

PHY 251
Lab 5 – Friction

Objectives:

The objective of this lab is to measure the coefficients of static and kinetic friction between an object and a surface.

Theory:

Friction is the resisting force encountered when one tries to slide (static) or does slide (kinetic) one surface over another. This force acts parallel 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 on the normal force. Experimentally, the force of friction is found to be directly proportional to the normal force. The constant of proportionality is called the coefficient of friction.

The coefficient of friction is equal to the force of friction divided by the total normal force pressing the surfaces together. Thus, $F_f = \mu n$, where F_f is the magnitude of the force of friction, n is the magnitude of the normal force, and μ is the coefficient of friction.

A method of checking the above relationship is to have one of the surfaces in the form of a horizontal plane, with a pulley fastened at one end. The other surface belongs to a box to which is attached a cord passing over the pulley and carrying weights. These weights may be varied until the box moves uniformly when given a small push. The normal force magnitude between the two surfaces can be changed by placing weights in the box, and the relationship between the coefficient of friction, the force of friction, and the normal force can thus be tested.

Another method of investigating the relationship is to experimentally determine the acceleration of a box sliding down an inclined plane. By starting the box from rest and timing a known distance, the acceleration can be calculated. From a free-body diagram, the relationship between the angle of incline, the normal force, and the friction force can be determined.

The **limiting angle of repose** is the smallest angle at which an object will just begin to slide down an inclined plane without being pushed to get it started. **The coefficient of static friction is equal to the tangent of the limiting angle of repose.**

When actual sliding is taking place, the frictional force acting is slightly lower than the maximum static frictional force that acts just before the object starts to slide. Thus, the coefficient of kinetic friction is lower than the coefficient of static friction.

Apparatus:

Dual surface board with pulley
Wood box with string
Support rod
Stopwatch

Balance
Protractor
Slotted masses
Weight hanger

Procedure:

1. Measure and record the mass of the empty wooden box.
2. Place the board rough side up in a horizontal position on the laboratory table with its pulley projecting beyond the edge of the table. Set the box on the board and place the cord which is attached to the box over the pulley. Place 100 g in the box. Hang some masses from the cord and slowly increase the hanging mass until it is just sufficient to keep the box sliding slowly with constant speed after it has been started with a small push. Record the hanging mass needed for this to occur.
3. Repeat Procedure 2, placing masses totaling 200, 400, 600, 800, and 1000 grams successively in the wooden box. Record the hanging mass needed in each case.
4. Place 400 grams in the empty box. Gradually increase the load on the cord until the box just starts to move without an initial push. Be careful to place the masses on the hangar gently so as not to jerk the cord. Notice whether this time the box moves with uniform speed or whether it is being accelerated. Record the load needed for this to occur. Take 4 independent measurements and determine the average load.
5. Adjust the board as an inclined plane at 30° with the bottom end towards the lab table wall. Place a wooden block and soft stopper at the bottom of the plane. Measure a distance of 0.90 m up the plane and mark this location.
6. Place two 100 g masses uniformly in the box and release the box from rest at the mark you made in the previous step, measuring the time for the box to slide 0.90 m. Repeat this 4 times.
7. Place six 50 g masses in the box and repeat the timing measurements as in Procedure 6.
8. Measure the limiting angle of repose (the angle at which an object begins to freely slide down an incline) with two 100 g masses in the box. Repeat this 4 times.
9. Turn the board over to the smooth side and repeat Procedures 5 and 6.

Calculations:

Reminder: Be sure to perform your calculations using forces, not masses. Also, the total weight of the box is the weight of the masses in the box plus the weight of the box itself.

1. From the data of Procedures 1–3, calculate and record the coefficient of kinetic friction for each of the trials. Then, calculate an overall average coefficient of kinetic friction from these values.
2. From the data of Procedure 4, compute the coefficient of static friction.
3. From the data of Procedures 5–7 for each mass and each angle:
 - a. Calculate the average time

- b. Calculate the acceleration
 - c. Calculate the coefficient of kinetic friction
 - d. Compare this with the results from Calculation 1 by calculating a percent difference.
4. From the data of Procedure 8, calculate the coefficient of static friction for this material and compare to the results of Calculation 2.
 5. From the data of Procedure 9, calculate the coefficient of kinetic friction for this new material. Compare these coefficients with the kinetic coefficients calculated for the first surface. Comment on whether this makes sense or not.
 6. From the data of Procedures 1–3, make a graph using the values of the total normal force on the abscissa (x axis) and the values of the friction force on the ordinate (y axis).
 7. Calculate the coefficient of kinetic friction from the slope of the best fit line of the data points. Compare this with the result from Calculations 1 and 3.

Questions:

1. In this experiment, why is it necessary that the body move with uniform velocity in Procedures 2 and 3?
2. Based on your experiment, does the coefficient of friction depend upon the normal force between the surfaces in contact?
3. How does the coefficient of static friction compare with the coefficient of kinetic friction for the same surface areas and normal forces? In this context, explain what happened in Procedure 4 once the box started moving.
4. Show the derivation of the relationship that exists between the coefficient of static friction and the limiting angle of repose on an object on an inclined plane.
5. Calculate the force needed to pull a mass of 20.0 kg at a uniform slow speed up a plane inclined at an angle of 30° with the horizontal if the coefficient of kinetic friction is 0.20.