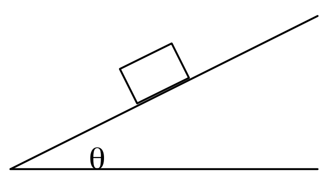
EXPERIMENT 5: FRICTION

As we continue our study of dynamics, we want to experience friction directly. We will measure the coefficients of friction by several methods. We will also have the chance to verify some of the accepted empirical facts of friction.

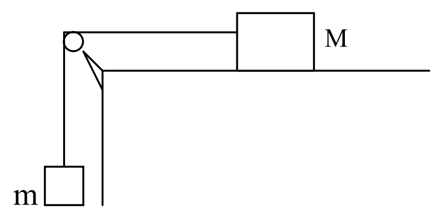
BACKGROUND

Review the sections in the beginning of chapter six dealing with friction. Note that, according to theory, the frictional force depends only on the normal force between two surfaces, and not on the area of the surfaces. We will attempt to verify that fact. We will also see that friction is dependent on the two surfaces in contact, not just on one surface. If necessary, review the concept of free body diagrams in chapters five and six, and review also the calculations of acceleration on an inclined plane (for example, examine Sample Problems 6-1, 6-2 and 6-3). You will be doing similar calculations in this experiment.

ADVANCE STUDY ASSIGNMENT



Sketch for Procedure A and ASA 1 & 2



Sketch for Procedure B and ASA 3 & 4

1. Derive a formula for the coefficient of static friction (in terms of θ_1) when a block is observed to just start moving when the angle of an inclined plane is increased beyond θ_1 (that is, θ_1 is the angle of maximum static friction).
2. Derive a formula for the coefficient of kinetic friction (in terms of θ_2, g and a, the acceleration) when a block accelerates down an incline with an angle of θ_2.
3. Derive a formula for the coefficient of static friction (in terms of m and M) when a mass, m, hanging from a string attached to a larger mass M on a horizontal surface just starts to move.
4. Derive a formula for the coefficient of kinetic friction (in terms of m, M, g and a, the acceleration) when a hanging mass, m, attached by a string to a block M accelerates the block on a horizontal surface.

PROCEDURE A

1. You will be using a two meter long metal track with wheeled cars and a wooden block. First level the track on the table by adjusting the screws on the four support legs. You should use both a circular spirit level and the wheeled cart, which should stay wherever it is put, and come to a stop (because of friction) when given a very slight push in either direction. If the car continues to move to the end of the track, the track is probably not level.

2. When you are convinced the track is level, adjust the angle indicator so it reads 0.0°. Tighten the indicator into position, and be careful not to bump it or knock it out of adjustment in the subsequent procedures.
3. Place the larger wooden block at the end of the table away from the computer, near the end of the track, and clamp it in position with a C-clamp. The purpose of this large wooden block is to prevent the track from slipping off the end of the table when we elevate the opposite end of the track.
4. Now place one or two large wooden boxes under the legs of the track near the computer. Adjust the height so the angle indicator reads approximately 15°. Now place the small wooden block with two sides covered with felt on the track, large exposed wooden side down. You are to adjust the angle of the incline of the track so that the block is ready to start sliding, with the static friction force at its maximum value. Call this angle θ_1. Read the angle (to 0.1°) and record it in Data Table A.
5. Calculate the coefficient of static friction, using the derivation of ASA 1, and enter the result in Data Table A.
6. Turn on the interface, then the computer. Select Data Studio, click on "Create New Experiment," and then, choose "Motion Sensor." Under the Data section, drag the Position onto Graph icon (to display a graph). For velocity and acceleration, do the same except drag each of them to "Graph 1" (to display all three onto one graph).
7. Next, raise the track an additional 6.0° (to θ_1 + 6.0°), and connect the motion sensor to the computer interface. Place the motion sensor at the top of the track, and place a small piece of foam at the bottom of the track to gently stop the block when it slides down. Now place the block (with the same side down) on the track, about 40 cm from the motion sensor. Allow the block to slide down the track, while recording data from the motion sensor. When the block nears the end of the track, one partner should click the Stop button.
8. Maximize the graph screen, and click the scale to fit button (top left corner of the graph window next to the zoom in button; you will need to click each graph in turn and click autofit). Now click on the velocity graph and hold the left mouse button down, while you draw a rectangle by moving the mouse pointer. The rectangle should enclose only the section of the velocity graph which looks like a straight line. Click on the Fit button at the top of the graph window, and then select linear fit. A straight line should be shown on the graph (relying on the components of the linear fit) and the slope and intercept will be displayed. Record the slope. Now go to the acceleration graph, highlight the same time interval on the acceleration curve (being careful to make the rectangle large enough to include all acceleration points). On the statistics menu (the button is marked Σ and is the third button to the right of the Cit button), select "mean" (for average) and record the value reported. If the mean value and the slope of velocity are not close, you need to determine what the problem is.
9. Calculate the coefficient of kinetic friction using the derivation of ASA 2, and the average of the two accelerations just entered on Data Table A, and enter it into Data Table A.
10. Now repeat steps 4 to 8 three more times, using next the large felt side, then the small exposed wooden side and finally the small felt side. Do the sides of the block in the order specified, and be sure to independently adjust the angle of the track each time. Be sure to rotate jobs among lab partners, so each member of the team does each job.

11. Repeat procedures 4 to 8 one more time, this time with the large wooden side of the block down (again) but with the wheeled car on top of the block (with wheels up in the air). This will increase the mass and the normal force, to determine if the size of the normal force affects the coefficients of friction.

PROCEDURE B

12. You will next do another, independent calculation of the two coefficients of friction. Remove the large wooden boxes and also the wooden block clamped to the edge of the cable. Check that the track is level. Add a pulley to the end of the track away from the computer, and attach a one meter long string to the block, with the large wooden side down against the track. Place the motion sensor on the track, at the end near the computer.
13. Now attach a 50 g hanger (or 5 g if 50 g is too big, but put no more than 50g on 5g hanger) to the end of the string hanging over the pulley, and add additional weight to the hanger until the block just starts to move. Record this as m on Data Table B. Determine the mass of the block, and enter it as M on Data Table B. Calculate with the derived formula from ASA 3 and enter the coefficient of static friction on Data Table B.
14. Increase m by approximately 50% and record this as m' on Data Table B. With the motion sensor on the end of the track, determine the acceleration as this larger mass accelerates the block, using the same method described in procedures 7 and 8. Then use the derived formula from ASA 4 to calculate the coefficient of kinetic friction.
15. Repeat procedures 12 and 13 with the wheeled cart on top of the wooden block, with the wheels up in the air. (This effectively increases the mass of the wooden block.)

QUESTIONS

1. From the results of your experiment, does the frictional force depend on the surface area? Answer with specific reference to your experimental results.
2. Judging from your results, is the coefficient of friction dependent on one or two surfaces? Explain.
3. Does the coefficient of friction depend on the size of the normal force between two surfaces? Justify your answer from your experimental results.

DATA TABLE A

	θ_1	θ_2	Slope ( )	a ( )	μ_s	μ_k
Large wooden side						
Large felt side						
Small wooden side						
Small felt side						
Large wooden side with extra mass						

DATA TABLE B

	M( )	m ( )	μ_s	m'( )	Slope ( )	a ( )	μ_k
Large wooden side							
Large wooden side with extra mass							