<u>Frictional Forces</u>

Most of the forces we've encountered so far are contact forces present when surfaces of two objects touch (with the gravitational force being the main exception). Contact forces can occur at any angle relative to a surface and are often separated into components parallel and perpendicular to that surface. You've already become familiar with the concept of the "normal" force, which is just the perpendicular component of a contact force. A frictional force is a component of a contact force parallel to the surface.

Broadly, friction can be classified as sliding, rolling, or fluid friction. For this lab we will investigate friction on objects that slide. We distinguish two types of sliding friction: kinetic and static. If the surfaces are in relative motion, the frictional force on each object is called the kinetic friction. If the surfaces are not in relative motion, this force is called the static friction. Since it is possible to move an object at rest along a surface by applying a sufficiently large force to it, static friction must always have some maximum value that gives way to kinetic friction. In this lab we will develop models for the static and kinetic frictional forces present when plastic bins with different materials on their underside are released on an inclined dynamics track. You should have three plastic bins with three different materials: felt, cork and plastic.

The Experiment:

Materials - dynamics track, stand to incline track, plastic bins with felt, cork, and plastic undersides, set of masses, motion detector, protractor attachment for the track, electronic balance, LabQuest interface and cables

<u>Part A: Static friction and the critical angle</u>

<u>1)</u> Your experience with Newton's second law tells you that an object at rest on a ramp must experience a force that opposes the component of the gravitational force acting downward along the ramp. Yet at some angle the object will slip and begin to accelerate. This is called the critical angle. Predict on the graph below how you think the critical angle, θ_c, depends on the mass of the object. How do you think this will change with different materials? Draw and label three separate curves on your graph for the felt, cork, and plastic bins.

<u>2)</u> Test your predictions by laying the bin flat on the track and having one group member slowly lift one end of the ramp until the bin starts to slip. Have a group member monitor the protractor attachment to determine the critical angle. Record the value just before the bin starts to slip. Add masses to your bin and repeat the experiment to get four or five data points. Do this for each of the three bins with the same set of masses. Note that the empty bins themselves have a mass that you should not neglect.

<u>3)</u> Plot your results in *Logger Pro* with all three data sets on the same graph. To do this create three different data sets (go to **Data > New Data Set** to add a data set) and enter your data for each one.

Make sure that all three columns for your horizontal axis have identical labels. Then click on the vertical axis label and select "More". The column for the first data set should already be checked. Open the boxes for the other two data sets and select the column to plot on the vertical axis. You should now see three sets of data on one graph. Fit three simple models to each of your data sets (you may need to adjust the axes options if the range of the vertical axis is too small). Do your results agree with your predictions for each of the materials?

4) Now apply Newton's second law to your system just before the block begins to accelerate down the ramp. You will have two independent equations, one for each direction. Use these equations to get an expression for the critical angle of the ramp. Does this expression agree with your results above? Explain why or why not.

5) The ratio of the $F_{s_{max}}/F_N$ should appear in your expression for the critical angle, where $F_{s_{max}}$ is the maximum static friction and F_N is the normal force. This ratio is referred to as the coefficient of static friction and is given the symbol μ_s. Based on your results, what property of the system does μ_s depend on? How is it related to the critical angle? What are the values of μ_s for the three bins?

Part B: Kinetic friction

1) We can define a similar quantity $\mu_k = F_k/F_N$ (where F_k is the kinetic frictional force) called the coefficient of kinetic friction. On the sheet below, make a prediction of what F_k looks like as a function of F_N for each of your three bins. (Draw all three on the same graph and label which curve corresponds to which bin.)

2) Now test your predictions by fixing the ramp several degrees above the critical angle for all your bins. Place the motion detector at the top of the ramp so it can measure the acceleration once the bin is released. Change the normal force by changing the mass in each bin and use the same set of masses each time. The bar masses have the advantage that they more evenly distribute the weight in the bin while on the incline, but are rather heavy. Keep the mass in the bin to less than a few hundred grams, lest the accelerations be too high or the friction strong enough to start rubbing off the cork. Stop the bin as it reaches the bottom of the track.

