Experiment P-24
Circuits and Series Resistance

Physics

Objectives

- To study the relationship between the voltage applied to a given resistor and the intensity of the current running through it.

Modules and Sensors

- PC + NeuLog application
- USB-200 module
- NUL-201 Voltage logger sensor
- NUL-202 Current logger sensor

Equipment and Accessories

▪ Circuit board	1
▪ 6 V cell holder	1
▪ Knife switch	1
▪ Black 4 mm connector cable	1
▪ Red 4 mm connector cable	1
▪ 10 Ω mounted resistor	1
▪ 47 Ω mounted resistor	1
▪ Bridge	2
▪ 1.5 V battery (type D)	2

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

Introduction

Electric current is the rate of charge flow past a given point in an electric circuit. It is measured in Coulombs/second which is called Amperes (symbol: A).

A current flows through a conductor as long as there is an excess of electrons at one end of the conductor and a deficiency at the opposite end. The electrical source creates this excess of electrons. The potential is the ability of the source to perform electrical work. The work accomplished in a circuit is the result of the difference of potential (the voltage) at the two ends of the conductor. It is measured in Volts (symbol: V).

When free electrons move through the circuit, they encounter atoms that oppose to the flow. This opposition to the flow is called resistance and it is measured in Ohms (symbol: Ω). The amount of resistance depends on the material's size, shape and temperature.

Ohm's law was first observed by George Ohm in 1827. It defines the relationship between these three fundamental factors: current, voltage and resistance. According to this law the current is directly proportional to the voltage and inversely proportional to the resistance.

The mathematical equation that describes this relationship is:

$$\mathbf{I} = \frac{\mathbf{V}}{\mathbf{R}}$$

Where:
I= current (amperes)
V= voltage (volts)
R= Resistance (ohms)

Resistors can be connected in series or in parallel. When connected in series, the current flows through them one after another. Since there is only one path for the current to travel, the current through each of the resistors is the same.

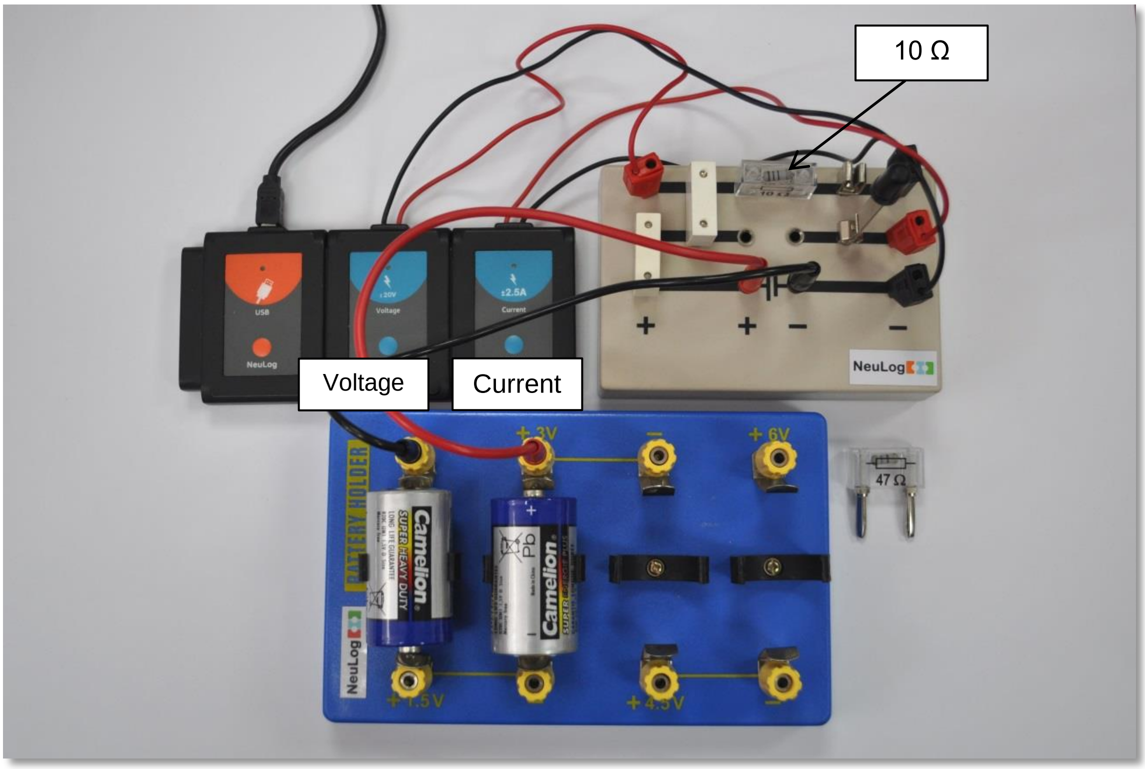
The voltage across the resistors must add up to the total voltage is supplied by the battery: $\mathbf{V_{total} = V_1 + V_2}$ and since $\mathbf{V = IR}$
$\mathbf{V_{total} = IR_1 + IR_2}$ and $\mathbf{R_{equivalent} = R_1 + R_2}$.

