Additional information on Resistors and the Wheatstone Bridge

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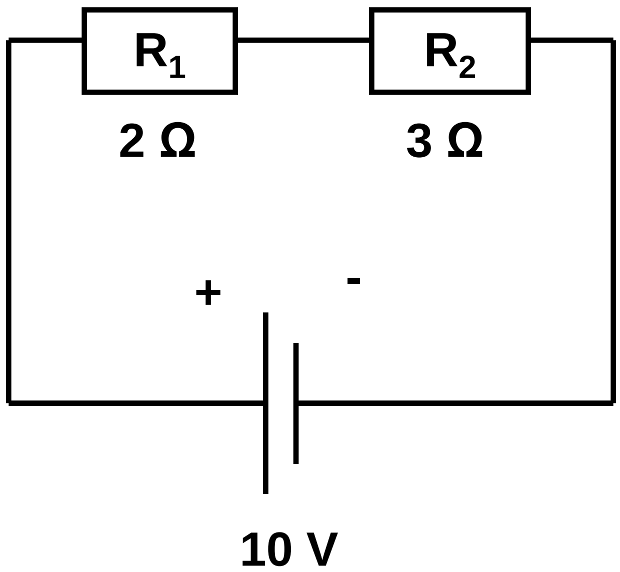
Resistors in series



Resistors in series redistribute **voltage**

Total resistance of circuit (R_s):

$$R_s = R_1 + R_2$$

$$R_s = 2 + 3$$

$$R_s = 5\,\Omega$$

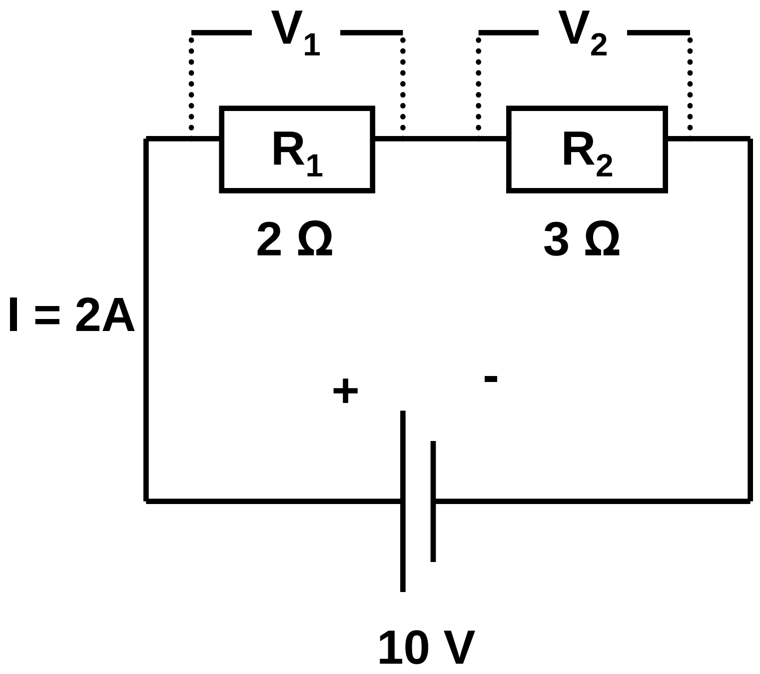
Total current flowing in circuit (I):

$$\text{Resistance (R)} = \frac{\text{Voltage (V)}}{\text{Current (I)}}$$

$$5 = \frac{10}{I}$$

$$I = 2\,\text{amperes}$$

Resistors in series



To calculate voltage (V_1) across resistor R_1:

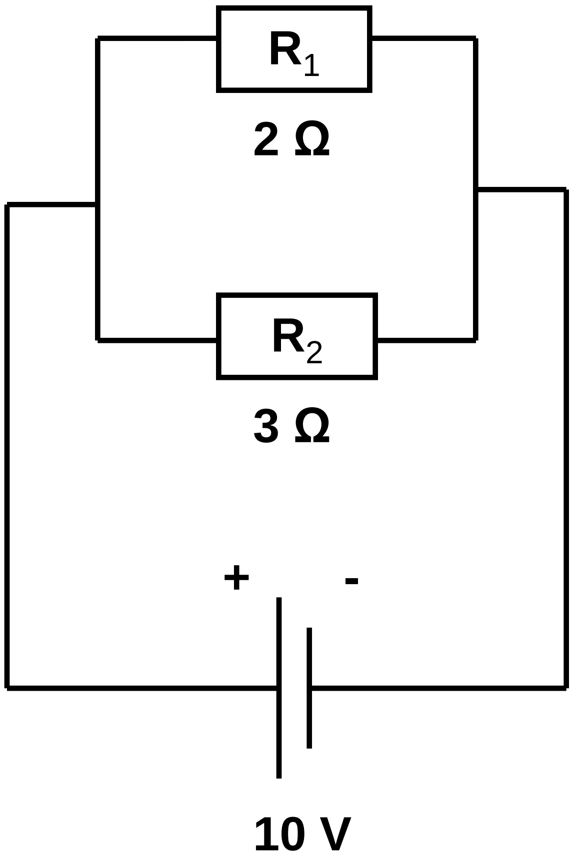
$$V_1 = I \times R_1$$
$$V_1 = 2 \times 2$$
$$V_1 = 4 \text{ volts}$$

