Measuring the Coefficient of Friction Between Two Surfaces

Introduction

This lab is designed to introduce students to the concepts of friction. A simple determination of the coefficient of friction between two surfaces is made by graphical analysis of a force normal vs. force of friction graph. Force of friction is measured using a spring scale to pull a block of known weight at constant velocity along a smooth surface or by measuring the tangent of the angle of a block on a ramp.

Background Information

We are constantly aware of the frictional force that opposes the motion of one surface in contact with another. When there is a sheet of ice on a side walk, friction is reduced, and it is difficult to walk. The lack of friction is an inconvenience. However, machines are lubricated to reduce friction where it is not an advantage.

In this lab, the frictional force will be measured while sliding a block of wood along a table surface. If you pull an object horizontally at constant velocity, the applied force just balances the frictional force. Since velocity is constant there is no acceleration, and if there is no acceleration, there is no net force on the object (F=ma, Newton's 2nd law). If no net force is on the object, then all forces must just balance, that is the force applied must just equal the force of friction. Therefore, the force applied (spring scale reading) is equal in magnitude to the force of friction.

Objectives:

The student will:

- measure the force of friction.
- graph force normal vs. force of friction.
- find the best line through the data points.
- determine the coefficient of friction between the surfaces.
- predict the force of friction from a given normal force.

Student Skills:

- measurement
- graphing
- algebra
- linear regression
- graphical analysis using a graphing calculator
- extrapolation

Materials:

- spring scale with 0 to 5.0 Newton range
- wooden block (5in x 3in x 2in)
- gram mass set
- wax paper or aluminum foil
- string
- graph paper and straight edge
- graphing calculator

5. Procedure

1. Mass the block of wood and record the value in kilograms.
2. Attach a loop of string around the hook in the block of wood.
3. Hook the spring scale to the string.
4. Place a mass on the block.
5. Practice until you can pull the block with constant speed and the scale reads a constant value.
6. **Find static friction:** Have your partner read and record the spring scale value while the block is static and you are pulling with the spring scale. The reading will increase until the block moves slightly. Try your best to "average" the value.
7. **Find Kinetic Friction:** Have your partner read and record the spring scale value while the block is in motion. The reading will vary slightly as the block is pulled along the table due to the unevenness of the surface. Try your best to "average" the value.

8. Calculate the value of the normal force and record the value in your table. The normal force is calculated by summing the mass of the block and the masses, be sure to use kilograms, and then multiplying by the value of g (9.81m/s^2).

Static: $F_s \leq \mu F_N$ Kinetic: $F_k = \mu F_N$

For example:

- F_n=M*g
- mass of block= 565g
- mass added = 0.1kg
- g=9.81 m/s^2
- Force normal= (.565kg + 0.1 kg) *9.81 m/s^2 = 6.5 N

*The point (0,0) was added to your data table. If there is no normal force, then there would not be a force of friction since the surfaces must be pressed together for friction to occur.

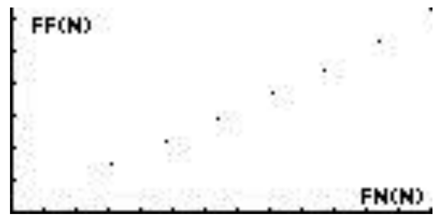
	Horizontal				Ramp			
F normal (N)	F_s (N)	μ_s	F_k (N)	μ_k	F_s (N)	μ_s	F_k (N)	μ_k
0.00	0.00		0.00		0.00		0.00	

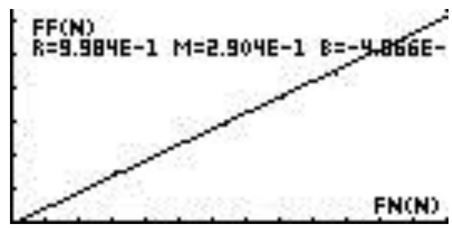
9. Pull the block and record the value of the frictional force.
10. Add an additional weight to the block and repeat until a total of 5 points are measured
11. Check your data table for "wild" values. If a number looks out of place, then repeat that measurement again with the same force normal.
12. Set the block on a ramp and determine the greatest angle without the block sliding. Determine the coefficient of static friction by finding the tangent of the greatest angle. Compare to results in previous horizontal experiment.
13. Set the ramp to the lowest angle where the block will continue to slide on its own once put in motion to determine kinetic coefficient. Compare to results in previous horizontal experiment.

