Static and Kinetic Friction

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 counters your force on 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 is 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 and kinetic friction depend on the surfaces of the box and the floor, and on how hard the box and 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 Dual-Range Force Sensor to study static friction and kinetic friction on a wooden block.

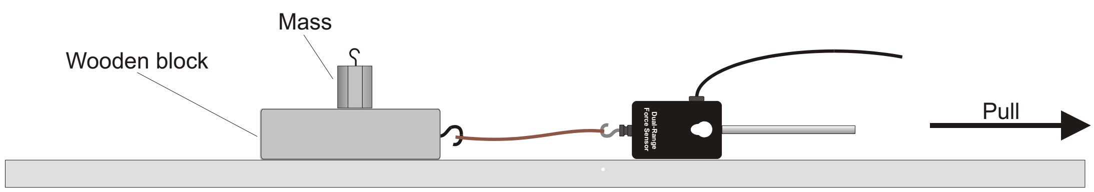

Figure 1

PRELIMINARY QUESTIONS

1. In everyday life, you often experience one object sliding against another. Sometimes they slip easily and other times they do not. List some things that seem to affect how easily objects slide.

2. Consider a box sitting on a table. It takes a large force to move it at constant speed. List at least two ways you could reduce the force needed to move the box at constant speed.

3. 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 answer?

***Name:*__________________________________ *Block:*________ *Date:*_______________**

OBJECTIVES

- Use a Dual-Range Force Sensor to measure the force of static and kinetic friction.
- Determine the relationship between force of static friction and the weight of an object.
- Measure the coefficients of static and kinetic friction for a particular block and track.
- Determine if the coefficient of kinetic friction depends on weight.

MATERIALS

computer	string
Vernier computer interface	block of wood with hook
Logger *Pro*	balance **or** scale
mass set	Vernier Dual-Range Force Sensor

PROCEDURE

Part I Starting Friction

1. Measure the mass of the block and record it in the data table.

2. Set the range switch on the Dual-Range Force Sensor to 10 N. Connect the Force Sensor to Channel 1 of the interface.

3. Open the file "12a Static Kinetic Frict" from the *Physics with Vernier* folder.

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. Before you collect data, practice pulling the block and masses with the Force Sensor using a 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 [Ø Zero] to set the Force Sensor to zero.

7. Click [▶ Collect] 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 use in the Analysis portion of this activity.

Part II Peak Static Friction and Kinetic Friction

In this part, you will measure the peak static friction force and the kinetic friction force as a function of the normal force on the block, as shown in Figure 1. 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.

8. Remove all masses from the block, then place masses totaling around 250 g on the block.
9. Click ▶ Collect to begin collecting data and pull as before to gather force *vs.* time data.
10. Examine the data by clicking Statistics, STAT. 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 Statistics, STAT, 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 ~500 g to the block. Repeat Steps 9–12, recording values in the data table.
14. Repeat for a total mass of ~1000 g. Record values in your data table.

DATA TABLE

Part I Starting Friction

Mass of block	kg

Part II Peak Static Friction and Kinetic Friction

Total mass (kg)	Normal force (N)	Peak static friction			Average peak static friction (N)	Coefficient of Static Friction, μ_s
		Trial 1	Trial 2	Trial 3		

Total mass (kg)	Normal force (N)	Kinetic friction			Average kinetic friction (N)	Coefficient of Kinetic Friction, μ_k
		Trial 1	Trial 2	Trial 3		

ANALYSIS

1. Inspect your 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 Preliminary Question 3?

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. For Part II, calculate the *coefficients of static* and *kinetic friction* for the block on the table surface using the friction equation from your notes or textbook. Fill in the μ_s and $\mu_{k.}$ columns in the appropriate tables.

6. Are all the coefficients of static friction the same or nearly so? Explain.

7. Are all the coefficients of kinetic friction the same or nearly so? Explain.

8. Does the *force* of kinetic friction depend on the weight of the block? Explain.

9. Does the *coefficient* of kinetic friction depend on the weight of the block? On what does it depend?

EXTENSIONS

1. How does the surface area of the block affect the force of friction or the coefficient of friction? 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 wax or furniture polish on the table. How much does it change?