Static and Kinetic Friction

Objectives

In this lab you will

- investigate how friction varies with the applied force.
- measure the coefficients of static and kinetic friction.
- learn how to use the Vernier Force Sensor.
- plot your data and analyze it using the Vernier Logger Pro™ software.

Equipment

Vernier Force Sensor, Vernier LabPro™ system (includes computer and Logger Pro™), a set of masses in a wooden mass holder (with a hook on one end), a mass scale, and string.

Theory

The friction forces that arise between any two contacting surfaces are divided into two broad categories based on the relative motion of the surfaces. *Static friction* exists whenever there is no relative motion and *kinetic friction* whenever one surface moves relative to the other. The magnitude of each friction force depends on the number of the chemical bonds formed between the two surfaces and their average strength. The direction of each friction force is always opposite the horizontal component of the applied force.

Suppose you wish to slide a heavy box of mass m along a horizontal surface with a force F. As you increase F, an equal and opposite static friction force f_s arises to keep the box at rest until F equals the maximum value of f_s:

$$f_s\,(\text{max}) = \mu_s N \qquad \textbf{Equation 1}$$

where μ_s is the coefficient of static friction and N is the normal force. When F exceeds f_s (max), static friction is no longer present. The box now slides in the direction of F. A kinetic friction force f_k now acts to opposite the motion. Unlike its static counterpart, f_k does not match the applied force up to a maximum value. Its magnitude is constant and given by the formula

$$f_k = \mu_k N \qquad \textbf{Equation 2}$$

where μ_k is the coefficient of kinetic friction. If you wish to slide the box at uniform velocity, then F must equal f_k by Newton's 1st Law. However, if you accelerate the box, then $F > f_k$ by Newton's 2nd Law.

Coefficients μ_s and μ_k are depend upon the average bond strength between the two surfaces. The normal force along a flat surface is simply equal to the weight of the object, or $N = mg$. N is an indirect measure of the number of bonds formed between the two surfaces. In other words, heavier objects require greater forces to get them moving because they press their supporting surface tighter thus forming more bonds.

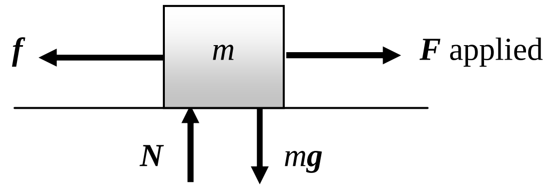

Figure 1 – A mass *m* pulled along a rough surface

Procedure

Preliminary Set-Up

1) Disconnect the motion detector from the Lab Pro interface. Connect the cable of the force sensor to Channel 1 of Lab Pro.

2) Set the force sensor at ±10 N.

3) Open the file "12a Static Kinetic Friction" in Program_Files/Vernier_Software/LoggerPros/Experiments/Physics_with_Computers.

A force-time graph will be displayed. If you encounter any problems accessing this file, ask your instructor for help.

Data Collection and Display

1) Remove the masses from their wooden holder. <u>Measure the mass of the empty wooden holder and record its value on your data sheet</u>.

2) Fasten a piece of string to the hook on the force sensor, and then fasten the opposite end to the hook on the wooden mass holder (Photo 1). Replace all the masses in the wooden holder.

3) Brush off any dust and other debris on the surface of the lab table.

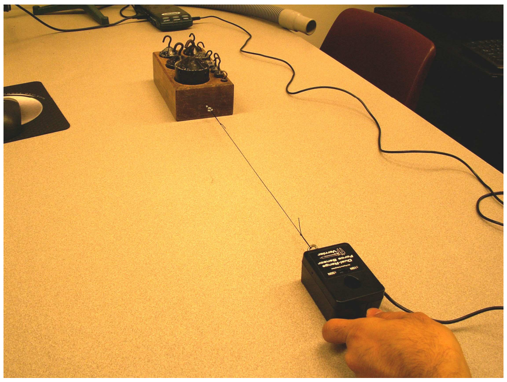

Photo 1 – Pulling the force sensor.

