Experiment P-3

Motion Parameters of a Moving Cart

Physics

Objectives

- To learn about motion parameters.
- To study the relationship between position, velocity and acceleration of a moving cart.

Modules and Sensors

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

Equipment and Accessories

▪ 1 m Track	1
▪ Track leg	2
▪ Track rider	1
▪ Magnet in plastic case	2
▪ Sellotape	1
▪ Cart with hook (or spring)	1
▪ Reflector plate	1
▪ Utility stand	2
▪ Right angle clamp	3
▪ 20" rod	1
▪ Extension clamp	1
▪ Rod with pulley	1
▪ 10 g slotted mass	2
▪ Slotted mass holder rod	1
▪ Slotted mass hanger	1
▪ 150 cm thread	1

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

Introduction

The position (or displacement) of a moving object is marked by the letter x. The object's velocity is marked by the letter v. The velocity is determined by the ratio between the change in position and the time it took for the object to move. The formula is:

$$\mathbf{v\,(average)} = \frac{\mathbf{x\,(final) - x\,(initial)}}{\mathbf{t\,(final) - t\,(initial)}}$$

When the velocity is constant it can be described as in the formula above. When the velocity changes with time, dividing the change in position by the time will give us the object's average velocity. In order to calculate the object's momentary velocity (v(t)), we divide a very small section of the position change by the time difference.

Acceleration is the rate at which an object changes its velocity and it is marked by the letter a. The acceleration is determined by the ratio between the change in velocity and the time it took. The formula is:

$$\mathbf{a\,(average)} = \frac{\mathbf{v\,(final) - v\,(initial)}}{\mathbf{t\,(final) - t\,(initial)}}$$

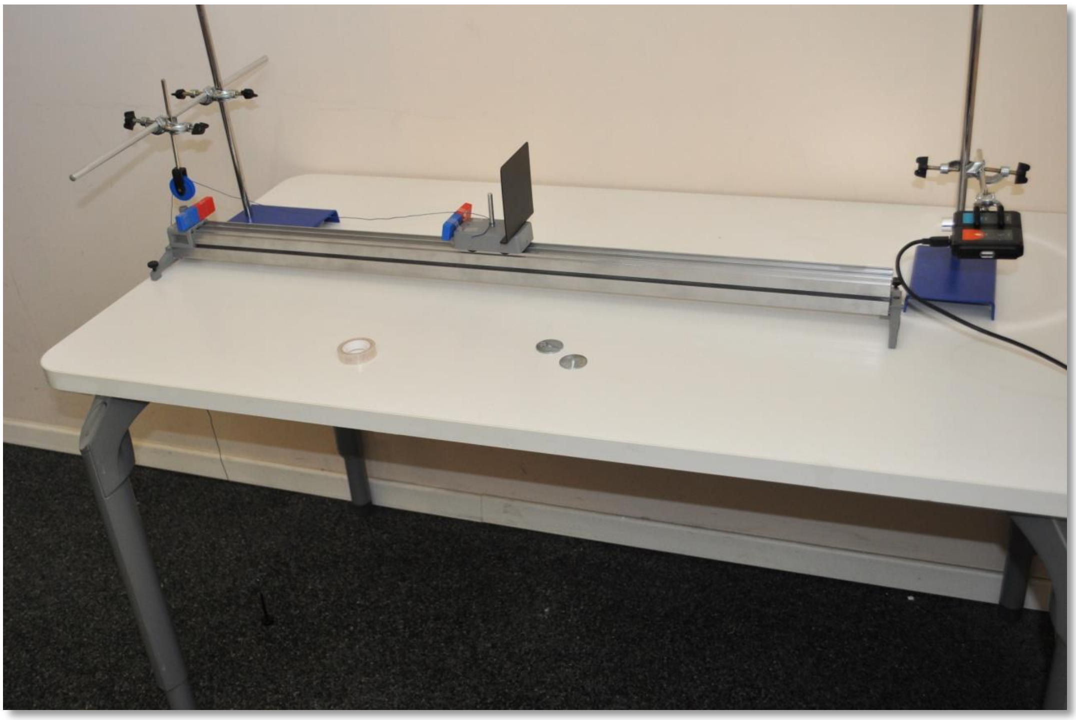
The formula above describes average acceleration (or constant acceleration). In order to calculate the object's momentary acceleration (a(t)), we divide a very small section of the velocity change by the time difference.

