially zero, then energy should be conserved. You can analyze this data from the standpoint of energy conservation.

The setup of the motion sensor on the track is shown in Figure 1.

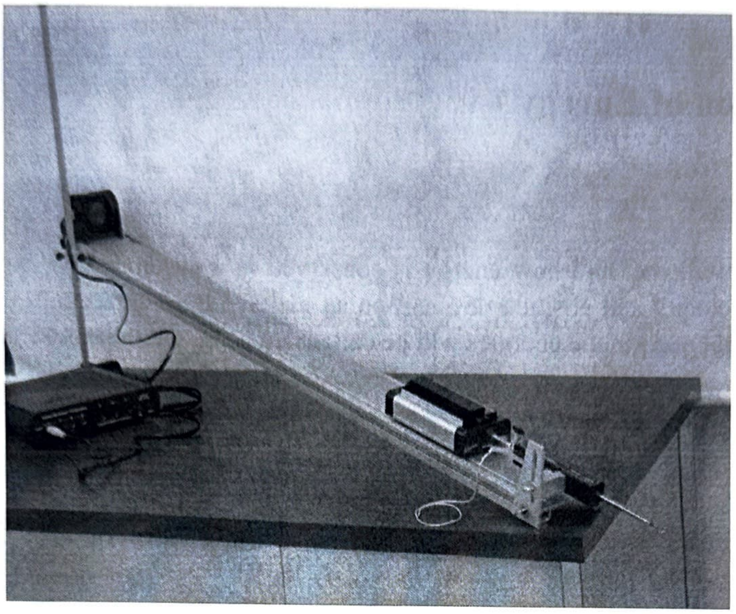

Figure 1: Experimental Setup showing launcher.

The motion sensor will record the position of the cart. This distance, $P$, is measured from the top of the track to the front of the cart, see Figure 2.

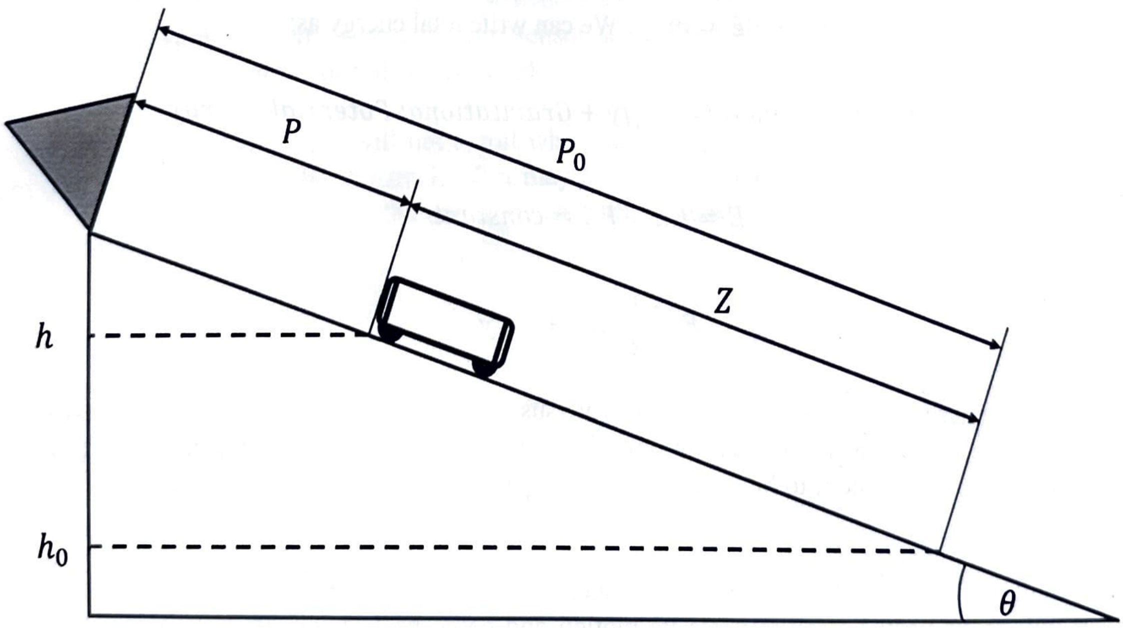


Figure 2: Reference system.

The velocity of the cart is calculated from the position data. The reference point, $P_0$, is the point after the cart leaves the launcher, when the spring is fully extended. $Z$ is the distance the front of the cart has moved up the track. You can calculate $Z$ by the equation:

$$Z = P_0 - P \tag{4}$$

To calculate potential energy, we need the vertical displacement, $h$. The vertical height of the cart, $h$, above the level of $P_0$ is given by:

$$h = Z \sin\theta \tag{5}$$

where $\theta$ is the angle of the track's incline.

