Experiment P-5
Motion of a Cart on an Inclined Plane

Physics

Objectives

- To learn about the four motion equations.
- To study the motion of a cart on an inclined plane.
- To study motion with constant acceleration.

Modules and Sensors

- PC + NeuLog application
- USB-200 module
- NUL-213 Motion logger sensor

Equipment and Accessories

▪ 1 m Track
▪ Track rider
▪ Cart with hook
▪ Reflector plate
▪ Utility stand
▪ Right angle clamp
▪ Extension clamp
▪ Rough and smooth wooden block with hook (or something to lift the track)

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

Introduction

There are four parameters associated with the motion of an object: Displacement, Velocity, Acceleration and Time. The kinematic equations can be utilized to predict unknown information about an object's motion if we have other information. They can be used only when the acceleration of the object is constant.

The kinematic equations are:

$$d = v_i * t + \frac{1}{2} * a * t^2$$

$$v_f^2 = v_i^2 + 2 * a * d$$

$$v_f = v_i + a * t$$

$$d = \frac{v_i + v_f}{2} * t$$

d is for displacement, **v** is for velocity (**i,** initial and **f,** final), **a** is for acceleration and **t** is for time.

In this activity we will measure the motion of a cart on an inclined plane with a motion sensor and investigate how the results fit these equations.

Procedure

Experiment setup

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

2.   Place the wooden block on the table.

3.   Place the 1 meter track on top of the block in order to prepare an inclined plane.

4.   Put the track rider on the lower part of the track.

5.   Assemble the cart with the reflector plate.

6.   Place the cart on the lower side of the track.

7.   Place a utility stand attached to the right angle clamp near the lower side of the track.

8.   Attach the motion sensor with the USB module to the utility clamp so that the motion sensor can detect the reflector plate. The reflector plate's size should be at least 10 x 10 cm.

Sensor setup

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

10. Check that the motion 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.

11. Run the NeuLog application and check that the motion sensor is identified.

Settings

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

13.   Click on the **Range** button.

14.   Select the Distance (2m) button to change the sensor's mode to position.
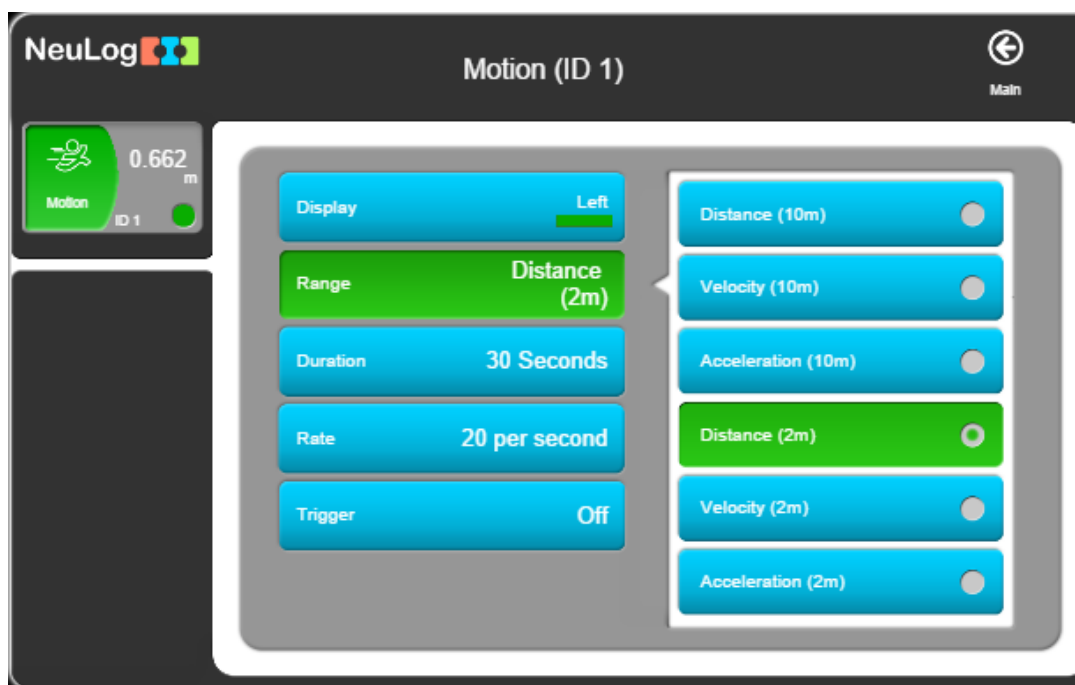
15.   Click on the ⊘ icon to go back to the graph.

