Experiment P-9
An Inclined Plane

Physics

Objectives

- To understand the principles of forces on an inclined plane.
- To measure the parallel component of the gravitational force and compare it to the calculated force.
- To compare the forces within different angles and masses.

Modules and Sensors

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

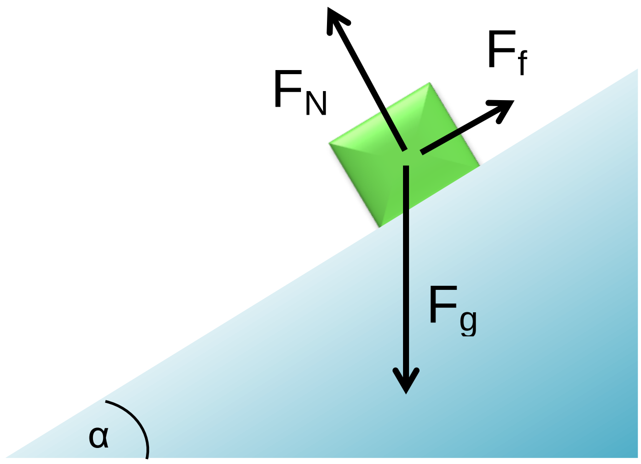
Equipment and Accessories

▪ 1 m Track
▪ Utility stand
▪ Right angle clamp
▪ Extension clamp
▪ Sellotape
▪ Cart with hook
▪ Slotted mass holder rod
▪ 100 g slotted mass
▪ 50 g slotted mass
▪ 3 m measuring tape
▪ Heavy object (about two Kg)

- The items above (except for the heavy object) are included in the NeuLog Mechanics kit, MEC-KIT.

Introduction

In physics, a tilted surface is called an inclined plane. Objects often accelerate down inclined planes because of an unbalanced force. There are a few forces that act upon an object on an inclined plane, and it is important to analyze them in order to understand this system. In the following system an object slides on a slope:



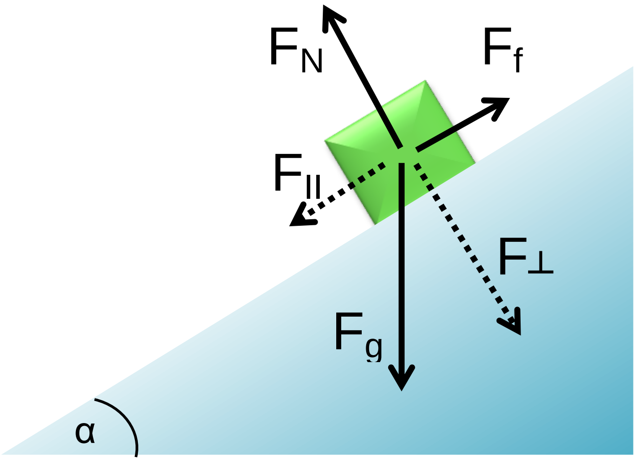
Gravity force: F_g points straight down, even though the object is on a slope.

$F_g=mg$ (mass of the object × gravitational acceleration)

Normal Force: F_N is always perpendicular to the surface that the object is on.

Friction Force: F_f is opposite to the direction in which the object moves.

In order to find the force that takes the object down the slope we need to break the gravity force into two components, F_{II} is parallel to the slope and $F_{\perp}$ is perpendicular to the slope.



$F_{II} = \sin\alpha \times F_g = \sin\alpha \times mg$

<u>In the absence of friction</u> and other forces (as tension), the acceleration of an object on an inclined plane is the value of the parallel component divided by the mass:

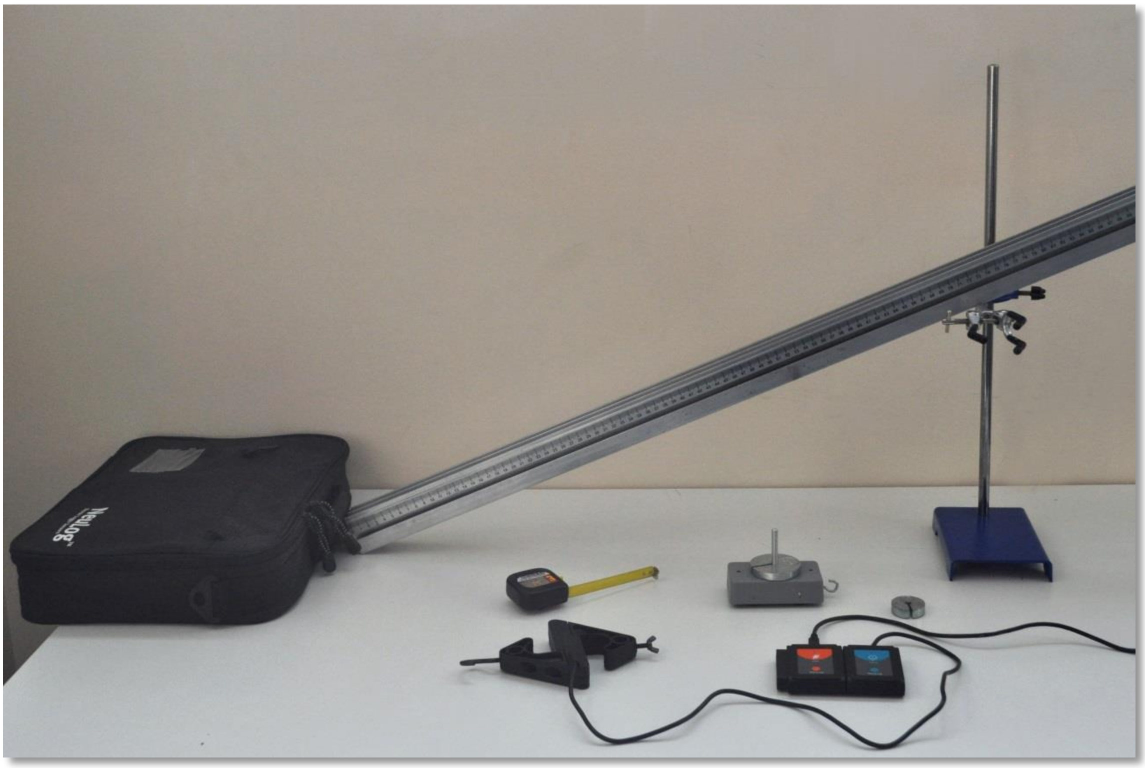
$a = \sin\alpha \times g$

In this activity, we will place an object on an inclined plane and hold it with a force sensor. The measured force is equal to the parallel component of the gravity force. This force can also be calculated since we know the mass of the object, the gravitational force and the angle of the slope. To make this model simple, we neglect the friction force.

Procedure

<u>Experiment setup</u>

1. Set up the experiment as shown in the picture below.



2. Attach the extension clamp to the utility stand with the right angle clamp.

3. Attach the holder rod to the cart.

4. Place the track on the extension clamp to form an inclined plane.

5. Place a heavy object at the end of the track if it slides down.

Sensor setup

6. Connect the USB-200 module  to the PC.

7. Check that the force sensor  is connected to the USB-200 module.

Note:

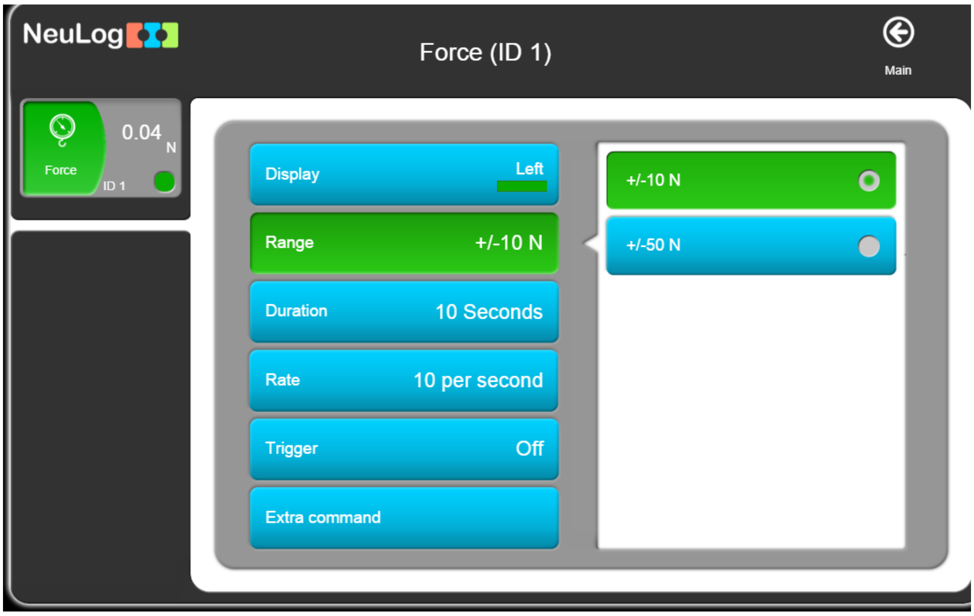
The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

