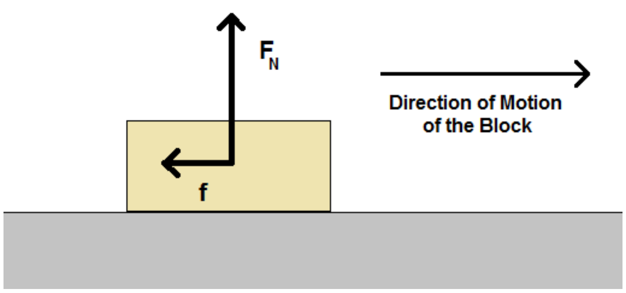
Friction

Equipment	Qty.
Force sensor	1
Data Studio	1
1 kg mass	1
2 kg mass	2
5 kg mass	1
Wooden block	2
Wooden board	1
Inclinometer	1
Triple Beam Balance	1

Friction between two surfaces is the result of weak molecular bonds between the surfaces. These bonds can be easily broken when one surface moves across the other, and this transforms kinetic energy and work into heat. Consequently, we say that friction is a **dissipative** force (mechanical energy is dissipated).



The figure shows a block sliding on a level smooth surface. The normal force is indicated, as well as the friction force resisting the motion. These two forces are proportional to each other. Also, we differentiate between kinetic and static friction.

$$f_k = \mu_k F_N$$

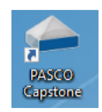
$$f_s = \mu_s F_N$$

Where f_k & μ_k are the kinetic friction force and coefficient of kinetic friction, f_s & μ_s are the static friction force and coefficient of static friction, and F_N is the normal force exerted by the surface.

The first expression gives the force of kinetic friction resisting the motion of a moving block, while the second gives the maximum frictional force that the surface can exert on a motionless block. The two friction coefficients are different and you will usually find that the static coefficient is higher.

Setup

1. Plug the force sensor into the A port of the "Analog Inputs" on the 850 data collection box. Note that the 8 pin DIN connector must be inserted with the arrows on top.
2. Double click the Capstone icon to start the data collection software.



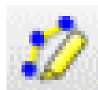
3. Click on the Hardware Setup icon.

4. You should see an image of the 850 box. Click on the port A plug in "Analog Inputs."
5. Choose "Force Sensor."
6. Click again on "Hardware Setup" to dismiss it.
7. The "Record" button should now be red, indicating that the photogate can collect data.

8. Double click on the graph icon (on the right-hand side

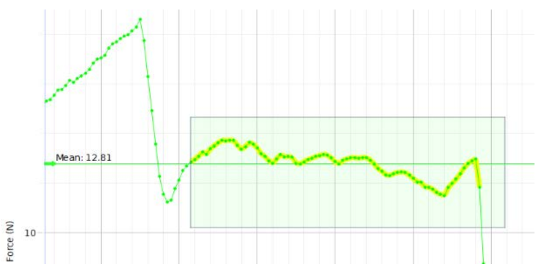
of the window) to bring up graph in the main page.

9. Click <Select Measurement> on the vertical axis and choose “Force.”
10. When running an experiment, be sure to begin pushing the force sensor lightly against the block and build up force slowly. When the block begins to move, try to push it along at a constant speed.
11. To find the average value of the kinetic friction measurements, click the Highlight button and frame just the desired data.



12. You can display the Mean of these data by clicking on the Statistics icon. Clicking on the pull-down menu on the Statistics icon will allow you to check “Mean.”

13. Your graph should look something like the figure below.

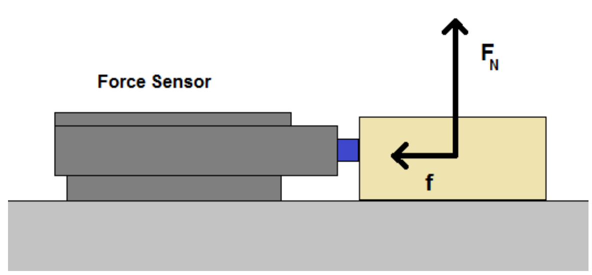


14. To find the static friction just before the block began to slide, you can expand the highlight box to include the peak of the graph, and then check “Maximum” in the Statistics pull-down menu.
15. When the experiment is finished, you can kill the Capstone window. When you’re asked whether to save changes, click “Discard.”

Procedure:

Both friction coefficients can be measured in the same trial. The force sensor will be used to push the block, and the computer will plot force as a function of time.

1. Weigh the small wooden block.
2. Place the 1 kg mass on the block.
3. Record the total mass including block in the appropriate column of the data table.
4. Calculate the weight of the total mass and record this under “Normal Force.”
5. Click “start” on the Capstone software.
6. Push the rubber knob on the force sensor against the block, slowly increasing force until the block “breaks free” of the static friction, then push the block for a short distance at a constant speed.
7. Click “stop” on Capstone.
8. Highlight the data points at the peak of the graphed data.
9. The “Max.” value is your static friction force. Record this under f_s for this trial.
10. Next, highlight only the data points associated with the block sliding at a constant speed.
11. Record the “Mean” value under f_k in your data table.
12. Now place 2 kg on the block and repeat the procedure starting from step 3. Do this in 1 kg increments up to 6 kg.



When you've finished all six trials (with 1 through 6 kg on the block), place the block on the wooden board and repeat the whole process.

Data Table for Block on Lab Tabletop

Total Mass (kg)	Normal Force (N)	f_s (N)	f_k (N)	μ_s	μ_k

Data Table for Block on Board

Total Mass (kg)	Normal Force (N)	f_s (N)	f_k (N)	μ_s	μ_k

When you've finished all the data collection, calculate μ_s and μ_k for each row of the tables. Then calculate the averages and standard deviations for the friction coefficients.

	μ_s Block: Table	μ_s Block: Board	μ_k Block: Table	μ_k Block: Board
Average				
St Dev.				
Avg/StDev				

Block on an Inclined Surface:

Now you'll do one more set of trials on an inclined surface. Remember that the normal force is always perpendicular to the surface, so it's different from the weight of the object being pushed. Also, there are now two forces resisting your push: friction, and the component of the block's weight that points downhill. As you push the block and mass up the slope, the total force being provided by the force sensor is

$$F_k = mg\sin\theta + \mu_k mg\cos\theta$$

Where θ is the slope of the incline from horizontal, m is the mass being pushed, and μ_k is the coefficient of kinetic friction between the block and the inclined board. This can be solved for μ_k:

$$\mu_k = \frac{F_k - mg\sin\theta}{mg\cos\theta}$$

A similar equation for the static friction force is as follows.

$$\mu_s = \frac{F_s - mg\sin\theta}{mg\cos\theta}$$

Procedure:

1. Place the big wooden block under the end of the board.
2. Use the inclinometer to measure the slope and record here: $\theta =$_____
3. Place the small block on the sloped board and place the 1 kg mass on it.
4. Record data as before, using 1, 2, 3, and 4 kg. This is total force against the block, not just friction force.
5. Using the equations above, determine μ_k and μ_s.

Total Mass (kg)	F_s (N)	F_k (N)	μ_s	μ_k
Average μ values				

Questions:

1. Theoretically, the coefficients should be independent of the normal force (the weight that's being pushed). If this is true, then each coefficient should be many times larger than its standard deviation. Divide each coefficient by its standard deviation.
2. For kinetic friction, is there greater frictional force for block/table or block/board?
3. For static friction, is there greater frictional force for block/table or block/board?
4. You determined μ_k for the block/board twice: once when the board was level, once when it was inclined. Find the percent difference between the two values.