Friction

"Science, at bottom, is really anti-intellectual. It always distrusts pure reason and demands the production of the objective fact."

H. L. Mencken

OBJECTIVES

To characterize the actual frictional forces in some situations.

THEORY

Concerned with their rising legal costs, the management of Everslip Soles, Inc., has decided to hire a consulting physicist (you) to help them improve the traction of their product. Being a conscientious consultant, you first review the friction literature and then set out to measure the frictional forces between shoe soles and typical flooring materials.

Physics textbooks provide a simple model of friction. The frictional force is assumed to act between any two surfaces in contact in such a way as to resist relative motion between the surfaces. The force is directed along a tangent to the plane of contact and is proportional to the force pressing the surfaces together. The constant of proportionality, called the "coefficient of friction", is therefore defined by the relation

$$\mu = F_f / F_N \tag{1}$$

where F_f is the frictional force and F_N is the force normal to the surface. More specifically, the maximum force that the surfaces can exert before relative motion starts defines a coefficient of static friction and the force that resists relative motion once sliding is underway defines a coefficient of kinetic friction:

$$F_s \leq \mu_s F_N \qquad F_k = \mu_k F_N \tag{2}$$

This is a very simple description of friction: The coefficients are claimed to be independent of the normal force and the contact area, and, for the kinetic case, independent of sliding velocity. The physical world may or may not be so simple.

EXPERIMENTAL PROCEDURE

To estimate the coefficients of friction you need to measure the frictional force as the sole starts sliding from rest and then moves at approximately constant speed. Both the frictional force and the speed will be measured and graphed with the computer data acquisition system.

1. Physical arrangement

In order to explore the various combinations customers might encounter you have obtained several types of floor material and some samples of Everslip soles. The flooring can be attached to a force table, to measure the friction. The shoe soles are attached to plywood, with a tow rope at one end and a target for the motion detector at the other end. You can stack metal weights on the slider to vary the normal force. Figure 1 is a general sketch of the arrangement.

To measure the force, the piece of flooring to be tested is clamped to a plywood platform sitting on rollers. One end of the platform is connected to a force sensor, which measures the force required to keep the platform from accelerating horizontally. If there are no other horizontal forces on the platform, then, by Newton's second law, the restraining force must be exactly opposite to the force of the slider on the platform. In turn, the force exerted by the slider on the platform is equal in magnitude but opposite in direction to the force of the platform on the slider, which is the frictional force. Although somewhat indirect, this means that the force probe measures the frictional force. If you are unsure of this argument, draw the free-body diagrams.

2. Data acquisition and analysis

Start the LoggerPro data acquisition program by double-clicking an icon labeled Friction.cmbl, or load the file after the program is running. This will give you a set of reasonable starting parameters and graphs for this exercise. This file may also help you get you back to useful settings if you make changes later in the experiment. You are welcome to save your own data and set-up parameters on the hard disk, but please use the Save As.... option to put the file under a different name so that others have the original set-up available.

To become familiar with the data acquisition, position one of the shoe sliders on the platform about half a meter from the motion detector. Click the Collect button in the top toolbar.

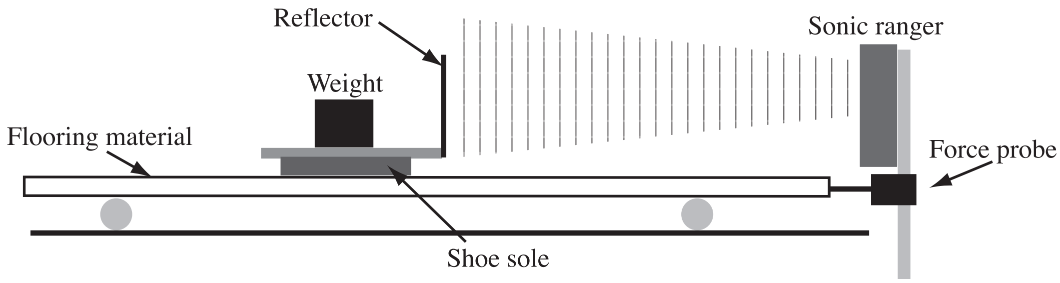

Fig. 1 Overall view of the friction measuring apparatus.