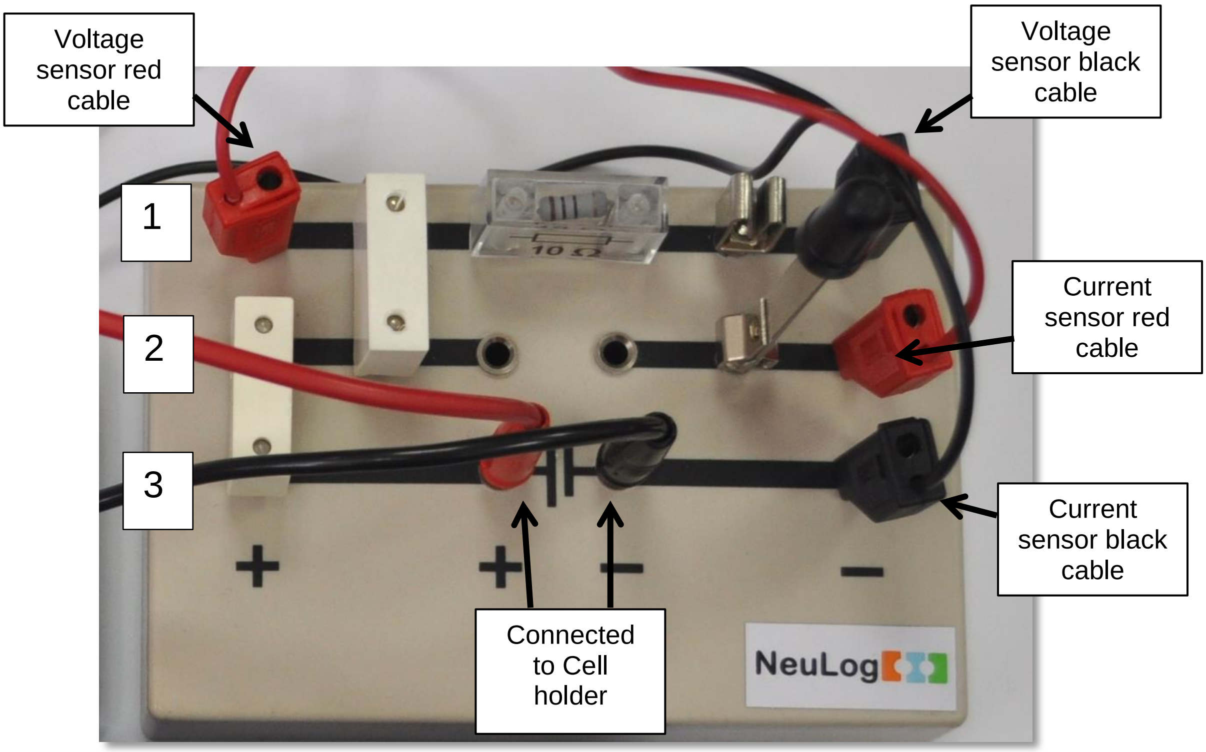
In this experiment, an electrical circuit with two resistors in series will be assembled. Voltage and current will be measured in five configurations in order to understand the principles of resistors in series.

