AP Physics C: Newton's 3rd Law

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1 Objective

The Newton's 3rd Law lab includes experimentally calculating the μ_k of the interaction between a friction block connected to the cart in a half-Atwood machine, and the track of the half-Atwood machine.

2 Procedure

1. First, before preparing the half-Atwood machine, measure the mass of the cart and the friction block.

2. Set up the experiment as shown in Figure 1.

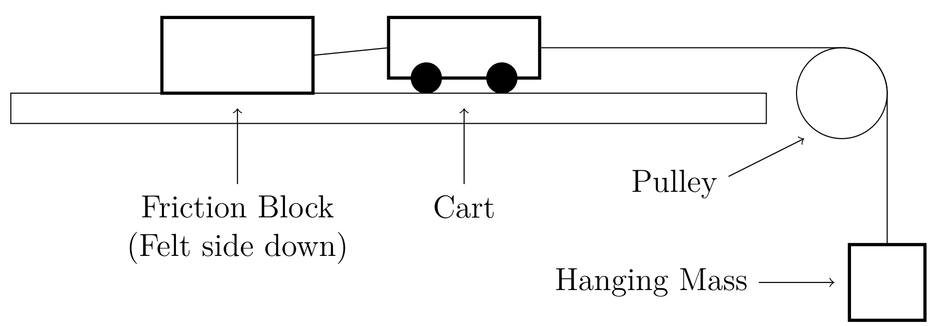

Figure 1: Diagram of Step 2 experimental setup.

3. Start data collection on the sensor cart.

4. Let go of the sensor cart.
5. Stop data collection when cart collides with pulley.
6. Determine the acceleration of the cart from the data collected.
7. Repeat from Step 3, adding mass to the system via adding masses to the top of the cart. We chose three trials with extra masses of 0 grams, 200 grams, and 250 grams.

3 Observations and Data

From Step 1, we found that the cart was 0.282 kilograms. As well, we found that the friction block was 0.331 kilograms.

From Steps 3-7, we captured three data points, shown in Figure 2.

Trial	m (g)	a (m/s^2)
1	0	0.418
2	200	0.305
3	250	0.275

Figure 2: Table of the data captured from Steps 3-7.

4 Analysis

Using data collected from Step 1, the mass of the entire system, which includes the mass, the cart, and the block, would be 0.663 kg. If we shift the data points acquired from Steps 3-7, we can find a correlation between the mass of the system and the final acceleration of the system. These new data points can be seen in Figure 3.

Trial	m (kg)	a (m/s^2)
1	0.663	0.418
2	0.863	0.305
3	0.913	0.275

Figure 3: Table of the modified data derived from Steps 3-7.

The line of best fit for these new data points in Figure 3 is $a(m) = -0.57m + 0.796$. Since, for the system as a whole, $\Sigma F = ma = F_g - F_{f_k}$, we can solve for F_{f_k}. Using the line of best fit for the acceleration as a function of system mass, we can calculate F_{f_k} as a function of system mass by doing:

$$\begin{aligned} F_g &= 0.050 \text{ kg} \cdot 9.8 \text{ m/s}^2 \\ F_g &= 0.49 \text{ N} \\ m \cdot a(m) &= F_g - F_{f_k} \\ m \cdot a(m) &= 0.49 \text{ N} - F_{f_k} \\ -m \cdot a(m) + 0.49 \text{ N} &= F_{f_k} \end{aligned} \tag{1}$$

Now, substituting in $a(m)$:

$$\begin{aligned} -m \cdot a(m) + 0.49 \text{ N} &= F_{f_k} \\ -m(-0.57m + 0.796) + 0.49 \text{ N} &= F_{f_k} \\ 0.57m^2 - 0.796m + 0.49 \text{ N} &= F_{f_k} \end{aligned} \tag{2}$$

This means that F_{f_k} is a function of the mass of the entire system. With the F_{f_k}, we can now find μ_k. Since $F_{f_k} = \mu_k \cdot F_N$, utilizing the mass of the block measured earlier, we can finally extract μ_k.

$$\begin{aligned} F_N &= 0.331 \text{ kg} \cdot 9.8 \text{ m/s}^2 \\ F_N &= 3.244 \text{ N} \\ F_{f_k} &= \mu_k \cdot F_N \\ 0.57m^2 - 0.796m + 0.49 \text{ N} &= \mu_k \cdot 3.244 \text{ N} \\ \frac{0.57m^2 - 0.796m + 0.49 \text{ N}}{3.244 \text{ N}} &= \mu_k \end{aligned} \tag{3}$$

A plot of the modified a data points, $a(m)$, F_{f_k}, and μ_k is visible in Figure 4.

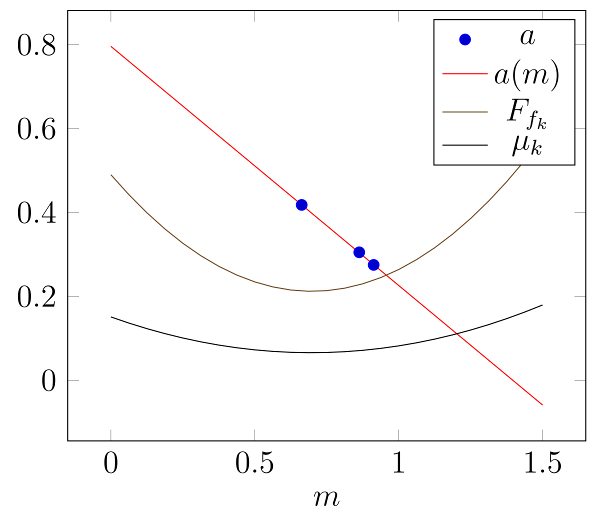

Figure 4: Plot of a, $a(m)$, F_{f_k}, and μ_k as functions of m.

We then averaged the μ_k at the three m data points, and got a final answer of $\overline{\mu_k} = 0.090$.

5 Conclusion

The expected value for the μ_k was 0.304, which means a percent error for our calculated value of about 70.55%. The likely reason for this anomaly is likely that, for one, the scale provided is inconsistent and not fully accurate, leading some of our mass values to be off. As well, we did not ensure data reliability by doing multiple trials at one mass. The tiny sample size of the final data does imply that there could be unreliability underlying the data.