The graph of position versus time will be parabolic. The minimum position value on the curve corresponds to the maximum height, $h$, of the cart, where potential energy is maximum.

## Procedure

### Conservation of Energy in the Laboratory

1. First measure the mass of the cart with an added 0.5 kg weight on it. To take data set up the Capstone software with a motion sensor set to **25 Hz** and set the switch at the top of the motion sensor to short distance ().

2. Hold the track so it will not recoil when the cart is launched. Press the **Record** button and launch the cart up the track. You may need to do this a couple of times to practice. It is important not to allow the cart to hit the motion sensor. If it goes too high, the launcher can be adjusted.

3. Press the **Stop** button after the cart has bounced off the launcher.

4. Figure 3, which shows the cart bouncing off the launcher. The horizontal line shows the position of the cart prior to launching. Remember, the motion sensor records itself as position zero so when you move toward it, you get closer to zero, and as you move away, you get larger numbers.

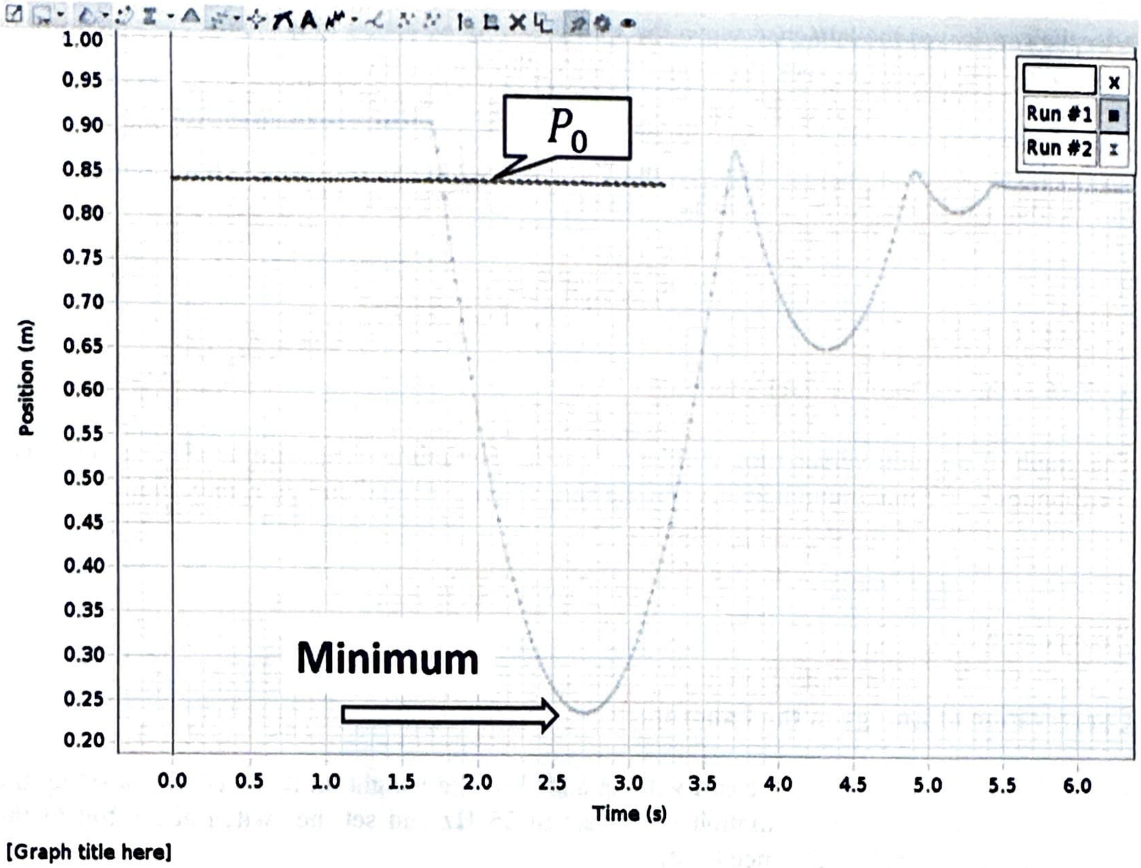


Figure 3: Position vs time.

5. In order to calculate $Z$ you must find the first point after the cart just leaves the launcher. This is your initial position and it corresponds to your reference height, $h_0$, shown in Figure 2. To obtain $P_0$ use data when the cart is stationary on the launcher with the spring fully extended.

6. After you have found $P_0$, highlight the data points for all points below it, see Figure 4. Make sure you do not choose any points that are higher than $P_0$ on either side of the parabola.