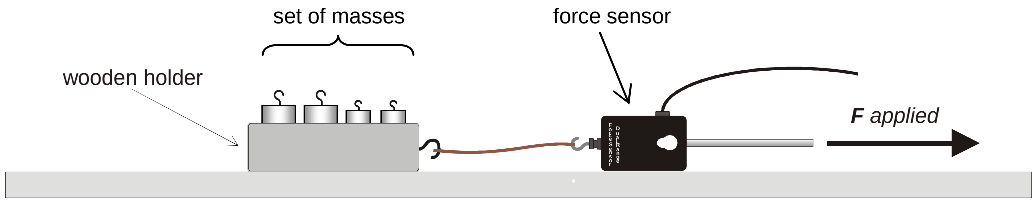

Figure 2 – A wooden block + hooked mass is pulled with the force sensor.

4) Gently pull the force sensor with a horizontal force *F* as shown in Figure 2. Increase ***F*** slowly and steadily until the wooden holder begins to slide. At this point, you may have to decrease ***F*** so that the holder maintains a uniform velocity.

5) Click Collect ▷ and repeat Step 4 for a 10-sec time interval. Your force-time graph should closely resemble Figure 3. If not, then repeat until you get the same behavior.

6) Before you are ready to graph your force data, you need to calibrate the force sensor. Do not pull the wooden mass holder. Make sure that there is slack in the string (i.e. zero tension) and click the Zero button.

7) Remove all the masses from the holder except the 1000-gram mass. Click Collect ▷ and repeat Step 4 for a 10-sec time interval. Use the X= button to measure the maximum value of the static friction force f_s (Equation 1) on your force-time graph. Use the STAT button to measure the mean value of the kinetic friction force along the horizontal portion of your graph. <u>In Table 1 of your data sheet, record the total mass, its total weight, and the maximum static friction under Trial 1. In Table 2, record the total mass, its total weight, and the mean kinetic friction under Trial 1. Do two more trials with the same total mass and likewise record the results. Compute the average of your three trials.</u> Continue recording data until each table is complete.

8) Open Excel to make two graphs. Enter the total weight in column A. For the first graph, input the average maximum static friction in column B. Its title should be "Average Max Static Friction vs. Total Weight." Fit the data set to a straight line. <u>Find the slope (which equals the coefficient of static friction) and record it on your data sheet</u>. For the second graph, input the average kinetic friction in column B. Its title should be "Average Kinetic Friction vs. Total Weight." Fit the data set to a straight line. <u>Find the slope(which equals the coefficient of kinetic friction) and record it on your data sheet</u>.

9) <u>Answer the questions after you have created and printed your graphs</u>.

Each student is required to submit a completed data sheet in order to receive full credit. Your lab group needs to submit only one set of force-time graphs (maximum static friction, kinetic friction). These two graphs are to be stapled to the data sheet of one of your lab partners – Each lab partner does not need to submit his/her own set of graphs.