3) You cannot measure the frictional force directly using this setup (and in general it is hard to directly measure the force of friction), but you can calculate it by measuring the acceleration and applying Newton's second law. Do so to figure out your frictional and normal forces for each trial.

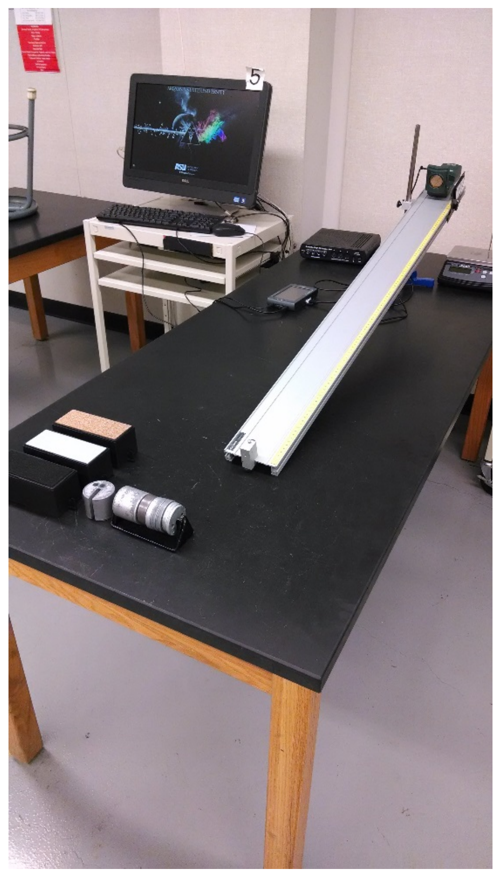


Figure 1 - The setup for Part B of the experiment with the motion detector at the top of the track..

Create three separate data sets as before and plot F_k vs. F_N for each of the three bins on the same graph.

<u>4)</u> Fit your data to get a value of μ_k for each of your bins. Does μ_k depend on the mass of the bin? Does it depend on the material? Does your graph match your prediction? How do your values for μ_k compare to your values for μ_s?

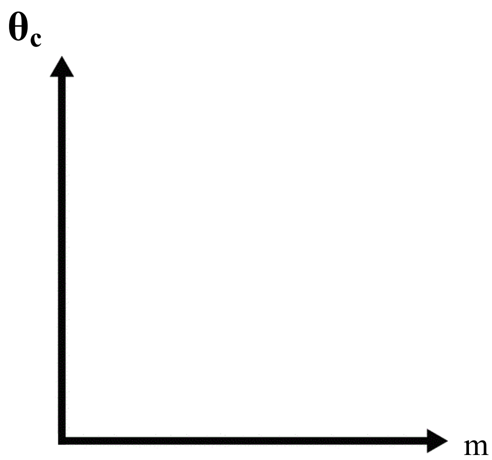
<u>5)</u> Prepare the two graphs you made in this lab on a whiteboard, along with your μ_s and μ_k values for a class discussion.

<u>6)</u> In the "Discussion" section of your lab report, explain in your own words what you think is going on at a microscopic level when two surfaces are experiencing sliding friction. Draw diagrams if they will aid your explanation.

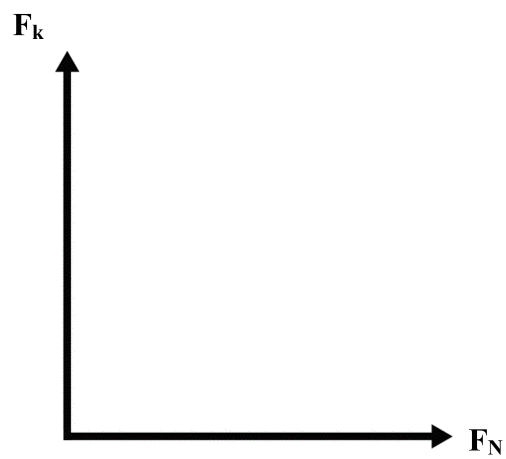
Predictions

Draw and label three curves on each graph, one for each of the three different materials.

Critical angle as a function of mass



Kinetic frictional force versus the normal force



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