Experiment P-48
Impulse and Momentum

Physics

Objectives

- To learn about the relation between impulse and momentum.
- To examine this relation by bouncing a ball on a force plate logger sensor and measuring the applied force.
- To calculate impulse and change in momentum, then compare these values.

Modules and Sensors

- PC + NeuLog application
- USB-200 module
- NUL-225 Force plate logger sensor

Equipment and Accessories

▪ Basketball	1
▪ Other type of ball (optional)	1

Introduction

Momentum is defined as the product of the mass and velocity of an object. It is hard to stop an object with a high momentum.

The quantity of **mass (m) × velocity (v)** is the **momentum**.
The quantity of **mass (m) × change in velocity (Δv)** is the change in momentum.
The quantity of **force (F) × time (t)** is known as **impulse**.

Impulse is equal to the change in momentum, **F×t = m×Δv**.

In this activity we will drop a basketball on a force plate. The basketball will bounce a few times on the force plate and the force applied on it will be measured throughout the time of the experiment. We will use the force value to calculate the impulse and we will use the time between the hits to calculate the momentum before the ball hits the force plate and after. This will give us the change in momentum. Then we will compare the impulse to the change in momentum and see if these are similar values.

Procedure

Experiment setup

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

2. Place the force plate sensor on the floor.

3. Make sure that your ball is fully inflated.

Sensor setup

4.   Connect the USB-200 module [icon] to the PC.

5.   Check that the force plate logger sensor [icon] 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.

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

<u>Settings</u>

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

8.   Click on **Extra command** button and then on the **Push=Positive** button to get positive values when hitting the force plate with the ball.
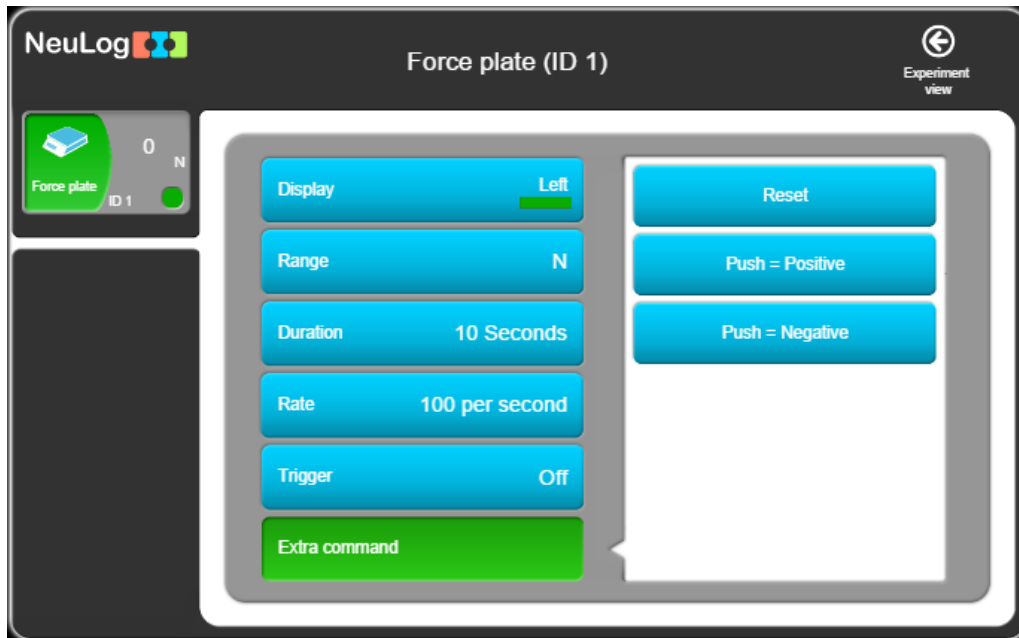
9.   Click on the **Reset** button to zero the sensor.

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

     Experiment duration to 10 seconds
   Sampling rate to 100 per second

Testing and measurements

11.   Weigh the ball with the force plate. Divide the value you see on the module box by 9.8 m/s^2 in order to get the mass in Kg instead of N. Another option is to weigh the ball on a scale.

12.   Before beginning the experiment, practice on releasing the ball (without any force) on the force plate from about a one meter height. The ball should bounce as many times as possible on the force plate.