In this experiment we will move a cart on a track (back and forth). We will observe and analyze the changes of position, velocity and acceleration over time.

Procedure

Experiment setup

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



2. Assemble a 1 m track with two legs and a track rider.

3. Place a utility stand in each side of the track.

4. Assemble the cart with the slotted mass holder rod and the reflector plate.

5. Tape magnets to the cart and to the track rider so they will reject each other. Another option is to use a cart with a return spring.

6. One side of the track should be near the end of the table. Set up the rod with the pulley (which should be directed to the floor) on the utility stand using two right angle clamps and a 20'' rod.

7. Tie a 150 cm thread to the cart's mass holder rod.

8. Move the other side of the thread through the pulley and tie it to the slotted mass hanger.

   Make sure that when the slotted mass hanger reaches the floor, the cart still has 30-40 cm to move on the track.

9. Attach the motion sensor, connected to the USB-200 module, to the utility stand.

   Direct the motion sensor to the cart reflector plate and check that the cart plate is in line with the motion sensor all along its path on the track.

   The reflector plate's size should be at least 10 x 10 cm.

Sensor setup

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

11. 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.

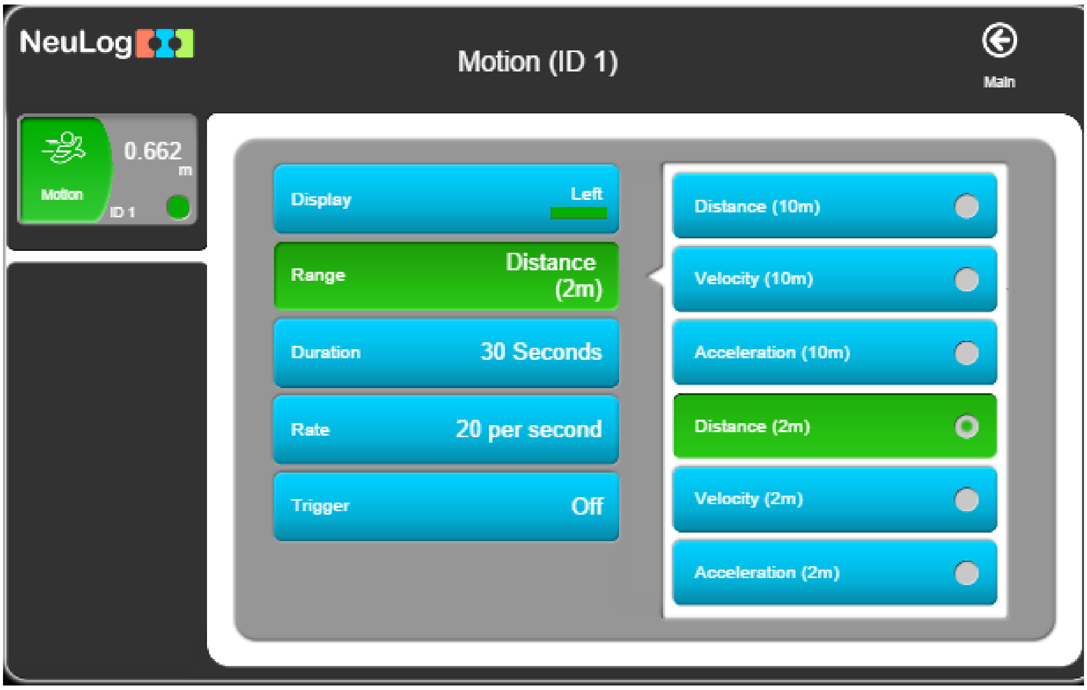
12. Run the NeuLog application and check that the motion sensor is identified.

