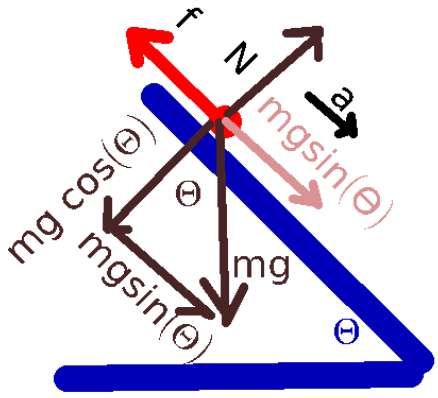
Lab 03 Kinetic and Static Coefficients of Friction Pandemic Version

You should download an app for your smart phone that will measure angles if your phone does not have one already. One I use is named clinometer from Google Play if you have an android phone in order to make quick measurements of the angles and it is free. There are also other choices available. I understand iphones may have this built into the system automatically.

Consider the following construction:



This shows the resolution of forces on an inclined plane. The gravitational force is reduced into parallel and perpendicular components to the surface of the plane. Doing this allows the acceleration to be parallel to the plane. We apply Newton's law here:

$$N - mg\cos(\theta) = 0$$
$$mg\sin(\theta) - f = ma$$
$$\text{and } f = \mu N$$

From the first equation, we have:

$$N = mg\cos(\theta)$$

and the frictional force is given by:

$$f = \mu N = \mu mg\cos(\theta) \quad .$$

We can then find the acceleration from the second equation:

$$mg\sin(\theta) - \mu mg\cos(\theta) = ma$$

Now solve this for the acceleration:

$$a = g\left[\sin(\theta) - \mu\cos(\theta)\right]$$

Now consider changing the angle so that the acceleration is zero. Note this does not mean the system can not still be moving, it just can not be accelerating. At this angle we have:

$$a = 0 = g\left[\sin(\theta) - \mu\cos(\theta)\right] \Rightarrow \sin(\theta) - \mu\cos(\theta) = 0 \Rightarrow \mu = \frac{\cos(\theta)}{\sin(\theta)} = \tan(\theta)$$

This means: place a material on an inclined plane and change the angle of inclination until the object starts sliding. We are going to simulate this for kinetic and static coefficients today in the lab.

The following parts of this lab you will be able to do at home also to include in your results and your lab report.

Experiment 1

Types of coefficients of frictional

The simulation

There are two predominate type of coefficients of friction. These are specific to the interface between two materials. The two types we will concern ourselves with are the static coefficient: μ_s and the kinetic coefficient: μ_k . The static coefficient is pretty much always larger than the kinetic coefficient. Suppose the kinetic coefficient were larger? Then an object that started moving would stop moving and then start moving again over and over. Physics does not work that way under normal circumstances.

So one of the points you should observe from the simulation today is that the kinetic coefficient is smaller than the static coefficient. In reality the kinetic coefficient is measured by giving the object a small push and varying the angle until it slides with a constant velocity. The static coefficient is measured by varying the angle (and not giving a small push) until the object starts to slide.

An additional test I want you to receive is the answer to this question:

is that the coefficient of friction is always less than one.

Experiment 2

In addition to the simulation, I want you to demonstrate this at home. Take a coin (such as a quarter). Place it on a book and while giving the coin a small push, tilt your book until the coin slides with a constant velocity. Record this angle. Next place the coin again on the book. Tilt the book until the coin slides (no pushing this time). You should record that angle also. What you should observe when you calculate the coefficients is that the kinetic coefficient is smaller than the static coefficient. This is also simulated today. Calculate your coefficients from $\mu=\tan(\theta)$.

Experiment 3

The coefficient of friction is also independent of mass. It is a bit hard to be able to do this at home but it is possible without knowing the exact mass to compare two identical objects. It can be accomplished with two pennies or two quarters. Place one coin on the surface of a book and tilt the book until it slides. Measure the angle with your smart phone. Next place two coins on each other and tilt the book until it slides again. Measure and record this angle. You should see that the angles are very close to each other. You should calculate your coefficient of friction (kinetic here is all you need to do) from $\mu=\tan(\theta)$.

Experiment 4

A second experiment you can do at home is to compare the area dependence of the coefficient. The coefficient is largely independent of area and here is the way to demonstrate this:

take a sheet of paper. place it on a book and tilt the book until it slides. Measure and record the angle. Next fold the paper in half. Again, place the paper on a book and tilt the book until it slides. Record this second angle. Compare the two results and you should find that the full sheet of paper has a coefficient close to the folded paper.

Again, calculate your coefficients from:

$$\mu = \tan(\theta)$$

Kinetic and Static Coefficients of Friction

This is included only for your reference to the physical lab the simulation represents.