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

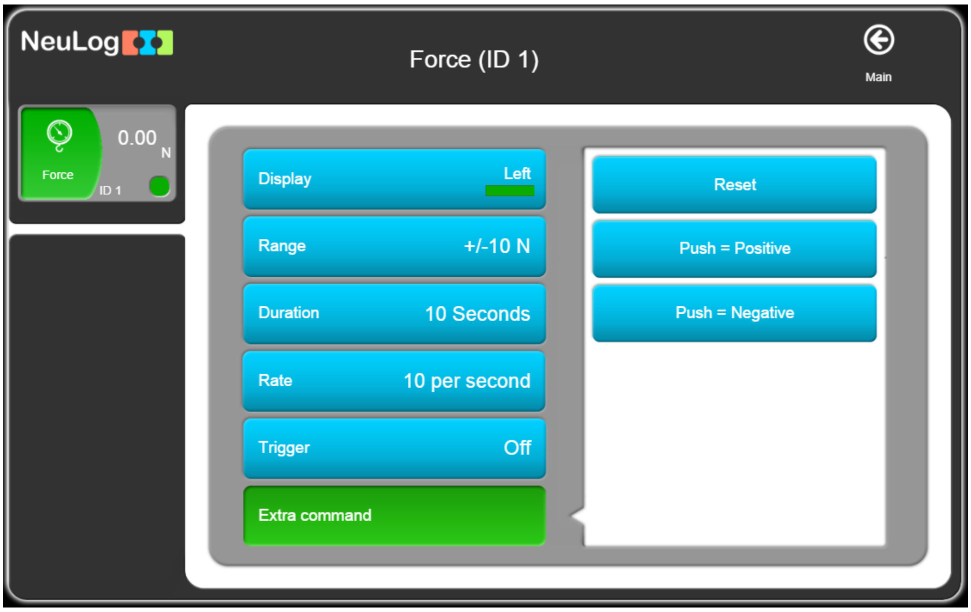
Settings

9. Click on the force **sensor's module** box.

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



11. Click on the **Extra command** button and then on the **Push=Negative** button to get positive values when hanging the cart from the force sensor's hook.



12. Click on the icon to go back to the graph.

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

    Experiment duration to 10 seconds
    Sampling rate to 10 per second

<u>Testing and measurements</u>

14. Hold the force sensor perpendicular to the table in order to zero it before measuring the weight of the cart with the rod.

15. Press the sensor's push button for 3 seconds to set its value to 0 N.

16. Hang the cart with the rod on the force sensor and write down the value you see on the module box.

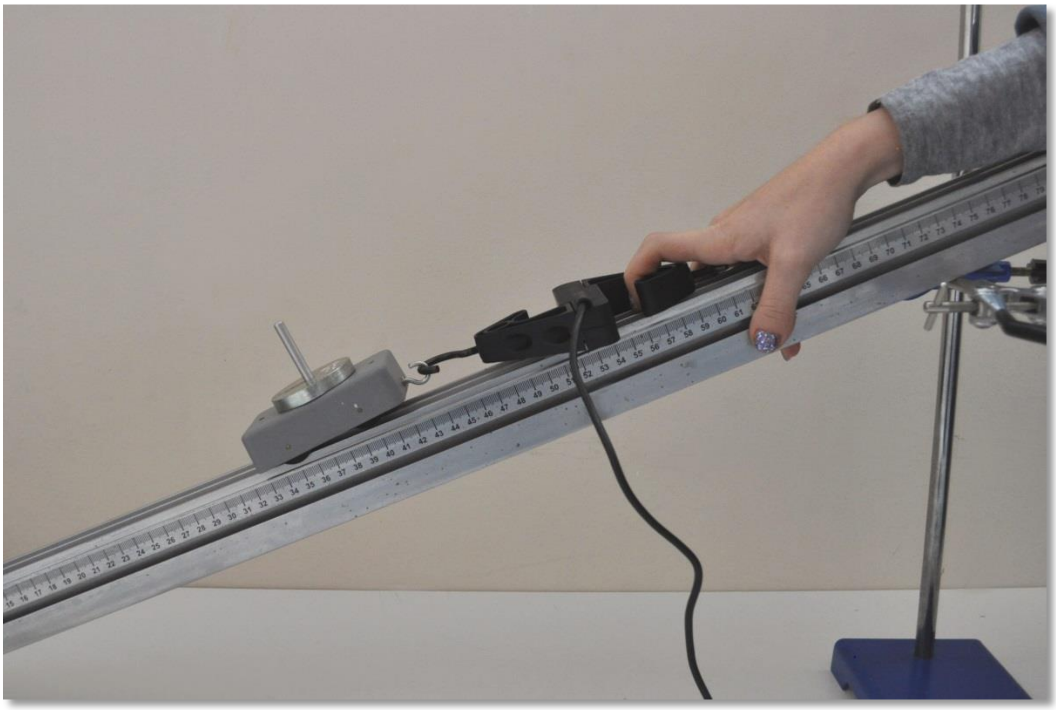
17. Divide this value (in N) by 9.8 m/s^2 in order to get the mass of the cart and rod. This is according to the equation: F_g=mg.

