Static and Kinetic Friction

1. Introduction

You probably take for granted how many times you interact with frictional forces on a daily basis. Frictional forces are everywhere. If you are sitting down right now, the friction between the seat and the fabric of your pants is keeping you from sliding onto the floor. If you are standing up then the friction between the floor and your shoes is preventing you from slipping. Frictional forces can be found between any two bodies that are in contact with each other. In this experiment we will study the concept of friction between a wooden block and a sliding surface, when stationary and when in motion.

2. Background

2.1 Static vs. Kinetic:

There are two types of frictional forces, static and kinetic. Static friction is what keeps a resting body at rest. Kinetic friction is what slows down an object when slid on a surface. Any two materials have a static and kinetic coefficient of friction which represents how much friction exists when they are in contact with each other. The coefficient of friction is represented by the Greek letter mu (μ), and it usually varies between 0 for slippery objects like ice and 1 for rougher objects.

Table 1[1, 2] has typical values of static and kinetic friction for different material combinations. Note that the static coefficient of friction is higher than the kinetic coefficient of friction for all combinations except Teflon.

Table 1: Coefficients of static and kinetic friction

Materials	Coefficients of Static Friction (μ_s)	Coefficients of Kinetic Friction (μ_k)
Steel on Steel	0.74	0.57
Aluminum on Steel	0.61	0.47
Copper on Steel	0.53	0.36
Rubber on Concrete	1.0	0.8
Wood on Wood	0.25-0.5	0.2
Glass on Glass	0.94	0.4
Waxed wood on Wet snow	0.14	0.1
Waxed wood on Dry snow	-	0.04
Metal on Metal (lubricated)	0.15	0.06
Ice on Ice	0.1	0.03
Teflon on Teflon	0.04	0.04
Synovial joints in humans	0.01	0.003

2.2 Frictional Forces

When we say that there is friction between two surfaces, we are actually talking about frictional forces. Frictional forces always act in the direction opposing the applied force (see figure 1 below). The force of static friction is calculated by multiplying the normal force of the object with its corresponding coefficient of friction ($F_s = N * \mu_s$). Similarly, the force of kinetic friction is calculated by multiplying the normal force of the object with its kinetic coefficient of friction ($F_k = N * \mu_k$). When an object is pulled upon, its static friction is what initially resists motion; until a force so strong is applied that it overcomes the static frictional force. Typically, the coefficient of static friction is greater than the coefficient of kinetic friction because the force to initiate movement is greater than the force required to slide the object at a constant velocity.

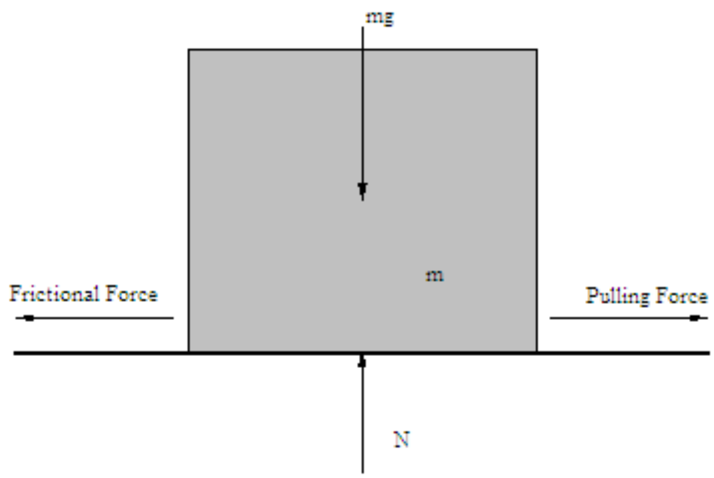


Figure 1. A block of mass m is pulled upon with a pulling force. The frictional force keeps it from moving

3. Objective:

· To gain an understanding of the different coefficients of friction and how they affect frictional forces between different objects.
·To find the coefficient of static friction between two objects by pulling on it until it starts to move and measuring the force required to do so on two different surfaces.
·To calculate the objects coefficient of kinetic friction by sliding the block on the table top and measuring its speed and displacement.

4. Equipment List:

-Wooden blocks
-Sliding surfaces
-PC
-Wire
-Vernier Load Sensor
-Vernier Data acquisition unit
-Vernier Motion sensor

5. Experimental Procedure:

Part 1: Calculating the coefficient of static friction

1. Connect the Dual-Range Force Sensor to Channel 1 of the interface. Set the range switch on the Force Sensor to 50 N.
2. Load the logger pro software. A plot should open automatically for force vs. time.
3. Click on the Data Collection icon on the menu, it's the one that looks like a clock. Change the length of time to 50 seconds.
4. Hold the Force Sensor in position, ready to pull the block, but with no tension in the string. Click [Zero] to set the Force Sensor to zero.
5. Suspend the block in the air with the force detector, steady the block so that it stops swinging. In the upper left corner of the screen, it should tell you how many Newtons the sensor is sensing. Record the weight of the block to the data table.
6. Lay the block on the table and connect the force detector to it as shown below in Figure 2 [3].
7. Click [Collect] to begin collecting data. Pull slowly and gently on the force sensor until the block begins to move, move it slowly with constant force for a few more inches. Click stop on the menu to finish collecting the data. Zoom in on the plot for each graph so you can see the results clearly. It may take several trials to master pulling smoothly. To clear your data for the next trial click on the tab that says data and select "clear data".
8. Look at the plot for position vs. time, note at about what time the block began to slide, this is where the maximum force was recorded by the sensor.
9. Scroll down the data table and look for the corresponding time. Record the corresponding maximum force.
10. Do this experiment one more time and average your results.
11. Do this experiment again using the rubber sliding surface.

