Friction

Objective

In this experiment, we will attempt to determine the coefficients of friction between a wooden block and the tabletop (apparently smooth, but "rough" at the microscopic level). We also wish to know if and how contact area and normal force affect the coefficients of static and kinetic friction.

Materials

1. 1-meter stick
2. BR bracket
3. Foam pad
4. Pasco 550 Interface
5. Smart pulley with chrome rod
6. Set of slotted weights
7. Mass hanger
8. String and scissors for room
9. Triple-beam balance
10. Wooden blocks

Procedure

Some of our measurements will utilize the Pasco capstone computer program. We will be using the Smart Pulley to monitor the velocity for objects connected by a string. The string passes over Smart Pulley and suspends a mass m. As the mass m falls, it causes the pulley to turn and mass M to be dragged along the surface. As the pulley turns, the spokes successively block the photogate beam. The velocity is automatically determined by the time intervals between successive blockings of the beam.

Setup

The Smart Pulley photogate should be plugged into digital Channel 1 of the Pasco interface. Mount the aluminum bracket (the flat bar with several holes in it) under the edge of the end of the table so that the bracket end with the two small holes is against the table support rail. Use the C-clamp to hold it firmly in place. Place the pulley support rod through the hole at the other end. Connect a wooden block and the empty weight hanger together by means of about 1.3 m of string as shown. Adjust the pulley height to make the string nearly horizontal and tighten the set screw against the rod. Make sure the string lines up with the pulley and that it will not rub against the clamp or bracket. Pull the block across the table to raise the hanger as high as possible without having it hit anything. We will soon have the descending hanger drag the block across the table.

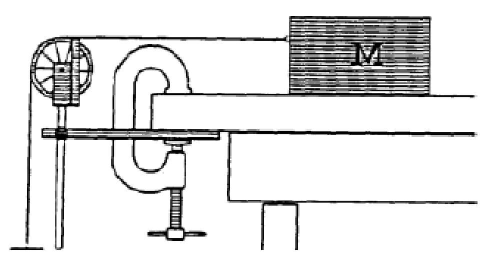

Figure 1: *Setup*

Now we'll setup the computer. Start the Pasco Capstone program by double-clicking its icon on your desktop. In the "Tools" windows panel on the left side of the screen, click on "Hardware Setup". Click on digital input 1 on the interface and select "Photogate and Pulley" from the drop-down. Now you'll need a graph. In the "Displays" window panel, double-click on "Graph". Click on "Select Measurement" on the vertical axis of your graph and choose "Linear Speed". You should now see a velocity vs time graph. You will use the "Record" (and, after recording, "Stop") buttons at the bottom of the screen to take your data.

Static Friction

The procedure for measuring the coefficient of static friction, μ_s, does not involve the computer and goes as follows:

1. Pull the block across the table to lift the hanger above the floor.
2. Carefully determine the maximum hanging mass m that will not cause the block of mass M to slide.
3. Measure M by means of the triple-beam balance. (Note – the triple-beam balance measures in grams. You'll want to convert your measurements to kilograms.)

The maximum static friction force is then mg, and the normal force is Mg. Therefore,

$$\mu_s = \frac{mg}{Mg} = \frac{m}{M} \quad (1)$$

Don't forget to include the mass of the hanger in m. Try starting the block at several spots on the table to make sure you haven't accidentally picked an especially sticky or slick spot.

Repeat the process with the other two blocks you have been provided and determine the coefficient of static friction, μ_s, for each.

Kinetic friction

Now we will use a hanging mass to drag the block and we will use the computer to measure the acceleration as the slope of your velocity vs time graph. Applying Newton's Second Law to each of the diagrams in Figure 2, we get:

$$T - f_k = Ma \quad (2)$$

$$mg - T = ma \quad (3)$$

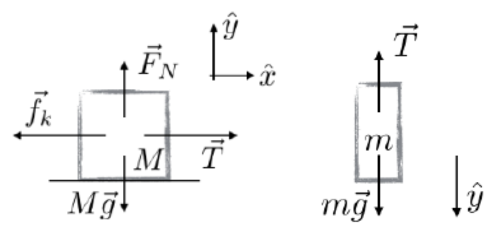

Figure 2: *Free Body Diagrams*

Combining equations (2) and (3), we have

$$f_k = m(g - a) - Ma$$
$$= mg - (m + Ma)$$

giving

$$\mu_k = \frac{f_k}{Mg} \quad (4)$$
$$= \frac{mg-(m+M)a}{Mg}$$

All we need now is to have the computer help us measure the acceleration, a.

Pull the block across the table to lift the hanging weight. For your first trial make the hanging mass at least 50 grams more than that required to start the block to slide; support this mass with your hand. Be prepared to press the “Record” button (to start the timer). Then release the hanging mass, press “Record”, catch the sliding mass before it slams into the pulley, and press “Stop" to stop the timer.

Proceed when you are ready. If you need to repeat (because you have bad data, etc.) click “Delete Last Run” at the bottom of your screen.

When you are satisfied with your data, concentrate on the diagonal, linear region of your graph only. Use the “Scale-to-Fit” tool and /or the “Data Highlighter” tool to zoom into and select the data region to apply a linear fit. (If your entire graph is one line then you can skip this step.) Then at the top your graph, click on the “Curve Fits” tool, and choose “Linear”. This should give you a small window of information about your linear curve-fit. Recall that acceleration is the slope of a velocity vs time graph. The slope of your graph should appear in your linear fit window (“m =” with units of m/s^2). Use this acceleration to obtain μ_k from equation (4).

Repeat the process with the other two blocks you have been provided and determine the coefficient of static friction, μ_k, for each. Again, you’ll need to delete your previous data runs by clicking “Delete Last Run” at the bottom of your screen.

Factors affecting μ_k

In order to arrive at equation (1), we have implicitly claimed that the force on mass M due to static friction is related only to the normal force Mg. Notice in Figure 3 that the total weight of the blocks (and therefore the normal force of the table on the blocks) is the same even though the amount of surface area of the blocks in contact with the table varies depending on the stacking of the blocks.

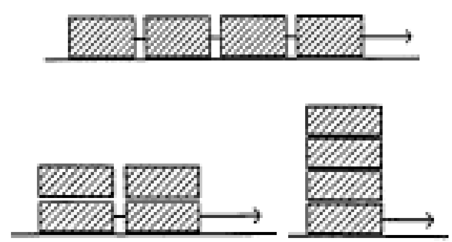

Figure 3

To test whether area of surfaces in contact is a factor, let’s make some changes to the setup. Link your three blocks together (using S-hooks or paper clips provided) in configurations suggested by your TA (you’ll see diagrams in the lab worksheet). Use enough hanging mass to create a non-zero (but not excessive!) acceleration in your blocks. Use the Pasco apparatus and Capstone software to find the acceleration of your black and then calculate μ_k. Repeat for the other arrangement, using the same amount of hanging mass.