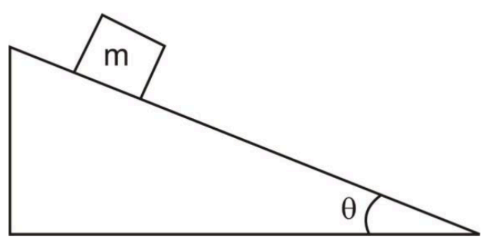
Friction

Learning objectives

- Use a spreadsheet to record and analyze data
- Draw a free-body diagram
- Apply Newton's first law of motion
- Understand friction

Part 1 - Friction on a Ramp

A block of mass m is at rest on a ramp. The ramp makes an angle θ with the horizontal.



Based on a free-body diagram of m, express the frictional force f and the normal force n in terms of the variables g,m, and θ.

When the block is at rest, static friction is the frictional force that is acting. Static friction has the value $f_s \leq \mu_s n$. As we increase the angle of incline, the frictional force grows until it reaches its maximum value. Then $f_s = \mu_s n$. If we go greater than this angle, the static friction cannot get any larger and the block slips. This angle is called the "critical angle" θ_c.

Substitute, into the equation for static friction, $f_s = \mu_s n$, the expressions for f and n that you solved for previously. Set $\theta = \theta_c$. You should now have an expression for μ_s that depends only on θ_c.

Make sure there is paper on the incline apparatus. Place the block on the inclined plane with the wide side facing down. Slowly and gently lift the incline until the block starts to move. Do this several times and **record a range of angles that you are sure the critical angle falls within.**

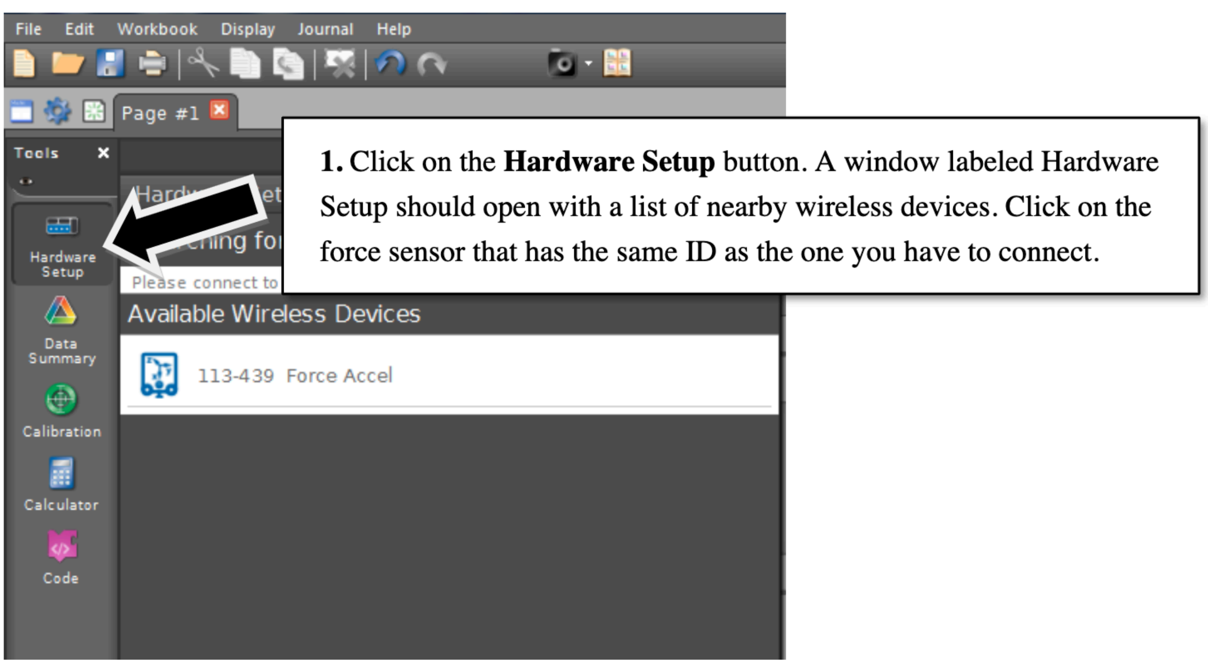
Use this range of angles to determine a range of coefficients that μs falls within.

Part 2 - Friction on a Horizontal Surface

Tie a string to the hook attached to the wooden block and place a 250-gram mass M on top of the block. Tie the other end of the string to the hook on the force sensor.