Introduction

You should recall from class the analysis of the inclined plane. This is important to be sure that you understand since you will see related problems again. I have reproduced this analysis on the class home page for your benefit. You should also watch the short movie that I made about the inclined plane. This is intended to help you with today's lab.

Materials & Equipment

You will need a weight hanger, two blocks (one with cork on it and one without) and also one block with sandpaper, glass, high friction boards, etc.

A note about angles: You might want to install the **FREE** clinometer from Google Play if you have an android phone in order to make quick measurements of the angles. I believe iphones may already have this feature built in. For the Android, at least, It works quite well and seems to give better angle measurements than is obtained with the protractors. You will need to calibrate both methods of measurement.

Read these two important details carefully!

(1) A very important detail:

Weigh and record the mass of the blocks you are using in this lab (for the portions using method one).

(2) A second important detail:

In order to measure the angle of inclination, you will look directly at the inverted protractor attached to the plane. Read the smaller of the numbers. Note: if you obtain a negative coefficient of friction, then you might be reading the wrong angle.

Setup

You should construct your equipment as was indicated in the movie. I will have an example set up for you in lab. You will want to choose an angle of about 35^0 for the inclination of the plane for use in method one. Record the angle in your lab writeup.
You will want to weigh (on the electronic scales) the mass of the wooden you are using today in the first part of the lab. You will want to weigh the hanging weights in part (1) also, with the electronic scales.

Brief summary of experiments to do:

(a) **Method (1)** pine on polyboard static
(b) **Method (2)** pine on polyboard static (to compare to experiment (a)
(c) **Method (2)** cork on polyboard static on **wide area** and **narrow area** for area comparison
(d) **Method (2)** Glass on polyboard, static and kinetic
(e) **Method (2)** Sandpaper on polyboard, static and kinetic

(f) **Method (2)** High friction on high friction static and kinetic
(g) **Method (2)** Several other materials (glass on wood, sandpaper on wood, etc.) static and kinetic.

You should perform the following experiments:

Method one (1):

1: I want you to measure the coefficient of static friction for your wooden (only wood) block using two methods. First **(a)** add enough weight to your weight hanger until the system starts to slide (on its own, without a push). This provides a measurement of the static coefficient of friction. T**his is a little bit like a game: gently place as much weight as possible on the hanger, one gram at a time if necessary.** Then measure the same thing using method two. Be sure to do the tilting of the plane only after you have finished (a). You will be able to obtain the relative error between the two methods of measurement by measurement using the two different methods.

The percent deviation between the two methods of measurement is given by:

$$\%\,\text{deviation} = \frac{|\text{measurement}_1 - \text{measurement}_2|}{\frac{1}{2}(\text{measurement}_1 + \text{measurement}_2)} \text{x}\,100$$

Do not be distressed if this deviation is large: method one is more susceptible to experimental error which is why the rest of the lab is done with method two.

For the rest of the lab, I want you to measure the coefficients only by tilting the plane which is **method two**. This will be used for all subsequent measurements in today's lab.

Method two (2):

2: (a) Measure wide cork block side and narrow cork block side for area (use the metal rulers here). Then find the static coefficient by tilting the plane. You will be able to have an indication as to how strongly area influences the frictional force from these experiments.

(b) Measure the static and kinetic coefficients of glass on wood by tilting the plane.

(c) Measure the static and kinetic coefficients of sandpaper on wood by tilting the plane. Use the block with sandpaper on it for this purpose or the sandpaper on the back of the glass.

(d) Measure the static and kinetic coefficients of the high friction boards.

(e) You should now measure other materials (static and kinetic) of your choice to include in your writeup as you desire. You can find the analysis for the mass connected to the inclined plane on the electronic handout entitled “Analysis of the inclined plane” on our website and also in the class worksheets. You should work through this analysis for your benefit and understanding. There is also a spreadsheet for this lab to help with the calculations. Be sure to save each under a different name in your root directory.

Note: only for the wooden block will the entire spreadsheet apply (rows 1-9). In the other cases, you will only calculate the coefficients of friction using the bottom portions of the spreadsheet. Be sure in your spreadsheet to denote if the experiment is kinetic or static and describe the experiment with a short (real short) description. Only submit in your work the portions of the spreadsheet that contain your actual data. The

spreadsheet also contains some simple checks for data in the top portion of the lab. If the checks are violated, look to see if something is wrong. Also note on your spreadsheet, the experiment areas are text only do describe the experiment there.

In your lab writeup, I would like for you to answer the following questions based upon your measurements. For each material, (cork on wood, wood on wood, etc), what is the value of the static and kinetic coefficients of friction? **Also, from a comparison of your measurements with different areas, does this coefficient depend upon area?** You will need to include your observations in your lab write up in addition to the normally required portions of the lab writeup. You should attempt to answer these questions based upon the % deviation.