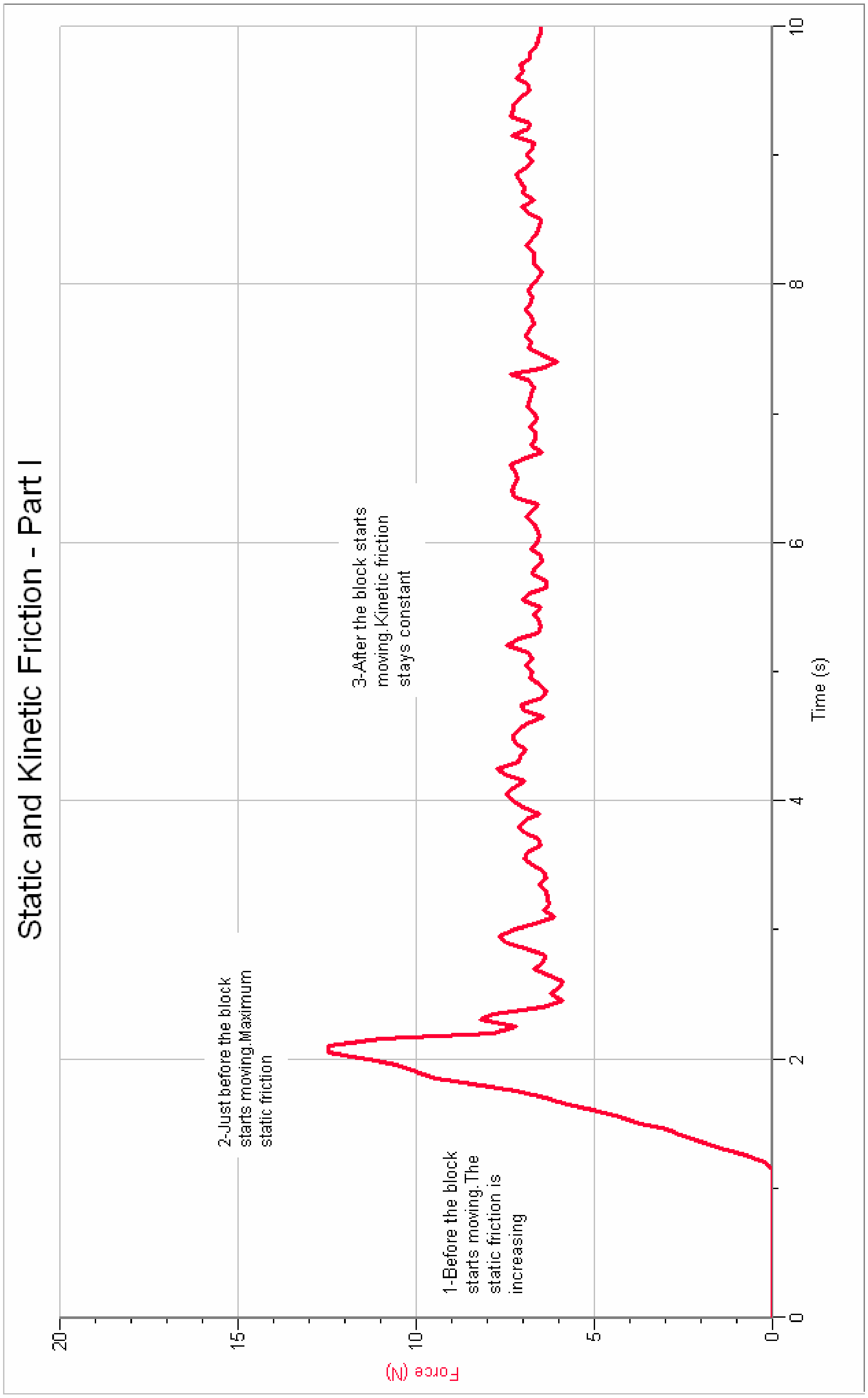

Figure 3 – A sample force-time graph

Data Sheet – Static and Kinetic Friction

Name ________________________________ Date ______________

Partners' Names ____

Data and Analysis

Mass of empty wooden holder = ____________________ kg

Table 1 – Static friction data

wooden holder +	total mass [kg]	total weight [N]	f_s (max) Trial 1 [N]	f_s (max) Trial 2 [N]	f_s (max) Trial 3 [N]	f_s (max) Average [N]
1000 g						
1500 g						
1700 g						
1900 g						
2000 g						

Table 2 – Kinetic friction data

wooden holder +	total mass [kg]	total weight [N]	f_k Trial 1 [N]	f_k Trial 2 [N]	f_k Trial 3 [N]	f_k Average [N]
1000 g						
1500 g						
1700 g						
1900 g						
2000 g						

Slope of the static friction graph μ_s = ____________________

Slope of the kinetic friction graph μ_k = ____________________

Questions on reverse side…

Questions:

1) For a fixed trial, compare your values for the average maximum static friction force (Table 1) and the average kinetic friction force (Table2). Based on your data, which one is larger? Is this reasonable? Explain your results.

2) Does the average kinetic friction force vary as the total weight increases? If so, explain why.

3) For a particular weight, compare the coefficient of static friction and the coefficient of kinetic friction. Based on your data, which is larger? Is this reasonable? Explain your results.

4) What are the SI units of these two coefficients? Justify your answer using Equations 1 and 2.