To calculate voltage (V_2) across resistor R_2:

$$V_2 = I \times R_2$$
$$V_2 = 2 \times 3$$
$$V_2 = 6 \text{ volts}$$

In this way, the 10 V **voltage** of the battery is **redistributed** across the two resistors

Resistors in parallel



Resistors in parallel redistribute **current**

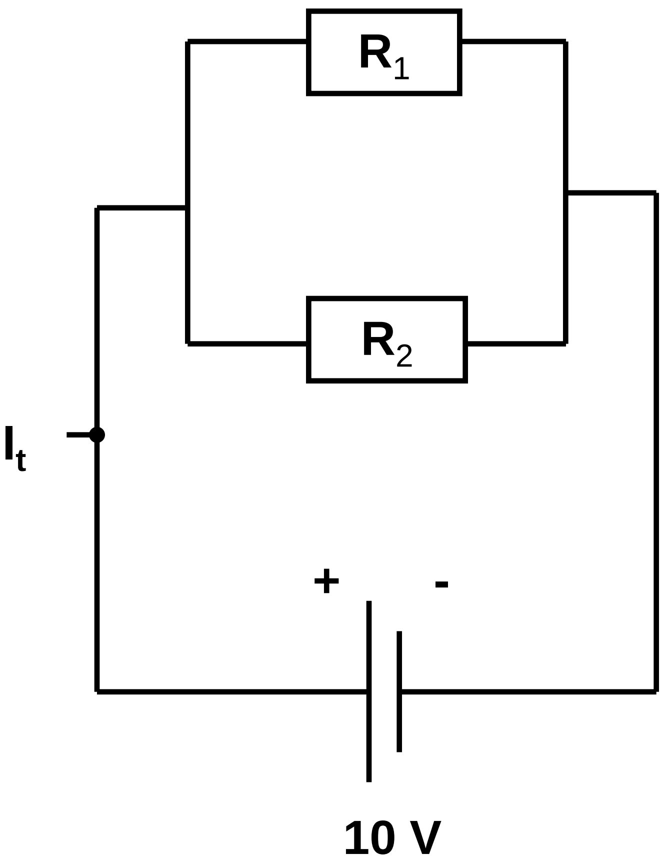
Total resistance of circuit (R_p):

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_p} = \frac{1}{2} + \frac{1}{3} = \frac{5}{6}$$

$$R_p = 1.2\ \Omega$$

Resistors in parallel



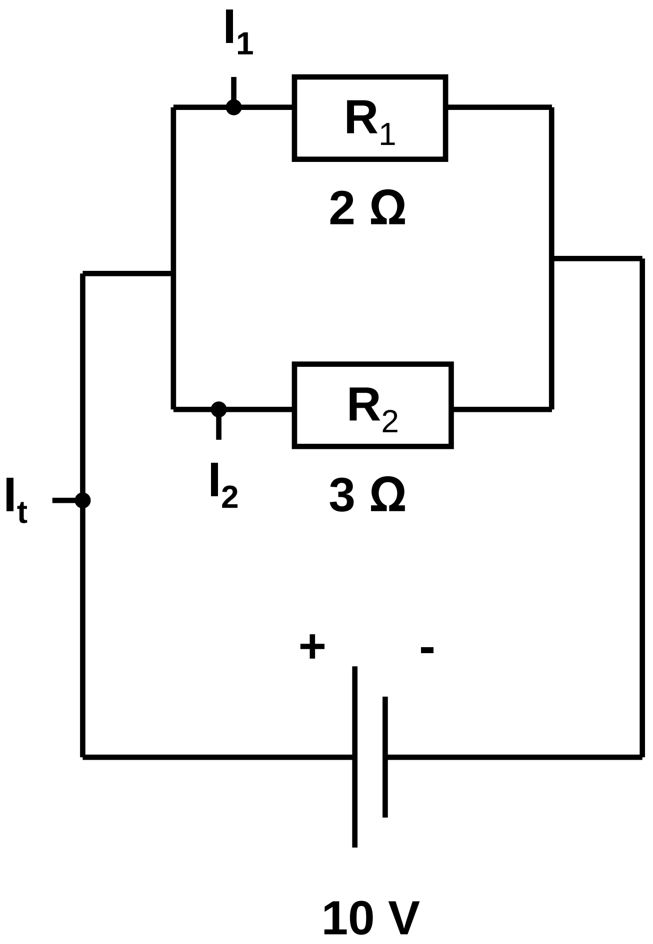
Total current flowing in circuit (I_t):

$$R_p = \frac{V}{I_t}$$

$$1.2 = \frac{10}{I_t}$$

$I_t = 8.33$ amperes

Resistors in parallel



The voltage across both R_1 and R_2 is always 10 V in this circuit

To calculate current (I_1) flowing to resistor R_1:

$$V_1 = I_1 \times R_1$$

$$10 = I_1 \times 2$$

$$I_1 = 5 \text{ amperes}$$

To calculate current (I_2) flowing to resistor R_2:

