Experiment 5: Friction

Introduction

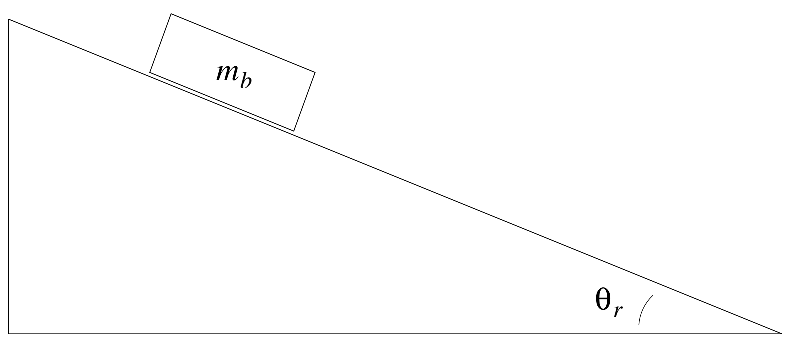
When one surface slides (or attempts to slide) over another surface, there is generally some friction between them, which produces a force that opposes the sliding motion. There are two kinds of friction, in terms of their effects: **static friction**, which keeps two surfaces "stuck together" (stationary with respect to each other), and **kinetic friction**, which opposes an ongoing sliding motion. In this experiment we will study static friction.

In general, static friction F_f is related to the **normal force** F_n (the force that the block and the incline exert on each other, perpendicularly to the surface) by the **coefficient of static friction**, μ_s:

$$F_f \le \mu_s F_n \tag{1}$$

Before the surfaces break loose and start to slide, the inequality holds; at the moment the surfaces break loose, the equality holds. In this experiment you will measure μ_s between two wooden surfaces, in two different ways.

Part I: Block on an Inclined Plane



In the first method, we place a block on an inclined plane, and gradually increase the angle of he incline from zero. At first, static friction keeps the block stuck to the incline. As the angle increases, the component of the gravitational force downhill along the incline increases, and the uphill static friction increases in step, so that the net force on the block remains zero. But the static friction can increase only to a certain size; when the angle gets big enough, the downhill force exceeds the maximum static friction, and the block breaks loose and starts sliding downhill. We call the angle at which this happens the **angle of repose**, θ_r.

It turns out that the coefficient of static friction has a simple relationship to the angle of repose:

$$\mu_s = \tan\theta_r \tag{2}$$

You will derive this equation in the advance questions. Generally, the coefficient of friction depends (approximately) only on the nature of the two surfaces (wood/wood, wood/glass, etc.).

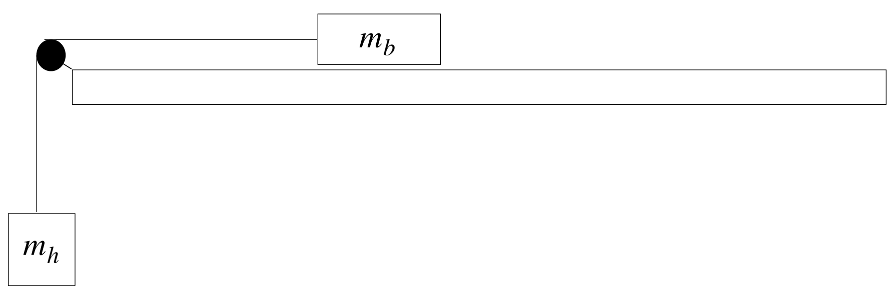
Procedure

Remove the string from the wooden block. With the block lying on its broad side on the top of the board, slowly lift up one end of the board. Measure and record the angle of the board, θ_r, when the block breaks away and slides down. Repeat four times, for a total of five trials. For consistent results, use the same face of the block each time, and start the block from the same place on the board each time. Calculate the average of these θ_r 's. Then use equation (2) to calculate the coefficient of friction.

Repeat this procedure with the wooden block lying on its long side. Does the coefficient of friction differ significantly between the two sides?

Part II: Two Blocks and a Horizontal Surface

Another way to supply a force for friction to act against is to use a weight hanging on a string attached to the block.



As we increase the "hanging mass", m_h, the tension in the string increases, and so does the static friction between the block and the table, until the static friction reaches its limit and the block breaks loose. At this point the equality holds in equation (1):

$$F_{f(\max)} = \mu_s F_n \tag{3}$$

Procedure

Measure and record the mass of the wooden block, m_b. Lay the board flat on the table. Attach one end of the string to the block and the other end to the mass hanger. Drape the mass hanger over the pulley, and place the block broad side down on the board.

Add mass slowly and gently to the hanger until the block breaks away from the board and begins to move. Record the total mass (including the hanger). Repeat four times, for a total of five trials. Again, for consistent results use the same face of the block each time, and start the block from the same place each time. Also, remove all of the mass from the hanger after each trial, and start adding weight from scratch in the next trial.

Find the average mass that was needed to start the block to move. Calculate the *weight* of this mass, $m_h g$,which gives the maximum force of static friction $F_{f(\max)}$. Calculate the normal force F_n between the block and the table, which in this situation is just the weight of the block, $m_b g$. Finally, calculate the coefficient of static friction, μ_s, from equation (3).

Repeat this procedure four times, each time adding 0.100 kg to the top of the block, so that you end up with five series of trials, with added masses of 0, 0.100, 0.200, 0.300, and 0.400 kg. You should get approximately the same value for μ_s in each trial; find the average and compare it with the value you got in part I (find the percent difference).

Data Tables

Part I: Block sliding on its broad side

Angle of Repose, θ_r						Coefficient of Friction, μ_s
Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	

Part I: Block sliding on its narrow side

Angle of Repose, θ_r						Coefficient of Friction, μ_s
Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	

Part II: Block pulled by hanging mass on horizontal surface

Mass of block (initial m_b) (kg)	

Added m_b (kg)	Total m_b (kg)	F_n (N)	Hanging mass, m_h (kg)						$F_{f(max)}$ (N)	μ_s
			Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Avg.		
0										
0.100										
0.200										
0.300										
0.400										

Average μ_s	

Questions

1. Make some comments and conclusions about the nature of the frictional force. Things you might consider: Does the frictional force depend on the area of surface contact? How does the coefficient of friction vary with the normal force? Etc. There will of course be random variations in your experimental data, so look for effects that are comparable in size to their causes.

Advance Questions

1. Starting with the diagram below for Part I, add vector arrows for the various forces acting on the block, just before it breaks loose, and use Newton's Second Law to derive Equation (2).