Settings

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

14. Click on the **Range** button.

15. Select the Distance (2m) button to change the sensor's mode to position.



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

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

    Experiment duration to 5 seconds
    Sampling rate to 20 per second

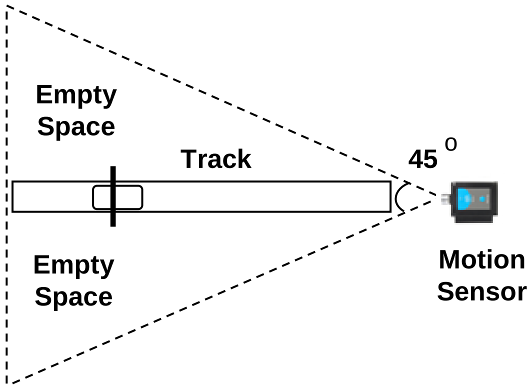
Testing and measurements

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^{o}. The sensor measures the time of the first received echo.

Make sure to remove any items located In the beam range.



18. Before starting the experiments, make sure that 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.

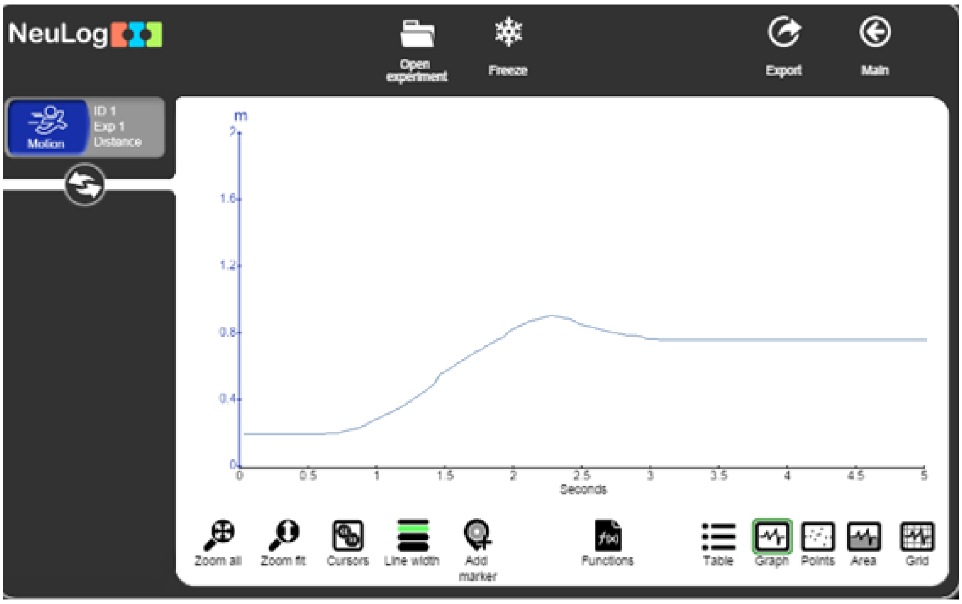
19. Move the cart from the starting point, which is at 30 cm from the motion sensor, to the edge of the track and make sure the sensor follows the cart distance all the way.

20. Put the two 10 g slotted masses on the mass hanger.

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

22. Drop the slotted mass hanger, release the cart and observe its movement.

23. Your graph should be similar to the following (use the **Zoom fit** icon if needed):



24. If your graph is not similar to the one above, check that the cart moves against the motion sensor all the time and check that there are no objects sending an echo to the sensor.

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.

