PHY 123 Lab 8– Conservation of Energy

The purpose of this lab is to verify experimentally the conservation of mechanical energy.

Equipment

- LabQuest 2
- Vernier Dynamics cart
- Vernier Dynamics track
- Vernier Photogate
- Ultra pulley
- Mass set
- Lightweight string

Introduction

For an isolated system, the total energy must be conserved. In this experiment we will examine the law of the conservation of total mechanical energy by observing the transfer of gravitational potential energy to kinetic energy, using a Vernier dynamics cart on a Vernier Dynamics track that is pulled by a falling mass. The apparatus has negligible friction. We consider the system, cart and attached mass, to be isolated from friction. The position of the mass (or cart) as a function of time can be accurately recorded by the LabQuest2 using the photogate device.

In this experiment, the cart on the track gains kinetic energy due to the loss of potential energy experienced by the small falling mass m.

When the system is moving with a velocity v, the kinetic energy of the hanging mass (of mass "m") plus cart (of mass "M") is given by

$$KE = \frac{1}{2}(M + m)v^2 \qquad (1)$$

The change in the gravitational potential energy ΔPE of the system, when the height h of the small mass m changes by Δh is given by

$$\Delta PE = mg\Delta h \qquad (2)$$

Note that Δh will be negative in this experiment, i.e., the system's gravitational potential energy should be reduced as the mass falls. The principle of conservation of energy leads us to expect that this decrease in the system's potential energy should result in an equal and opposite increase in its kinetic energy. Therefore,

$$\Delta KE = -\Delta PE \qquad (3)$$

We can also use Newton's second law to calculate what we expect the acceleration of the system to be and check that with our experiment as well.

$$F_{net} = mg = (M + m)a; \rightarrow a = \frac{m}{M+m}g \qquad (4)$$

Procedure

1. Connect the photogate to the digital channel port of the LabQuest2 and check that it has the right setup for this experiment.
   On the right of the Meter screen (Tab A) you will find a Data-Collection details row, verify that the "Mode" says "Photogate Timing," click in the Mode option, and in "Photogate Mode" select "Motion" and choose the "Pulley " – "outside edge" option.

2. Measure the mass of your cart (approximately 500 g). Depending on the type of balance, assume the error for this measurement will be approximately 1 gram.
3. Level the track by adjusting the leveling screws at each end of the track. When the track is level, the cart should remain nearly stationary at any point on the track. **The leveling of the track is very important. If the track is not level your results will be incorrect.**
4. Attach a 20 gram mass to the cart with a piece of lightweight string and rest the string on the pulley at the end of the track so that the mass hangs over the edge of the table and can fall freely. Record the value of this mass and an assumed error of ±0.2 gram. Make sure the string with the weight attached is long enough so that you can reach the far end from the pulley.
5. Select the Graph screen (Tab B from previous figure) and click Collect to start the data collection.
6. Release the system and stop it before the cart rebounds from the end of the track, or before the falling mass hits the ground, whichever comes first.

Analysis

7. Check if the graph of velocity vs. time is linear; if it is not linear you will have to repeat the measurement (step 6).
8. Go to the table Tab and copy at least 5 values of distance with its corresponding value of velocity, you can also do this in the Graph screen by selecting a point on the graph, in the right side of the screen you will see the respective value of the distance, velocity and time for that point.
9. Calculate potential and kinetic energy for each value you chose, with their uncertainties, using the following equations:

$$\Delta(M + m) = \sqrt{(\Delta M)^2 + (\Delta m)^2} \qquad (5)$$

$$\frac{\Delta K}{K} = \frac{\Delta(M+m)}{M+m} \qquad (6)$$

$$\frac{\Delta U_g}{U_g} = \frac{\Delta m}{m} \qquad (7)$$

Note: To calculate the uncertainties you will neglect any uncertainty from the distance and velocity because we assume the software measures these values more accurately than our measurements from the mass. Therefore, the relative uncertainty in distance and velocity (which are based on the time measurement for the software) is much less than the relative uncertainty in either m or M.

10. Plot potential energy (y-axis) vs. kinetic energy (x-axis) using the online plotting tool.
11. Find and record the slope of this graph and compare it to your expectation based on the conservation of mechanical energy. **What do you expect the slope to be? Is your result consistent with your expectation?**
    Hint: Look at equation (3) carefully.

Answer the following questions:

1. **Why is leveling the track is so important? How and why would your results be affected if the track were not level?**
2. **Assume that you do the experiment one more time, and at the same time that the cart is being pulled by the falling mass, you also push it with your finger for the entire motion. You examine values for velocity and Δh from LabQuest2 and calculate the kinetic energy and potential energy. Would mechanical energy still be conserved? Why or why not?**