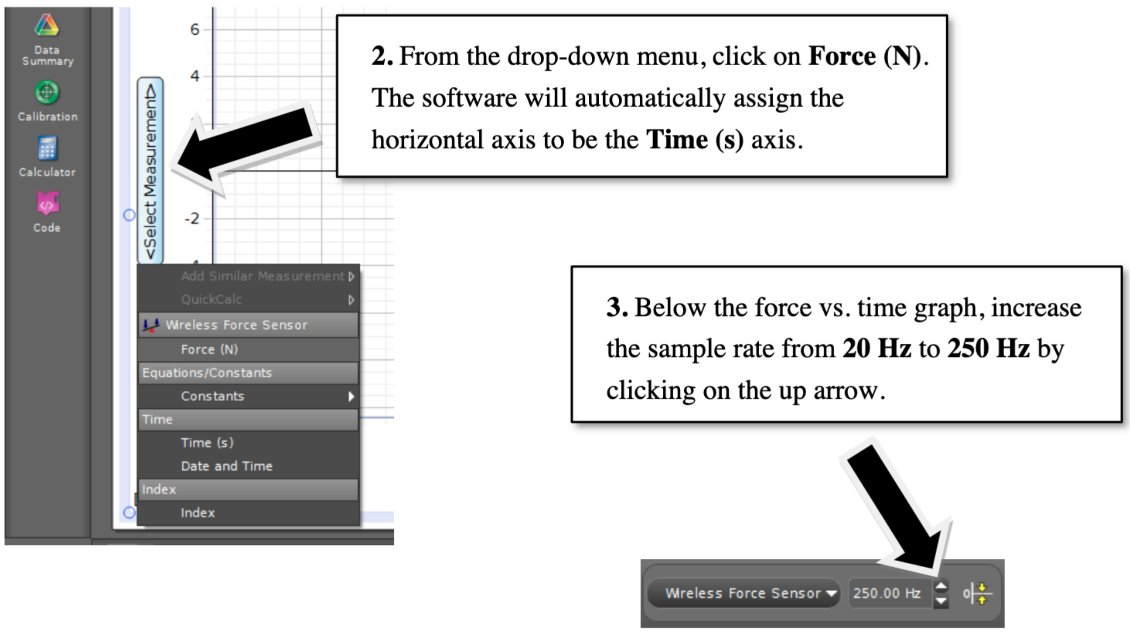
Press the power button located on the side of the wireless force sensor to turn it on. When the Bluetooth indicator light is flashing red, it means the sensor is waiting to be connected to a laptop.

Boot a laptop up into Windows and open the Capstone software (an icon should be on the desktop). Click on the Hardware Setup button located on the left side of the screen. This will open a window displaying nearby wireless devices.



After connecting the force sensor, click on the sliders located next to Wireless Acceleration Sensor and Wireless Gyro Sensor to disable them. The force sensor will only be used to measure force in this experiment. Click on the Hardware Setup button again to close the Hardware Setup window.

Double-click on the Graph icon to open a graph. On the vertical axis, click on the <Select Measurement> button.



Remove any tension in the string connected to the force sensor hook and click on the icon with the two yellow arrows to zero the force sensor.

Click on the Record button to start collecting data. Note that when the force sensor hook is pulled, it measures force to be negative. When it is pushed, it measures positive values.

Pull the block horizontally along the paper with a slowly increasing force until the block just starts to move. Once the block is in motion, try your best to pull at a constant speed. You may need to do a few practice pulls to get it right.

Sketch the general shape of the plot shown on the force vs. time graph.

Label the region of the plot where it was at rest and static friction was acting. Label the point of maximum static friction. Label the region where you were pulling at a constant speed and kinetic friction was acting.

Is the maximum static friction greater than the kinetic friction? Describe how your plot answers this question.

Is the kinetic friction a constant value? Describe how your plot answers this question.

What is the normal force in newtons between the block and the table? Explain your reasoning behind how you got this value.

Make a spreadsheet table of normal force, maximum static frictional force, and kinetic frictional force. There will be six sets of data entries.

Let m be the mass of the wooden block and M be the mass placed on top of the wooden block. Record a plot of force vs. time when pulling the wooden block with the following values of mass M placed on top: 250, grams, 500 grams, 750 grams, 1 kg, 1.25kg, and 1.5 kg.

For each of these plots, record the normal force between the block and the table, the maximum static frictional force, and the kinetic frictional force.
If the kinetic frictional force varies, choose what you think is a reasonable representative value. All your entries should be in newtons. Record the force values that you measure as positive.

What shape do you expect for a plot of maximum static frictional force vs. normal force? Why?

Using Excel or another graphing program, plot maximum static frictional force vs. normal force.

Does the shape of the plot match what you expected?

How can this plot be used to get the coefficient of static friction?

What is the coefficient of static friction?

What shape do you expect for a plot of kinetic frictional force vs. normal force? Why?

Using Excel or another graphing program, plot kinetic frictional force vs. normal force.

Does the shape of the plot match what you expected?

How can this plot be used to get the coefficient of kinetic friction?

What is the coefficient of kinetic friction?

How does your estimate of the coefficient of static friction compare to that of the coefficient of kinetic friction? Is that what you'd expect?

How does your estimate of the coefficient of static friction compare to the range you obtained in part 1?