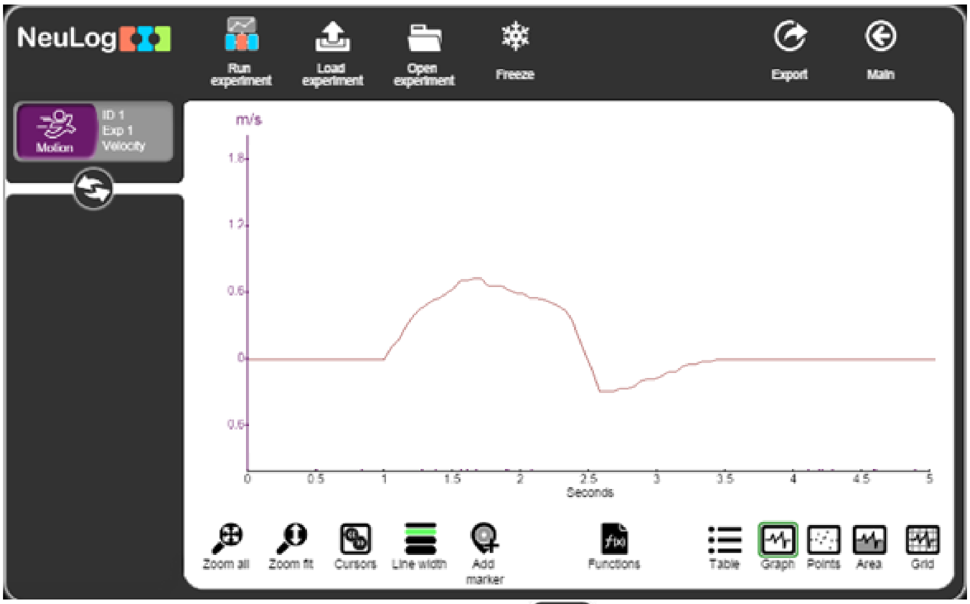
27. How do the velocity and acceleration graphs should look like? Draw the expected graphs. Identify the part in the graph where the cart moves towards the starting position.

29. Click on the sensor's **Module box** and change the sensor´s mode to velocity; **m/s**.

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

31. Drop the slotted mass hanger, release the cart and observe its movement.

32. Your graph should be similar to the following (use the **Zoom fit** icon if needed):



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

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

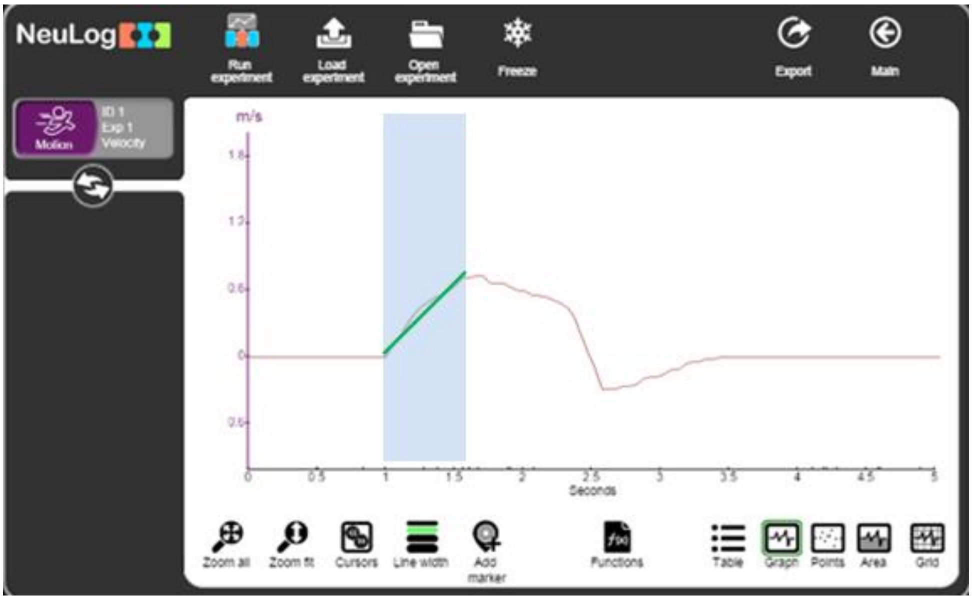
35. Let us study the cart's movement by analyzing its velocity and calculating its acceleration in each part.

36. To calculate the acceleration of the first part, click on the **Cursors** icon and select the part of the graph that represents the velocity increase of the cart.

