# Experiment P-57
# Charging a Capacitor

*Physics*

## Objectives

- To learn about charging and discharging of capacitors.
- To measure voltage and current while charging and discharging a capacitor.

## Modules and Sensors

- PC + NeuLog application
- USB-200 module
- NUL-201 Voltage logger sensor ±20V
- NUL-248 mA Current logger sensor ±250mA

*It is also possible to conduct this experiment with the NUL-202 Current logger sensor.

## Equipment and Accessories

| | |
|---|---|
| ▪ Circuit board | 1 |
| ▪ 6 V cell holder | 1 |
| ▪ Black 4 mm connector cable | 1 |
| ▪ Red 4 mm connector cable | 1 |
| ▪ 47 Ω mounted resistor | 1 |
| ▪ 1.5 V battery (type D) | 4 |
| ▪ 4700 µF capacitor | 1 |

- The items above are included in the NeuLog Electricity kit, ELE-KIT.

## Introduction

A capacitor is, in a way, like a battery; both store electrical energy, but work in completely different ways. Batteries have two terminals; chemical reactions inside them produce electrons on one terminal and absorb electrons on the other. A capacitor cannot produce new electrons, it can only store them.

A capacitor consists of two plates separated by an insulator. The capacitance of the capacitor equals the charge stored on the plates divided by the potential difference across the plates.

$$C = \frac{Q}{V}$$

The unit for capacitance is farad (F), often measured in mF. One farad equals one coulomb per volt.

A charging circuit contains only a resistor, a capacitor, a switch and a constant DC source of voltage ($V_{max}$); if the capacitor is initially uncharged while the switch is open, and the switch is closed at $t_0$ then, while charging:

$$I(t) = \frac{V_{max}}{R} e^{\frac{-t}{RC}}$$

$$V(t) = V_{max}(1 - e^{\frac{-t}{RC}})$$

During discharge:
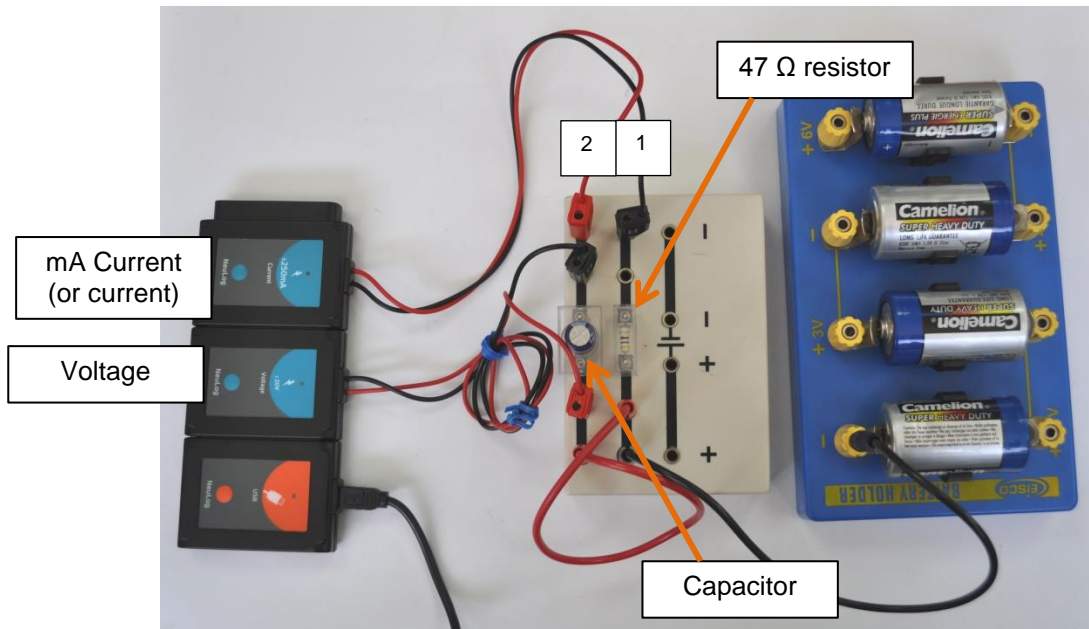
$$I(t) = -(\frac{V_{max}}{R})e^{\frac{-t}{RC}}$$

$$V(t) = V_{max}e^{\frac{-t}{RC}}$$

In this experiment, a charging circuit will be used for measuring voltage and the current while charging and discharging a capacitor.

# Procedure

## Experiment setup

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



2.  Connect the 47 Ω resistor to the middle of row number one on the circuit board.

3.  Connect the capacitor to the middle of row number 2 (in the picture above).

4.  Connect the black and red cables of the voltage sensor in each side of the capacitor as in the picture.

5.  Connect the black and red cables of the mA current sensor on rows 1 and 2 as in the picture.

6.  Connect one side of the black 4 mm cable to the end of row number one, and the other side to the "-" sign of the 6 V cell holder.