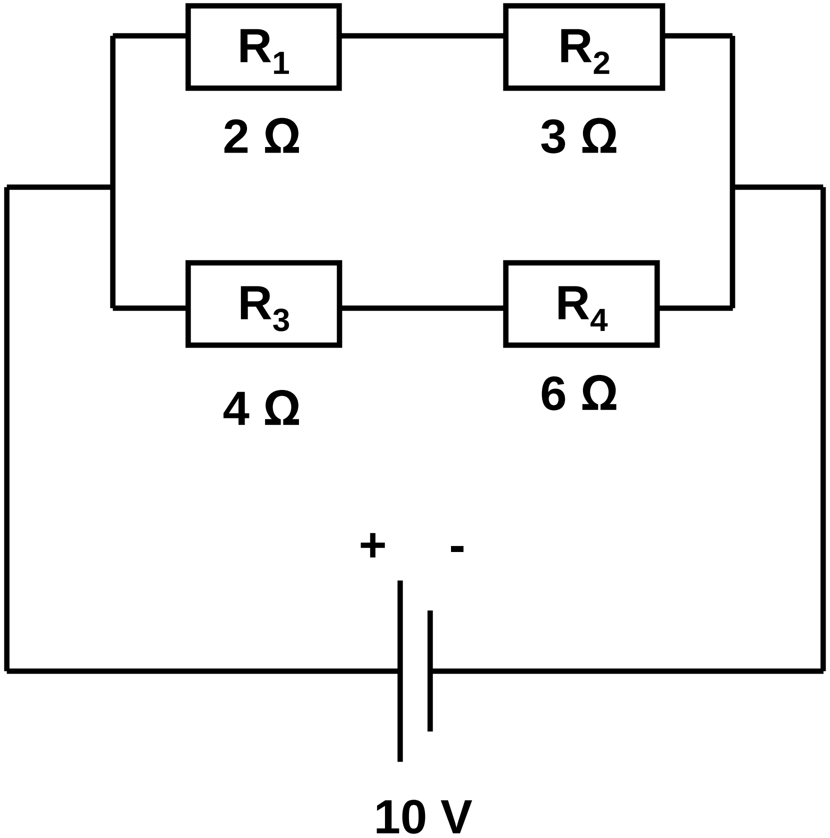
$$V_2 = I_2 \times R_2$$

$$10 = 3 \times I_2$$

$$I_2 = 3.33 \text{ amperes}$$

In this way, the 8.33A **current** produced by the battery is **redistributed** across the two branches of the circuit

Resistors combined in series and parallel



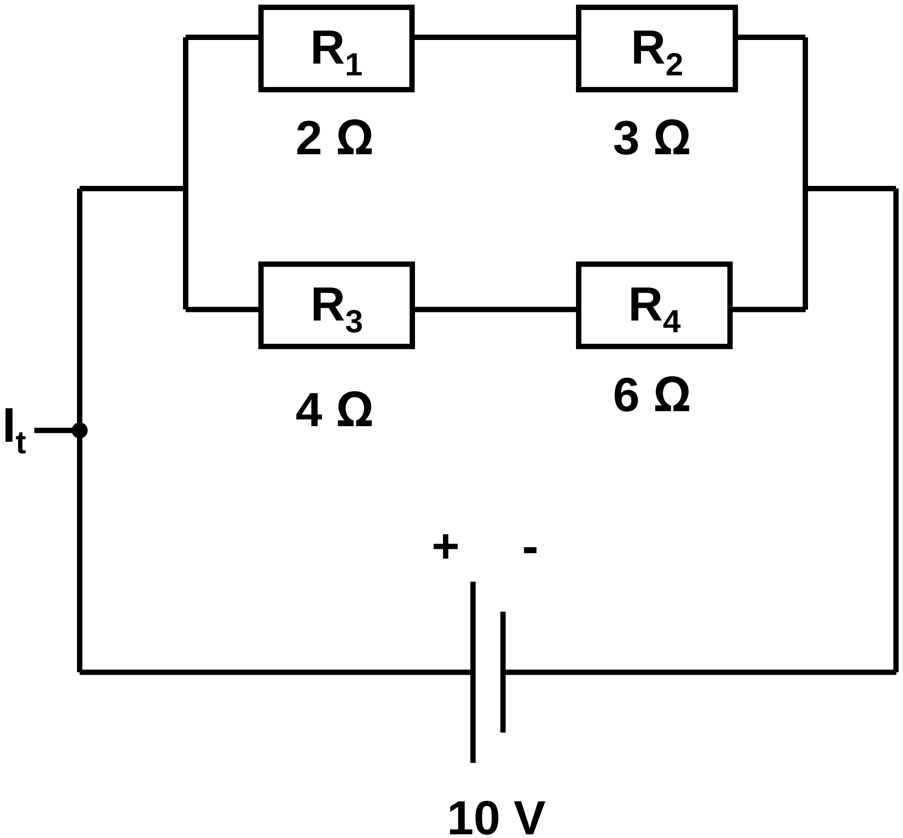
Total resistance of circuit (R_t):