18. Place the 100 g slotted mass on the rod.

19. Place the force sensor on the track and hold it on the side without the hook. The hook should be pointed down the slope.

20. Press the sensor's push button for 3 seconds to set its value to 0 N. You should zero the sensor in the position of the following measurement each time.

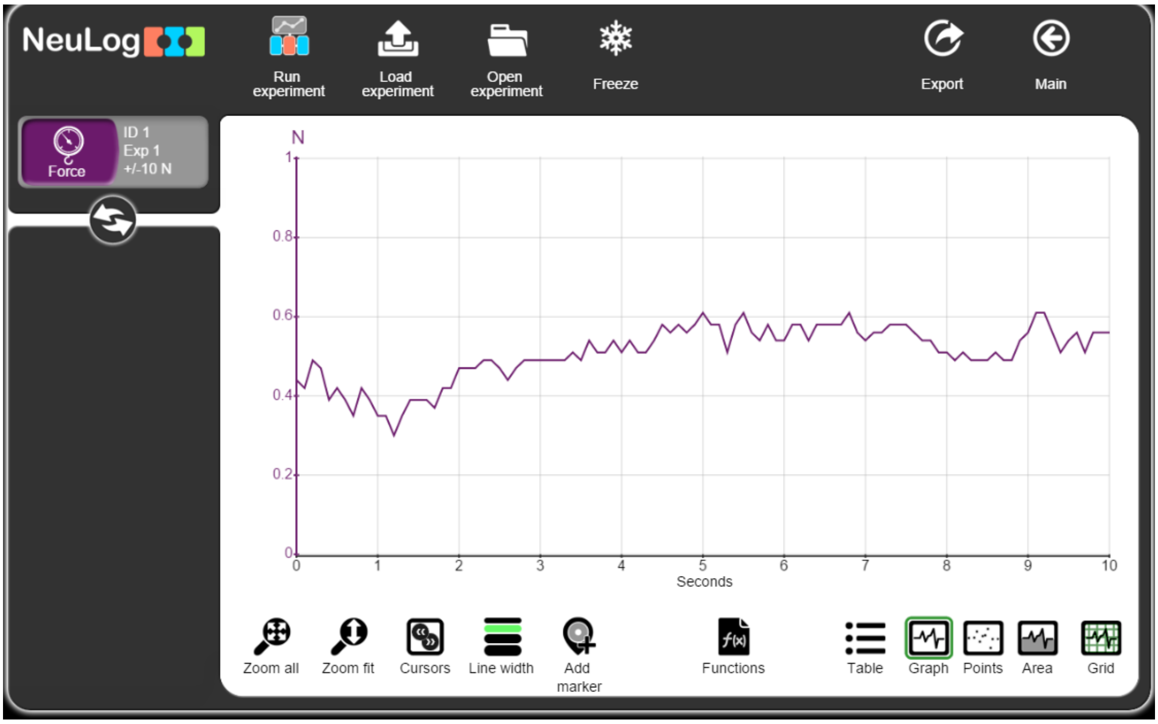
21. Place the cart on the track and hold it with the force sensor's hook. Make sure the cart does not move.



22. Click on the **Record** icon to start the measurement.

23. In order to focus on the desired range, click on each experiment's module box and choose the range between 0 and 1 N (instead of 0 to 10 N).

