Name: ________________________________

Partner(s): ____________________________

1125 Section: __________

Desk # _______________

Date: _________________

Static and Kinetic Friction

Apparatus

Computer, LabPro interface box, string, block of wood with hook, motion detector, force sensor, 2-pan balance, masses set.

Part I Observing the Starting and Sliding Friction

Set the switch on the force sensor to 10 N and connect it to Channel 1 of the LabPro interface box.

Run the LoggerPro program and open the file _*Physics with Vernier\12a Static Kinetic Frict.cmbl*. One graph will appear on the screen. The vertical axis will have force scaled from 0 to 10 Newtons. The horizontal should have time scaled from 0 to 5 seconds.

With only the 1 kg mass in the mass box, wedge the mass box on top of the wooden block so that it will not shift.

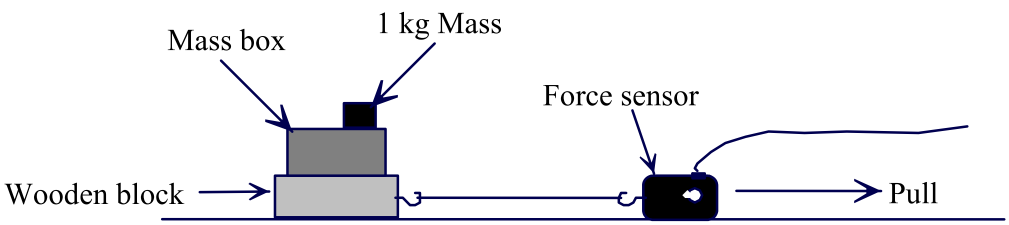

Figure 1

Practice pulling the block and masses horizontally as shown in Figure 1. Only pull on the knob or the sensor itself; do not pull on the cable. 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.

"Zero" the sensor with the string slack. Then click the "Collect" button to collect data, repeating as needed until you have a graph that reflects the desired motion, including the force increasing from zero and pulling the block at constant speed. Re-scale the graph if needed.

In the space below, sketch the force vs. time graph as you see on the screen, and label following *regions or instants*. (You may use letters A, B, C to label.)

(A) when the block was at rest
(B) when the block started to move
(C) when the block was moving at constant speed

Answer the questions below:

The force sensor measures the tension in the string, but we use its readings to represent the static and kinetic frictional forces. To do so, we must keep the acceleration of the block almost zero. Why?

From your graph, compare the force necessary to keep the block sliding and the force necessary to start the slide. Which is greater?

Is your answer above consistent with your answer to the prelab?

☐ Yes ☐ No

Part II Measure the Coefficients of Static Friction and Kinetic Friction

In this part, you will calculate the coefficient of static friction and the coefficient of kinetic friction based on measurements of the appropriate friction forces from the graph.

Measure the mass of the assembly (wooden block and the empty mass box) using the 2-pan balance and record it below.

Mass of the assembly: (___________ ± ________) g (_____ counter masses were used)

With the empty mass box, collect force vs. time data as you did in Part I. Check that the highest peak happens when the block is starting to move, and that there is a constant region when the block moves at constant velocity. If not, re-do the run, zeroing the sensor between runs.

Use the "Statistics" button to find the maximum static friction force $f_{s,max}$ and separately, the mean or average kinetic friction force f_k. Record both values in the first row of the table below.

		Max. static friction force $f_{s,max}$ (N)	Kinetic friction force f_k (N)	Total mass m (kg)	Coefficient of static friction μ_s	Coefficient of kinetic friction μ_k
Assembly only	Trial 1					
	Trial 2					
Assembly + 500g	Trial 1					
	Trial 2					
Assembly + 1000g	Trial 1					
	Trial 2					
				Average:		
				Uncertainty from scatter:		

Convert the total mass into kg. Then use your equations from the prelab to calculate the coefficients of static friction and kinetic friction. Fill these results in the table to finish the first row. Do another trial and observe the size of variations between trials. Then repeat with 500g and 1000g masses in the mass box, two trials for each configuration.

When you have done all 6 trials, find the average and the uncertainty of each coefficient to complete the table. We will not do uncertainty propagation for this problem. Instead we will calculate the uncertainty from the scatter of the 6 coefficients:

The scatter of multiple numbers is (max. number − min. number)/2.

Conclusions

In sentence form, state both coefficients with uncertainties, in proper conclusion format: First, the uncertainty must be rounded to one or two non-zero digits. Second, the value and the uncertainty must have same decimal precision.

Answer the questions below:

From your data, does the maximum static friction force or the kinetic friction force appear to be dependent on the weight of the block?

☐ Dependent ☐ Independent ☐ Hard to say

From your data, does the coefficient of static friction or the kinetic friction appear to be dependent on the weight of the block?