37. Click on the **Functions** icon .

38. Click on the **Functions** button on the left of the screen and then on the **Linear fit of A** button.

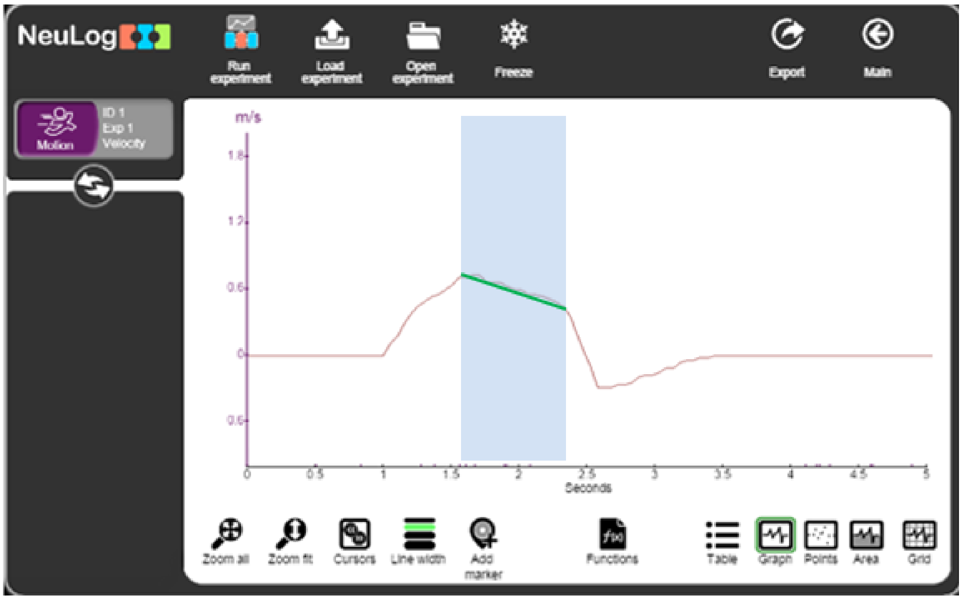
39. Click on the Linear fit module box; you will see the linear fit equation.



40. At this range, the cart moves away from the sensor (because of the slotted masses) and its velocity increases; therefore the acceleration is positive. The slope of the equation (1.2 m/s^2) equals the acceleration.
The equation is: **Y=1.2X -1.125**

41. Click on the **Functions** icon  and then on the **Clear all functions** button.

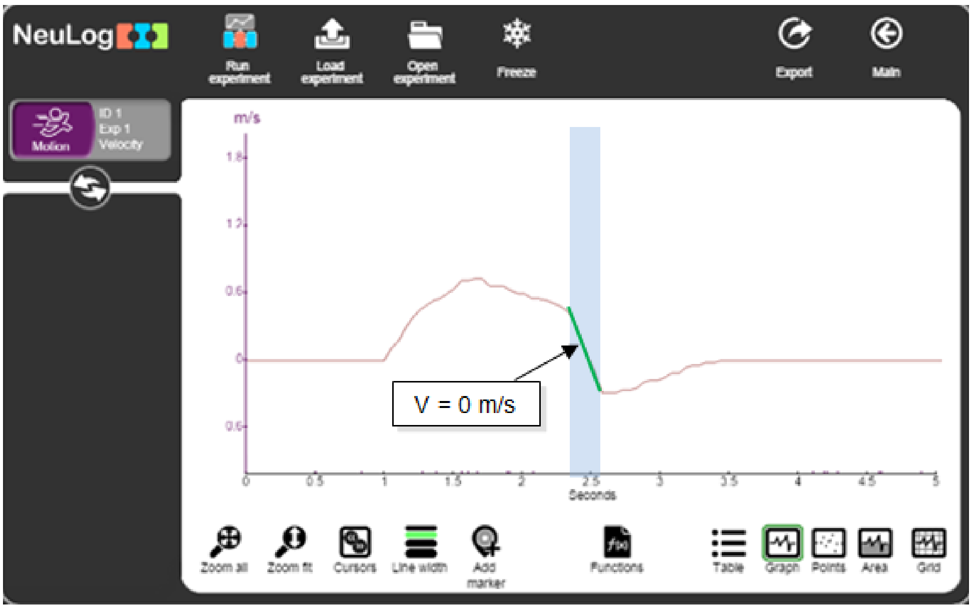
42. Select the next range and select again the **Linear Fit** option (repeat the previous steps on the second part).