$$\frac{1}{R_t} = \frac{1}{R_1 + R_2} + \frac{1}{R_3 + R_4}$$

$$\frac{1}{R_t} = \frac{1}{5} + \frac{1}{10} = \frac{3}{10}$$

$$R_t = 3.33\,\Omega$$

Resistors combined in series and parallel

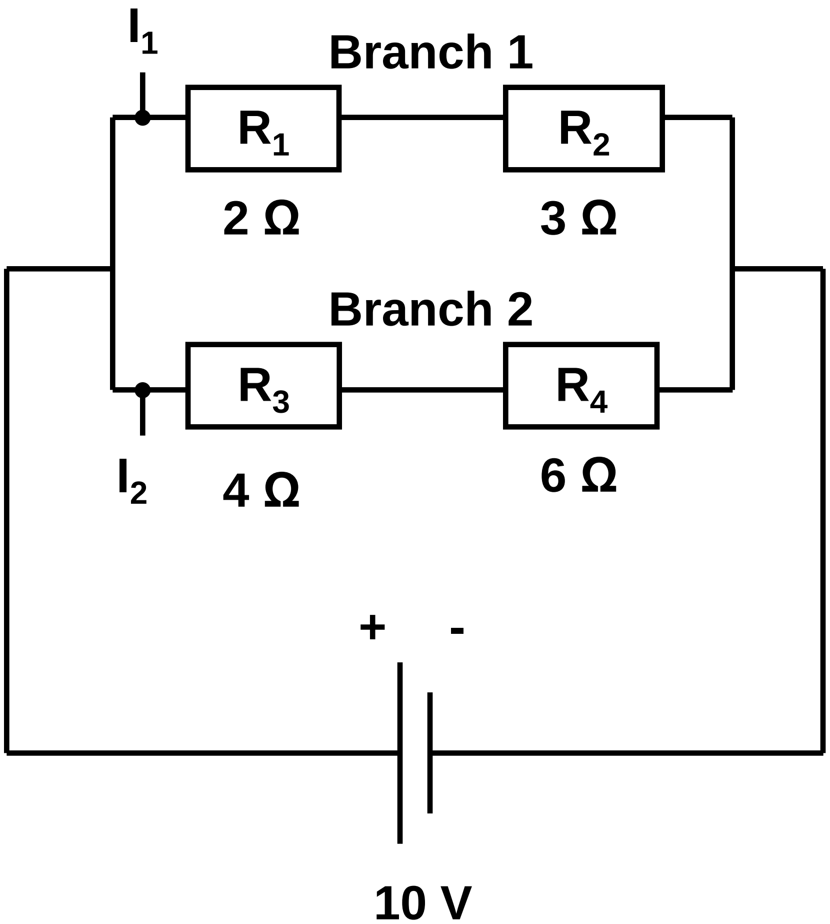


Total current flowing in circuit (I_t):

$$I_t = \frac{V}{R_t}$$

$$I_t = \frac{10}{3.33} = 3 \text{ amperes}$$

Resistors combined in series and parallel



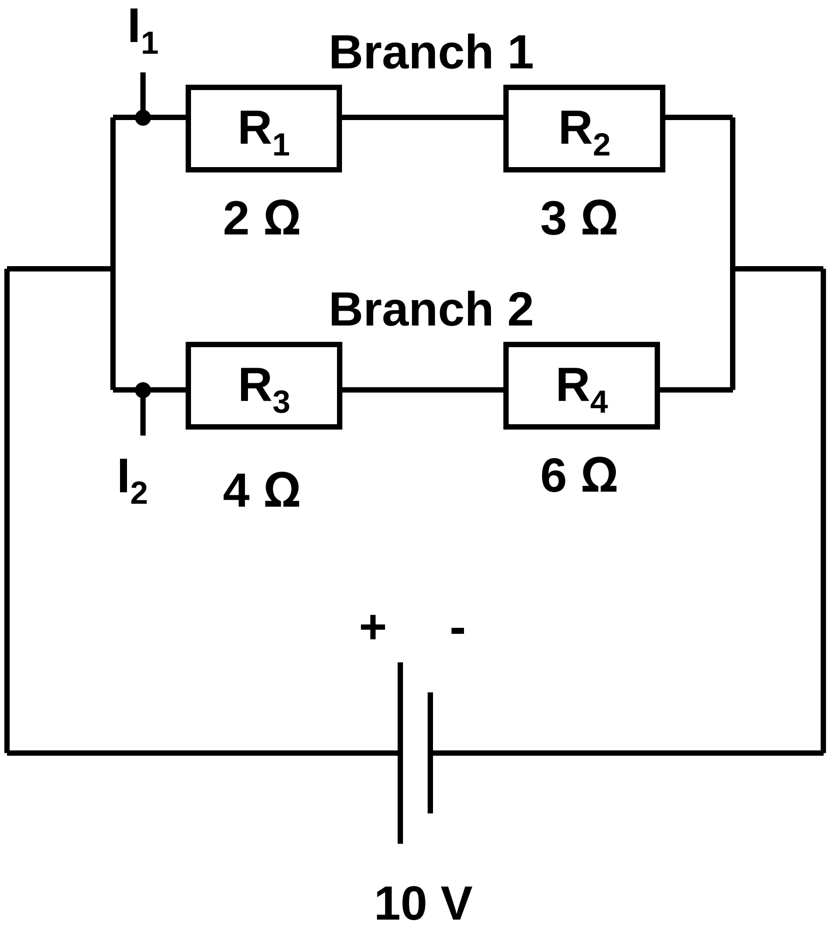
Branch 1:

Total resistance of Branch $1 = 2 + 3 = 5\ \Omega$

Voltage across Branch $1 = 10$ V

Current flowing in Branch $1\ (I_1) = \frac{10}{5} = 2$ amperes

Resistors combined in series and parallel



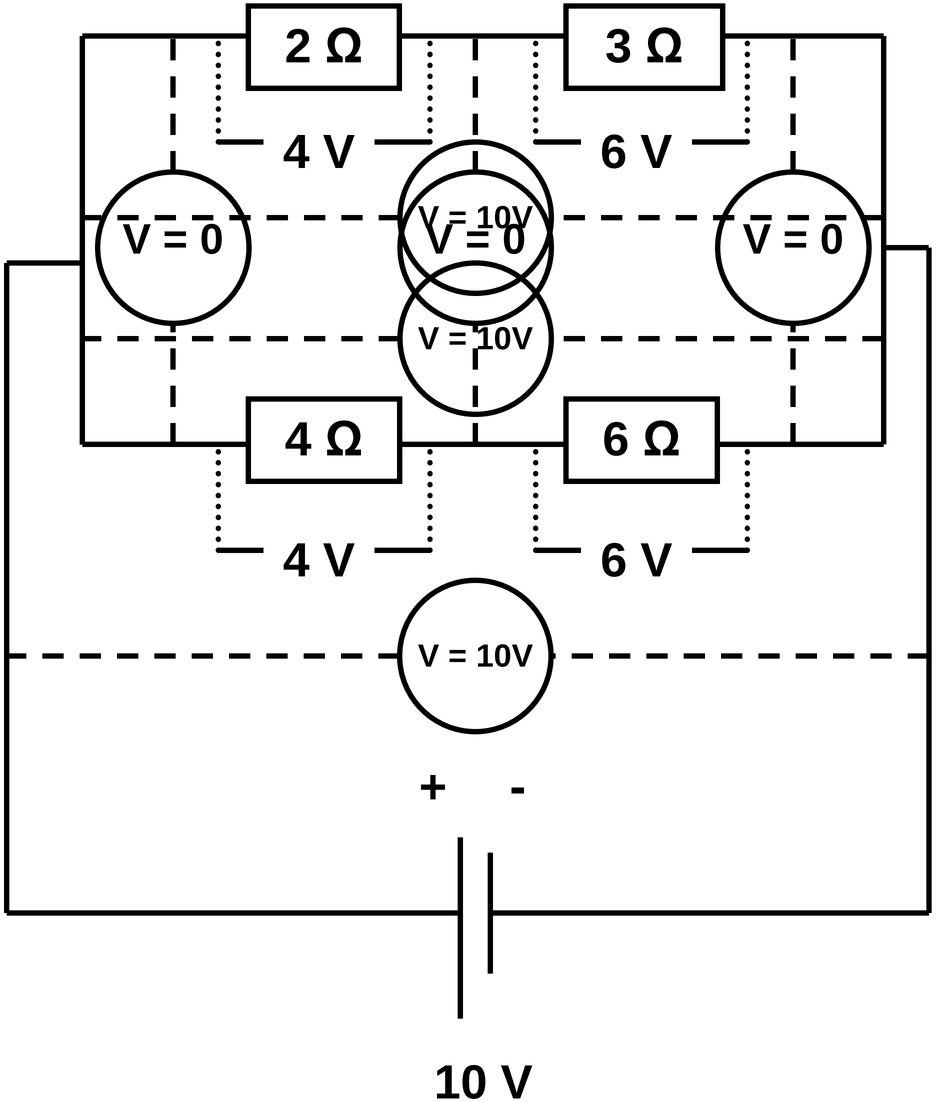
Branch 2:

$$\text{Total resistance of Branch 2} = 4 + 6 = 10\ \Omega$$

$$\text{Voltage across Branch 2} = 10\ \text{V}$$

$$\text{Current flowing in Branch 2}\ (I_2) = \frac{10}{10} = 1\ \text{ampere}$$

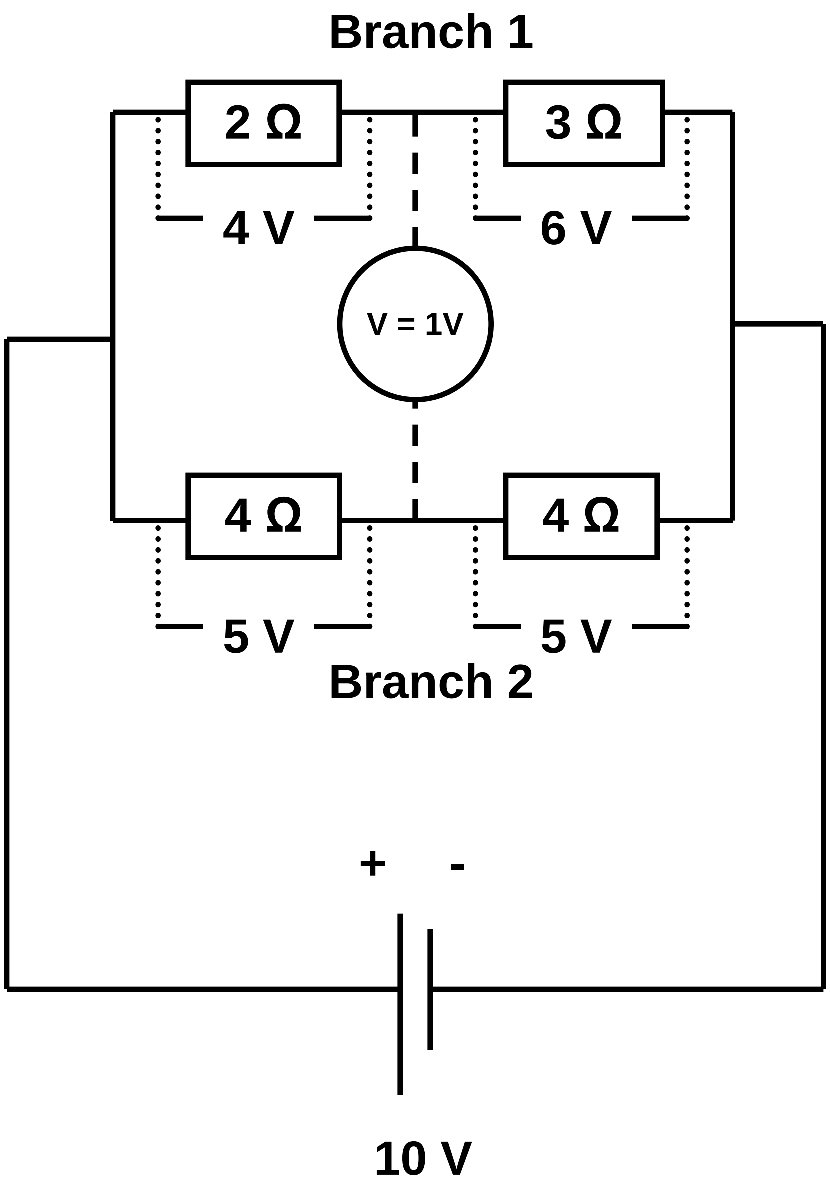
Resistors combined in series and parallel



A voltmeter measures the potential difference (in volts) between two points in an electrical circuit

Observe the readings of the voltmeter as it is connected to different parts of the circuit

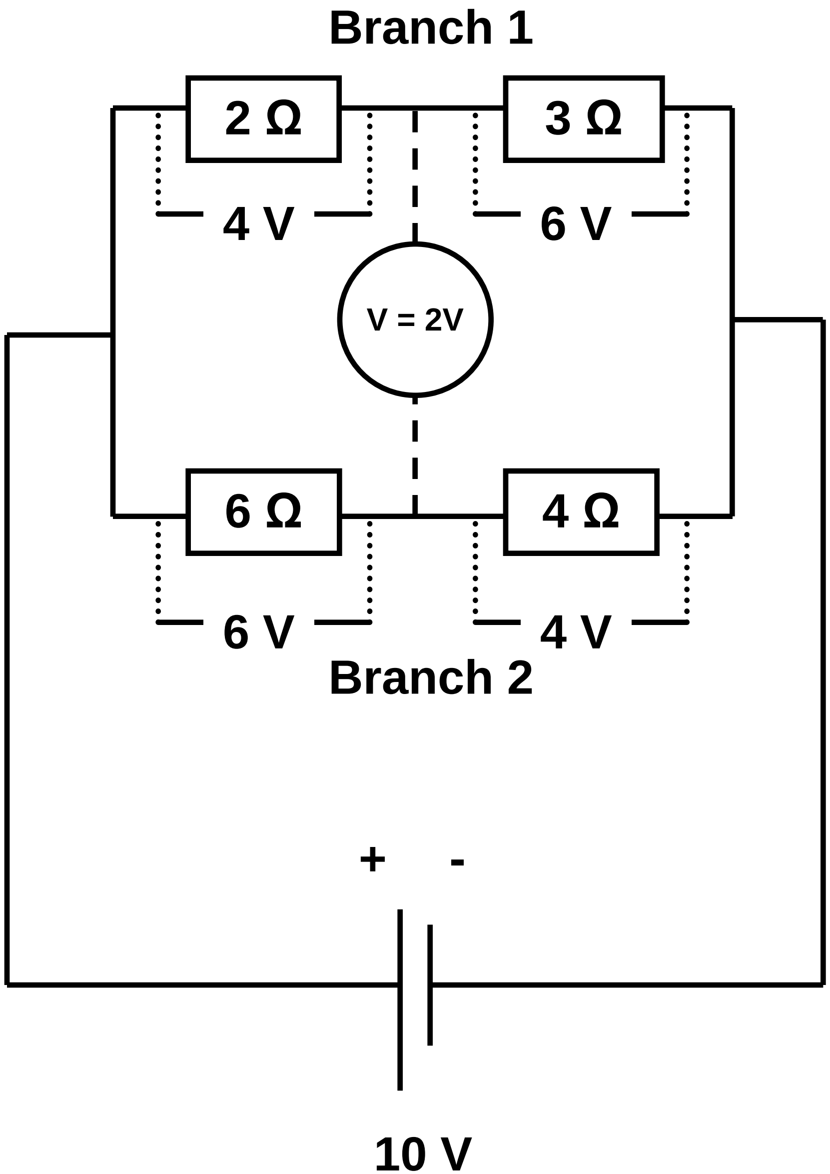
Resistors combined in series and parallel



