Friction

I. Theory

Friction is the resisting force encountered when one surface slides over another; this force acts along the tangent to the surfaces in contact. The force necessary to overcome friction depends on the nature of the materials in contact, their roughness or smoothness, and the normal force, but not on the area of contact. It is found experimentally that the force of friction is directly proportional to the normal force. The constant of proportionality is called the coefficient of friction.

When the contacting surfaces are actually sliding one over the other, the force of friction is given by:

$$F_k = \mu_k N \qquad (1)$$

where F_k is the force of kinetic friction and is directed parallel to the surfaces and opposite to the direction of motion, N is the normal force, and μ_k is the coefficient of kinetic friction. When one body lies at rest on a surface and an attempt is made to push it, another type of friction, static friction, must be overcome. The maximum static friction resisting motion is:

$$F_s = \mu_s N \qquad (2)$$

where μ_s is the coefficient of static friction. In this laboratory we will measure the coefficients of static and kinetic friction of wood on wood and plexiglass on wood.

To determine μ_s, we will measure the so-called *limiting angle of repose*, defined as the maximum angle to which an inclined plane may be tipped before a block placed on the plane just starts to slide. We will slowly tilt a plane of wood upwards until a mass residing on it just starts to move. The coefficient of static friction can then be calculated from the angle of repose θ_{max}:

$$\mu_s = \tan \theta_{max} . \qquad (3)$$

You should derive this expression in your notebook before coming to class.

To measure μ_k, we will examine the force necessary to keep a block on a level surface moving at constant speed. By adding weights to the block we will also be able to examine whether the friction force is indeed proportional to the normal force as Eq. (1) claims.

II. Procedure

1. Weigh the wood block and record the weight in newtons.

2. Place the board in a horizontal position on the lab table with its pulley projecting beyond the table's edge. Be sure that the surfaces of both the board and the wood block are clean, dry and free of any dust or grit. Wipe them off if necessary with a clean, dry, lintless cloth or paper wiper. After this has been done, do not touch these surfaces with your hands. Handle the block with the cloth or a wiper and set it down only on the clean board. Begin the experiment by setting the block on the board with its largest surface in contact with the board's surface. Run the cord attached to the block over the pulley and attach it to the weight hanger. Place some weights on the hanger and slowly increase the load until it is just sufficient to keep the block sliding slowly with constant speed after it has been started with a very small push. Record this load. Don't forget to include the weight of the hanger.

It is important to note that every place on the board has a different coefficient of friction. This is due to the non-uniform surface of wood. The difference may be slight or very great in a small area. If there is a scuff or change in the grain this will be sufficient to produce a visible effect on your data. Always try to position the block in the same place when performing each set of trials. Use masking tape to mark the block position on the edge of the board, out of the way of the block's slide path. Due to the rough range of values that will be obtained throughout this experiment, precise accuracy will not be possible. Do not waste your time worrying about 1 gm here or there. Work in units of 5 gm. When trying to achieve a slide of constant speed it is important to note that the velocity of the block should be relatively slow. After obtaining a mass that produces the desired motion, attempt the trial again, removing small weights from the total to try and achieve a slower velocity of motion. The block may start and then stop, encountering a change in the coefficient of friction. Only use data that produces a steady motion over a large section of the board.

3. Repeat Procedure 2 placing masses of 200, 400, 600, 800 and 1000 gm successively on top of the wood block. Record the load needed to produce constant speed in each case. When placing weights on the block, make sure they are positioned symmetrically; uneven weight placement will result in errors. Place a piece of paper between the weights and the Plexiglass so as not to scratch the surface, thus changing the coefficient of friction.

4. Since the block is moving with constant velocity in Procedures 2 and 3 above, the force provided by the masses on the hanger is equal to the force of kinetic friction. Graph your measured frictional force as a function of the total normal force in your experiments. If Eq. (1) is correct, this should yield a straight line which passes through zero. The slope of the line is your experimental value of μ_k. Don't forget to include an error analysis!

5. Now we will measure μ_s, the coefficient of static friction. Set up a board as an inclined plane. Place the wood block on the plane and gradually tip the plane up until the block just breaks away and starts to slide down. Be very careful to tip the plane slowly and smoothly so as to get a precise value of the angle with the horizontal at which the block just breaks away. This is the limiting angle of repose θ_{max}. Measure it by means of a protractor and record the result obtained in three separate trials. These trials should be independent, meaning that in each case the plane should be returned to the horizontal, the block placed on it, and the plane carefully tipped up until the limiting angle of repose is reached. Don't forget to estimate the error on your final measurement of μ_s.

6. Repeat Procedure 5 using the glass block. Record the limiting angle of repose obtained in three independent trials. Calculate μs for the Plexiglass on wood and compare with that of wood on wood. Again, don't forget your error analysis.