

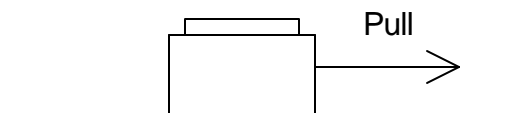
## LAB A7: KINETIC AND STATIC FRICTION

11/5/03

**Equipment required:** Wooden friction box with hook, set of standard masses, 20 N spring scale, adjustable angle friction plane

### A. Relationship between friction and normal force (horizontal surface)

**PRELAB PROBLEM:** In this experiment, you will apply a horizontal force (a Tension) to a box loaded with weights, in order to pull the box at constant velocity across a horizontal plane. Follow the usual force diagram procedure (net force equations, etc.) to show: (1) the magnitude of the force of the pull will equal the magnitude of the force of kinetic friction, and (2) the magnitude of the weight will equal the magnitude of the normal force.



1) Use a 5 N spring scale to measure the weight of the wooden box, and record your result. Then, using the spring scale, apply a HORIZONTAL force to the box to pull the box at a constant, slow velocity along the HORIZONTAL friction plane (NOT along the classroom table!). Try to make the box's velocity as constant as you can - start with a gentle pull and increase your pull gradually until you can move the box with constant speed. Read the force of pull for five values of mass (0 to 1 kg in increments of 0.2 kg) placed in the box. Distribute the weight in the box as uniformly as possible. Make a table of the weight of the loaded box (box + added weight) and the corresponding pull force.

Added Mass (kg)	Total Weight (N)	Pull Force (N)
0.200		
0.400		
0.600		
0.800		
1.000		

2) As you were carrying out the measurements above, what did you notice about the reading on the scale just as the box began to move? Make a conclusion about the difference between the friction force on an object at rest and that on the object while moving.

3) Use your TI calculator or Graphical Analysis to plot and fit graph of *FRICTION FORCE* vs *NORMAL FORCE*. (Where will the data come from?) Sketch (or paste a printout of) the graph in your lab journal, and write the equation of the fit in the usual way (math equation, physics equation, 5-column matching table: math and physics variables, actual and expected fit coefficients (if known) -- numbers and units, % difference).

4) If 0.700 kg of mass were placed in the box, what would you expect the force of friction to be? Use your equation of fit to calculate the answer. Then check your answer by making the measurement. Quantitatively compare the measured value to the calculated value. Show all work for predictions, and record all measurements in your lab journal. Compare the prediction with measurement (% difference?).

## B) Relationship between friction force and normal force (inclined surface)

**PRELAB PROBLEMS:** In the experiment you just completed, the weight of the box was equal to normal force of the table on the box, and the horizontal pull was equal to the friction force. In the next experiment, you will incline the friction plane. In this situation, how will the normal force be related to the weight? the pull related to the friction force? To answer these questions, do the following in advance of the lab.

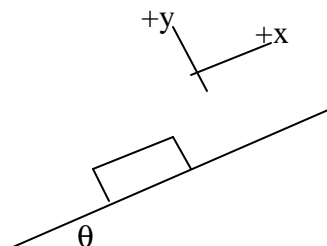
- On a diagram in your lab journal, draw and label the forces acting on the box. The box is being pulled at constant velocity upward along the inclined plane and parallel to it. Use axes parallel and perpendicular to the plane.
- Write the net force equation for the axis perpendicular to the plane. Then solve for the normal force in terms of the weight of the box,  $mg$ , and the angle of inclination,  $\theta$ . Make it clear on your diagram how the angle is used in finding force components.
- Write the net force equation for the axis parallel to the plane. Then solve for the friction force in terms of the force of the pull,  $F$ , and  $\theta$ .

**When your answers to the prelab problems are complete, do the following.**

- Using a box loaded with 400 g, pull the box at constant velocity upward along the plane for angles of  $0$  to  $50^\circ$  in increments of  $10^\circ$ . Be sure to keep the pull parallel to the plane. Record your results in a table similar to the one below. Use your results from b) and c) to calculate the normal and friction forces.

Record the weight of the loaded box.

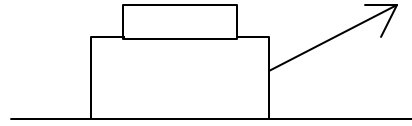
Angle ( $^\circ$ )	Pull Force (N)	Normal Force (N)	Friction Force (N)



- Using your TI calculator or Graphical Analysis, fit a graph of FRICTION FORCE vs NORMAL FORCE. Sketch (or paste a printout of) the graph in your lab journal (label axes with quantities plotted and units) and give the results of the fit in the usual way.
- Compare your results to those of step 3 in Part A.

### C) More about Normal and Friction Force

1) Now put the box, loaded with 400 g, on a horizontal friction plane. Pull the box with the spring scale at constant velocity, exerting the force at an angle of  $30^\circ$  to the horizontal. Give the value of the pull force that you measured. Then calculate what the friction force must have been. Explain your answer using a force diagram and net force equation.



2) Given the friction force determined in step 1, what would you expect the normal force to be? Use a result from Part A or B in determining your answer.

3) Calculate the normal force by a second method, using your force diagram from step 1 and another net force equation.

4) Quantitatively compare your answers to 2 and 3.

### D) Coefficient of static friction

In this experiment, you will use a simple technique to measure the coefficient of static friction. The method involves placing a box on a horizontal ramp and increasing the ramp's inclination angle gradually until the box just begins to slide. The largest angle at which the box does not slide is called the critical angle,  $\theta_c$ .

**PRELAB a):** Following the usual force problem procedure, find all inclination angles such that the box does NOT slide down the plane.

**PRELAB b):** Show that the maximum angle for which the box will not slide down the ramp is  $\theta_c = \tan^{-1}(\mu_s)$ , where  $\mu_s$  is the coefficient of static friction.

1) Use the method described above in the pre-lab to determine  $\mu_s$  for a box loaded with 400 g. How does your result compare to the coefficient of kinetic friction obtained in part A ?

2) If time permits, repeat step (1) with a different box mass. How do you expect your result for the critical angle  $\theta_c$  to depend on mass?