16.   Click on the **Run Experiment** icon 📊 and set the:

        Experiment duration to 5 seconds
   Sampling rate to 50 per second

Testing and measurements

Note:

The sensor measures the distance from an object by sending a short pulse of sound that we cannot hear (ultrasonic) and measures the time it takes the echo to return.
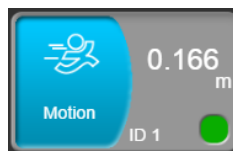
The sound beam angle is approximately 45°. The sensor measures the time of the first received echo.

Make sure to remove any items located in the beam range.
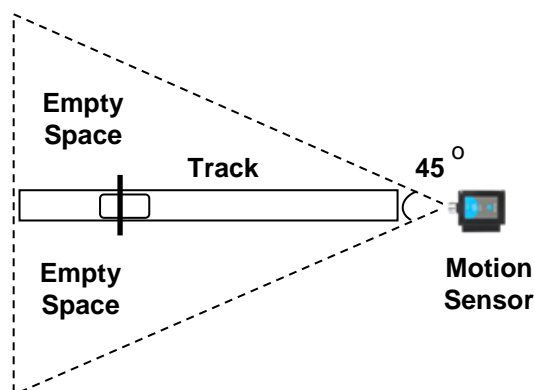
17. Before starting the experiments, make sure the motion sensor is well aligned with the cart's path.

   Observe that the position (distance from sensor) values already appear in the sensor's module box.


18. Make sure that the sensor is around 16 cm from the cart and that it follows the cart distance all the way.

19. Place the cart on the starting position and click on the **Record** icon to start the measurement.

20. Push the cart a bit up the inclined plane so it will move by itself the rest of the way (about 15 cm). Observe the movement of the cart.

21. Your graph should be similar to the following (use the **Zoom fit** icon if needed):
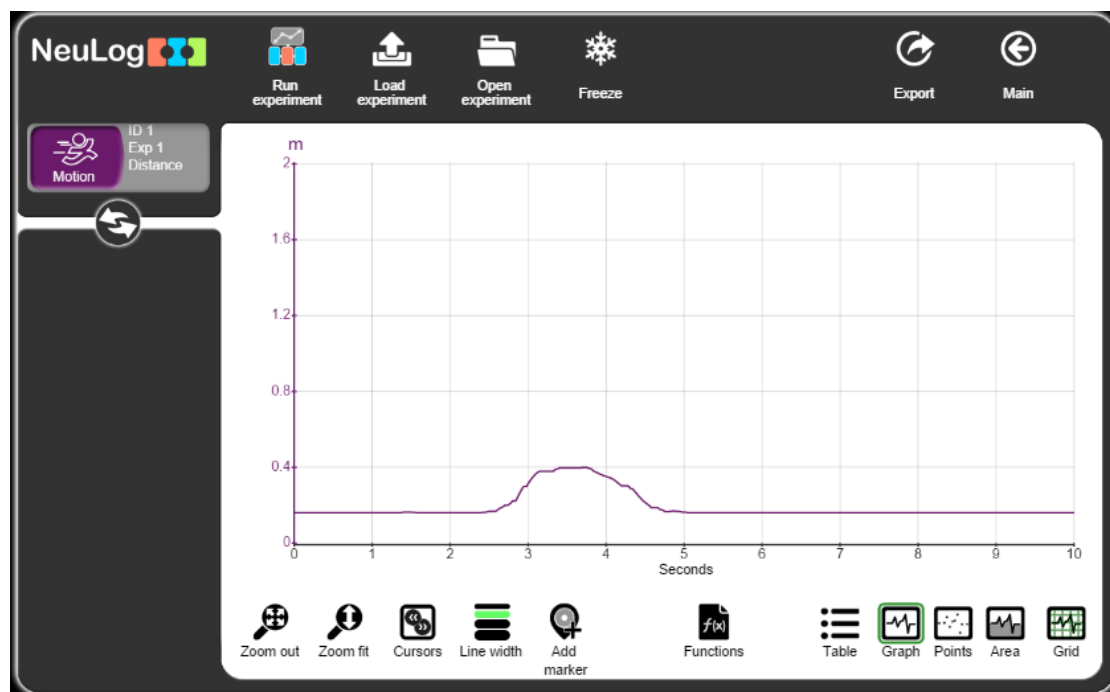
22. If your graph is not similar to the one above, check that the cart moves against the motion sensor all the time and that there are no objects sending an echo to the sensor.

