AP Physics C: Non-Conservative Forces Lab

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Abstract

The purpose of this lab is to determine the coefficient of friction utilizing the energy lost in a half-Atwood system. Utilizing the difference between an ideal frictionless prediction of the kinetic energy and the kinetic energy based off of measurements one can find the loss from other forces, such as friction. To calculate the kinetic energy, we use derivations completed in class, which require v, which we measure through the Vernier Go Direct® Sensor Cart. I am too lazy to actually learn the `titling` package to create a smaller abstract so I have just compensated by writing gibberish in the very large abstract at the top of the page.

1 Procedure

1. Weigh the cart.

2. Set up half-Atwood system as show in Figure 1.

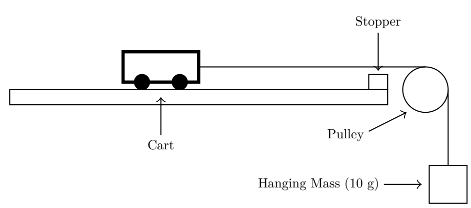

Figure 1: Diagram of half-Atwood setup used.

3. Start the recording from Vernier Graphical Analysis.

4. Release the cart from a distance of one (1) meter from the stopper.

5. Wait until the cart hits the stopper at the end of the track, and then stop the recording.

6. Record the maximum velocity before the collision with stopper. If the mass hits the floor, record the maximum velocity before the mass hits the floor (visible as a plateau on the graph).

7. If the mass hits the floor, measure the distance that the cart travels before the hanging mass hits the floor once.

8. Repeat from Step 3 five (5) times.

2 Observations and Data

The cart weighed 284 grams. The hanging mass hit the floor after travelling 0.71 meters.

Trial	v (m/s)
1	0.643
2	0.643
3	0.654
4	0.652
5	0.646

Figure 2: Table of data collected for $\overline{v}$.

3 Data and Error Analysis

Using the distance that the cart travels before the mass hits the floor, we can predict the energy that the cart has. The difference between the ideal energy and the real energy will allow us to predict the amount of energy lost to friction, as the only other force on the cart should be the friction from the pulley and the friction of the cart. These can be combined later to predict the coefficient of friction μ.

$$U_g = 0.010 \text{ kg} \cdot 9.8 \text{ m/s}^2 \cdot 0.71 \text{ m} \tag{1}$$
$$U_g = 0.0696 \text{ J} \tag{2}$$

With the average velocity, we can find the actual kinetic energy that the cart had before the mass hit the floor. Using the data in Figure 2:

$$\overline{v} = 0.646 \text{ m/s} \tag{3}$$
$$KE = \frac{1}{2} \cdot (0.284 \text{ kg} + 0.10 \text{ kg}) \cdot (0.646 \text{ m/s})^2 \tag{4}$$
$$KE = 0.0613 \text{ J} \tag{5}$$

Now the energy lost from the system from the friction force:

$$E_f = 0.0696 \text{ J} - 0.0613 \text{ J} \tag{6}$$
$$E_f = 0.0082 \text{ J} \tag{7}$$
$$\%E = \frac{0.0082 \text{ J}}{0.0696 \text{ J}} \cdot 100 \tag{8}$$
$$\%E = 11.8346\% \tag{9}$$

This means that 0.0082 J of the total energy of the system was lost to friction, or about 11.8% of the total energy of the system.

With the energy lost to friction, we can find the force of friction that acted on the cart over the track. To make this calculation simpler, we assumed that the friction force does not change over the track. Since the cart traveled 0.71 m, we can use the work integration to find the force:

$$0.0082 \text{ J} = \int_{0 \text{ m}}^{0.71} F_f \, dx \tag{10}$$
$$0.0082 \text{ J} = 0.71 \text{ m} \cdot F_f - 0 \text{ m} \cdot F_f \tag{11}$$
$$0.0116 \text{ N} = F_f \tag{12}$$

Now, with the force of friction, we can solve for the coefficient of friction, μ:

$$F_f = 0.284 \text{ kg} \cdot 9.8 \text{ m/s}^2 \cdot \mu \tag{13}$$
$$0.0116 \text{ J} = 0.284 \text{ kg} \cdot 9.8 \text{ m/s}^2 \cdot \mu \tag{14}$$
$$0.004167 = \mu \tag{15}$$

This assumes that all friction from the pulley is negligible.

4 Conclusion

I believe that the friction force is not necessarily negligible, considering the percentage of energy lost just to friction. 10% of the system energy is more than enough to affect past labs which assumed the cart to be fully frictionless.

For example, the Netwon's 3$^{\text{rd}}$ Law lab assumed that the cart was frictionless. This could change the final result of the lab, making the calculated μ far smaller than originally thought.

However, it could be argued that the μ that was calculated in Equation 15 is too small to affect measured velocity results, especially with higher masses attached to the half-Atwood system. The force itself, calculated in Equation 12, only provides a counter-acceleration of about 0.041 m/s^2 to the cart.