Friction

Objective:

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 μ_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*** $f_{s\text{-}max}$ and corresponding normal force N by formula

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

In this lab, one increases gradually the friction force f_s till its maximum value $f_{s\text{-}max}$ 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*

$$\overrightarrow{F_G} + \vec{f}_{s-max} + \vec{N} = m\vec{a} = 0 \qquad (3)$$

After projecting it on Ox, Oy axes, one get

Ox: $+F_G sin\theta_s - f_{s-max} = 0$ $\qquad f_{s-max} = F_G sin\theta_s$ (4)

Oy: $-F_G cos\theta_s + N = 0$ *i.e.* $N = F_G cos\theta_s$

Finally $f_{s-max} = F_G sin\theta_s = \mu_s N = \mu_s F_G cos\theta_s$ $\qquad \mu_s = tan\theta_s$ (5)

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.**

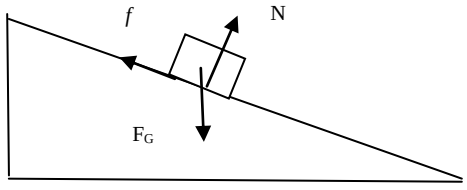

Fig. 1 Identification of forces applied on the block

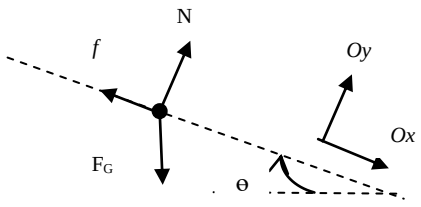

Fig. 2 Isolation diagram (or FBD)

Equipment:

An inclined ramp, a wooden block with " two different surface structures " 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 at rest; ***larger smooth area*** on the paper and align its upper side to the drawn line.
3. Increase carefully the ramp angle till the block just ***starts sliding*** and stops; ***measure the angle*** θ_s.
4. Repeat three to five times the measurement and include angles values in the table 1.
5. Calculate the best, max and min estimated values for θ_s (two types of uncertainty involved).
6. Use the expression (2) to calculate the best, max and min estimations values for μ_s.
7. Repeat the same steps for the ***smaller smooth area*** of block.
8. Fill tab#2 with those data and calculate best, max and min estimated values.
9. Verify whether the friction force on the block depends on the area of surfaces in contact.

Contact surface: ***__towel paper- smooth wood surface***

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		

Repeat the same measurements for the other contact surface(block/ paper) and fill tables 3 and 4.

Contact surface: ***__towel paper - rugged surface of block***

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

$$\mu_k = \tan \vartheta_k \qquad (6)$$

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 smooth large area of block***.

1. Place the block on the towel paper at smallest inclination and give it a small push by your finger. 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 follow sliding uniformly and will not stop (for a long path over 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 the found values for the angle θ_k in table 5. Use the relation (6) in order to calculate the coefficient of kinetic friction μ_k .

4. Repeat the steps 1 to 3 for the ***large rugged*** surface in contact to towel paper 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 the angle 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 surfaces in contact.)

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 type 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?