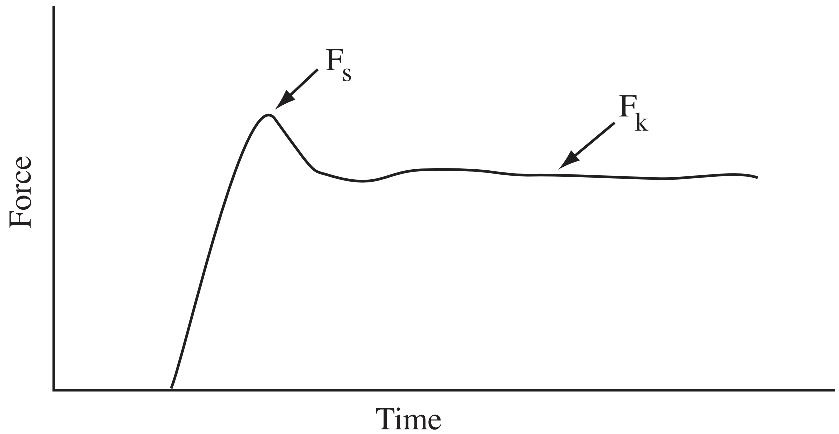

Fig. 2 Typical plot of force vs time for a slider. The initial peak (not always present) is the maximum force of static friction, followed by the steady force of kinetic friction on the moving slider.

After a pause of a few seconds you will hear a clicking from the motion detector, indicating that it is taking data. Use the cord to tow the slider along the platform, watching the graphs of distance, velocity and force. Be particularly careful that the plotted force does not exceed 50N, to avoid damaging the probe. The force graph should look similar to Fig. 2, and the velocity graph should be consistent with the motion you produced. If there seem to be problems, make sure that the ranger is not being confused by fixed obstacles or consult the instructor. Click again on the Collect button to clear the data when you want to acquire a new set.

Note that if the force changes quickly, subsequent readings may scatter due to the springiness of the force probe. Try to move the slider as smoothly as possible, avoiding all abrupt motions.

For a typical analysis, you would use Examine to read the peak force as the slider starts to move. After the initial peak force, if any, you can select a region where the velocity is approximately constant and use Statistics to get the average force while sliding. Repeating the measurement as closely as you can will give you a measure of the uncertainty in the force.

Before taking serious data you must calibrate the force probe on the ±50N range. Disconnect the probe from the rolling platform and connect a long string to the force probe. Place the string over the pulley at the opposite end of the bench and adjust the positions of the pulley and probe so the string is level. Set the zero in the calibration procedure with no weight on the string. Use a weight hanger to suspend a known mass from the string to get the other calibration point. Be sure that the platform and rollers are aligned properly and move freely when you reconnect the force probe.

3. Measurement Program

When you are satisfied that you understand the methods and can make reasonable measurements of the friction, you should determine coefficients of friction for several of the available pairings of sole and floor material. Your efforts should be focused on resolving the following issues:

a. Is there any systematic variation with normal force? That is, can we even define the coefficient of friction as a constant for a given sole-floor system?

b. Is the coefficient for 'static' friction different from 'sliding'. Is there velocity dependence once sliding starts? (The software lets you plot force vs velocity directly.)

c. Are some soles or surfaces much slipperier than others? Is there any pattern to the variation? Do some soles have a lower coefficient than others on most surfaces? Are some surfaces more or less slippery than others for most soles?

d. Does the condition of the surface matter? For example, you can compare a freshly-cleaned sole and floor with the same surfaces after scuffing up some dirt from the lab floor. You can also spray some water on the vinyl flooring and see how that affects the friction. (Do not get the carpet or other surfaces wet. They won't be dry for the next group, and they mildew.) Slippery when wet?

Keep in mind that the measurements may not be very precise, so you need to consider experimental uncertainties in reaching conclusions. Since this is only a preliminary study you need not try all possible combinations in all possible conditions, but do gather enough examples to identify the important features of the problem.