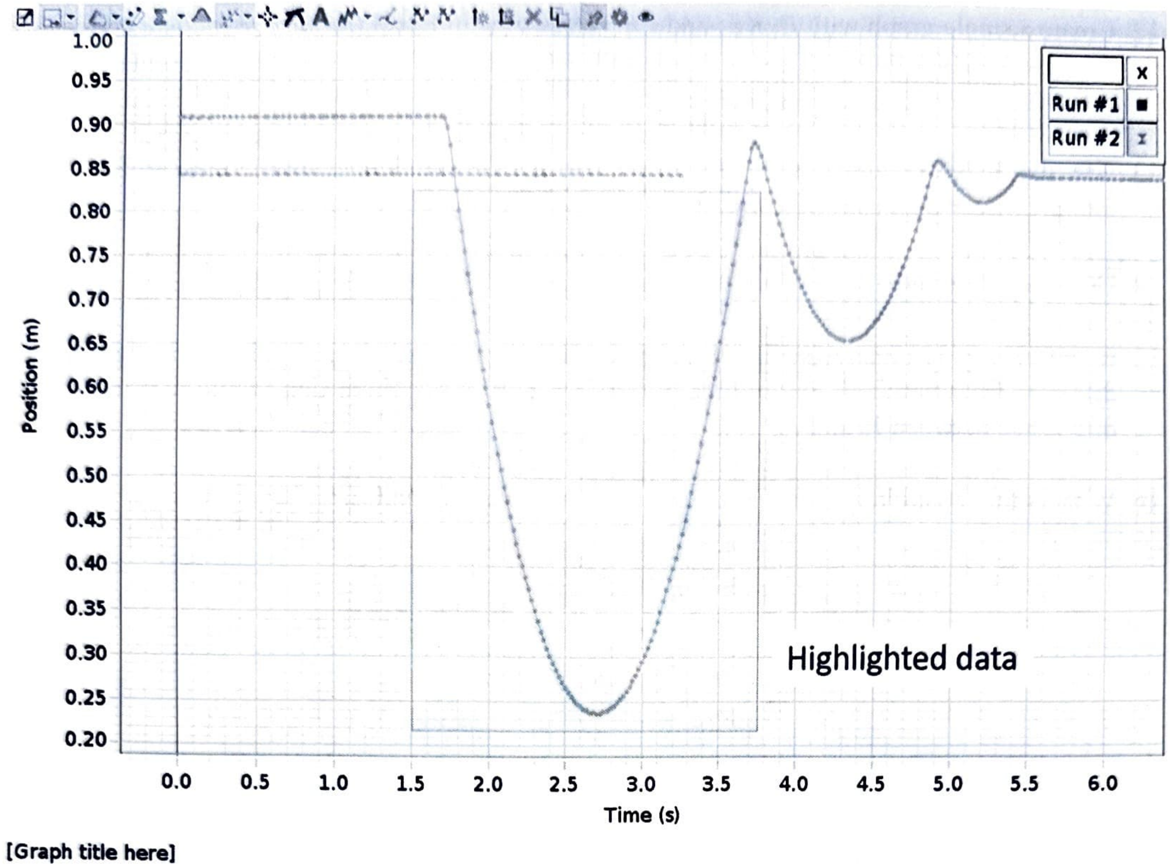


Figure 4: Highlighted points under $P_0$.

7. Copy the data to Excel and create a table with the following format:

| $Time\ (s)$ | $P\ (m)$ | $Z\ (m)$ | $h\ (m)$ | $v(m/s)$ | $PE\ (J)$ | $KE\ (J)$ | $E\ (J)$ |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

8. Calculate and record $Z$ for each point using Equation (4) with the appropriate sign correction.

9. Multiply the values of $Z$ by the sine of the angle of the incline to find and record the height, $h$, at each point in time. See Equation (5) and Figure 2.

10. Use your original position data $P$ to calculate the velocities of the cart along the track in Excel (*recall the central-difference method from the Projectile Motion lab, and before*). Because the motion is in one dimension, you have only one component for the velocity.

11. With the heights and velocities that you calculated in Steps 9 and 10, use Equation (3) to determine the potential energy, the kinetic energy and the total energy in Excel.

12. Create a single graph with $E$, $KE$, and $PE$ versus time in Excel (*be sure to include a legend!*). Average the first three points of $E$ and call it $E_i$, and average the last three points of $E$ and call it $E_f$.

13. Use the LINEST function to solve for the average and standard deviation for the y-intercept($\bar{E}_1 \pm \sigma_{E_1}$) as well as the slope($\bar{\alpha} \pm \sigma_\alpha$) of the line that fits $E$.

14. Does $\sigma_{E_1}$,the standard deviation of $E_1$, account for the different between $E_i$ and $E_f$?

15. If the energy is conserved the slope of $E$ should be zero. Is your slope, $\bar{\alpha}$, significantly different from zero? Is it significantly different from the slope that would account for the difference between $E_i$ and $E_f$?

16. What is the most likely cause of the difference between $E_i$ and $E_f$?