13.   Click on the **Record** icon ⏺ to start the measurement.

14.   Release the ball as practiced before.

15.   Click on the **Zoom fit** icon 🔍.

16.   Your graph should be similar to the following:
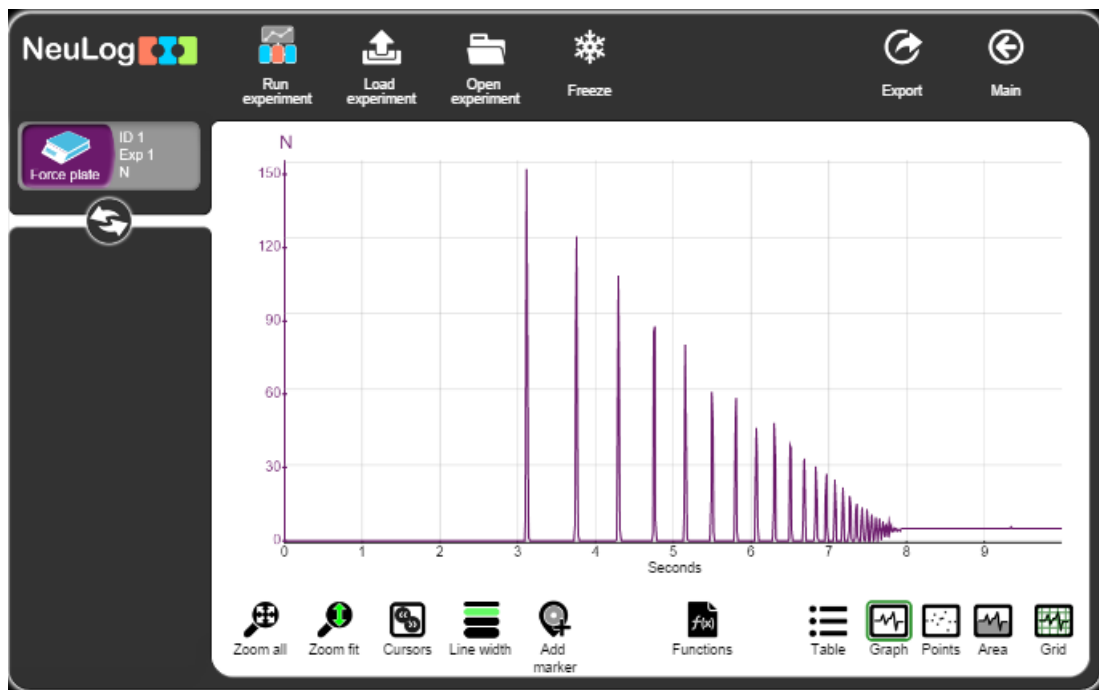
17.   Click on the **Export** Icon and then on the **Save value table (.CSV)** button to save your graph.

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

NeuLog

19. Click on the **Cursors** icon in order to select the area of the second spike as shown in the picture below.
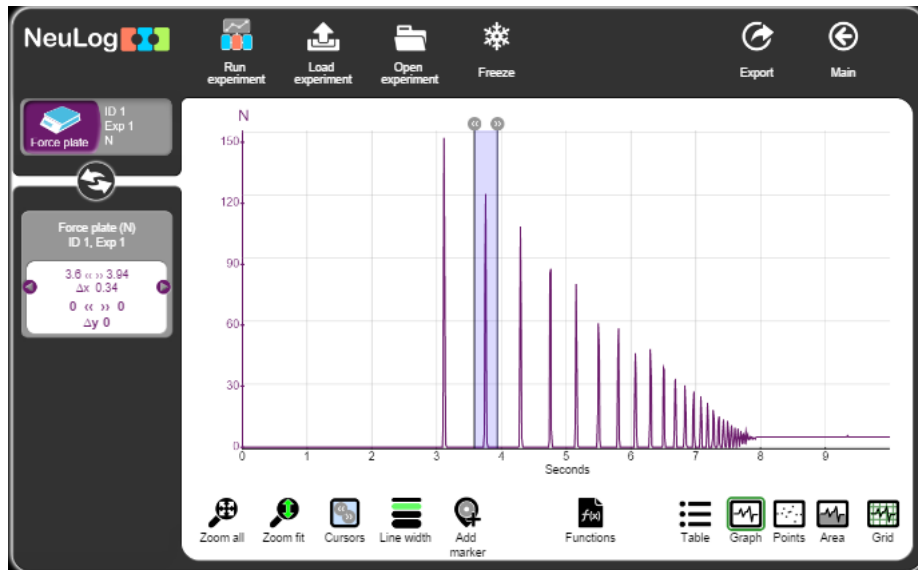
20. Click on the **Functions** icon and then on the Functions button.