In this circuit, the ratio of the resistances of branch 2 has been altered from 4Ω:6Ω to 4Ω:4Ω

A potential difference of 1 volt now occurs between the two branches

Resistors combined in series and parallel

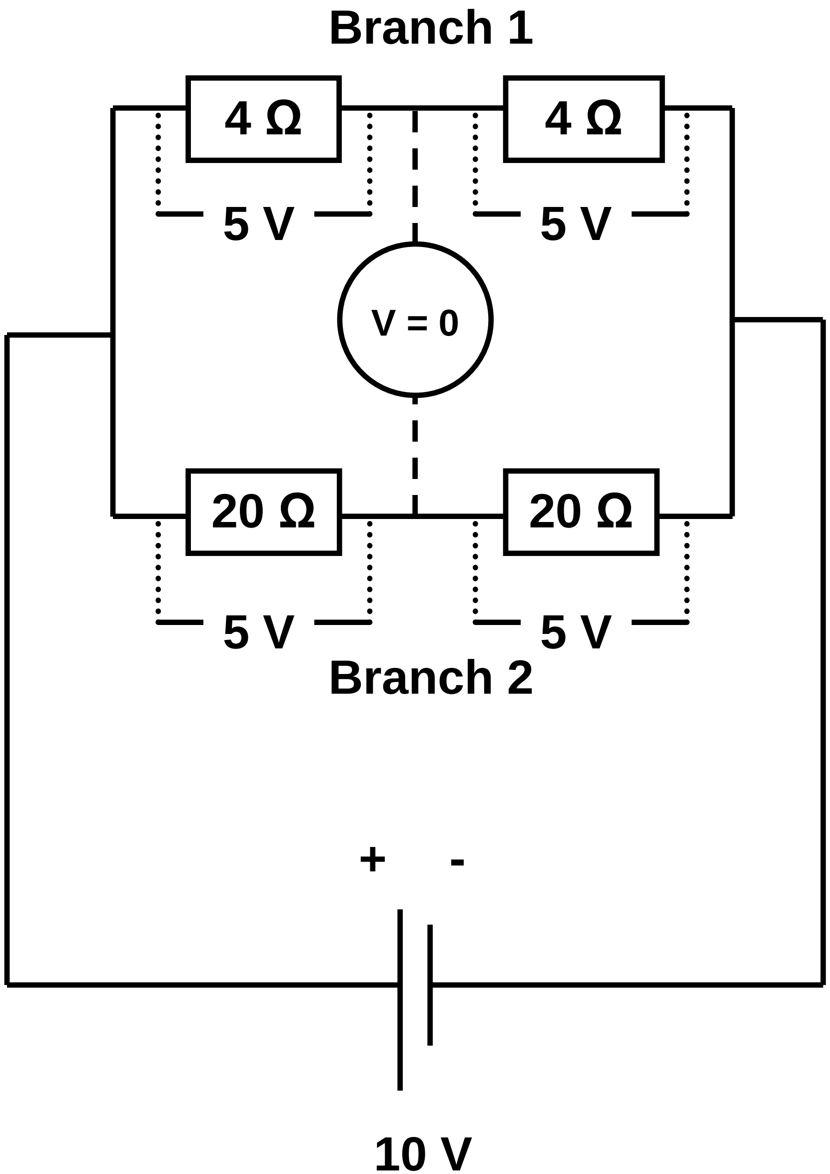


The ratio of the resistances of branch 2 has now been altered from 4Ω:6Ω to 6Ω:4Ω

