Friction

Purpose:

In this lab, you will measure the coefficients of **static friction** and **kinetic friction** between two combinations of surfaces using an inclined plane.

Part 1: Static Friction

Theory:

The coefficient of static friction $\boldsymbol{\mu_s}$ can be measured experimentally for an object (wood block) placed on an inclined plane (ramp). The coefficient of static friction is related to the magnitudes of ***maximum friction force*** $\boldsymbol{f_{s\text{-}max}}$ and corresponding normal force N by formula

$$\mu_s = f_{s-\max} / N \qquad (1)$$

In this lab, one increases gradually the friction force $\boldsymbol{f_s}$ till its maximum value $\boldsymbol{f_{s\text{-}max}}$ by increasing the angle θ of an inclined ramp shown in figure. One measures the angle $\theta = \theta_S$ at the moment the block just start to slide and calculates the static friction coefficient as

$$\mu_s = \tan \vartheta_s \qquad (2)$$

One can get expression (2) by writing the second law for the block *just before it starts to slide*

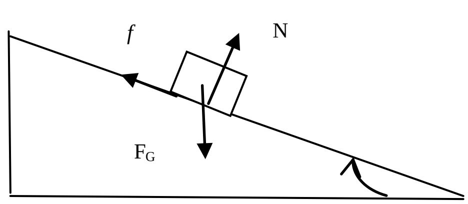
$$\overrightarrow{F_G} + \overrightarrow{f_{s-max}} + \vec{N} = m\vec{a} = 0$$

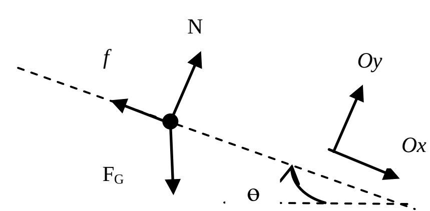
After projecting it on Ox, Oy axes, one get

Ox: $+F_G sin\theta_s - f_{s-max} = 0$ *i.e.* $f_{s-max} = F_G sin\theta_s$ *and* Oy: $-F_G cos\theta_s + N = 0$ *i.e.* $N = F_G cos\theta_s$

Finally $f_{s-max} = F_G sin\theta_s = \mu_s N = \mu_s F_G cos\theta_s$ and $\mu_s = tan\theta_s$

This last relation allows to calculate the static friction coefficient by the smallest value of angle θ_S **for which the bloc just starts sliding.**





Equipment:

For this lab, you will use an inclined ramp, a wooden block with "two different materials on surface" and a towel paper.

Experiment#1: Measuring static friction coefficient

1. Cover the ramp by a piece of towel paper and draw a line on it upper side.
2. Place the block on the paper and align its upper side to the line.
3. Increase carefully the ramp angle till the block starts sliding and measure the angle θ_s.
4. Note the angle in the table 1.
5. Repeat three to five times the measurement and include angles values in the table.
6. Calculate the best, max and min estimated values for θ_s(two types of uncertainty involved).
7. Use expression (2) to calculate the best, max and min estimations values for μ_s.
8. Repeat the same steps for the smaller area of block having the same material.
9. Fill tab#2 with those data and calculate best, max and min estimated values.
10. Verify whether the friction force on the block depends on the area of surfaces in contact.

Contact surface: __***towel paper- smooth wood***

Large contact area

Tab#1

	θ_s	μ_s
First		
Second		
Third		
Fourth		
Fifth		
Best		
Max		
Min		

Small contact area

Tab#2

	θ_s	μ_s
First		
Second		
Third		
Fourth		
Fifth		
Best		
Max		
Min		

Next, you repeat those measurements for the other contact surface of the block and the towel paper and fill tables 3 and 4.

Contact surface: __***towel paper - rugged surface***

Large contact area
Tab#3

	θ_s	μs
First		
Second		
Third		
Fourth		
Fifth		
Best		
Max		
Min		

Small contact area
Tab#4

	θ_s	μs
First		
Second		
Third		
Fourth		
Fifth		
Best		
Max		
Min		

Part 2: Kinetic Friction

Theory:

One can measure the coefficient of kinetic friction, μ_k, by using the same method used for the coefficient of static friction by referring to a situation where the ***block is sliding at constant velocity***, i.e. **zero acceleration**. In this case, though, one must make sure that, once starting to slide, the block will follow sliding uniformly. This situation corresponds to a precise inclination angle $\theta = \theta_k$ and

$$\mu_k = \tan \vartheta_k \qquad (3)$$

Experiment:

You can measure μ_k using a procedure similar to the one you used to measure μ_s. This time, just pick one area (say the large one) for each of two combinations of different surfaces in contact.

1. Place the block on the towel paper at smallest inclination and give it a small push. The block will stop after a small displacement.

2. Increase slowly the plane inclination and repeat the point 1 each time. At a given angle, the block will not stop; it will slide until the end of inclined plan. Here we are dealing with a uniform motion. You have to measure the smallest angle θ_k for which this happens and write it in table 5. ***Question: Why do we have to refer to the smallest angle?***

3. Repeat three to five times steps 1-2 and record in table 5 the found values for the angle θ_k. Use the relation (3) you derived above in order to calculate the coefficient of kinetic friction μ_k .

4. Repeat the steps 1 to 3 for the other set of surfaces in contact and fill the table 6.

Contact surface: ***towel paper– smooth wood*** ***towel paper - rugged surface***

Tab#5

	θ_k	μ_k
First		
Second		
Third		
Fourth		
Fifth		
Best		
Max		
Min		

Tab#6

	θ_k	μ_k
First		
Second		
Third		
Fourth		
Fifth		
Best		
Max		
Min		

Analysis:

Use the following questions to write a meaningful analysis. (Don't answer them in a "telegraphic way")

1. Why do you have to include the two types of uncertainty in calculations for θ?

2. How do the values of μ_s compare to the values of μ_k?
   (Of course, you can only compare them for the same pairs of materials.)

3. Do these values μ_s and μ_k fit to what you expected?

4. Do the friction coefficients μ_s and μ_k depend on the nature of surfaces in contact? Explain.

5. Of the two parts of the experiment, measurement of μ_s and measurement of μ_k, which one had more possible sources of uncertainty ? Explain.

6. Could μ_k or μ_s ever be *greater than 1*? Explain why or why not.

7. Does the coefficient of friction depend on the size of the contact area or not?