**Determining the Coefficient of Friction Lab**

**Theory:**

A frictional force is the force exerted by a surface as an object moves across it or makes an effort to move across it. The two most common frictional forces that you will come across in nature are kinetic and static. Though it may not always be the case, the frictional force often opposes the motion of an object. For example, if a block of wood slides across the surface of a desk, then the desk exerts a frictional force in the opposite direction of its motion. Friction results from the two surfaces being pressed together closely, causing intermolecular electrostatic attractive forces between the molecules of the two different surfaces. As such, friction depends upon the nature of the two surfaces (*coefficient of friction*) and upon the degree to which they are pressed together (*the normal force*). The frictional force between two surfaces sliding relative to one another can be calculated using the formula below

(1)

On a horizontal surface, the normal force is equivalent to the force due to gravity, or the weight of the object as shown below. In the diagram, an applied force causes the block to move across a horizontal surface at a constant velocity. Therefore, the acceleration is 0 m/s2 and the net force acting on the block will be zero. As a result, the applied force through the tension in the string will equal the frictional force as shown below.

*F*A

*Ff*

*F*N

*F*g

0

In this experiment, the force acting on the block will be applied through a string attached to a force sensor as shown below.



**PRELIMINARY QUESTIONS**

1. In pushing a heavy box across the floor, is the force you need to apply to start the box moving greater than, less than, or the same as the force needed to keep the box moving? On what are you basing your choice?

1. How do you think the force of friction is related to the weight of the box? Explain.

**Objective:**

To determine the coefficient of static friction between two pieces of wood.

To determine the coefficient of kinetic friction between two pieces of wood.

To investigate the effect of the normal force and the angle of the incline on the coefficient of friction.

**Materials:**

|  |  |
| --- | --- |
| * Inclined plane (wooden board) | * Block of wood with eye screw |
| * Power Macintosh or Windows PC | * Vernier force sensor |
| * LabPro or Universal Lab Interface | * Logger *Pro* |
| * Scale | * Masses |

**Procedure A: Determining the kinetic and static coefficients of friction on a horizontal surface.**

1. Place the wooden plane flat on the lab table and note its starting position. **You will use the same starting position for each trial.**
2. Determine the mass of the wooden block to the nearest gram.
3. Add 500g (0.5 kg) to the block.
4. Attach a string to the wooden block.
5. Complete all connections to the LabPro interface and the computer. Connect the force sensor to a DIG/SONIC port on the LabPro. ***Set the force sensor to the 10N scale.***
6. Start Logger Pro 3.5.0 or higher. The screen should show a graph with force on the y-axis and time on the x-axis. The time should be scaled from 0-10 seconds. This will be the allotted time to collect your data for each trial.
7. Connect the string from the block to the hook on the force sensor, and hold it in your hand such that the string is parallel to the wooden surface.
8. Press the collect button . on the screen and gradually increase the tensional force acting on the block until it begins to move. Continue to pull on the block such that it moves at a relatively constant speed until the data collection times out. ***The block should be moving at an extremely slow pace.***
9. Determine the average kinetic frictional force by highlighting the region on the graph where the block was in motion (click and drag). This should be pretty clear to you. Then click on the Statistics button, . Record the value in your data table. **Note: You may want to rescale your y-axis from 0-10N.**
10. To determine the maximum static frictional force, click the Examine button, , and move the mouse across any graph to find the force required to get the block to begin to move. Record this value in your data table.
11. Repeat steps 9 and 10 two more times for the same mass.
12. Add mass to your wooden block in 250g increments for different values of Fg and repeat steps 8-11.
    1. **Make sure you return the block back to its starting position.**
    2. **Do not exceed 3.0 kg of total mass including the block**.
13. Print out the force vs. time graph for the last trial in Procedure A. Label the portion of the graph corresponding to the block at rest, the time when the block just started to move, and the time when the block was moving at constant speed.

**Table A: Determining the Coefficients of Kinetic and Static Friction on a Horizontal Surface:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Massblock (kg) | Fg(block) = FN (N) | Kinetic FT(Avg)  (N) | | | Avg. FT (N) | µk | Static FT(Max)  (N) | | | Avg. FT (N) | µs |
| 0 degrees |  |  |  |  |  |  |  |  |  |  |  |  |
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|  | | | | | Avg. µk | |  |  | | Avg. µs | |  |

In the second part of this experiment, you will look at the effects of inclining the plane on the normal force on the coefficient of friction. We will start with a block of wood on an incline at some angle θ (5º to 20º) that is being pulled up by a string at **constant velocity** in the upwards direction. Since the acceleration of the system is zero, as before, there is no unbalanced force acting on the block. In this situation, the tension (FT) on the block must provide enough force to equal the sum of the friction and parallel component of the weight (Fg(||)).