Procedure

Experiment setup

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





2. Connect the 10 Ω resistor to the middle of row number one on the circuit board.

3. Connect the knife switch on the resistor's right side, on rows number 1 and 2.

4. Connect one bridge on the resistor's left side, on rows number 1 and 2.

5. Connect another bridge on the first bridge's left side, on rows number 2 and 3.

6. Connect the black cable of the current sensor next to the "-" at the side of the board, on row number 3.

7. Connect the red cable of the current sensor to the socket next to the black cable, on row number 2.

8. Connect the black cable of the voltage sensor next to the knife switch, on row number 1.

9. Connect the red cable of the voltage sensor next to the bridges, on row number 1.

10. Connect a red 4 mm connector cable to the "+" side of the battery sign ⊣⊢ .

11. Connect a black 4 mm connector cable to the "-" side of the battery sign ⊣⊢ .

12. Place two 1.5 V (type D) batteries in the 6 V cell holder as shown in the picture (the "+" side of the battery should be on the "+" side of the cell holder).

13. Connect the other end of the red 4 mm connector cable to the socket next to the "+ 3 V" writing at the 6 V cell holder.

14. Connect the other end of the black 4 mm connector cable to the socket next to the "-" writing.

Sensor setup

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

16. Check that the voltage 

and current 

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.

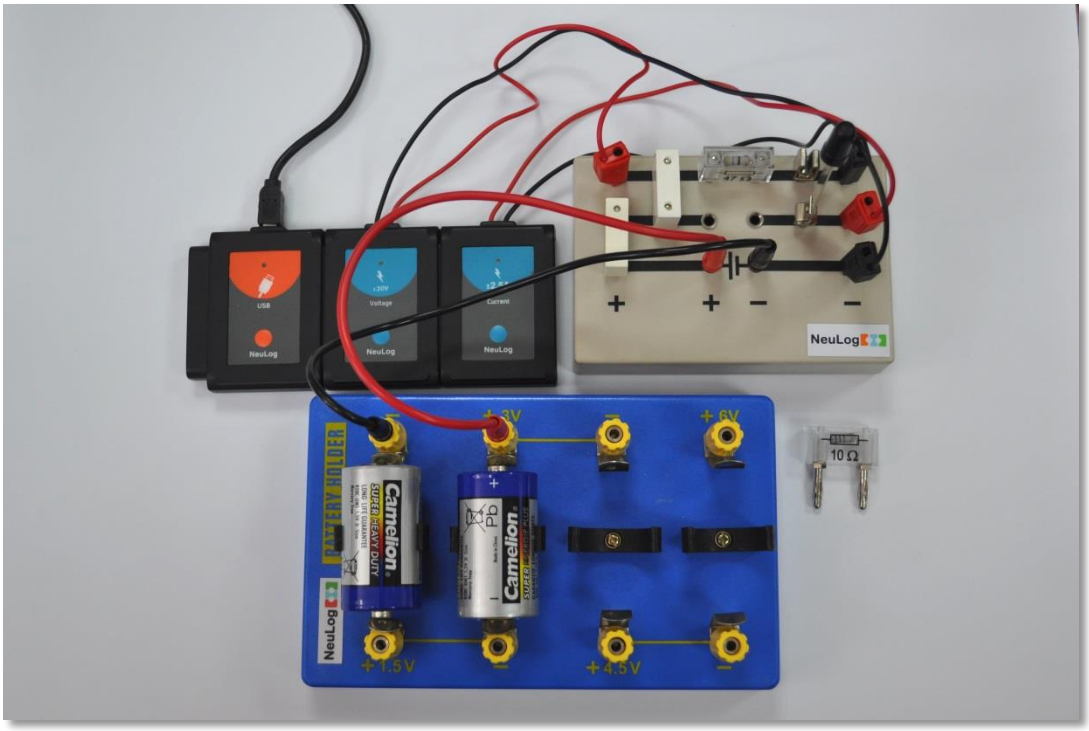
17. Run the NeuLog application and check that the sensors are identified.

