Measuring the Coefficients of Friction

Materials: Dynamics track, felt friction block, pulley, blue mass set, 1 set of extra masses, mass balance

1 Purpose

The goal of this experiment is to measure the coefficient of static and kinetic friction for a system in equilibrium.

2 Introduction

This experiment will introduce the student to a simple method for measuring the coefficients of static and kinetic friction between two surfaces. The experiment is sensitive and care must be taken to obtain good results.

The general principle behind the experiment is to determine the coefficients of static and kinetic friction between two surfaces by varying the mass of a block of material and measuring the force necessary to either break the block free (static friction) or to keep it moving at constant velocity (kinetic friction). The theoretical formulation that relates the normal force (F_N) exerted on an object to the static or kinetic frictional force (f_s and f_k, respectively) is

$$f_{(s,k)} = \mu_{(s,k)} F_N. \tag{1}$$

The coefficient of friction μ is a constant that depends on the material properties at the relevant interface and defined by the ratio of frictional force to the normal force. While the representation for both *static* and *kinetic* frictional forces is the same, there are different conditions under which each are valid.

In this laboratory, each group will experimentally determine the coefficient of kinetic friction between the felt side of the block and the metal track (in 3.1) and the coefficient of static friction between the same two surfaces (in 3.2).

3 Procedure

Data in this experiment will be collected by direct observation.

3.1 Kinetic Coefficient of Friction

1. Measure the mass of the block of wood on the balance.
2. Connect the string to the block of wood (if not done yet) and to the blue mass hanger from the blue mass set and suspend over the super pulley.
3. Add some mass to the blue hanger (10-g or so but make sure the block does not move).
4. Now *gently* tap the track to break the static friction. Does the block continue to move? If the answer is no then add a little more mass to the blue hanger and repeat. Continue this until the block will move at a constant speed. NOTE: It's important to use the same spot on the track every time to ensure that one is taking data on the same part of the block-track interface.
5. Once constant velocity has been achieved, record the total mass of the hanger and the total mass of the block. Constant velocity means that the block is moving at a steady rate without signs of stuttering.
6. Add 100-g to the block and repeat the experiment. Continue doing this until you have a total of 800-g added to the block.

3.2 Static Coefficient of Friction

NOTE: This experiment can be very difficult to perform. There are various differences in the track surface which may cause various differences in the static friction force from run to run. It is a good idea to repeat the measurement two or three times to verify the value.

1. Reset the system to the beginning of the first experiment.
2. Now carefully place mass on the blue hanger until the block moves suddenly. Take care to not drop the mass onto the hanger. **DO NOT TAP THE TABLE OR THE TRACK!**
3. Record the total mass of the blue hanger and the total mass of the block.
4. Add 100-g to the block and repeat the experiment. Continue doing this until you have a total of 800-g added to the block.

4 Analysis

Generate the following two plots and perform a linear fit on each.

1. Applied force vs. normal force for the kinetic friction case
2. Applied force vs. normal force for the static friction case

5 Questions

For each experiment, address following questions.

1. What is the value of the slope (with units! If no units then write ‘unitless quantity’)?
2. To what does the slope physically correspond?
3. What is the value of the y-intercept (with units! If no units then write ‘unitless quantity’)?
4. To what does the y-intercept physically correspond?

6 Reference

- OpenStax, *Physics*, Chapters 4 and 5
- Cutnell and Johnson, 8th Edition, Chapter 4

What to submit

Submit the following in the prescribed order

- Experiment 1: Kinetic coefficient of friction

  1. On a single page, include
     - Data table

Trial	Total mass of block, $m_{Block} + m_{added}$ [kg]	Total block weight, F_{Bl} [N]	Total hanging mass, $m_{hanger} + m_{added}$ [kg]	Total hanger weight, F_h [N]
⋮	⋮	⋮	⋮	⋮

     - One full calculation for total block weight
     - One full calculation for total hanger weight
     - Analysis: Plot of *Applied force* vs *Normal force*
       * Informative title, axes labels, units, etc (the usual)
       * Linear fit with analysis program (Excel is okay); include equation and R^2 on the plot)
       * Include units on the fit equation (may be written by hand)

- Experiment 2: Static coefficient of friction

  1. Same as *Experiment 1* (except for the actual data, of course)

- Questions

  1. On a fresh sheet of paper, completely address the questions in the handout
  2. Address any other questions or requirements set by the instructor