7.  Connect one side of the red 4 mm cable to the end of row number 2, and the other side to row number 1 (between the resistor and the black 4 mm cable).
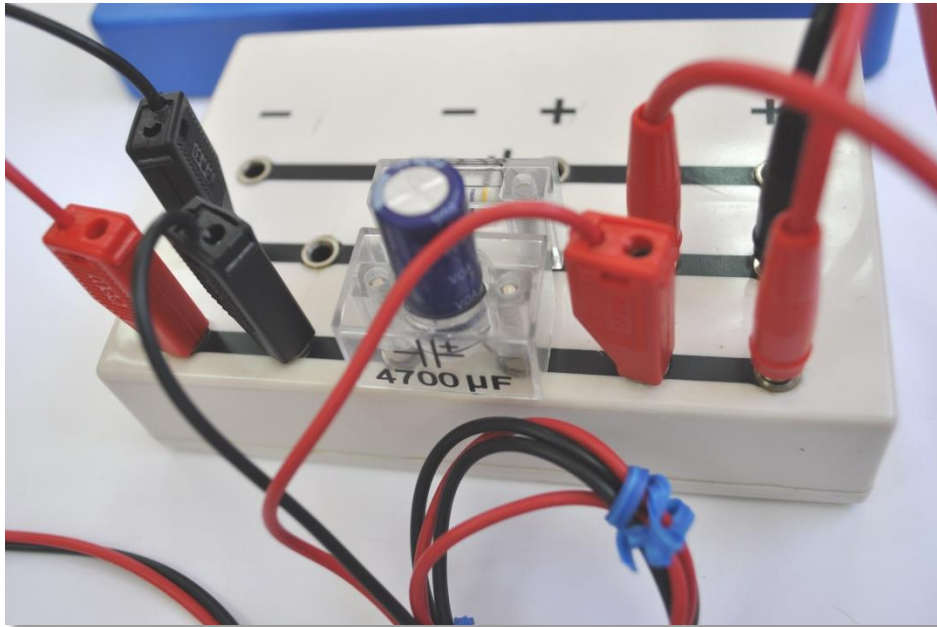
8.      Make sure the capacitor's + side is near the red cable of the voltage sensor.

**Sensor setup**

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

10.     Check that the voltage [±20V] and mA current [±250mA] sensors are connected to the USB-200 module in a chain.

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 sensors are identified.

## Settings

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

        Experiment duration to 10 seconds
        Sampling rate to 100 per second

## Testing and measurements

13.     Make sure the voltage value is zero at the beginning of the measurement.

14.     Click on the **Record** icon .

15.     Immediately take the end of the red cable near the resistor and move it to the battery "+6V" sign of the battery holder. Do not insert the cable, just touch the hole with the red cable.

16.     After two seconds, move the red cable end back near the resistor. Again, do not insert the cable, just touch the hole with it.

