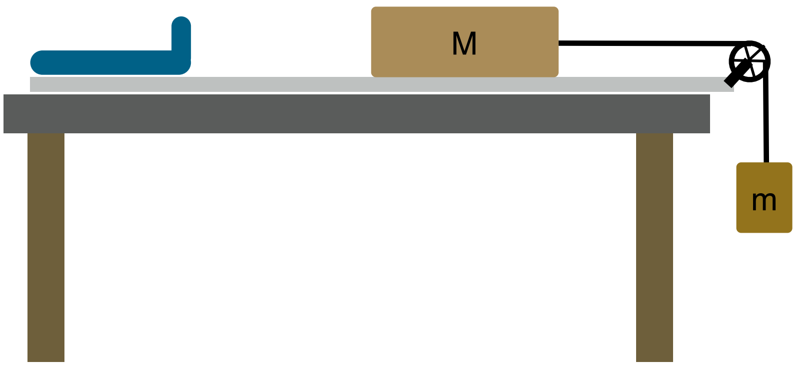
LAB 04: NEWTON'S LAWS

The Objectives

This week, we want to explore Newton's laws of motion. Some specific objectives:

- Measure and record motion data accurately
- Analyze motion in the context of applied forces
- Identify the forces acting on the system, and the forces acting on specific elements of the system
- Prepare free-body diagrams to predict experimental results
- Graphically determine the relationship between applied force and acceleration
- Compare the predicted and actual accelerations to determine which sources of error have the greatest impact on the results
- Examine the systematic effects of errors caused by an incorrect or incomplete set of premises or initial conditions



The Procedure

The experimental set up is a basic Atwood's machine. When the system is released from rest, the hanger (m) will be pulled down by gravity. Because it is attached to the cart (M), wherever m goes, M has to follow. The acceleration of the system will be determined using the motion sensor equipment. The sensor will record position as a function of time, from which we know we can determine the acceleration by finding the slope of the velocity vs time plot.

You will perform multiple trials in which you gradually transfer masses from the cart to the hanger. The total system mass (m + M) will remain constant, but its distribution will change as M decreases and m increases. You should perform a few practice runs, then make sure to save your data runs as you transfer mass from M to m.

The Data

Your raw data consists of the position vs time data for each trial. Make sure that you have noted how much mass is located at both M and m for each trial you run. Save the individual trials, save the data file in the appropriate folder on the computer.

The Analysis

1. Carefully draw a free–body equation for each mass. Use these force diagrams to write Newton #2 for each mass, in terms of the forces you have identified. Solve to predict the system acceleration. Calculate the **predicted acceleration** for each trial, and record it.
2. For each trial, the slope of the velocity vs time graph is the system acceleration. Fit a best line, and record the slope. This is the **experimental acceleration** for each trial. How well do these values match the predictions?
3. Your free body analysis of the problem indicates that, if Newton #2 is correct, your combined trials should prove it:
   $$F = (m + M)a$$
   corresponds to
   $$y = mx$$
   Prepare a graph of your results with **F** on the **y–axis** and **experimental average acceleration** on the **x–axis**. Your free–body equations show that the force causing the entire system to accelerate is gravity pulling on the hanger:
   $$F = mg$$
4. Determine the **slope** of the best–fit line and its **y–intercept**.
5. Compare the total system mass (m + M) to the experimental value of your slope:
   $$\%error = \left[\frac{(m + M) - slope}{(m + M)}\right] \bullet 100$$
6. Identify sources of random error, and whether you can quantify them or not. Are your results seriously compromised by random error? How do you know?
7. Is your analysis of the forces complete? If not, what is missing? How significant is this oversight? How does this affect the relationship between your actual and predicted accelerations? Random or systematic effect?
8. Is your assumption of $v_o = 0$ valid? If $v_o \neq 0$, what is the impact? Does this show up in your actual or predicted acceleration? Explain exactly how this could happen, and exactly what the consequence of this would be. How can you use your graph to determine whether a missing force or non–zero v_o is the culprit?

The Conclusions

Comment on whether your experiment concluded successfully. If you have not already, suggest how the procedure or prediction could be modified to bring the actual and predicted accelerations into closer correlation.