6. Analysis of the Data

1. Once all of the data points have been measured, plot the points on graph paper with F normal on the X axis and F friction on the Y axis. Be sure to label your axes with dimensions and units.
2. Using a straight edge, draw the best line through the data points.
3. Find the equation in slope-intercept form (**Y=mX+b**) for the "best" straight line passing through the data points. To find this equation, choose two points that are on the line and calculate the slope, m, using the change in Y divided by the change in X or "rise over run". Next, find the value of the Y-intercept, b, this is point where the "best" line crosses the Y axis. Once these two values are found, substitute them into the equation:(**Y=mX+b**).

7. Graphing Calculator Analysis





1. Enter the data points into the calculator
2. Create a scatterplot of the data points
3. Use the Linear Regression function of the calculator to find the "best" straight line through the data points.
4. Record the slope and intercept of the regression equation.

8. Extensions (if time permits)

- Repeat the procedure with a different surface wax paper or aluminum foil. Simply wrap your block in the paper or foil. What do you think will be different?
- Repeat the procedure using a different surface area. Simply use a smaller side of the block.

9. Summary Questions

1. Using the equation from the analysis, calculate the value of the static frictional force if 3.0 kilograms is placed on the block (show your work!)
2. Using the equation from the analysis, find the value of the kinetic frictional force if 3.0 kilograms is placed on the block. (show your work!)
3. List 3 examples of where friction helps you and 3 examples where friction is a hindrance.
4. What is indicated by the slope of the line in your graph.
5. Which factors influence the force of friction? Support your answers with justifications from you graphs.

The **Coefficient of friction** is defined as the ratio of force of **friction** to the normal force, $\mu = F / N$. Consider the following two Figures. ... F_k = Force of **kinetic friction**, μ_k = **coefficient of kinetic friction**, N = Normal force or the force perpendicular to the contacting surfaces.

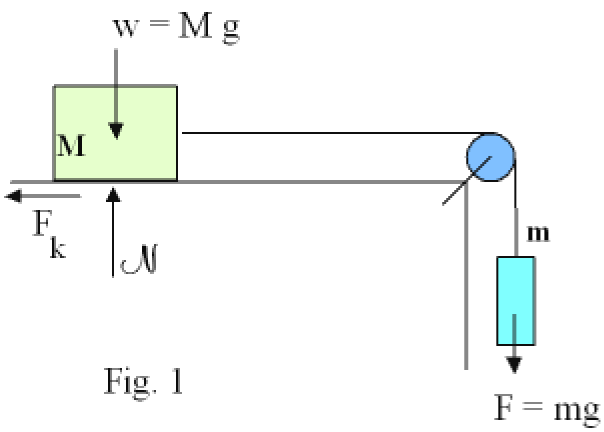


Fig. 1

$$F_s = \mu_s N$$

F_s = Force of static friction.

μ_s = Coefficient of static friction.

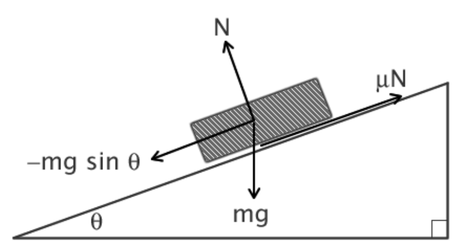
N = Normal force.

The force of **static friction** can be calculated by taking the **coefficient** of **friction** between the two surfaces and multiplying it by the normal force that the surface is applying to the object. On a flat surface, the normal force is equal to the force of gravity acting down on the object

Use a coordinate system with +x down the slope and +y perpendicular to the slope. Split the force of gravity into x and y components. So, the **coefficient of static friction** is equal to the **tangent** of the angle at which the objects slide.

Coefficients of Friction   f= μ x N

Materials	**Static Friction** μ_s	**Kinetic Friction** μ_k
Steel on Steel	0.7	0.6
Aluminum on Steel	0.6	0.5
Copper on Steel	0.5	0.4
Rubber on Concrete	1.0	0.8
Wood on Wood	0.5	0.2
Glass on Glass	0.9	0.4
Waxed wood on Dry snow	0.2	0.04
Metal on Metal (lubricated)	0.2	0.06
Ice on Ice	0.1	0.03
Teflon on Teflon	0.04	0.04



$N = \cos\theta \times w$