17.	Click on the **Zoom fit** icon.

18.	Your data should be similar to the following.
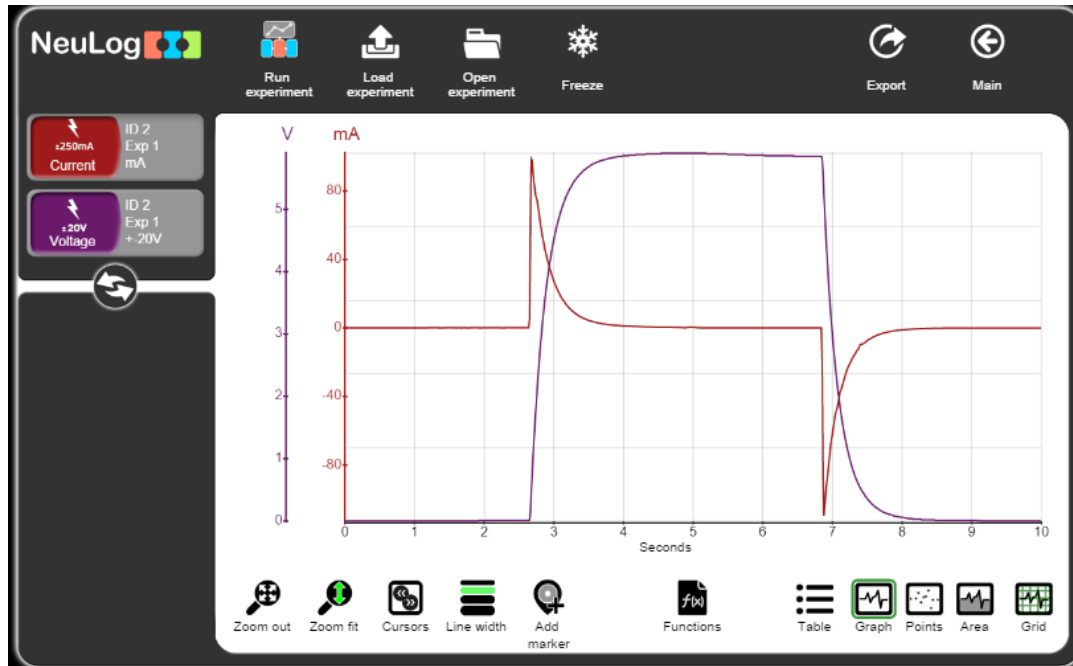


19.	Save your data.

We can see that as the circuit closes and charging of the capacitor begins, the current increases to maximum and then decreases to zero. The voltage of the capacitor increases.

When discharging the capacitor, we see that the current decreases from zero to a minus value; it then increases gradually until it reaches zero and the capacitor is discharged. The voltage of the capacitor decreases to zero.

20. Click on the **Cursors** icon ⬚ and select the part where the current decreases as in the picture below.
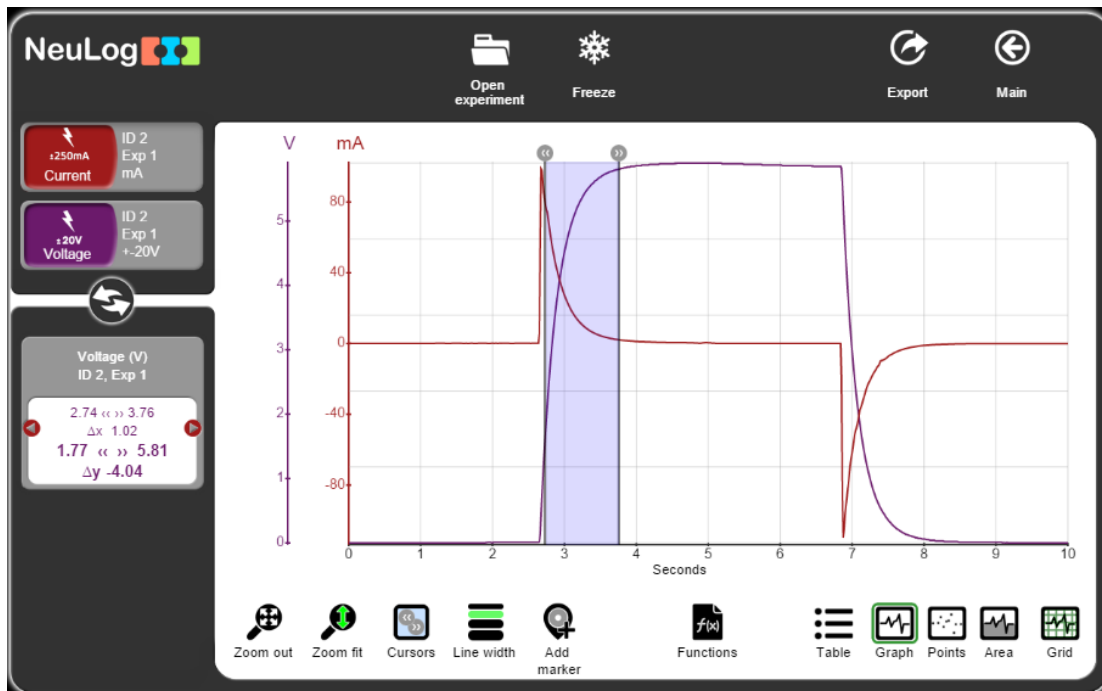