☐ Dependent ☐ Independent ☐ Hard to say

Is the coefficient of static friction bigger than the coefficient of kinetic friction, as expected?

☐ Yes ☐ No

Part III Measure the Coefficient of Kinetic Friction with a Motion Detector

In this part, we will use a different method to measure the coefficient of the kinetic friction. When you let a block slide on the floor by itself, its speed will decrease and it will finally come to a stop. The acceleration is determined by the kinetic friction and mass of the block. As shown in your prelab, one can calculate the coefficient of kinetic friction from the acceleration of the block, which can be measured by a motion detector and the Logger Pro program.

Connect the motion detector to one of the DIG/SONIC ports of the LabPro interface box. Open the file *_Physics with Vernier\12b Static Kinetic Frict.cmbl*. Two graphs, position and velocity, will appear on the screen.

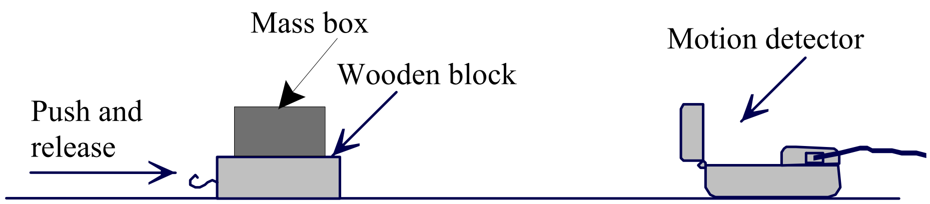

Figure 2

After clicking the "Collect" button, give the block a quick push, to let it slide toward the motion sensor. You should see on the *v-t* graph a portion where the speed decreases linearly to 0. Sketch the *v-t* graph in the box below and label following regions or instants. (You may use letters A, B, C.)

(A) when the block was pushed by your hand
(B) when the block was released from your hand
(C) when the block was moving under kinetic friction only

How will you find the acceleration due to the kinetic friction from the *v-t* graph?

The motion detector takes "the positive" to be away from itself. Therefore, the velocity of the block is ____________ (positive/negative), and the acceleration due to the kinetic friction is ____________ (positive/negative). They are in the ____________ (same/opposite) direction, which is why the block is _________________ (speeding up/slowing down).

Once you get a good run, record the acceleration due to the kinetic friction in the table below to finish the first row. The correlation value reflects the quality of the linear fit, with 1 (and −1) being perfectly linear. If the correlation is less than 0.99, retry the fit or redo the run. Do another trial with the empty mass box to observe the variations, then repeat with 200g and 500g masses in the mass box.

Calculate the average and the uncertainty from scatter (a and δa).

		Acceleration due to the kinetic friction a (m/s^2)	Correlation value
Assembly only	Trial 1		
	Trial 2		
Assembly + 200g	Trial 1		
	Trial 2		
Assembly + 500g	Trial 1		
	Trial 2		
	Average:		
	Uncertainty (from scatter):		

Answer the questions below:

From your data, does the acceleration appear to be dependent on the mass of the block?

☐ Dependent ☐ Independent ☐ Hard to say

According to Newton's Second Law, acceleration is inversely proportional to the mass, so a heavier mass is harder to accelerate. Why doesn't the heavier mass have a smaller acceleration in this case?

Can we tell from this experiment if the kinetic friction depends on the speed? Students give different answers below:

Student A: Yes, the kinetic friction does depend on the speed. Because a higher speed leads to higher acceleration, there will be a bigger force.

Student B: No, the kinetic friction does not depend on the speed. It only depends on the acceleration.

Student C: No, the kinetic friction does not depend on the speed. Because the *v-t* graph is linear, the acceleration was constant during the slide, and the force was the same for high and low speeds.

Which student gives the correct answer? ☐ A ☐ B ☐ C

Calculations

Calculate μ_k from the average acceleration using the equation you derived in the prelab.
$g = (9.81 \pm 0.01)$ m/s^2.

Uncertainty Analysis

Calculate $\delta\mu_k$ using the equation you derived in the prelab.

Conclusions

State the result of the coefficient of kinetic friction μ_k in the sentence form and in proper format.

Answer the questions below:

Compare the two values of μ_k found in Part II and III. Do you expect them to be same or different? Explain why.

Bonus Questions (Each answer is worth 0.5 marks.)

How is the force of friction or the coefficient of friction affected by the size of the surface area in contact with the floor? Describe an experiment using the available apparatus to test your hypothesis.

Examine the forces on a wooden block on an incline. Draw the FBD of the block just before it starts to slide. How is the coefficient of static friction related to the angle of the incline?