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Energy Conservation on Inclined Track (MER)

Abstract:
We experimented with the cart moving along an inclined track to determine the conservation of total energy on the cart. By measuring the car's kinetic and potential energy every 30 times per second, we can compare how the cart's total energy is being conserved or not at every point before the subsequent collision. Lastly, we graphed three plots (KE, PE, E) shown as a function of time to look at the total energy change. Therefore, the summation of kinetic and potential energy equals total energy at every point. $KE + PE = E$ After graphing three plots, we concluded that the energy was not conserved due to the external forces.

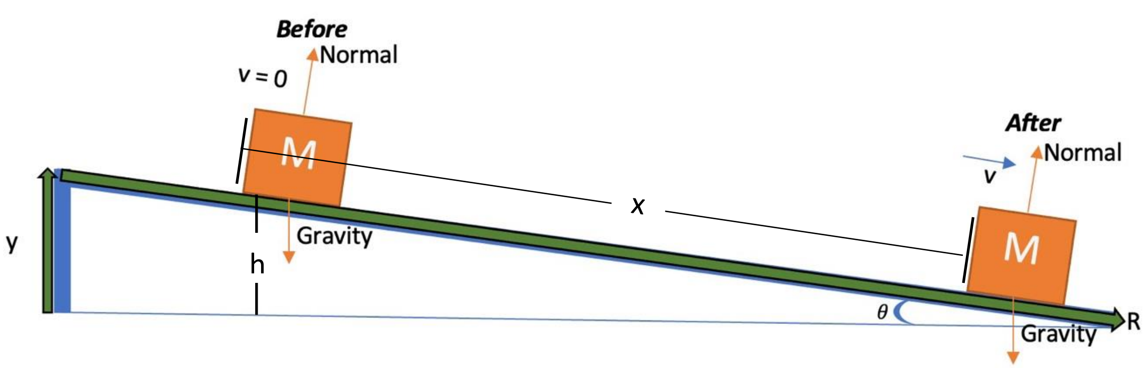
Theory:
For a system with only conservative forces doing work, the total mechanical energy can be represented by:

$$(\mathbf{1})\ \ E_{mech} = KE + PE$$

And as long as only conservative forces are acting, the total mechanical energy in a system will be conserved.

$$(\mathbf{2})\ \ \Delta E_{mech} = \Delta KE + \Delta PE = 0$$

A before and after diagram for a portion of our experiment can be seen below:



As we're only measuring the gravitational potential energy and the kinetic energy in our experiment:

$$\Delta KE = \frac{1}{2}m(v_f^2 - v_i^2)$$

$$\Delta PE_g = mg(h_f - h_i)$$

With the height, speed, and position changing and being recorded throughout the run, they can be represented by:

$$x = x(t)\,, \quad v = v(t)$$

$$sin\theta = \frac{h}{x(t)}\,, \quad h = x(t)sin\theta$$

So, plugging these equations into the ones for energy result in:

$$(\mathbf{3})\ \ K(t) = \frac{1}{2}m[v(t)]^2$$

$$(\mathbf{4})\ \ U_g(t) = mgx(t)sin\theta$$

Combining these with equation (1) gives:

$$E_{mech} = K(t) + U_g(t)$$

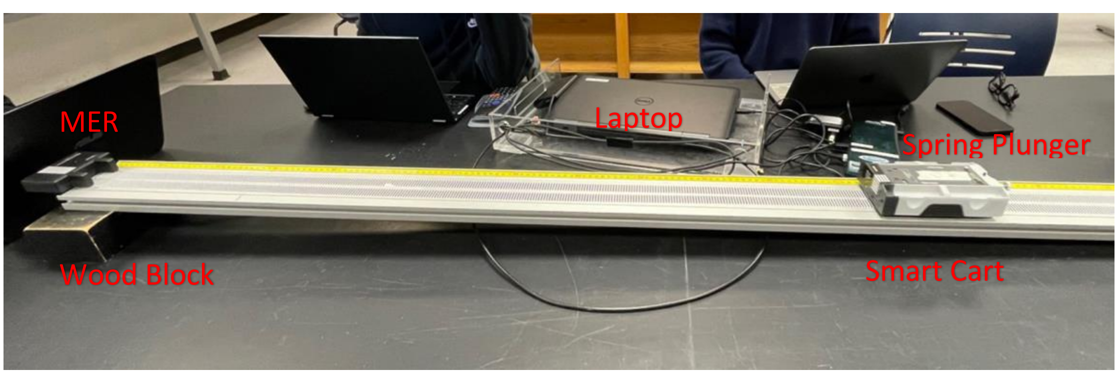
$$E_{mech} = \frac{1}{2}m[v(t)]^2 + \ mgx(t)sin\theta$$