Testing and measurements

18. Close the switch to apply 3 V to the circuit and click the **Single step** icon .

19. Click on the **Table** icon  on the bottom part of the screen. A table will be displayed for data record.

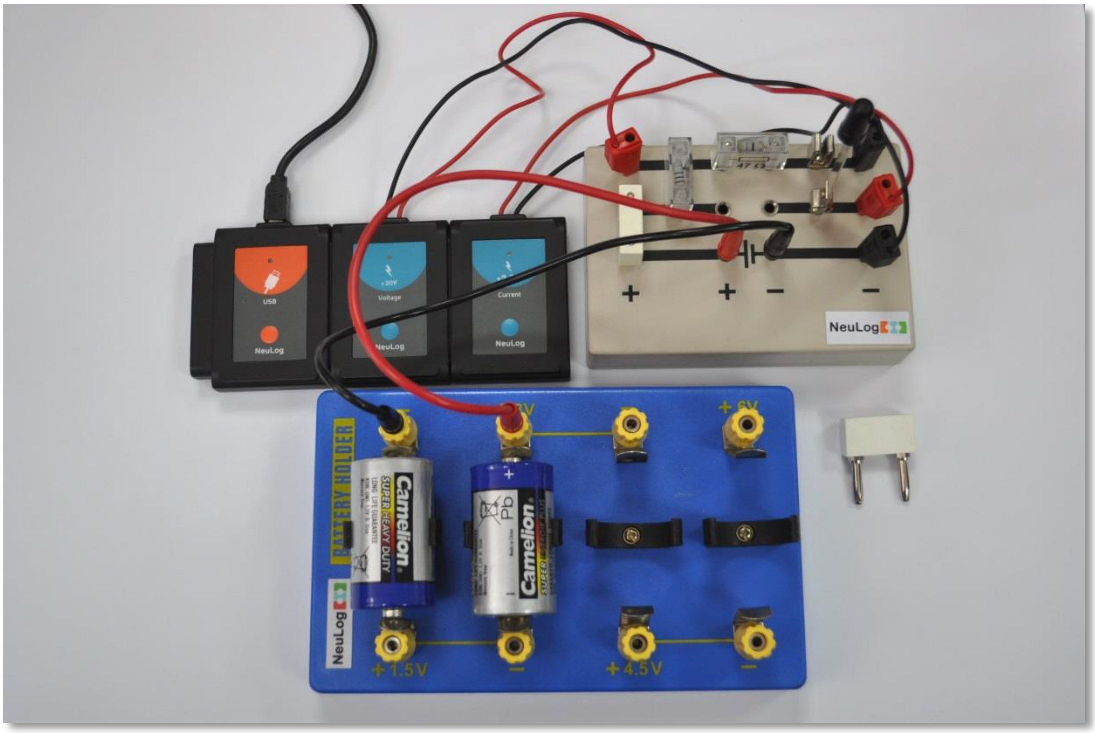
20. Open the knife switch and replace the 10 Ω resistor with the 47 Ω resistor.



21. Close the knife switch.

22. Click on the **Single step** icon  again for a new measurement.

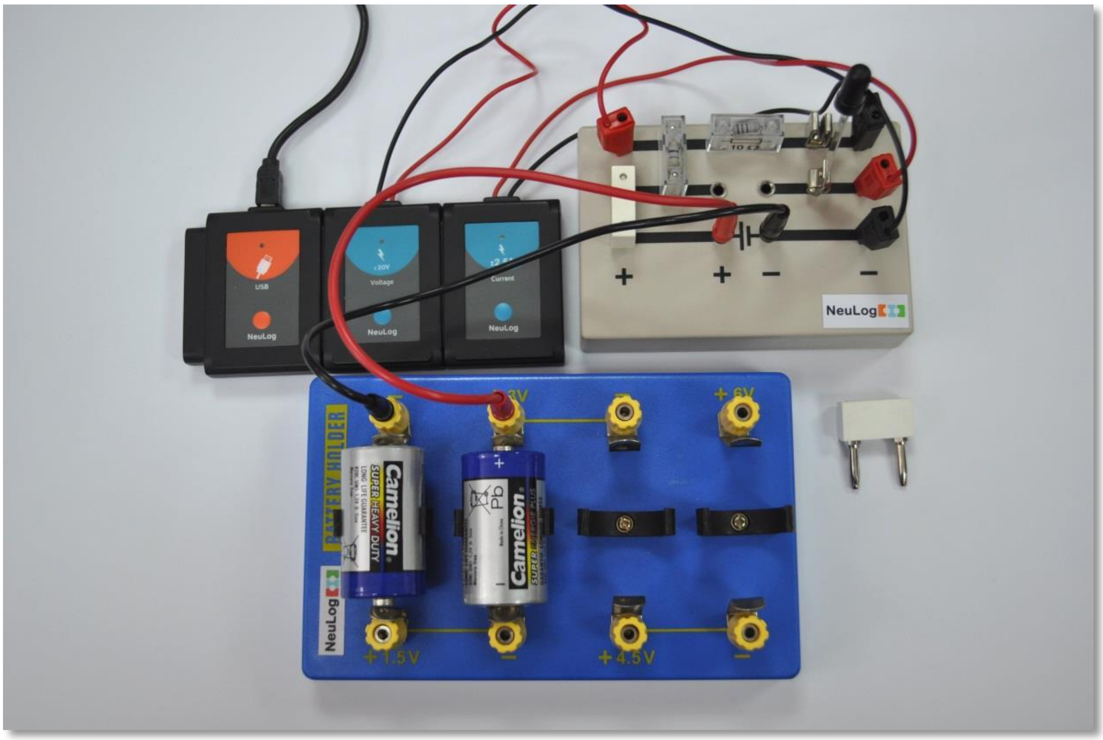
23. Open the knife switch and replace the bridge next to the 47 Ω resistor with the 10 Ω resistor. You will measure the current that flows through two resistors, and the voltage across only the 47 Ω resistor.



