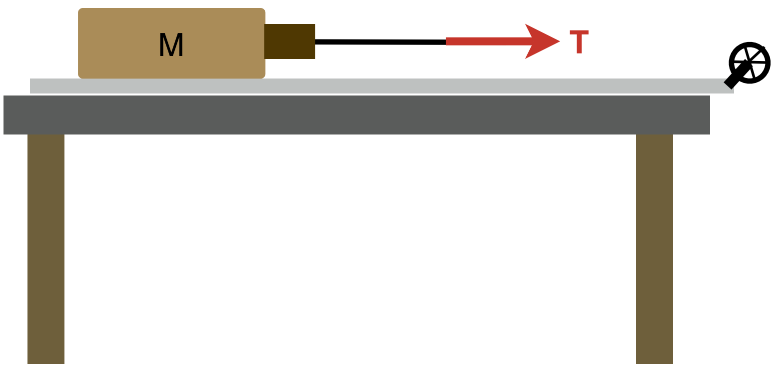
Lab 05: Static and Kinetic Friction

The Objectives

This week, we want to further explore Newton's laws of motion. Our previous analysis indicated to us that we needed to consider the effect of kinetic friction on our moving cart. Using a set up similar to last week's, we will be able to answer the question: *What are the coefficients of static and kinetic friction between a pair of surfaces?*

Some specific objectives:

- Incorporate the direct measurement of force into our automated data collection
- Continue the analysis of 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 coefficients of static and kinetic friction for a pair of surfaces
- Examine any random or systematic effects on the results



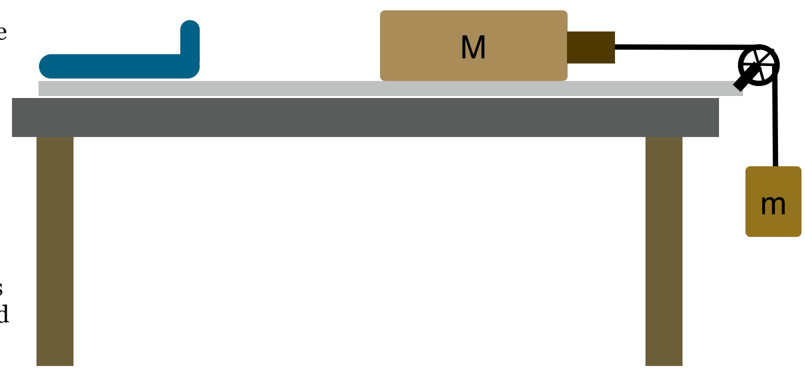
The Procedure

The experimental set up is similar to the Newton's Law set-up from last week. However, initially, we will not be using a hanging mass to pull our cart. To measure the coefficient of static friction, attach the force sensor to the front of the cart, and tie a length of cord to the sensor. The sensor will then record the applied force, which will be the tension in the cord. By slowly increasing the amount of applied force until the cart begins to move, the maximum static friction can be measured directly. The maximum amount of static friction will occur just at the instant before the cart begins to move.

For a given cart mass M, you should repeat the trial several times, recording at least five values for T_{max}. You will perform multiple trials in which you gradually add mass to the cart. You should have at least **four different cart masses**, with **five trials** at each mass.

To measure the coefficient of kinetic friction, set the motion sensor on the track, just as we did last time. You will be recording position and force simultaneously with each trial. This week, we are not concerned with keeping the system mass constant. You will be adding mass to the cart, and the force sensor will be recording the value of the tension in the cord.

When the system is released from rest, the cart should experience constant acceleration as it moves down the track. This acceleration and the measured tension will be used to determine the coefficient of friction.



You should add mass to the cart in 0.500kg increments, and repeat. You may have to add mass to the hanger to insure that the system will move when released. Keep track of how much mass you hang, even though we will not be using the value directly.

The Data

Because we are running so many static trials, you do not need to retain every single set of data. If you have a trial that produces a particularly good graph, save that. Your static data consists of a table of recorded mass (cart + any extra mass) and the resulting maximum force of tension. Plan to spend some time carefully collecting good quality data. Not every trial will be acceptable.

You will want to save the trials for the kinetic measurements. Make sure to record how much cart mass (M) and hanger mass (m) corresponds to each trial. Your kinetic data should include the masses, the average tension while the cart accelerated, and the acceleration. Both tension and acceleration will be extracted from our graphs. Make sure to save individual trials, and also save your entire worksheet in the proper folder on the hard drive.

The Analysis

1. Carefully draw a free–body equation for the static mass. Use the force diagram to write Newton #2 in terms of the forces you have identified. Solve to predict the coefficient of static friction μ_s. Based on your mass and tension data, you should be able to construct a graph (T vs N) to find a value for μ_s.

2. For the kinetic trials, draw a free–body equation and write Newton #2. Notice that in this case, the tension does not match the force of friction! Solve algebraically for the kinetic coefficient μ_k.
3. Use the tension and acceleration data to calculate a coefficient for each trial. Find the average value, and calculate the standard deviation to give you the uncertainty.
4. 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?

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.

An Example Graph

Below is an example of a force vs time plot. This is real data collected using the same set up that you will be using. However, not all of your graphs are going to look this good. Certainly not all of mine do. Anyway, this shows you pretty clearly what you are looking for. The value of the maximum tension gets you the static coefficient, and the flat part of the graph shows you where there was constant force (and thus constant acceleration).