Experiment P-6
Friction Force

Physics

Objectives

- To learn about the relationship between friction force, normal force and friction coefficient.
- To observe changes in the friction force within different surfaces and different masses.
- To calculate the friction coefficients (static and kinetic) in these different conditions.

Modules and Sensors

- PC + NeuLog application
- USB-200 module
- NUL-211 Force logger sensor

Equipment and Accessories

■ Rough and smooth wooden block with hook	
■ 20 cm of thread	
■ 1000 g mass	
■ 500 g mass	

- The items above are included in the NeuLog Mechanics kit, MEC-KIT.

Introduction

Friction force is created when two surfaces move or try to move against each other. The direction of the friction force is always opposite to the direction of motion (or motion attempt) and parallel to the surface, therefore it resists the relative motion of the surfaces. Friction force depends on the roughness of the surfaces, and the "normal force" which presses the surfaces together. It can be described by the following equation:

$$F_{Friction} = \mu N$$

When the object is on a horizontal surface and there are not any other force components acting on it perpendicular to the surface, then the normal force equals the object's weight, thus:

$$F_{Friction} = \mu mg$$

The coefficient of friction (μ) is the ratio between the force of friction and the normal force that presses the surfaces together. Because it is a force divided by a force, μ does not have any units. Friction force depends on the object's mass (part of the normal force), however the friction coefficient is not a function of mass; it depends only on the properties of the surfaces.

When an object is at rest, the amount of force required to move it is usually greater than the force required to keep it moving. Therefore, typically there is a difference between the coefficient of static friction (before motion starts) and the kinetic friction (in motion). The static friction coefficient μ_s is calculated at the threshold of motion while the kinetic friction coefficient μ_k is calculated during motion (friction force is constant).

In this experiment we will use a force sensor to study the frictional force of different surfaces and different weights.

Procedure

Experiment setup

1.   Set up the experiment as shown in the picture below.
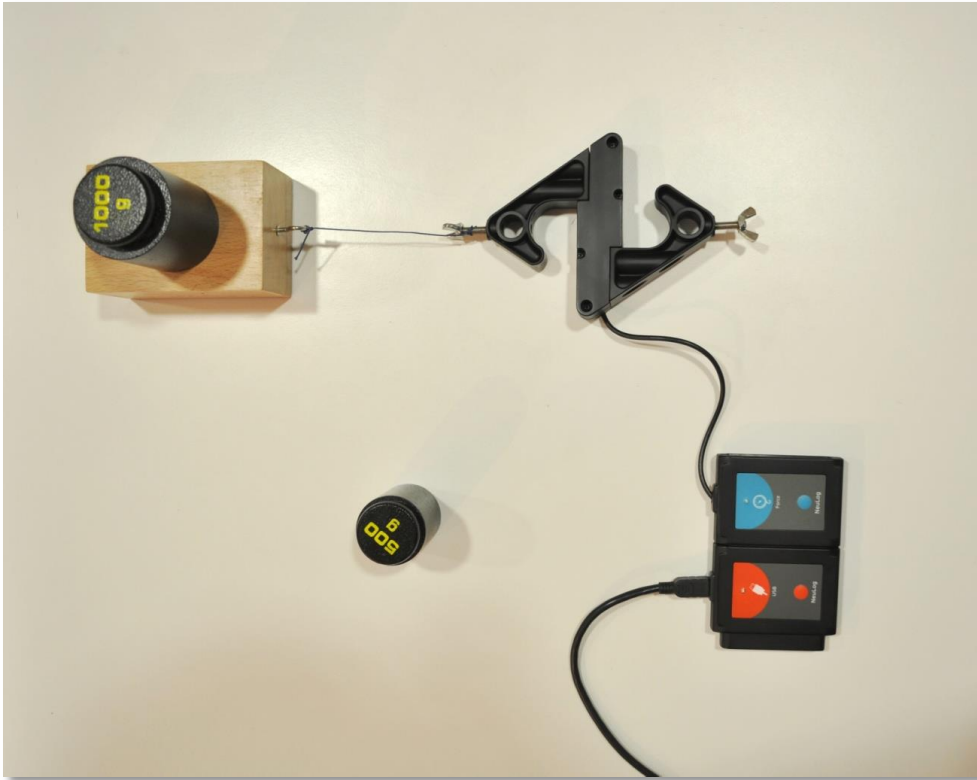
2.   Place a block with one smooth side and one rough side on the table. The rough side should be in contact with the table.