24. Close the knife switch.

25. Click on the **Single step** icon  again for a new measurement.

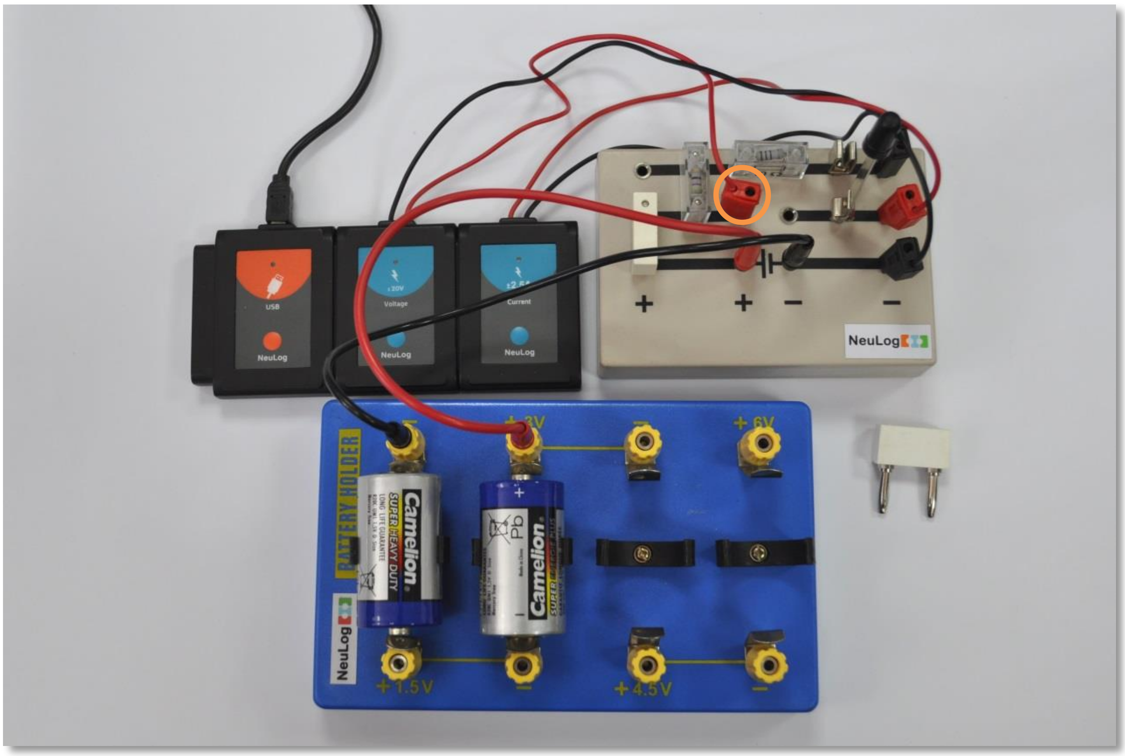
26. Open the knife switch and exchange between the 10 Ω resistor and the 47 Ω resistor. You will measure the current that flows through two resistors and the voltage across only the 10 Ω resistor.