(1)

Ff

FN

Fg

Fg(||)

Fg( | )



FT

Force Sensor

Remembering that Ff = μFN  (1)

We can then develop a relationship for the forces acting along the plane as follows:

Fnet = FT - Fg(||) - Ff

Since the block is moving at a constant speed, Fnet = 0 and the formula can be solved for FT as follows:

FT = Fg(||) + Ff (2)

Since FN = Fg( | ), we can use a little trig and substitute (1) into (2) to arrive at:

FT = Fgsin + μFgcos (3)

where μ is the coefficient of friction.

**Procedure B: Determining the kinetic and static coefficients of friction on an inclined surface**

1. ***Remove all the mass added to the block during procedure A before proceeding to the next step.***
2. Incline the plane at some angle between 5 and 20 degrees using textbooks in your classroom and record this value in the table below. **Repeat steps 8-12 from Procedure A**. Record the total mass. This is the tension (FT) at angle .

**Table B: Determining the Coefficients of Kinetic and Static Friction on an Inclined Surface:**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Massblock (kg) | FN = Fg cosθ (N) | Fg(||) = Fg sinθ (N) | Kinetic FT(Avg)  (N) | | | | Avg. FT(N) | µk | Static FT(Max)  (N) | | | | Avg. FT(N) | µs |
| degrees |  |  |  |  |  | |  |  |  |  |  | |  |  |  |
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|  | | | | | | Avg. µk | | |  |  | | Avg. µs | | |  |

**Data Analysis (Procedure A: Friction on a Horizontal Surface):**

1. Determine each value for for both kinetic and static friction in the table using equation (1) above.
2. Determine the average value of for both kinetic and static friction.
3. Plot the value of k versus the block weight on a horizontal surface for the data in Table A. **Scale the y-axis from 0 – 1.**
4. On the same graph, plot the value of s versus the block weight on a horizontal surface for the data in Table A.
5. Draw a free body diagram for the block on the plane for Procedure A and put it in your lab book
6. Show a sample calculation for starting with equation (1).

**Data Analysis (Procedure B: Friction on an Inclined Surface):**

1. Since the plane is inclined at an angle, the frictional force no longer equals the tensional force. **Create a space in your lab book to show these calculations.** *Hint: Solve equation (2) for Ff.*

|  |  |  |
| --- | --- | --- |
| Normal Force | Kinetic Frictional Force | Static Frictional Force |
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1. Continue your calculations by solving for . **As for #1, create a space in your lab book to show these calculations.**

***If you do not perform steps 1 and 2, you will not plot your data correctly.***

1. As in Table A, determine the average value of for both kinetic and static friction.
2. Plot the kinetic frictional force (*You should have done this in #1 above*) versus the normal force for the data in Table B.
3. Plot the static frictional force (*You should have done this in #1 above*) versus the normal force for the data in Table B.
4. Find the slope of each of the lines in number 3 and 4.
5. Draw a free body diagram for the block on the inclined plane for Procedure B and put it in your lab book.
6. Show a sample calculation for starting with equation (3).

**Analysis Questions:**

1. Describe the relationship between and total block weight in Procedure A, i.e. is there a trend, and what does it tell you? *Hint: Look at your graph.*
2. Compare the average value of µk when the block moved along the horizontal surface to the average value obtained when the incline was set between 5 and 20 degrees. *Explain what these two pieces of data tell you about the influence of the angle on the coefficient of friction.*
3. Describe the relationship between the frictional force and the normal force in Procedure B. What is the significance of the slope of this line?
4. Using the force vs. time graph you created in step 13 of Procedure A, compare the force necessary to keep the block sliding compared to the force necessary to start the slide. How does your answer compare to your answer to question 1 in the Preliminary Questions section
5. Why was it important to have the block move at a constant speed?

**Error Analysis & Conclusions:**

*In your conclusion, make sure you discuss the key trends that you observed, and comment on whether or not your data supports the theory you learned during this laboratory investigation.*