3.   Attach the block to the force sensor's hook with a thread. There should be around 10 cm between the block and the force sensor.

4.   Place the 1 kg mass (1000 g) on the block. We add weight to the block in order to see the different types of friction forces.

Sensor setup

5.   Connect the USB module [icon] to the PC.

6.   Connect the force sensor [icon] to the USB-200 module.

> Note:
>
> The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

7.   Run the NeuLog application and check that the force sensor is identified.

Settings

8.   Click on the **On-line Experiment** icon ![icon] in the NeuLog main icon bar.

9.   Click on the **Sensor's Module** box.

10. Click on the **Push=Negative** button to get positive values when pulling the hook.

11.　Click on the **Range** button.

12.　Select the +/- 10 N button to change the sensor's mode.

13.　Click on the **Experiment setup** icon and set the:

　　Experiment duration to 5 seconds
　　Sampling rate to 50 per second

Testing and measurements

Note:

The orientation of the sensor is very important. Before each measurement, hold the sensor in the same position you will use for the specific experiment and zero it.

14. **Sensor Zeroing:** hold the sensor in its proper position (on the table) and press the button in the sensor's box for about 3 seconds.
Alternatively, you can click on the **Reset** button in the **Module Setup** box menu.

15. Click on the **Run experiment** icon ▶ to start the measurement.

16. Hold the force sensor on the table and slowly pull the block horizontally while increasing the force (the direction should be in a straight line); when you reach a certain force the block will start to move, keep the block moving at a about the same velocity until the end of the measurement. The part in which you increase the applied force should be done in around one second. Practice this until you see a relatively smooth motion in your graph.

17. If needed, click on the **Zoom fit** icon (or click on the **Zoom** icon and locate the mouse cursor at a point above the graph and press its left button; keep it pressed and create a rectangle that includes the whole graph).

