Physics I – Lab #5 – 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 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 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 Force Sensor to study static friction and kinetic friction on a wooden sled. A Motion Detector will also be used to analyze the kinetic friction acting on a sliding sled.

Part 1 – Wood Sleds on Lab Tables

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

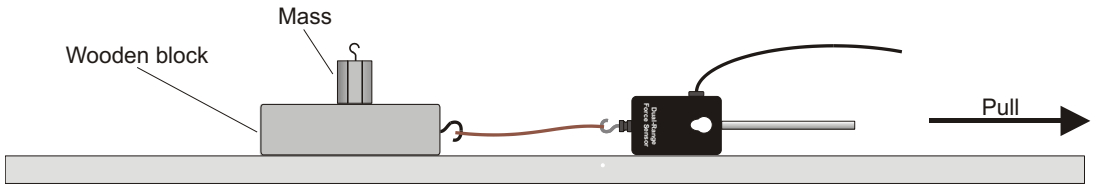
Part 1A Starting Friction

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

2. Connect the Dual-Range Force Sensor to Channel 1 of the interface. Set the range switch on the Force Sensor to 50 N.

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 "sled". Place a total of 1 kg mass on top of the sled, fastened so the masses cannot shift. Practice pulling the sled 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 sled starts to slide, and then keep the sled 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 sled at rest, the time when the sled just started to move, and the time when the sled was moving at constant speed.

6. Hold the Force Sensor in position, ready to pull the sled, but with no tension in the string. Click Zero to set the Force Sensor to zero.

7. Click Collect 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 sled at constant speed once it begins moving. Print or copy the graph for use in the Analysis portion of this activity.

Part 1B 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 sled. In each run, you will pull the sled as before, but by changing the masses on the sled, you will vary the normal force on the sled.

8. Remove all masses from the sled.

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

10. Examine the data by clicking the Statistics button, STAT. The maximum value of the force occurs when the sled 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 sled 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 sled. 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.

ANALYSIS

1. Inspect the printout or sketch of force *vs.* time graph from Part I. Label the portion of the graph corresponding to the sled at rest, the time when the sled just started to move, and the time when the sled 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 sled 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 (sleds 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 sled alone and with each combination of added masses. Since the sled is on a horizontal surface, the normal force will be equal in magnitude and opposite in direction to the weight of the sled 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) *vs*. the normal force (horizontal axis). Use either Logger *Pro* or graph paper.

6. Since $F_{maximum\ static} = \mu_s N$, 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 $F_{kinetic} = \mu_k N$. Should a line fitted to these data pass through the origin?

8. Draw a free body diagram of the sled with the masses on it as it pulled. Which forces need to be equal to each other over different parts of the experiement?

DATA TABLE

Part 1A Starting Friction

Mass of sled	kg

Part 1B 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	

Part 2 – Wood Sleds on Another Material

Using the technique from Part 1, determine the coefficients of static and kinetic friction between the wooden sleds and some other surface. You are free to use anything you can find in the lab for your secondary surface, including aluminum foil, granite, sand paper, etc. Before you conduct your experiment, ***make a prediction*** about whether you think the coefficients of friction will be larger, smaller, or the same. Then, using the protocols you used in Part 1, determine your coefficients of static and kinetic friction.