21. Click on **Integral of A.**

22. Click on the **Integral of Force plate** module box on the left of the screen.

23. Look at the highest sample value; it is the area beneath this part of the graph:
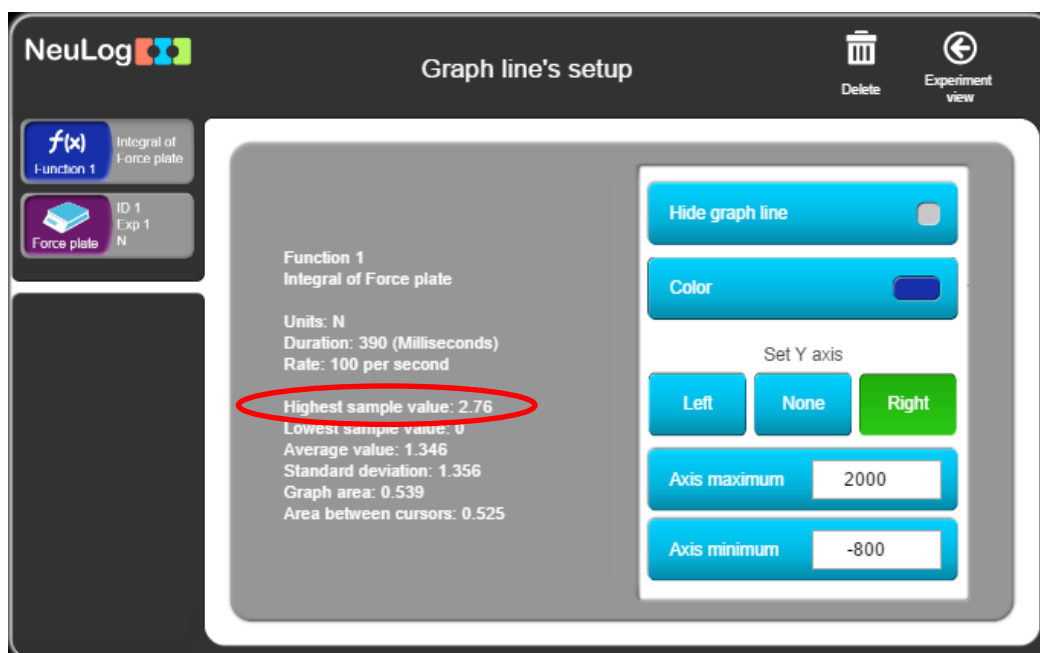
24. Fill the area value in the table below. In the sample experiment the area is 2.76 N×s.

The area of the spike equals the force applied on the force plate during the time of the hit.

The ball in the sample experiment has a mass of 0.489 Kg.

Hit number	Impulse: surface area of the spike [N×s]	t_1: time between this spike and the spike before [s]	velocity before hitting the plate $v_1= -g×t_1/2$ [m/s]	t_2: time between this spike and the next spike [s]	velocity after hitting the plate $v_2= g×t_2/2$ [m/s]	Change in momentum $m× (v_2-v_1)$ [Kg×m/s]= [N×s]	Ratio: Impulse / momentum × 100%
2 (example)	2.76	0.65	-3.185	0.53	2.597	2.827	97.6
2							
3							
4							
5							
6							
7							