18. Your graph should be similar to the following:
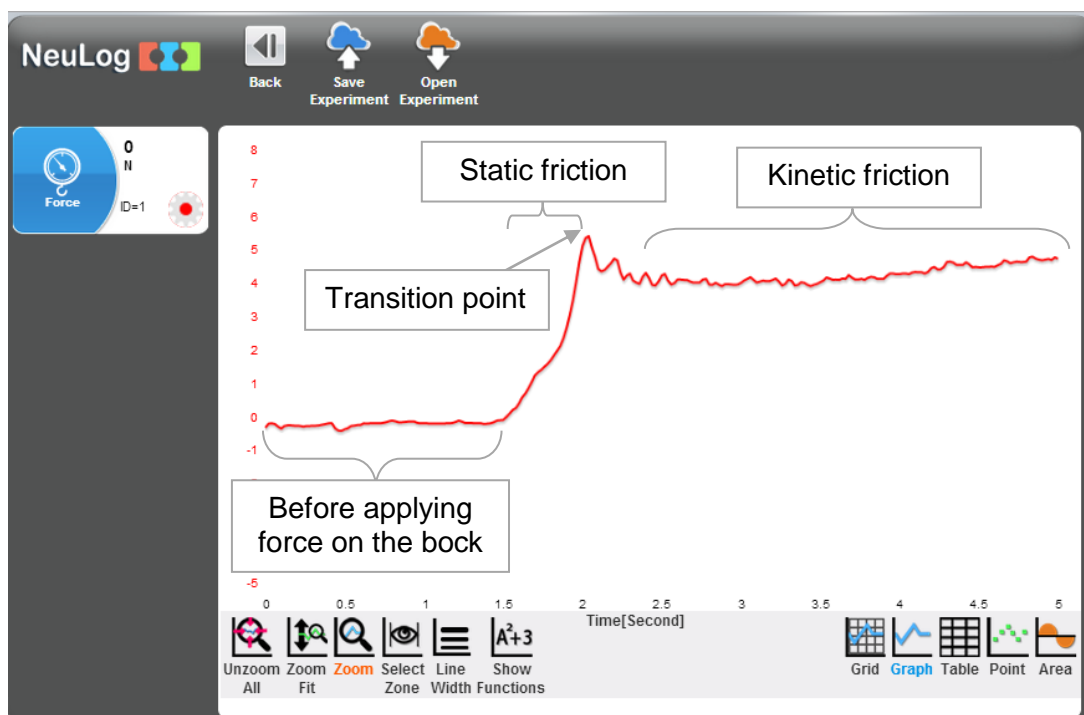
19. Save your graph.

20. The sensor measures the resistance of the block to motion i.e. the friction force. At the beginning of the graph, the friction force is zero because the block does not move and there isn't any applied force on it.

As we apply force on the block by pulling it, the block resists and do not move, at this part, the friction force equals the applied force and is considered **static friction**.

The highest possible static friction value is called the **transition point**. We can use this value in order to calculate the static coefficient:

$$F_{s\,max} = \mu_s mg$$

After this point the block starts moving as we pull it, the friction force decreases and then becomes constant. We can use the friction value at this range to calculate the kinetic friction coefficient:

$$F_k = \mu_k mg$$

21. It is recommended to repeat every measurement three times.

22. In each graph, click on the **Select Zone** icon and select the part between the transition point static friction force and the other one to the point where the force becomes constant.
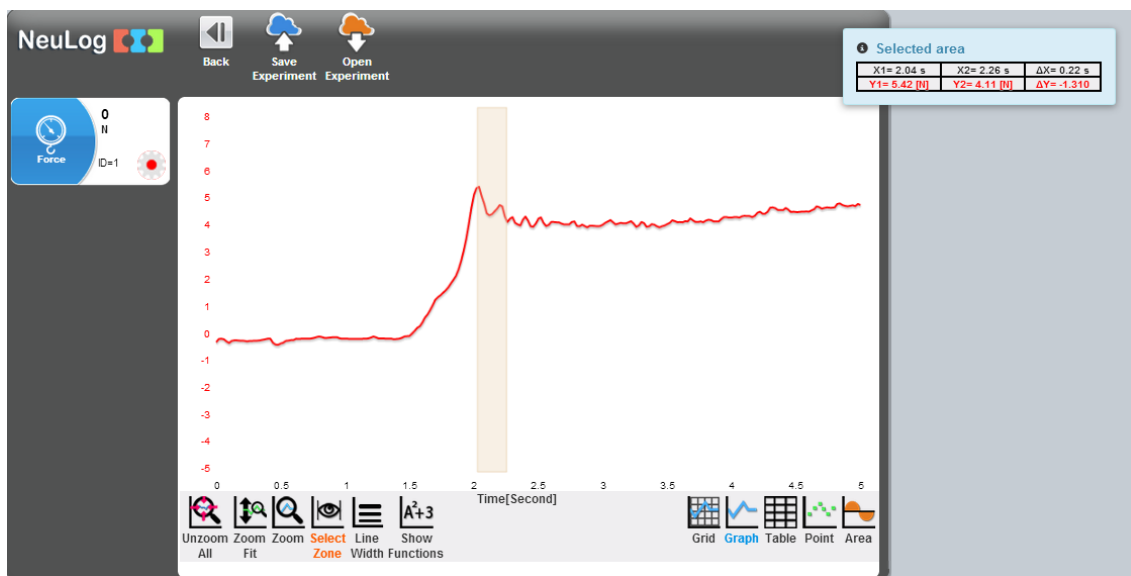
X1= 2.04 s	X2= 2.26 s	ΔX= 0.22 s
Y1= 5.42 [N]	Y2= 4.11 [N]	ΔY= -1.310

23. In the sample experiment, the friction force at the transition point is 5.42 N. In order to calculate the static friction coefficient, we should place this value in the following equation:

$$F_{s\,max} = \mu_s mg$$

The friction force at motion is 4.11 N. In order to calculate the kinetic friction coefficient, we should place this value in the following equation:

$$F_k = \mu_k mg$$

In our case the total mass is 1.24 kg, therefore mg = 1.24 kg x 9.8 m/s^2 (g, gravitational acceleration) = 12.15 kg x m/s^2 = 12.15 N.