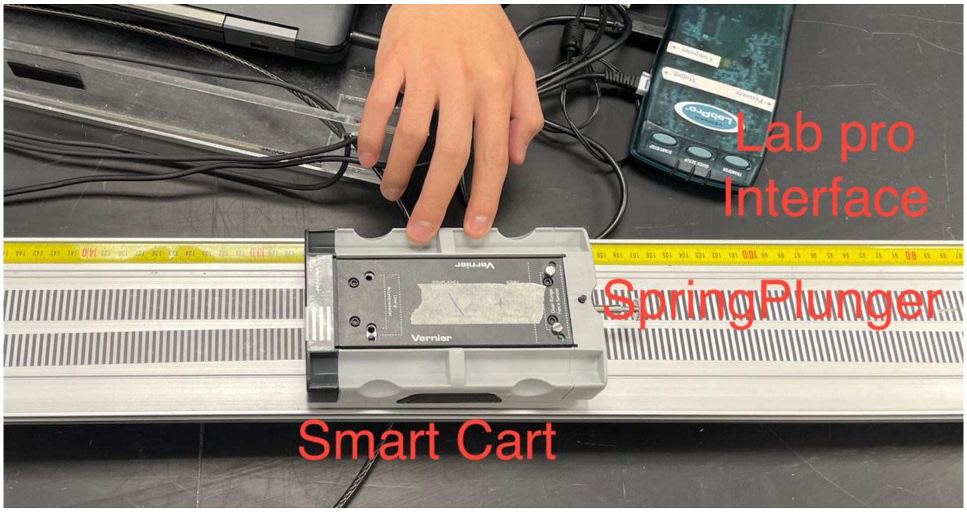
If only conservative forces are exerting work in the system, the total mechanical energy should be conserved and at any position on the track, it should be the same.

Procedure:

The goal of this lab was to test the principle that total energy is conserved. We did this by monitoring the motion of a lab cart as it moved along an inclined track. Our installation consisted of a track with a height of one end. There was a laboratory cart, a motion encoder receiver (MER) at the high end, and a spring plunger cart at the other. The MER was connected to the lap-pro interface device, and the lap-pro interface device was connected to the laptop with software that displays recorded data. (Figure 1)

The speed $v(t)$ and position $D(t)$ were recorded at a rate of 30 times per second using MER. The length of the data collection period is set to 20 seconds. The distance the track touches the laboratory bench, the distance the track touches the post r, and the length of the post y with the track raised were measured. We measured the mass m of the lab cart, placed it randomly away from the MER, released it from the high end of the track, and collided with the spring plunger cart at the other end.





Data and Calculations:

The motion detector measures the distance away from the motion detector D without measuring x directly. A graph was prepared by calculating kinetic energy KE using the mass m and velocity $v(t)$ of Equation 2. The potential energy U of the cart was calculated from the distance x on the track using the height H of the cart, and Equation 3 was used. To calculate the total energy $E(t)$ we used the potential and kinetic energy and equation 4. Data was collected and subsequent graphs were generated using the software.

$$H = x\, sin\theta$$

$$x(t) = D_{max} - D(t) \qquad \text{(Equation 1)}$$

$$K(t) = \frac{1}{2}m[v(t)]^2 \qquad \text{(Equation 2)}$$

$$U(t) = mgx(t)sin\theta \qquad \text{(Equation 3)}$$

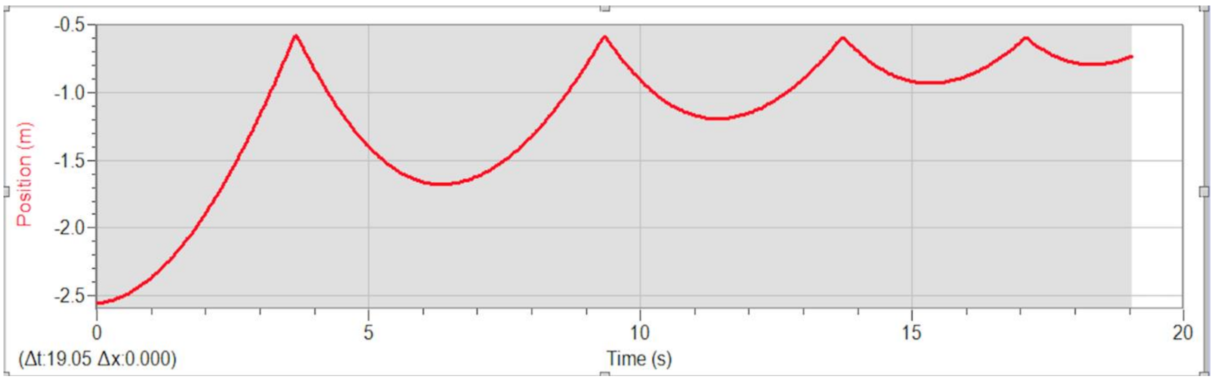
$$E_{total} = K(t) + U(t) \qquad \text{(Equation 4)}$$

Table:

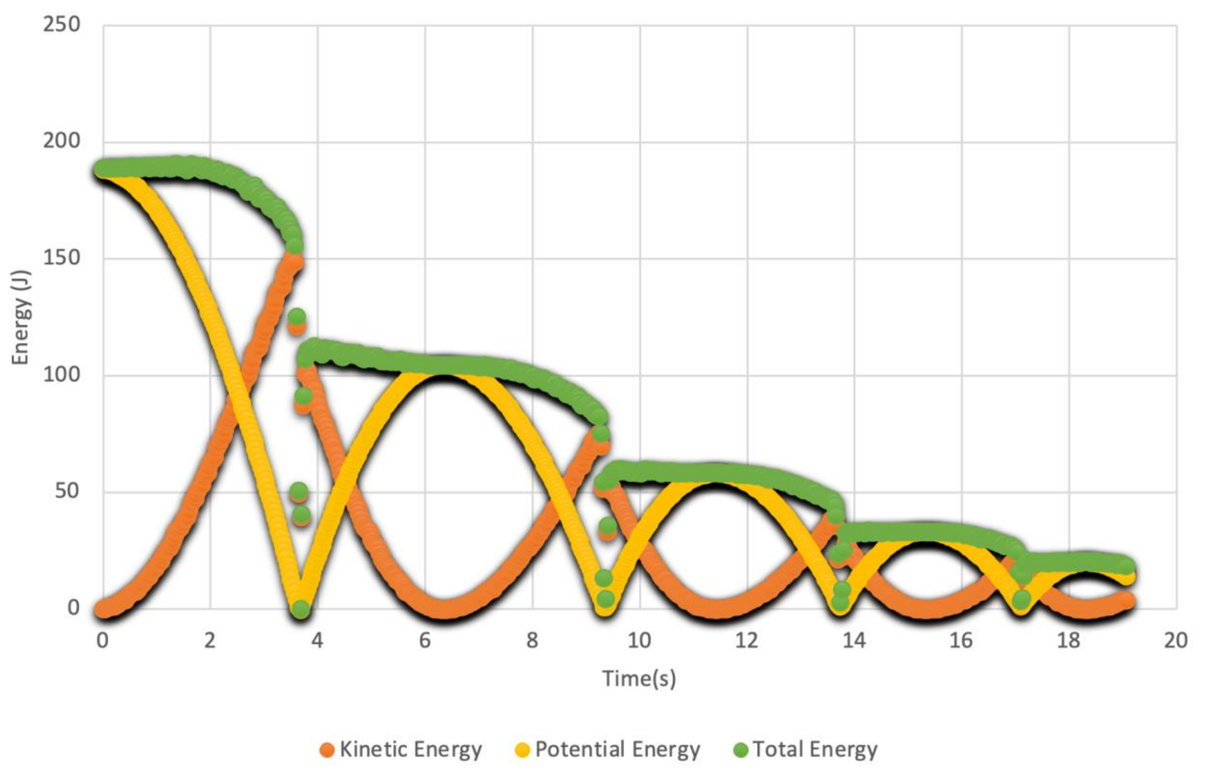
	Measured value	Uncertainty
Mass of Cart (g)	338.1g	±0.05
H(cm)	6.4 cm	±0.05
R(cm)	222 cm	±0.5

Graphs:

(Position Vs Time Graph)



Energy vs. Time



Analysis:

Our results support what we currently know of kinetic and potential energy. As the cart moves downhill the potential energy decreases and increases when it moves uphill. Conversely, kinetic energy increases going downhill and decreases going uphill. Furthermore, as potential energy increases, kinetic energy decreases because it is converted into potential energy. Whereas, as kinetic energy increases, potential energy decreases because it is converted into kinetic energy. That is all to say that the summation of kinetic and potential energy equates to the total energy. On the other hand, as the cart moves back up the hill the kinetic energy momentarily increases as the spring accelerates it back up the hill. The kinetic energy peaks the moment the spring loses contact with the track and slowly decreases as it is converted into potential energy. Now, the overall goal of this experiment was to find if the energy was conserved. Based on our data, we conclude that the energy was not conserved. A notable trend in the data is that the total energy slowly decreases for each section of motion as time progresses. This is due to external forces, namely friction, causing thermal dissipation. Drag is also a dissipative force acting on the cart but given the slow velocity it will have a negligible effect. Similarly, when the cart reaches the bottom in each instance there is an appreciable reduction in the total energy. This is due to the frictional forces within the spring mechanism converting the energy into heat. Moreover, after each successive bounce the cart has less and less energy. Most of this energy loss is transferred into the track when the spring reaches maximum compression. Put together, all these dissipative forces cause thermal energy to be released into the environment resulting in a system that does not conserve energy. Also, regarding the experimental setup, the levelness of the table where the track was set up is another source of error. Given that our calculated value for θ is 1.65 degrees, minor variance will yield a large change resulting in poor repeatability. In the end, the experiment should be run in a vacuum chamber to eliminate drag and dropped to mitigate the frictional forces. This will also eliminate the track angle as a source of error.

Conclusion:

In this experiment, the goal was to find whether the total energy of the cart was conserved or not. We concluded that the total energy of the cart was not conserved by looking at the graph. The total energy for each section slowly decreases because of friction. The two sources of uncertainty in our data come from instrumental uncertainty due to using a digital scale to measure the mass of the cart; ±0.05 g and using a wooden ruler to measure the length of the slope; ±0.05 cm. We learned that the summation of Kinetic and potential energy is equal to the total energy of the cart and that total energy will not be conserved when there are external forces. Further experiments should use more precise instruments to measure mass and length, limiting human error for a more accurate result.