21. Click on the **Functions** icon ⬚.

22. Click on the **Data set A** button and choose Current.

23. Click on the **Functions** button on the left of the screen and select the **Ln (A)** button.
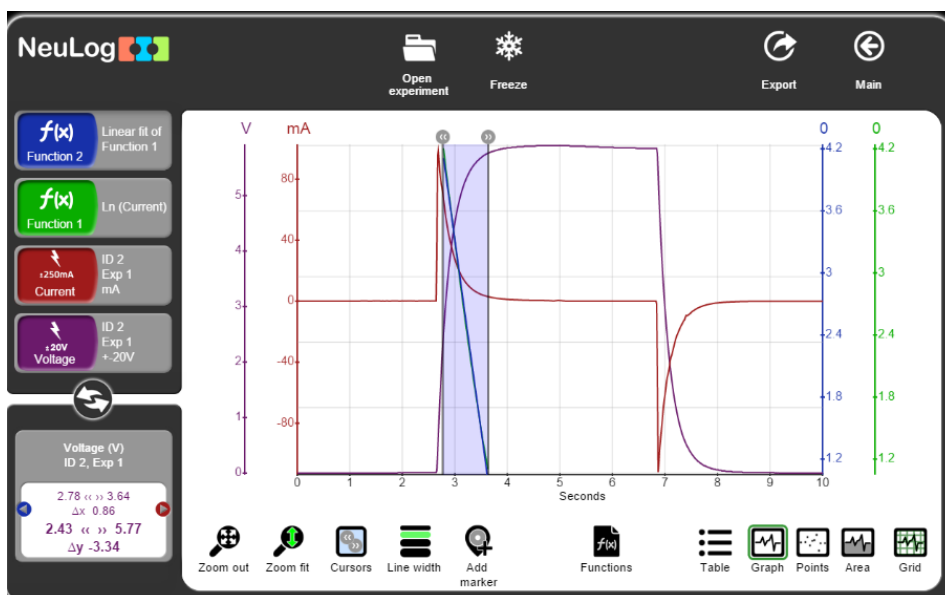
24.    Click on the **Zoom fit** icon.
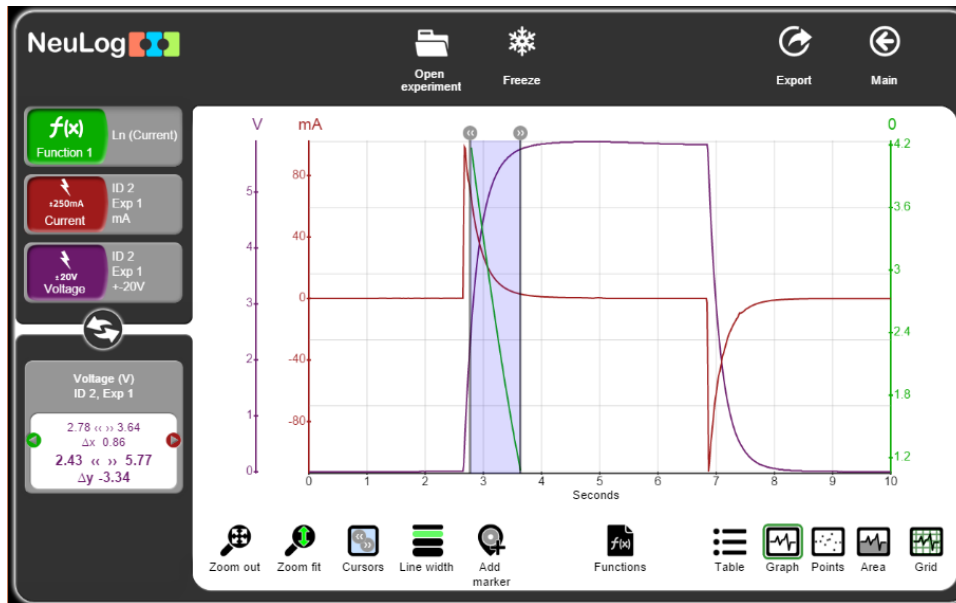


10.    Click on the **Functions** icon.

11.    Click on the **Data set A** button and choose Function 1.

12.    Click on the **Functions** button on the left side of the screen and then click on the **Linear fit of A** button.

13.    Click on the **Zoom fit** icon.

14.  Click on the Linear fit module box, you will see the linear fit equation.

Function 2
Linear fit of Function 1
-3.6832X+14.3706

The current is equal to the following equation while charging:

$$I(t) = \frac{V_{max}}{R} e^{\frac{-t}{RC}}$$

Therefore, when applying the Ln function, its slope is equal to -1/RC.

15.  Fill in the first part of the table:

| Part of the graph | Ln function slope (-1/RC) | -1/RC from given values | Error percentage |
|---|---|---|---|
| Current decrease (charge) | | -1/(47Ω*0.0047F) = -4.5 Ω F | |
| Voltage decrease (discharge) | | -1/(47Ω*0.0047F) = -4.5 Ω F | |

16.  The voltage is equal to the following equation while discharging:

$$V(t) = V_{max} e^{\frac{-t}{RC}}$$

Therefore when applying the Ln function, its slope is equal to -1/RC.

Repeat the procedure you did for the current charge for the voltage discharge. Fill in the table above.

## Summary questions

1.  Compare the results from the two parts of the graph. Explain.

2.  How do the resistance and the capacitance affect the charging and discharging rate of the capacitor?

3.  Give two examples of how capacitors are used in real life electronics circuits.