Physics 4A

Lab 7: Conservation of Mechanical Energy

Objective: To verify that when no external forces are present, kinetic energy and gravitational potential energy are conserved.

Theory:

Assuming no net external forces act on a system, the system's total energy is conserved. In this lab we will be looking at kinetic energy and gravitational potential energy. For a cart on a track, assuming minimal friction, the total energy of the cart is constant. As the cart moves up and down the track, kinetic energy is converted to gravitational potential energy and back again. If there is friction, then the total energy of the system will decrease because friction is doing work on the system.

Procedure:

Part 1: Minimal Friction

1.1. Setup

Assemble the ramp so that when the cart rolls downward it is traveling toward the motion sensor. The slope of the ramp should be small.

Measure the length of the ramp, and the height of the ramp, and calculate the sine of the angle of the ramp. Record all values in excel.

Measure the mass of the cart and record it in excel in kilograms.

Hook up the motion sensor to the Pasco interface. In Capstone, under hardware setup, select Channel 1 as Motion Sensor II. Increase the data collection rate to 40 Hz. Drag and drop a table into the central region of the Capstone software. Drag and drop a graph into the central region of the Capstone software. Select the y-axis as position.

1.2. Data

Start the cart at the bottom of the track near the motion sensor. Practice giving the cart a push so that it climbs up to the top of the track, and returns back to the starting position. Click 'record' immediately after you push the cart up the track, and click 'stop' right before you catch the cart at the bottom of the track.

When you have a good data set, in the table, select measurement > create new > calculation. Near the top you will see 'calc1 ='. Click next to the equal sign, type '[', select velocity. Type '^2*0.5*mass', where 'mass' is the value of mass of the cart in kilograms, then hit enter. Calc 1 is the kinetic energy of the cart.

In the table, select measurement > create new > calculation. Near the top you will see 'calc2='. Click next to the equal sign, type '[', select position, then type '*sinθ', where sinθ is the value calculated in excel. Calc2 is the height of the cart off the top of the table.

Click the add column icon ( ) to add a column to the table. Select measurement > create new > calculation. Next to 'calc3=' type '[', select Calc2, then multiply Calc2 by mass of the cart and multiply by the acceleration due to gravity, g. The equation is m*g*y. Calc3 is the gravitational potential energy of the cart.

Click the add column icon to add a column to the table. Select measurement > create new > calculation. Next to 'calc4=' type '[' to select Calc1, then type '+', then type '[' to select Calc 3. Calc4 is the total energy of the system.

Click the add digits icon ( ) for all 4 columns.

In the graph, change the y-axis from position to calc 1. Use the add new y-axis icon ( ) to graph Calc3 and Calc4. Adjust all 3 axes so the values line up and are the same.

Have the instructor check your graph to make sure the calculations look right. Once checked, take a screenshot of the result.

Part 2: Some Friction

2.1. Introduction and Data

We will repeat part one, but with friction. Tape a small wad of paper to the bottom of the cart so it drags slightly against the ramp as it moves. When you have it so that it will roll, but with some friction, then give it a push up the ramp, as before. Take a screenshot of the potential energy, kinetic energy, and total energy vs. time of your best effort.

2.2. Work done by Friction

Choose an initial and final time from the graph that encloses most of the period of free motion of the cart. Find the work done by friction during this time. Remember, $W = \Delta TE$. Record your answer in excel.

2.3. Frictional Force

Drag and drop another graph into the central region of Capstone. On the y-axis choose position, so you obtain a graph of position vs. time. Use the position graph to find the total distance traveled during this same time interval (as used in section 2.2). Record this distance in excel. This is the distance over which the friction acted. Use this information along with the work done to find the average frictional force acting on the cart during this time period. Record your answer in excel. Remember: $W = Fd$.

Part 3: Energy of Cart and Mass

3.1. Introduction and Data

In this part, the cart will be connected to a hanging mass, and the kinetic energy and potential energy of both systems will be calculated.

Remove the friction pad and connect the cart to a hanging mass over a pulley. Adjust the pulley so the string is parallel with the track. Choose a hanging mass that pulls the cart up the ramp, and record this mass (in kg) in excel.

Start the cart at the top of the ramp and give it a push down the ramp, allowing it to go down, turn around, and accelerate up the ramp. Practice giving the cart a push so that it comes close to the opposite end of the track, and returns back to the starting position. Click 'record' immediately after you push the cart down the track, and click 'stop' right before you catch the cart at the top of the track. Take a screenshot of your best effort.

3.2. Potential and Kinetic Energy of the Mass

Add two more calculated columns for the kinetic and potential energy of the hanging mass. The equation for potential energy is '-m*g*position'. The potential energy is negative the position because as the cart moves down the track, the hanging mass moves upwards.

Add another column, and select time. Select all data and copy/paste into excel. Create a graph in excel that plots the kinetic energy of the cart and mass, the potential energy of the cart and mass, and the total energy of the system, all vs. time.

Laboratory Report:

The results for this lab will be written in a lab report, in the same style as previous labs, using LaTeX. However, for the data section, insert the graphs into the LaTeX document. There should be graphs from section 1.2, 2.1, 3.1, and 3.2. Refer to the graphs as: Section 1.2 Cart Only; Section 2.1 Cart with Friction; Section 3.1 Cart only, but with hanging mass attached; and Section 3.2 Kinetic, Potential and Total Energy of the Cart and Hanging Mass. Submit the .tex file and the PDF file. The remainder of the excel spreadsheet will not be submitted.

Questions

Answer the following questions in the results section of your laboratory report.

- Explain how the total energy changes as shown in the graph from section 1.2.
- Explain how the total energy changes as shown in the graph from section 2.1. Why is this answer different from the previous question?
- What was the work done by friction as calculated in section 2.2?
- What is the frictional force calculated in section 2.3?
- Explain how the total energy changes in the graph from section 3.1. Why is this answer different from the first 2 questions asked?
- Explain how the total energy changes in the graph from section 3.2, and explain why.