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 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} £ m_s N where m
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 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 $F_{kinetic}$ = m
kinetic friction.

In this experiment, you will use a Force Sensor to study static friction and kinetic friction between a sled and a wooden board.

OBJECTIVES

- Use a Force Sensor to measure the force of static friction.
- Determine if the force of static friction depends on the weight of an object.
- Measure the coefficients of static and kinetic friction between a sled and a wooden board.
- Determine if the coefficient of kinetic friction depends on weight.

MATERIALS

Windows PC	Wooden board
Universal Laboratory Interface	Vernier Force Sensor
Logger *Pro*	Sled or block of wood
string	balance or scale
Graphical Analysis or graph paper	mass set
	Vernier Motion Detector

PROCEDURE

Part I Interpreting the Force graph

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

2. Tie one end of a string to the hook on the Force Sensor and the other end to the hook on the block of wood. Place the block felt side down on the board and put a total of 500g mass on top of the block. 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 sled moving at a constant speed.

3. Hold the Force Sensor in position, ready to pull the sled, but with no tension in the string. Click on **0** at the top of the graph to set the Force Sensor to zero.

1. Click 

to begin collecting data. Pull the sled 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 the graph. Label the portion of the Force graph corresponding to the block at rest, the time when the block just started to move, and the time when the block was moving with constant speed.

2. Compare the force necessary to keep the block sliding compared to the force necessary to start the slide. 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?

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 it.

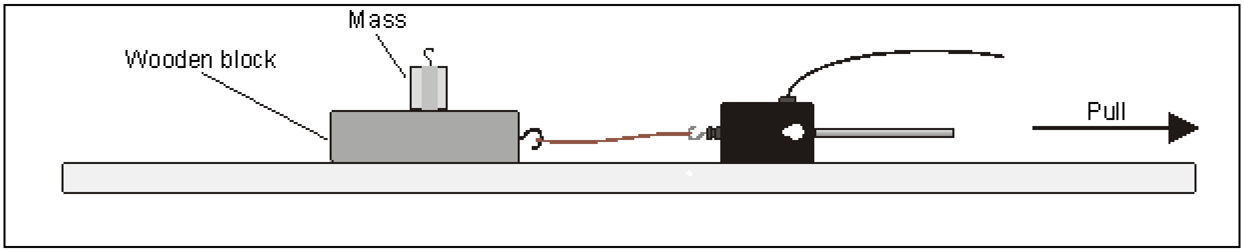

Figure 1

1. Place the block felt side down on the board and put a total of 500g mass on top of the block.

2. Click to begin collecting data and pull as before to gather force *vs.* time data.

3. 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.

4. 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 force during the time interval. This force is the magnitude of the kinetic frictional force. Record this number in your data table.

5. Repeat Steps 2-4 for two more measurements and average the results to determine the reliability of your measurements. Record the values in the data table.

6. Add masses totaling 700 g to the sled. Repeat Steps 2 – 4, recording values in the data table.

7. Repeat for additional masses of 900g, and 1200g, and 1500g. Record values in your data table.

8. Draw a free body diagram for the block. Calculate the *normal force* on the sled alone in each case. Clearly explain your reasoning. Fill in the Normal Force entries in both data tables.

9. Explain why in this experiment the tension force measured by the force sensor is equal to the friction force.

10. Since $F_{maximum\ static}$ = m
static friction m_s. Construct a graph, and include uncertainties as uncertainty bars on the graph. Use the graph to find m_s ± *uncertainty*. Explain how you used the graph to find the coefficient. Include your reasoning.

11. In a similar graphical manner, find the coefficient of kinetic friction m
friction forces, and recall that $F_{kinetic}$ = $m_k N$.

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

13. Does the ***coefficient*** of kinetic friction depend on the weight of the block?

Part III Another Way to Measure the Peak Static Friction

1. Place the block with the felt side down on the board. Slowly raise the board to get the block on the verge of sliding down. Measure the vertical distance between the edge of the board and the table.

2. Repeat this process six more times. Average the result and find the uncertainty. Measure the length of the board an determine the Sin of the angle of incline and its associated uncertainty.

3. Draw a free-body-diagram for the block on the incline when it is on the verge of sliding down. Apply Newton's Second Law to the block and use your measurement to determine the coefficient of static friction between the block and the board.

4. Compare (find % difference between) the coefficient of static friction from part II with the coefficient of static friction from part III.

Total mass (m)	Normal force (N)	Peak static friction			Average ± uncertainty
		Trial 1	Trial 2	Trial 3	peak static friction (N)

Total mass (m)	Normal force (N)	Kinetic friction			Average ± uncertainty
		Trial 1	Trial 2	Trial 3	kinetic friction (N)