25.   Click on the **Cursors** icon 🔲 and select the area between the first spike and the second spike as shown in the picture below.
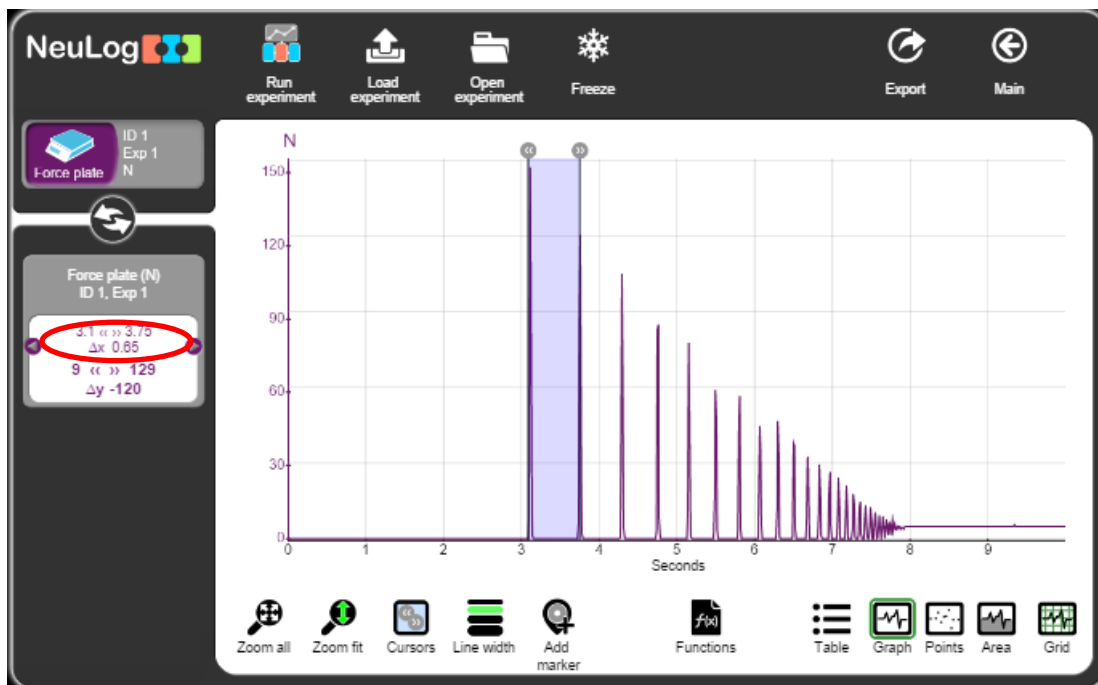
26.   Look at the time difference (ΔX) between the first and second spike.

27.   Fill the table above with this value. In the sample experiment the ΔX is 0.65 seconds.

28. Repeat the last three steps but this time look for the time difference between the second and third spike.

   The time values will help us calculate the velocity before and after the second bounce.

Calculations:

29. **Velocity before hitting the plate:**
   Insert the "time between this spike and the spike before" into the equation:

   $v_1 = -g \times t_1 / 2$ **[m/s]**

   For the sample experiment:
   $V_1 = -9.8 \ m/s^2 \times 0.65 \ s / 2 = -3.185 \ m/s$

   The minus sign is due to the direction of the hit.

   We divide the time by two to get only the time in which the ball falls down.

   Insert your value into the table.

30. **Velocity after hitting the plate:**
   Insert the "time between this spike and the next spike" into the equation:

   $v_2 = g \times t_2 / 2$ **[m/s]**

   For the sample experiment:
   $V_1 = 9.8 \ m/s^2 \times 0.53 \ s / 2 = 2.597 \ m/s$

   We divide the time by two to get only the time in which the ball bounces up.

   Insert your value into the table.

31. **<u>Change in momentum:</u>**
The product of the object's mass and the average velocity equals the change in momentum:

m×Δv = m× (v$_2$-v$_1$) [Kg×m/s]=[N×s]

Insert your parameters into the equation.

For the sample experiment:

0.489 Kg × (2.597 m/s +3.185 m/s) = 2.827 Kg×m/s = 2.827 N×s

Insert your value into the table.

32. **<u>Impulse and change in momentum ratio:</u>** divide the impulse by the change in momentum and multiply by 100%.

For the sample experiment:

2.76 N×s / 2.827 N×s × 100% = <u>97.6 %</u>

Insert your value into the table.

Please note that for this simple activity, in fact, we do get a very nice and accurate confirmation that the impulse is equal to the change in momentum.

33. Repeat these steps for the rest of the hits and Insert your values into the table.

Challenge research

34. Repeat the experiment with a different ball (with a different mass or elasticity).

Summary questions

1. Did you get similar values for the impulse and the change in momentum?

2. If you release the ball from a lower height, how will the impulse change? How will the velocities change?

3. How did the force change in each bounce? How did the time between bounces change? Explain.

4. How did the results change in the challenge experiment? Explain the difference between the results.