27. Close the knife switch.

28. Click on the **Single step** icon  again for a new measurement.

29. Open the knife switch and move the red cable of the voltage sensor to the right side of the 47 Ω resistor on line number 2. You will measure the current that flows through two resistors, and also the voltage across both of them.

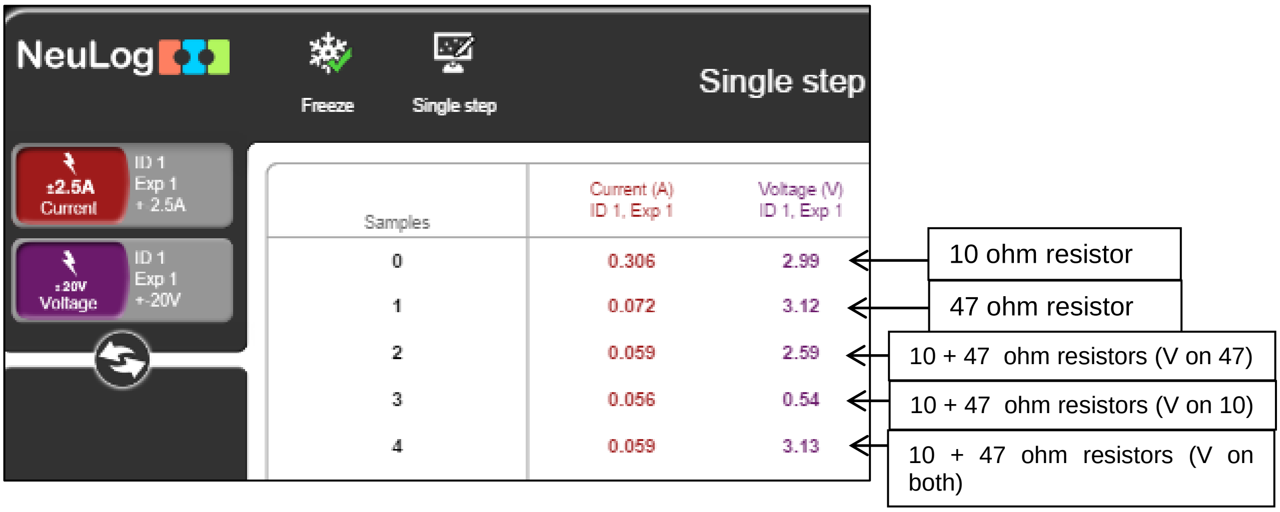


30. Close the knife switch.

31. Click on the **Single step** icon  again for a new measurement.

32. Open the knife switch.

33. Your data should be similar to the following.



Samples	Current (A) ID 1, Exp 1	Voltage (V) ID 1, Exp 1
0	0.306	2.99
1	0.072	3.12
2	0.059	2.59
3	0.056	0.54
4	0.059	3.13

34. Save your data.

35. We can see that the voltage measured with either the 10 Ω or 47 Ω resistors was around 3 V (the voltage of the batteries).

As expected, the current measured with the 47 Ω resistor was lower than the one measured with the 10 Ω resistor.

When using both resistors in series, we got a current of 0.059 A in the sample experiment. When combining two resistors, we can sum up their resistance; it is as if we used a resistor of 57 Ω (10 Ω +47 Ω). As expected, the current was lower than only with one resistor.

This data should fit the Ohm's law equation $\mathbf{I} = \frac{\mathbf{V}}{\mathbf{R}}$; you will check it in the summary questions section.

When measuring the voltage of the 47 Ω resistor and the 10 Ω separately in the sample experiment, we got a voltage of 2.59 V and 0.54 V respectively. We can sum up the two voltage values, 2.59 V + 0.54 V = 3.13 V. We got the batteries voltage (around 3 V).

Summary questions

1. Did the measured current and voltage with either the 10 Ω resistor and the 47 Ω resistor fit the Ohm's law equation $\mathbf{I} = \frac{\mathbf{V}}{\mathbf{R}}$? Write down your calculations.

2. Did the measured current and voltage with both resistors in series fit the Ohm's law equation $\mathbf{I} = \frac{\mathbf{V}}{\mathbf{R}}$? Look at the last measurement where the voltage was measured on both of the resistors. Write down your calculations.

3. Explain how the voltage is divided by the two resistors. Address the equation in the introduction and write down your calculations.