

Name \_\_\_\_\_ Date \_\_\_\_\_ Period \_\_\_\_\_

## Coefficient of Friction Lab

The purpose of this lab is to determine the relationship between a) the force of static friction and the normal force and b) the force of kinetic friction and the normal force.

### Background Information:

When the surfaces of two objects are in contact, molecules on the surface of one object are attracted to the molecules of the other. Microscopic ridges and valleys of one surface settle into the valleys and ridges of the other surface. When one surface slides over another, a slip-and-stick sequence occurs as molecules cling and break away from each other.

Air between the surfaces tends to act as a lubricant. The more tightly the surfaces are pressed together, the more air is squeezed out and the greater the electrical interaction between molecules on each surface. So the force of friction between the surfaces depends on the nature and condition of the surfaces and on how hard the surfaces are pressed together.

When motion occurs, we speak of the *coefficient of kinetic friction*. When friction holds an object at rest, we speak of the *coefficient of static friction*.

For a block sitting on a horizontal surface, the force that presses the surfaces together is simply the weight of the block. The force that presses the surfaces together is perpendicular to the surface and is called the *normal force*,  $N$ . (The term normal means perpendicular in mathematics).

### Pre-Lab Questions

1. What is the difference between static and kinetic friction?
2. What does the term normal mean?

### Procedure

#### Setting up the Computer

We will be using the electronic force probe and computer interface to measure the force of friction. Make sure the force sensor is plugged into a USB port in the back of the computer.

- Start Data Studio and select "Create Experiment". A Force Vs time graph is displayed, delete it.
- Click on "Setup" and uncheck "Force push positive" and then check "Force pull positive".
- Increase the sample rate to 50 Hz and close the window.
- Drag the "Graph" icon in the Displays window to Force pull positive in the Data window.
- Expand the graph by dragging the lower right corner.

## Collecting Data

1. Measure the mass of the cart and the friction block and record it below.
2. Place the friction block WOOD SIDE DOWN on the track. Place the cart upside down on top of the block.
3. Place the requested mass on top of the cart for each set of trials.
4. Calculate the total weight of the block for each trial and record it in the data table. Since the track is level, the Normal force is the weight (hint: mass and weight are NOT equal).
5. Click Start then press the ZERO button on the force sensor while it is in a horizontal position.
6. Put the force probe in the loop of string on the block and pull on the Force Sensor very slowly and horizontally. Pull the block at a steady, slow speed for about 2 seconds.
7. Click Stop. Click the first icon on the left at the top of the graph. This should rescale the graph around your data. The graph should show a spike in force at the beginning and then a relatively steady force to keep it moving.
8. Note the spike in force required to get the block moving. This is the static friction force, record its maximum value in the data table. Note the average force required to keep the block moving. This is the kinetic friction force, record it in the data table.
9. Repeat for all added mass trials.

Mass of Cart = \_\_\_\_\_g = \_\_\_\_\_kg

Mass of Friction Block = \_\_\_\_\_g = \_\_\_\_\_kg

HINT: \_\_\_\_\_g = \_\_\_\_\_kg      Total Mass \_\_\_\_\_kg

| Trial # | Added Mass (kg) | Total Mass (kg) | $F_{\text{Earth on object}}$ (N)<br>AKA: Weight<br><i>Show Work!</i> | $F_{\text{track on object}}$ (N)<br>AKA: Normal | Force of Static Friction (N) | Force of Kinetic Friction (N) |
|---------|-----------------|-----------------|--|---|------------------------------|-------------------------------|
| 1       | .5              |                 |  |   |                              |                               |
| 2       | 1.0             |                 |  |   |                              |                               |
| 3       | 1.5             |                 |  |   |                              |                               |
| 4       | 2.0             |                 |  |   |                              |                               |
| 5       | 2.5             |                 |  |   |                              |                               |

## Evaluation of Data

1. Close Data Studio and start Graphical Analysis. Plot Force of Static Friction (y axis) vs. Normal Force (x axis). Be sure to label your axes, units, and draw a line of best fit.

2. Name the graph and after checking it with your teacher, print your graph AND Record the following:

Static Friction: slope\_\_\_\_\_ Y-intercept\_\_\_\_\_

3. Develop a mathematical model for the relationship between the force of static friction and the normal force. Follow the format on the "How to Make a Mathematical Model" worksheet.

4. Use the 5% Rule to determine if the y-intercept is significant to this relationship? Follow the format on the "How to Make a Mathematical Model" worksheet.

5. Write out your final mathematical model, after taking in to consideration the 5% rule.

6. Use your Mathematical Model to predict the Force of Static Friction for a 5 kg *total mass* cart/block system.

7. Plot the Force of Kinetic Friction vs. Normal Force. Be sure to label your axes, units, and draw a line of best fit. Print your graph AND Record the following:

Kinetic Friction: slope\_\_\_\_\_ Y-intercept\_\_\_\_\_

8. Develop a mathematical model for the relationship between the force of static friction and the normal force. Follow the format on the "How to Make a Mathematical Model" worksheet.

9. Use the 5% Rule to determine if the y-intercept is significant to this relationship? Follow the format on the "How to Make a Mathematical Model" worksheet.

10. Write out your final mathematical model, after taking in to consideration the 5% rule.

11. Use your Mathematical Model to predict the Force of kinetic Friction for a 5 kg *total mass* cart/block system.

12. The slope of your mathematical models represent the coefficient of friction, symbolized by the Greek letter  $\mu$  (pronounced "mew"). The coefficient of kinetic friction,  $\mu_k$  is used when the block was moving and the coefficient of static friction,  $\mu_s$  is used when the block was still stationary. In general, how does  $\mu_s$  compare to  $\mu_k$ ?

13. How does the Force of Kinetic Friction change as the weight of the cart increases? How does  $\mu_k$  change as the weight increases?

14. Why are there no units for  $\mu$ ?

15. What is the general model that describes the relationship between the force of friction and the Normal force?

### Practical Applications

A 50. kg package from Amazon.com arrives on your doorstep. It is blocking the front door so you wish to move it to the side. You push on it, but it doesn't move.

a. Draw a force diagram and write a sum of the forces equation in the space below.

b. Calculate the force of Earth on the package. What is a common term for this force?

c. Calculate the force of the ground on the package. What is a name physicists use for this force?

d. What is the mathematical relationship between the coefficient of static friction ( $\mu_s$ ) and the force of static friction? If the coefficient of static friction is 0.3, what is the force of static friction on the package?

e. What will happen if you push on the box with a force of 200N? Draw a new force diagram.

f. You apply enough force to overcome static friction and it is now moving at a constant speed. Would your force diagram look like the one you drew in part a or part e above? Explain.

g. If you push with 100 N of force while it is moving, what is the coefficient of kinetic friction?