24. Your graph should be similar to the following:

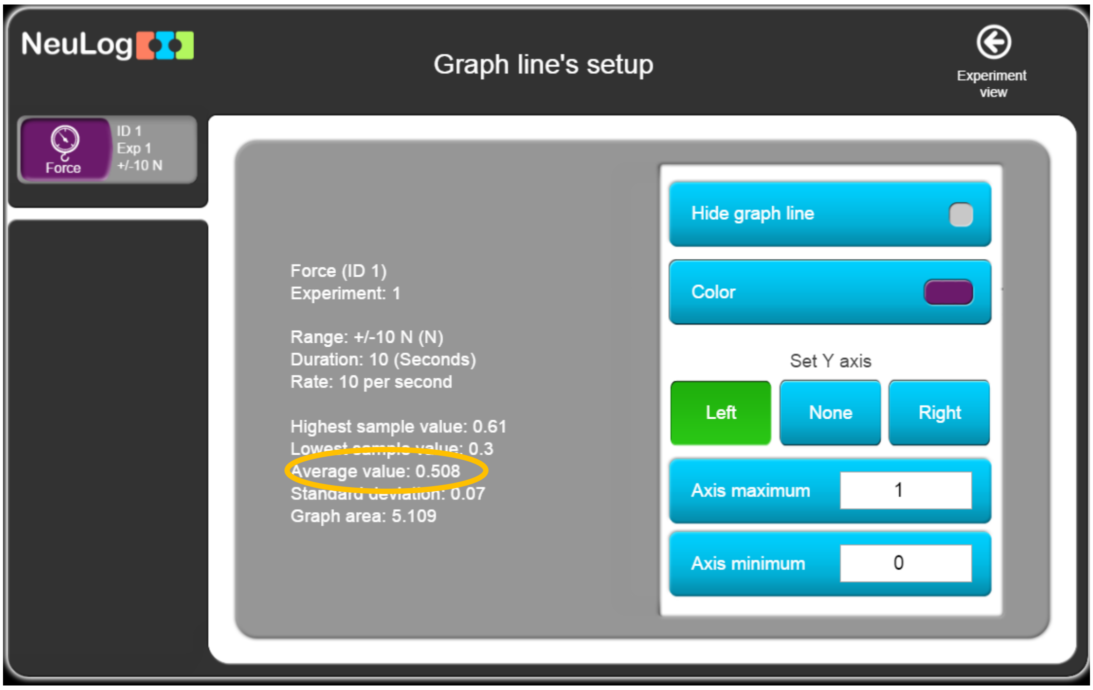


25. Click on the **Export** Icon and then on the **Save value table (.CSV)** button to save your graph.

26. Click on the icon to go back to the graph.

27. Click on the **Experiment module box** on the left side of the screen.

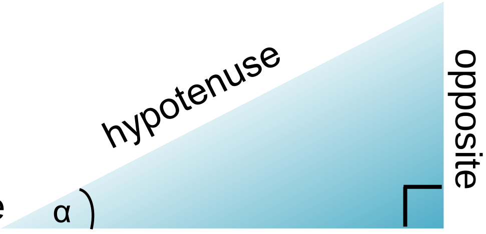
You will see the average measured force. This force is the parallel component of the gravity force (if the friction force is neglected). It is equal to the force applied by your hand.



28. We now want to compare the measured parallel force to the calculated one.

F_{II} = sinα × mg

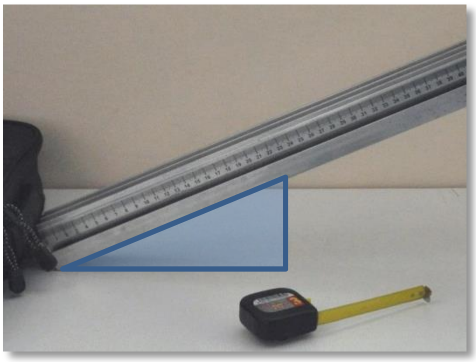
We have the value of m:
m= 100 g + the mass of the cart with the rod. For the sample experiment it is 0.18 Kg.



g=9.8 m/s^2

In a right triangle:
Sinα = opposite / hypotenuse

The meter track also forms a triangle: Use the 3 m tape and sellotape to measure the "opposite" and "hypotenuse" parts of your triangle.



For the sample experiment
Sinα = 7cm/21.5cm = 0.32

Therefore, **F_{II} = sinα × mg =** 0.32 × 0.18 Kg × 9.8 m/s^2 = **0.564 N**.
This value is very close to the measured value: **0.508 N**.

29. Repeat these steps for different angles. Each time, change the height of the extension clamp but leave the track on the table at around the same place.

Height of the track [cm]	Average measured parallel force [N]	**Sinα** = opposite / hypotenuse	Calculated parallel force [N]	Measured F_{II} / calculated F_{II} × 100%
10				
20				
25				
30				

Challenge research

30. Repeat the experiment with different slotted masses (50 g, 100 g + 50 g). How did the results change?

Summary questions

1. How did the angle of the slope affect the parallel component of the gravity force? Explain.

2. Compare the measured component of the gravity force to the calculated force and explain the difference between them.

Challenge questions

3. Assume that the kinetic friction coefficient in your first experiment was 0.15. Find the estimated acceleration of the cart after you let it go in order to fall down the slope.

4. An object is targeted to reach a certain height. It is decided that the cart will be dragged on an inclined plane instead of lifting it straight up. Which method requires more work? What is the advantage of the inclined plane? How could you check your answer in the lab?