

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, F_{static} , with the inequality $F_{static} \leq \mu_s N$, where μ_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 $F_{kinetic} = \mu_k N$, where μ_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*

LabPro with AC adapter

LabPro → computer cable

Vernier Force Sensor

mass set

Graphical Analysis or graph paper
string

block of wood with hook

balance or scale

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 or 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.
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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.
7. 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.

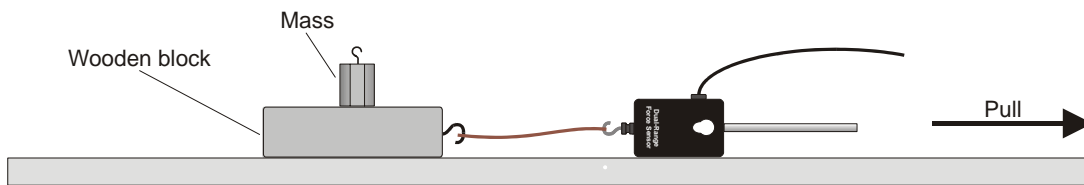



Figure 1

8. Remove all masses from the block.
9. Click to begin collecting data and pull as before to gather force *vs.* time data.
10. 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.
11. 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.

12. 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.
13. Add masses totaling 250 g to the block. Repeat Steps 9 – 12, recording values in the data table.
14. Repeat for additional masses of 500, 750, and 1000 g. Record values in your data table.

Part III Kinetic Friction Again

In this section, you will measure the coefficient of kinetic friction a second way and compare it to the measurement of Part II. Using the Motion Detection, you can measure the acceleration of the block as it slides to a stop. This acceleration can be determined from the velocity vs. time graph. While sliding, the only force acting on the block in the horizontal direction is that of friction. From the mass of the block and its acceleration, you can find the frictional force and finally, the coefficient of kinetic friction.

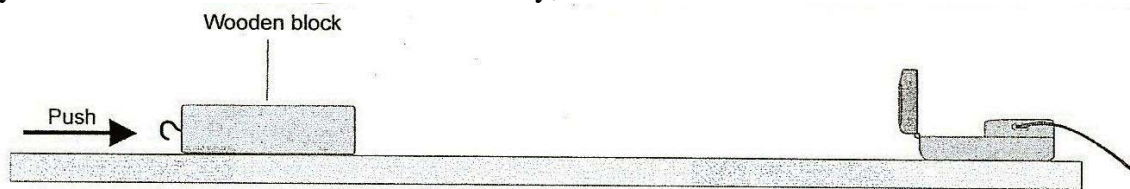



Figure 2

15. Connect the Motion Detector to DIG/SONIC 1 of the Vernier computer interface. Open the "12b Static Kinetic Frict" in the *Physics with Computers* folder.
16. Place the Motion Detector on the lab table 2-3 m from a block of wood, as shown in Figure 2. Position the Motion Detector so that it will detect the motion of the block as it slides toward the detector.
17. Practice sliding the block toward the Motion Detector so that the block leaves your hand and slides to a stop. Minimize the rotation of the block. After it leaves your hand, the block should slide about 1 m before it stops and it must not come any closer to the Motion Detector than 0.4 m.
18. Click to start collecting data and give the block a push so that it slides toward the Motion Detector. The velocity graph should have a portion with a linearly decreasing section corresponding to the freely sliding motion of the block. Repeat if needed.

Static and Kinetic Friction

19. Select a region of the velocity vs. time graph that shows the decreasing speed of the block. Choose the linear section. The slope of this section of the velocity graph is the acceleration. Drag the mouse over this section and determine the slope by clicking the Linear Fit button, . Record this value of acceleration in your data table.
 20. Repeat Steps 18-19 four more times.
 21. Place masses totaling 500 g on the block. Fasten the masses so they will not move. Repeat Steps 18-19 five times for the block with masses. Record acceleration values in your data.
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DATA SHEET

Name _____

Name _____

Period _____ Class _____

Date _____

STATIC AND KINETIC FRICTION**DATA TABLES****Part I Starting Friction**

Mass of Block	kg
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Part II Peak Static Friction and Kinetic Friction

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

Total Mass (m)	Normal Force (N)	Kinetic Friction			Average Kinetic Friction (N)
		Trial 1 (N)	Trial 2 (N)	Trial 3 (N)	

Part III Kinetic Friction

Data: Block with no additional mass			
Trial	Acceleration (m/s ²)	Kinetic friction force (N)	μ_k
1			
2			
3			
4			
5			
Average coefficient of kinetic friction:			

Data: Block with 500 g additional mass			
Trial	Acceleration (m/s ²)	Kinetic friction force (N)	μ_k
1			
2			
3			
4			
5			
Average coefficient of kinetic friction:			

ANALYSIS

1. Printout or sketch of force *vs.* time graph from Part I. 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?

Static and 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 (vertical axis or y axis) *vs.* the normal force (horizontal axis or x axis). Use either *Logger Pro* or graph paper.
6. Since $F_{\text{maximum static}} = \mu_s N$, the slope of this graph is the coefficient of static friction μ_s . Find the numeric value of the slope, including any units. Should a line fitted to these data pass through the origin?
7. In a similar graphical manner, find the coefficient of kinetic friction μ_k . Create a plot of the average kinetic friction forces *vs.* the normal force. Recall that $F_{\text{kinetic}} = \mu_k N$. Should a line fitted to these data pass through the origin?
8. Your data from Part III also allow you to determine μ_k . Draw a free-body diagram for the sliding block. The kinetic friction force can be determined from Newton's second law, or $\Sigma F = ma$. From the mass and acceleration, find the friction force for each trial, and enter it in the data table.
9. From the friction force, determine the coefficient of kinetic friction for each trial and enter the values in the data table. Also, calculate an average value for the coefficient of kinetic friction for the block and for the block with added mass.
10. Does the coefficient of kinetic friction depend on speed? Explain, using your experimental data.
11. Does the force of kinetic friction depend on the weight of the block? Explain.
12. Does the coefficient of kinetic friction depend on the weight of the block?
13. Compare your coefficients of kinetic friction determined in Part III to that determined in Part II. Discuss the values. Do you expect them to be the same or different?

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° .
 3. Try changing the coefficient of friction by using water, wax, or furniture polish on the table. How much does it change?
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