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

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

25. How do the velocity and acceleration graphs should look like? Draw the expected graphs.

26. Click on the **cursors** icon and choose the part where the values go up and then down.

27. Click on the **functions** icon and change **Parameter K** to 2.

28. Click on the **functions** button and then click on **Polynomial K of A**.

29. Your graph should be similar to the following.
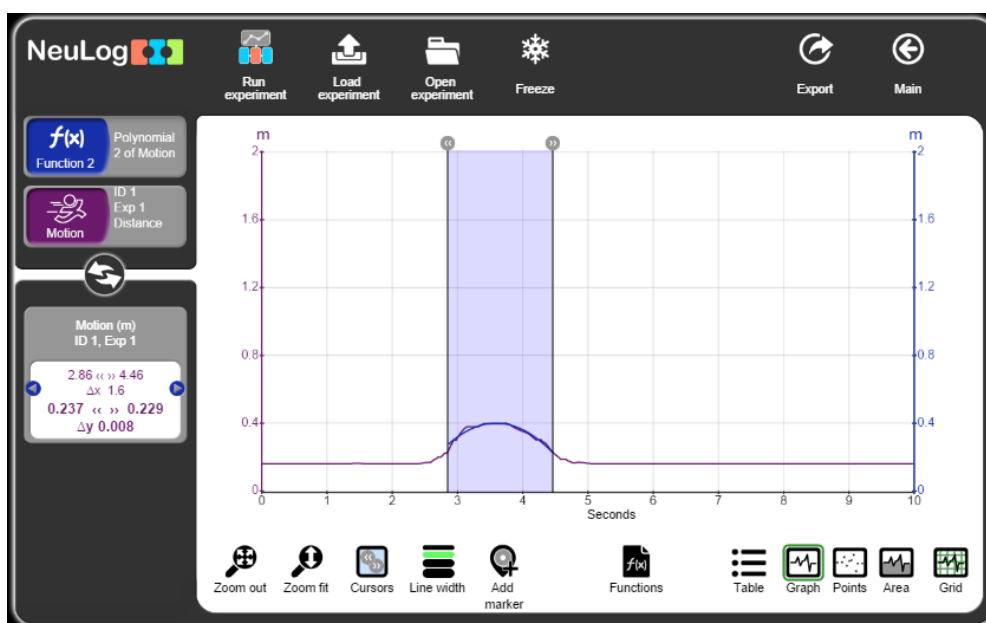
30. Click on the polynomial module box and look at the equation. For the sample experiment, this is the equation:

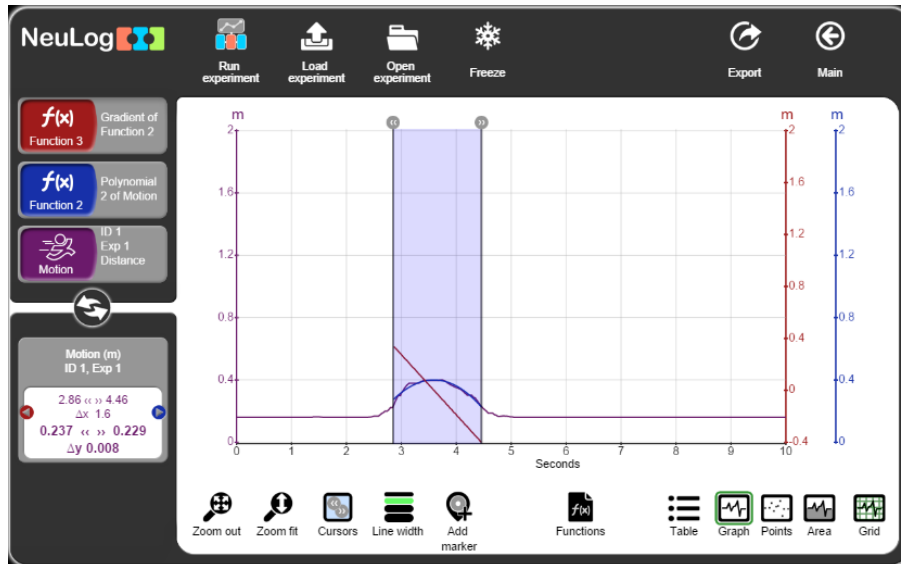> Function 1
> Polynomial 2 of Motion
> -0.2483X^2+1.7932X-2.8363

We know that:

$$d = v_i * t + \frac{1}{2} * a * t^2$$

Therefore, $\frac{1}{2} * a * t^2 = -0.2483t^2$ ($t^2 = X^2$)

a (acceleration) = -0.2483*2 = -0.4966 m/s^2

31. Click on the **Functions** icon .

32. Click on the **Data set A** icon and choose **Function 1**.

33. Click on the Functions button and then click on the **Gradient of A** button.

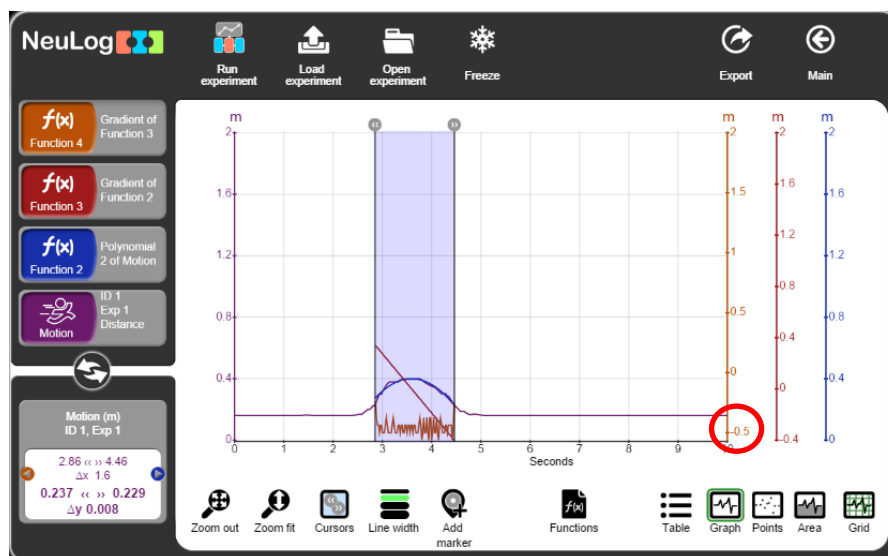34. You will receive the velocity graph:

35. Click on the **Functions** icon .

36. Click on the **Data set A** icon and choose **Function 2**.

37. Click on the Functions button and then click on the **Gradient of A** button.

38. You will receive the acceleration graph:

We can see that the velocity graph is a straight line and the acceleration graph is also a straight line (with some noise). The acceleration is constant and equals to around -0.5 m/s^2.

Summary questions

1. Find the Δd of the first part of the graph (the cart moving up) in two ways: One way with only the application (use the cursors and the window on the bottom left). The other way with the application and this equation:

$$d = \frac{v_i + v_f}{2} * t$$

Compare the two values.

2. What is the equation of the velocity graph (with using the displacement equation only and not the application functions)?