43. At this range, the mass hanger is on the floor. The cart keeps moving away from the sensor but its velocity decreases, therefore the acceleration is negative (-0.45 m/s^2).
The equation is: **Y= -0.4536 +1.481**

44. Click on the **Functions** icon and then on the **Clear all functions** button.

45. Select the next range and select again the **Linear Fit** option.



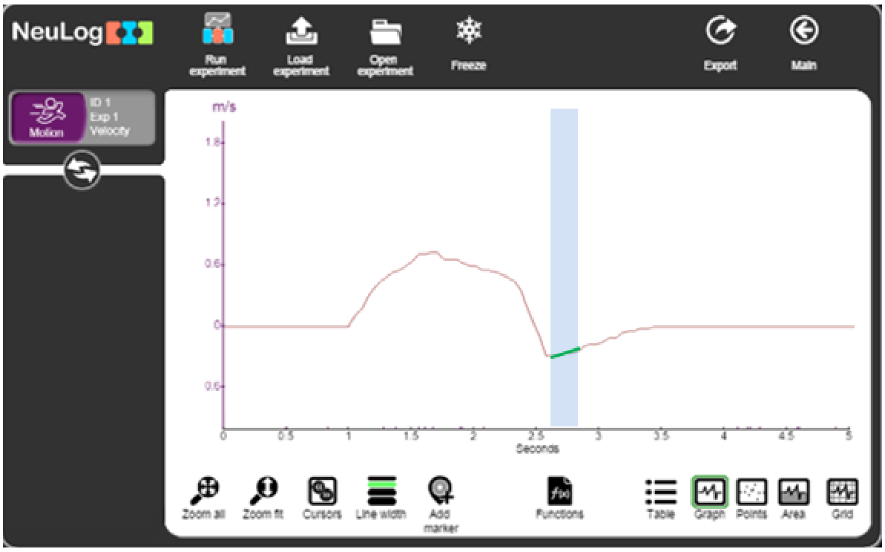
46. At this range the magnetic force stops the cart, the velocity decreases to zero on the moment it does not move. The acceleration is still negative but with a larger absolute value (-2.909 m/s^2).
The equation is: **Y= -2.909X +7.164**

After the cart stops, it increases its speed but in the other direction, hence the velocity is still negative.

The speed decreases and then increases, at that point the direction changes, thus the acceleration stays constant.

47. Click on the **Functions** icon  and then on the **Clear all functions** button.

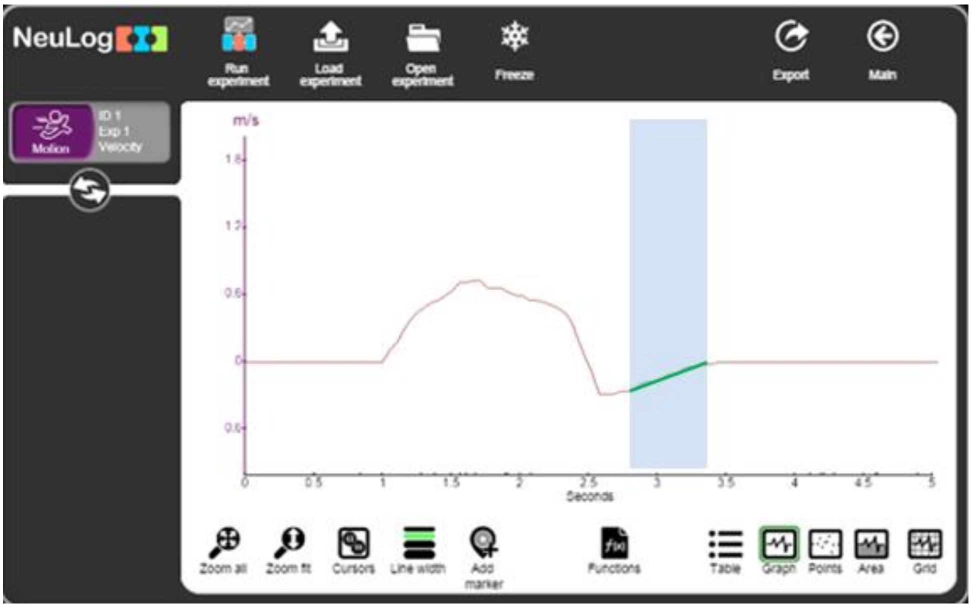
48. Select the next range and select again the **Linear Fit** option.



