Experiment 6
The Coefficient of Friction

Advanced Reading:
Halliday, Resnick & Walker,
Chapter 6, Sections 1, 2 & 3

Equipment:
1 ULI with force probe
1 Inclined Plane (see Figure 6-1)
1 Wooden Block
1 Dial-o-gram balance
Masses

figure 6-1 Inclined Plane

Objectives:
To measure the coefficients of static and kinetic friction between a wooden block and a wooden plane.

Theory

Friction is the force that resists the relative motion of one surface in contact with another. There are two types of friction: static and kinetic. Usually, the kinetic frictional force is less than the maximum value of the static frictional force. The static frictional force is given by $f_s = \mu_s N$ and the kinetic frictional force is given by $f_k = \mu_k N$, where μ_s is the coefficient of static friction, μ_k is the coefficient of kinetic friction and N is the normal force. Note that if f_k versus. N is graphed, the slope of the line should be μ_k for the system.

The *angle of repose* is defined as the angle at which an object just starts to slide down an inclined plane. If θ is the angle of repose, it can be shown that $\mu_s = \tan\theta$. We will call this method to determine the static coefficient of friction the *angle of repose method.*

In this experiment, the frictional force between a wooden block and the wooden surface of a horizontal and inclined plane will be measured, and from this data, the coefficients of *static and kinetic friction* will be obtained. The angle of repose method will also be used to determine the coefficient of static friction. Lastly, the coefficient of kinetic friction will be determined by a second method *(called constant velocity method*) by noting the angle that the block slides down an incline without accelerating and then using $\mu_k =$ tangent of that angle.

Procedure:
1. Turn on the ULI and the computer. Open the *Logger Pro* application. Go to the **Setup/sensors** menu and choose the port which force probe sensor is plugged in. Go through list of probes and highlight Dual Range 50N Force Probe.

2. Calibrate the force probe by using the path **Setup/Sensors/Calibrate**. Follow the directions given to you on the screen. Use 1/2 kilogram on the weight hanger for the calibration. **Be sure to use units**

of force (not mass) when calibrating the force probe.

3. Measure the mass of the wooden block with the Dial-o-gram balance and calculate its weight in newtons.

4. With plane in the horizontal position, place 500 grams on the block and pull the block across the plane at a constant speed with the force probe. Be sure to pull horizontally. Note the "bump" at the start of the graph. This peak represents a maximum force which can be used to calculate μ_s. See fig 6-2 and theory section.

5. Highlight the constant force portion of your run. Determine the mean force. *The force needed to pull the block is your* **frictional force** *and the combined weight of the block and mass is your* **normal force**. Note that normal force here is also used in step 4 to determine μ_s.

6. Repeat steps 4 & 5, adding 500 grams each time until a total of 3000 grams has been added to the block. *Record the frictional and normal forces needed for* **each trial**.

7. Plot a graph of the frictional force vs. the normal force using *Graphical Analysis*, with the frictional force on the Y axis and the normal force on the X axis. Plot a "best fit line" between the points by pulling down the **Graph** menu to **Regression line.** To obtain the slope of this line, pull down the **Graph** menu to **Statistics**. This will print the value of the slope at the bottom of the graph. If F_{fr}, the frictional force is proportional to F_N, the normal force ($F_{fr}=\mu_k F_N$), then the slope of this line should be the coefficient of kinetic friction between the two surfaces. Determine this value from the graph.

Block on an inclined plane

8. Calculate the force needed to pull the block up a plane inclined to 30^0 at a constant speed when loaded with 500 grams. Draw a force diagram labeling all the forces acting on the block as it moves up the inclined plane. Use the coefficient obtained from your graph.

9. Measure the force needed to pull the block up the plane (same angle as part 8) at a constant speed. If there is a large difference between the calculated and the experimental values, check the calculations carefully. (Common mistakes: Neglecting the mass of the block and improper force diagrams) Calculate the percentage difference between this value and the calculated value.

Angle of repose method

10. Find the coefficient of *static friction* by slowly raising the incline plane until the block just starts to slide. Note the angle and use $\mu_s = \tan\theta$.

Constant Velocity Method

11. Find *kinetic coefficient* of friction by tilting the inclined plane and noting the angle at which the block slides at a constant speed. You should have to tap the block in order to get it started. Use $\mu_k = \tan\theta$.

Questions/Conclusions:

1. Show that $\mu_s=\tan\theta$ for the constant velocity method. Include a diagram of all the forces on the block as it slides down the inclined plane.

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2. If the mass on the block is doubled, what happens to the angle of repose?

3. Why was it necessary to tap the block to get it started in section 9 of the lab?

4. Why can anti-lock brakes stop a car in a shorter distance than regular brakes?

5. Which method do you think would yield the more accurate value for the coefficient of kinetic friction and why?

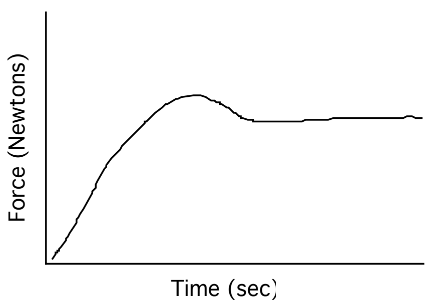

figure 6-2