To find the friction coefficients we divide each force value by mg (total weight).

Surface	Block's mass [kg]	Mass on the block [kg]	Total mass [kg]	Max. static friction force [N]	Static friction coefficient μ_s	Kinetic friction force [N]	Kinetic friction coefficient μ_k
Rough	0.24	1	1.24	5.42	5.42 N / 12.15 N= **0.45**	4.11	4.11 N / 12.15 N = **0.34**

24. Fill the first row in the following table with your results and calculations. If you repeated the measurement, use the average values.

Surface	Block's mass [kg]	Mass on the block [kg]	Total mass [kg]	Max. static friction force [N]	Static friction coefficient μ_s	Kinetic friction force [N]	Kinetic friction coefficient μ_k
Rough	1						
Smooth	1						
Rough	1.5						
Smooth	1.5						

25. Proceed in this way with the smooth side on the table (will the friction force be different? Will the friction coefficients be different?):
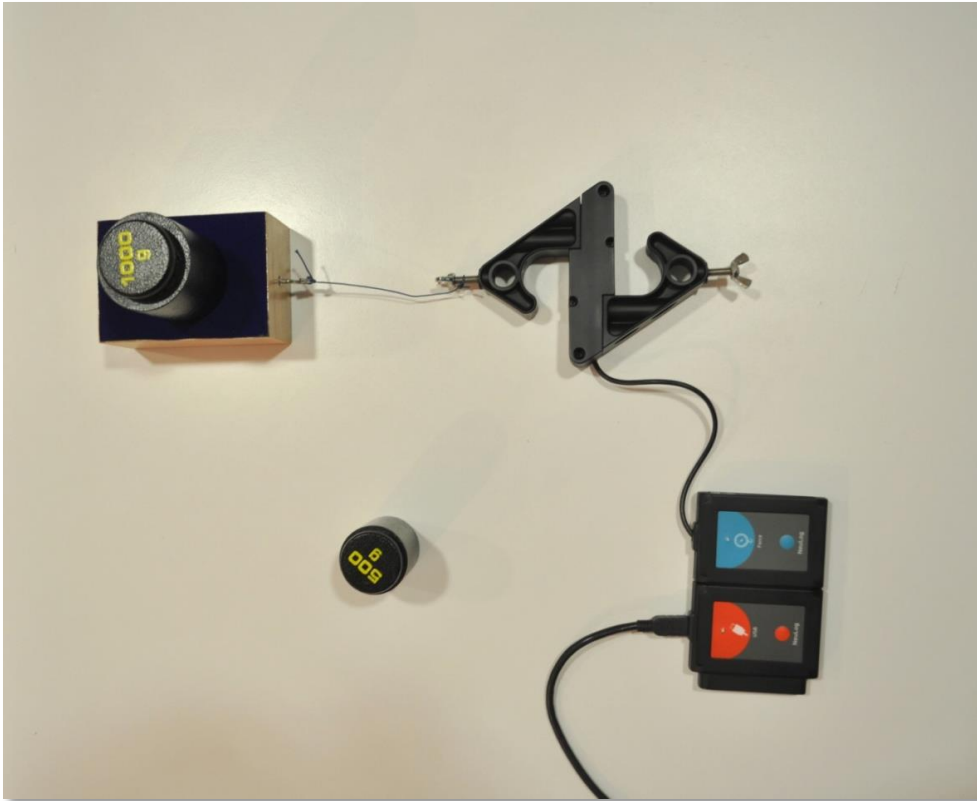
26. Fill the second row of the table with your results and calculations.

27. Proceed in this way with each side of the block, but now put also the 500 g mass on the block.

28. Fill the third and forth rows of the table with your results and calculations.

Summary questions

1. Compare the following values you received. If there is a difference between the values, explain it:

   a. <u>Static</u> vs. <u>kinetic</u> friction coefficients in each measurement.

   b. Friction coefficients of the <u>rough surface</u> vs. the <u>smooth surface</u> (with the 1000 g).

   c. Friction coefficients of the rough surface with the <u>1000 g mass</u> vs. the same surface with the <u>1500 g mass</u>.

2. Think about what would happen in a world without friction. What would happen if you tried to walk? What would happen if you slide an object across the ground?