49. At this range, the magnetic force becomes weaker, but still pushes the cart away. The velocity decreases but still in the opposite direction, therefore the acceleration is positive (0.176 m/s^2).
The equation is: **Y= 0.176X-0.7421**

50. Click on the **Functions** icon  and then on the **Clear all functions** button.

51. Select the next range and select again the **Linear Fit** option.



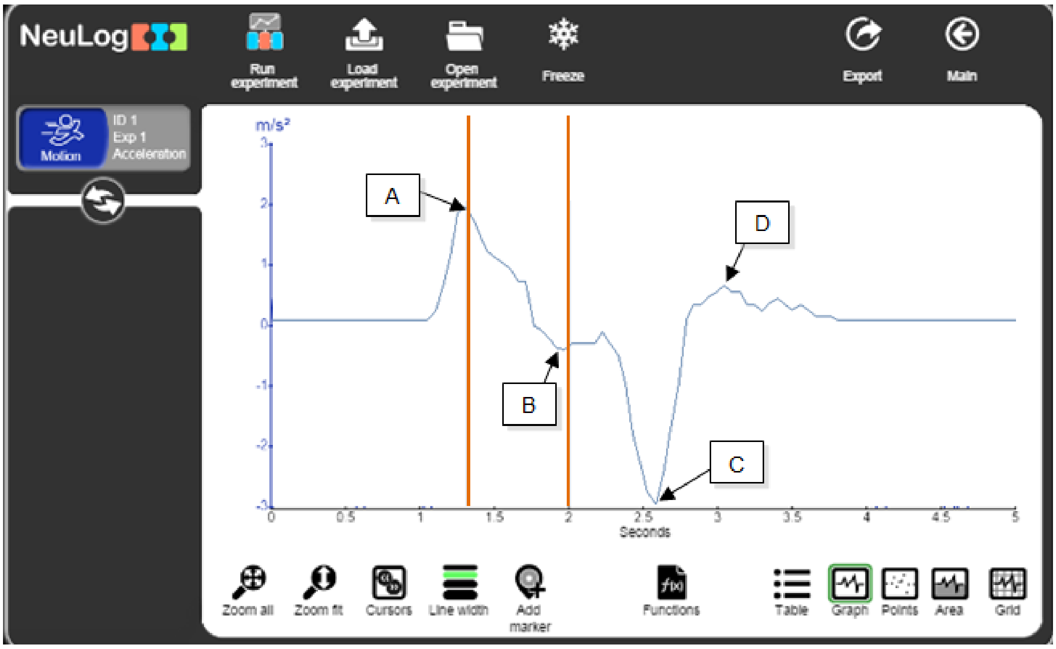
52. At this range, the magnetic force is not effective, the cart slows down and stops (due to friction force). The velocity decreases but still in the opposite direction, therefore the acceleration is positive (0.39 m/s^2). The velocity is zero when the cart stops completely.
The equation is: **Y= 0.3968X-1.33**

53. Click on the sensor's **Module box** and change the sensor´s mode to acceleration; **m/s^2**.

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

55. Release the cart and observe its movement.

56. Your graph should be similar to the following (use the **Zoom fit** icon  if needed):



57. Analyze the acceleration graph and compare it with the velocity graph. Refer to points A, B, C, and D on the example graph.

58. The sensor measures distance. From every two samples, it calculates the velocity and from every three samples it calculates the acceleration.
We only use 20 samples per second because of the time it takes for the echo to return to the sensor. Therefore, the acceleration graph is not very accurate, but shows the various accelerations of the cart.

Challenge experiment

59. Take away one slotted mass of 10 g from the slotted mass hanger (leave a 10 g mass on it) and repeat the position and velocity measurements.

Summary questions

1. Analyze the position and velocity graphs of the challenge experiment.

2. Analyze the following position graph as you learned in this activity.