**STATIC AND KINETIC FRICTION**

## LAB MECH 3.COMP

From *Physics with Computers,* Vernier Software & Technology, 2000.

# INTRODUCTION

If you try to slide a heavy box resting on the floor, you may find it difficult to get the box moving. *Static friction* is the force that is acting against the box. If you apply a light horizontal push that does not move the box, the static friction force is also small and directly opposite to your push. If you push harder, the friction force increases to match the magnitude of your push. There is a limit to the magnitude of static friction, so eventually you may be able to apply a force larger than the maximum static force, and the

box will move. The maximum static friction force is sometimes referred to as *starting friction.* We model static friction, *Fstatic*, with the inequality *Fstatic* *s N*, where *s* is the coefficient of static friction and *N* the *normal* force exerted by a surface on the object.

The normal force is defined as the perpendicular component of the force exerted by the surface. In this case, the normal force is equal to the weight of the object.

Once the box starts to slide, you must continue to exert a force to keep the object moving, or friction will slow it to a stop. The friction acting on the box while it is moving is called *kinetic friction.* In order to slide the box with a constant velocity, a force equivalent to the force of kinetic friction must be applied. Kinetic friction is sometimes referred to as *sliding friction.* Both static friction and kinetic friction depend on the surfaces of the box and the floor. Both types of friction also depend on how hard the box and the floor are pressed together. We model kinetic friction with *Fkinetic* = *k N*, where *k* is the coefficient of kinetic friction.

In this experiment, you will use a Force Sensor to study static friction and kinetic friction on a wooden block.

# PURPOSE

The purpose of this experiment is to understand the difference between static friction and kinetic friction. A Force sensor will be used to study how static and kinetic friction act on objects and to determine the coefficients of static and kinetic friction.

# EQUIPMENT/MATERIALS

|  |  |
| --- | --- |
| Laptop computer with Logger *Pro* | Graphical Analysis or graph paper |
| LabPro with AC adapter | string |
| LabPro computer cable | block of wood with hook |
| Vernier Force Sensor | balance or scale |
| mass set |

**PRELIMINARY QUESTIONS**

1. In pushing a heavy box across the floor, is the force you need to apply to start the box moving greater than, less than, or the same as the force needed to keep the box moving? On what are you basing your choice?
2. How do you think the force of friction is related to the weight of the box? Explain.

# PROCEDURE

## Part I Starting Friction

1. Measure the mass of the block and record it in the data table.
2. Connect the Force Sensor to Channel 1 (Student Force Sensor and Dual-Range Force Sensor) of the LabPro.
3. Open the Experiment 12 folder from *Physics with Computers*. Then open the experiment file that matches the force sensor you are using. Set the range switch on the Force Sensor to 50 N. One graph will appear on the screen. The vertical axis will have force scaled from 0 to 20 Newtons. The horizontal has time scaled from 0 to 5 seconds.
4. Tie one end of a string to the hook on the Force Sensor and the other end to the hook on the wooden block. Place a total of 1 kg mass on top of the block, fastened so the masses cannot shift. Practice pulling the block and masses with the Force Sensor using this straight-line motion: Slowly and gently pull horizontally with a small force. Very gradually, taking one full second, increase the force until the block starts to slide, and then keep the block moving at a constant speed for another second.
5. Sketch a graph of force *vs.* time for the force you felt on your hand. Label the portion of the graph corresponding to the block at rest, the time when the block just started to move, and the time when the block was moving at constant speed.
6. Hold the Force Sensor in position, ready to pull the block, but with no tension in the string. Click at the top of the graph to set the Force Sensor to zero.

1. Click to begin collecting data. Pull the block as before, taking care to increase the force gradually. Repeat the process as needed until you have a graph that reflects the desired motion; including pulling the block at constant speed once it begins moving. Print or copy the graph for later reference. Choose Store Latest Run from the Data Menu to store the run as Run 1 for later analysis.


## Part II Peak Static Friction and Kinetic Friction

In this section, you will measure the peak static friction force and the kinetic friction force as a function of the normal force on the block. In each run, you will pull the block as before, but by changing the masses on the block, you will vary the normal force on the block.

Mass

Wooden block

Pull

*Figure 1*

**Dual-Range Force Sensor**

1. Remove all masses from the block.
2. Click to begin collecting data and pull as before to gather force *vs.* time data.

1. Examine the data by clicking the Statistics button, . The maximum value of the force occurs when the block started to slide. Read this value of the *maximum* force of static friction from the floating box and record the number in your data table.
2. Drag across the region of the graph corresponding to the block moving at constant velocity. Click on the Statistics button again and read the average (or mean) force during the time interval. This force is the magnitude of the kinetic frictional force.
3. Repeat Steps 9-11 for two more measurements and average the results to determine the reliability of your measurements. Record the values in the data table.
4. Add masses totaling 250 g to the block. Repeat Steps 9 – 12, recording values in the data table.
5. Repeat for additional masses of 500, 750, and 1000 g. Record values in your data table.

**DATA SHEET** Name

Name Period Class Date

# STATIC AND KINETIC FRICTION

**DATA TABLES**

## Part I Starting Friction

Mass of Block

kg

**Part II Peak Static Friction and Kinetic Friction**

|  |  |  |  |
| --- | --- | --- | --- |
| Total Mass (m) | Normal Force (N) | Peak Static Friction | Average Peak Static Friction(N) |
| Trial 1 | Trial 2 | Trial 3 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Total Mass (m) | Normal Force (N) | Kinetic Friction | Average Kinetic Friction (N) |
| Trial 1 | Trial 2 | Trial 3 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
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**ANALYSIS**

1. Print out or sketch the force *vs.* time graph drawn in Part I (stored as Run 1). Label the portion of the graph corresponding to the block at rest, the time when the block just started to move, and the time when the block was moving at constant speed.
2. Still using the force *vs.* time graph you created in Part I, compare the force necessary to keep the block sliding compared to the force necessary to start the slide. How does your answer compare to your answer to question 1 in the Preliminary Questions section?
3. The *coefficient of friction* is a constant that relates the normal force between two objects (blocks and table) and the force of friction. Based on your graph (Run 1) from Part I, would you expect the coefficient of static friction to be greater than, less than, or the same as the coefficient of kinetic friction?
4. For Part II, calculate the *normal force* of the table on the block alone and with each combination of added masses. Since the block is on a horizontal surface, the normal force will be equal in magnitude and opposite in direction to the weight of the block and any masses it carries. Fill in the Normal Force entries for both Part II data tables.
5. Plot a graph of the maximum static friction force (*y* axis) *vs*. the normal force (*x* axis). Use either Graphical Analysis or graph paper.
6. Since *Fmaximum static* = *s N*, the slope of this graph is the coefficient of static friction

*s*. Find the numeric value of the slope, including any units. Should a line fitted to these data pass through the origin?

1. In a similar graphical manner, find the coefficient of kinetic friction *k*. Use a plot of the average kinetic friction forces *vs.* the normal force. Recall that *Fkinetic* = *k N*. Should a line fitted to these data pass through the origin?

# EXTENSIONS

1. How is the force of friction or the coefficient of friction affected by the surface area of the block? Devise an experiment that can test your hypothesis.
2. Examine the force of static friction for an object on an incline. Find the angle that causes a wooden block to start to slide. Calculate the coefficient of friction and compare it to the value you obtain when the angle of the incline is 0 degrees.