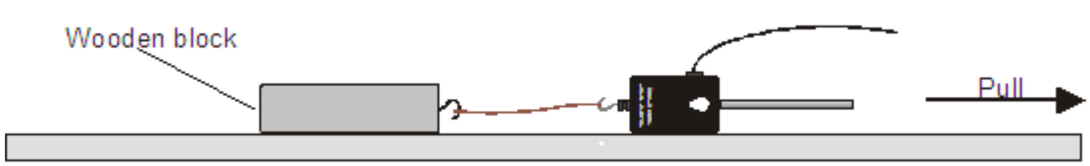


Figure 2. A schematic of the experiment

Part 2: Calculating the coefficient of kinetic friction

1. Set up the motion sensor so that it faces the sliding surface, as shown below in figure 3 [3]. Do not use the rubber mat for this experiment.

2. Practice sliding a block from 2-3 meters away gently until you are able to get it to stop about ½ meter from the detector

3. Connect the Vernier Motion Detector to the DIG/SONIC 1 channel of the interface. Make sure that a plot opens up for position, velocity and acceleration

4. Press [Collect] to being collecting data

5. Slide the block as practiced before

6 Click stop after the block has stopped moving to finish collecting data

7. Look at the graph for velocity, there should be a region that decreases linearly, while the block is slowing down

8. Record the slope of this line, this is the acceleration. If you need assistance, refer to the data sheet.

9. Do this experiment two more times.

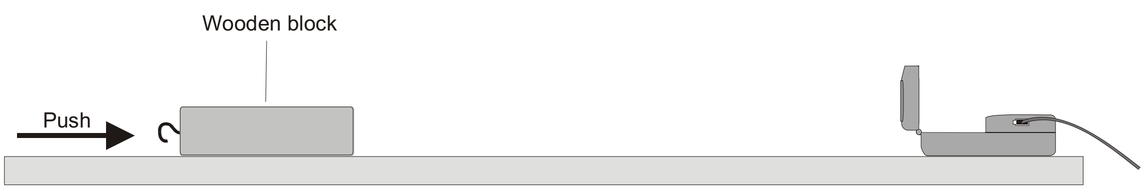


Figure 3[3]. A schematic of the experiment

6. Analysis/Questions:

Part 1: calculating the static coefficient of friction

1. Print out or sketch the graph of force vs. time (one for each experiment is sufficient). Label the areas on the graph that correspond to when the block is at rest, when the block first starts to move, and when the block is moving.

2. Using the values for force collected in your experiment; calculate the coefficient of kinetic friction between the block and the sliding surface for each trial.

3. What is the difference in the coefficient of friction when you used the table top and when you used the rubber mat? Is this what you expected?

4. Why does the graph of force vs. time peak at the moment the block began to slide?

5. What are some possible sources of error in this experiment and what could you change to improve the accuracy?

Part 2: calculating the kinetic coefficient of friction

1. Print out or sketch the graph of velocity and circle the area where the block is slowing down at a constant rate.

2. Using the calculated acceleration, and the blocks mass, figure out the frictional force that was slowing it down (do for each trial).

3. Now that you know the frictional force, using the normal force, calculate the coefficient of friction.

4. How does the coefficient of kinetic friction compare to the coefficient of static friction?

5. What are some possible sources of error in this experiment and what could you change to improve the accuracy?

Data Sheet

		Part 1, Measuring Static Friction		
Trial #	Mass of Block (grams)	Weight of Block (Newtons)	Force recorded by load sensor	Coefficient of Friction
1-Table				
2-Table				
		Average=		
1-Rubber				
2-Rubber				
		Average=		
		Part 2, Measuring Kinetic Friction		
Trial #	Mass of Block (grams)	Weight of Block (Newtons)	Acceleration (m^2/s)	Coefficient of Friction
1				
2				
3				
		Average=		

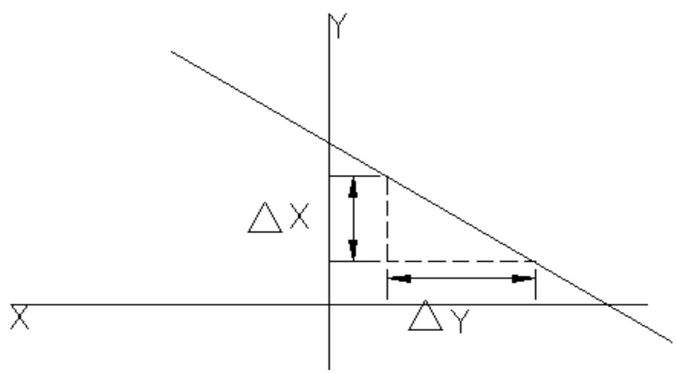
Equations and values of Interest:

$F = M \cdot A$

$F_F = \mu \cdot N$

Gravitational Acceleration = $9.81 m/s^2$

Slope of line = $\frac{\Delta Y}{\Delta X}$



References:

[1] Online: http://www.physlink.com/Reference/FrictionCoefficients.cfm, web site of Physlink.com containing coefficients of static and kinetic friction.
[2] R.A. Serway and R.J. Beichner, Physics for Scientists and Engineers. Saunders College Publishing, Orlando, FL, 5th Ed., (2000).
[3] K. Appel, J. Gastineau, C. Bakken, D. Vernier, Physics with Computers. Vernier Software & Technology, Beaverton, Oregon, 3rd Ed., (2003).