A larger potential difference of 2 volts now occurs between the two branches

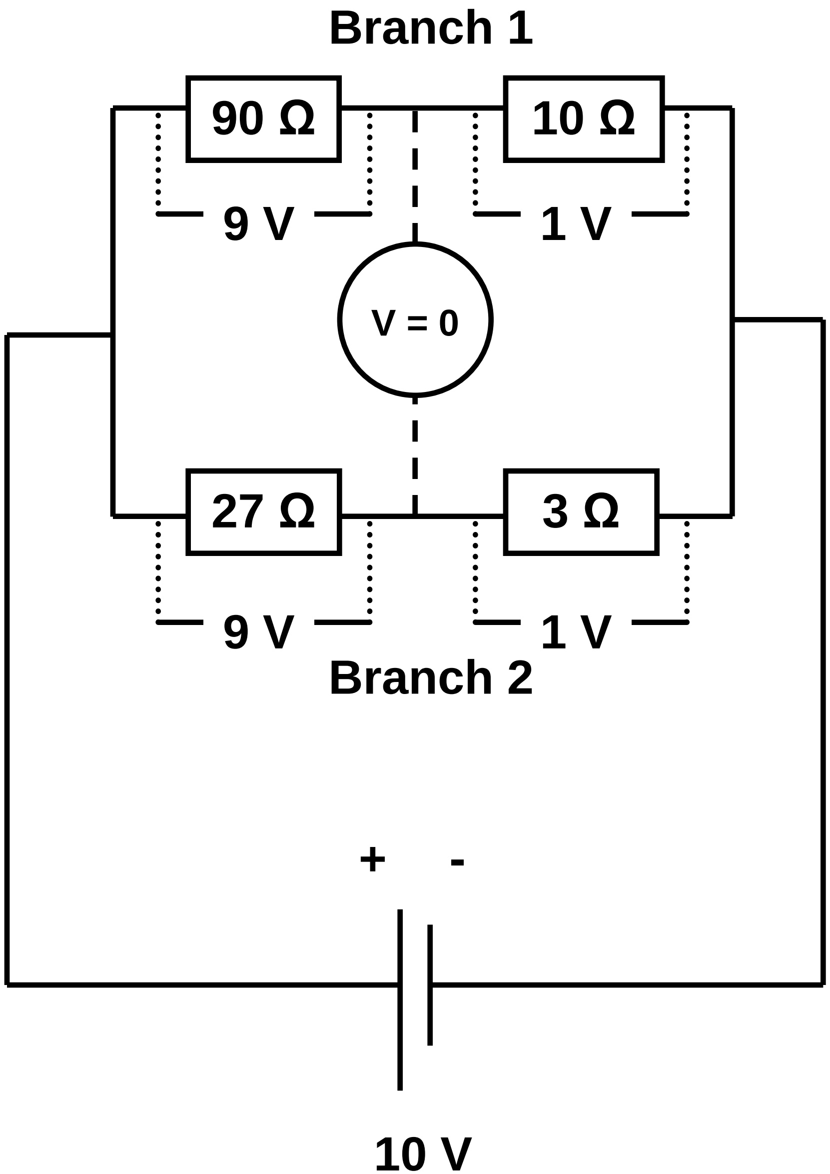
This is known as a potential divider and forms part of the basis for the wheatstone bridge circuit

Resistors combined in series and parallel



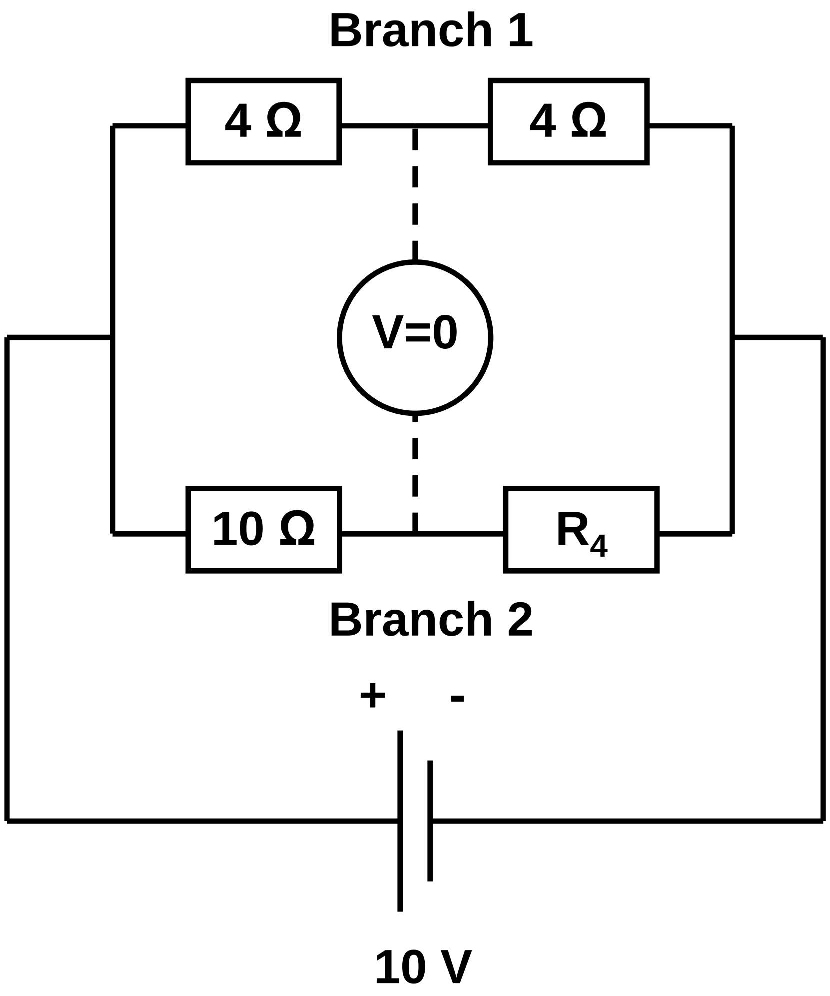
Here is another situation when the voltmeter reads zero

Resistors combined in series and parallel



- Again the voltmeter reads zero
- It should become clear that the actual values of the resistors are not important
- It is their ratios within each branch that divide the voltage proportionally

Resistors combined in series and parallel



What does R_4 equal in the following example?

Answer:

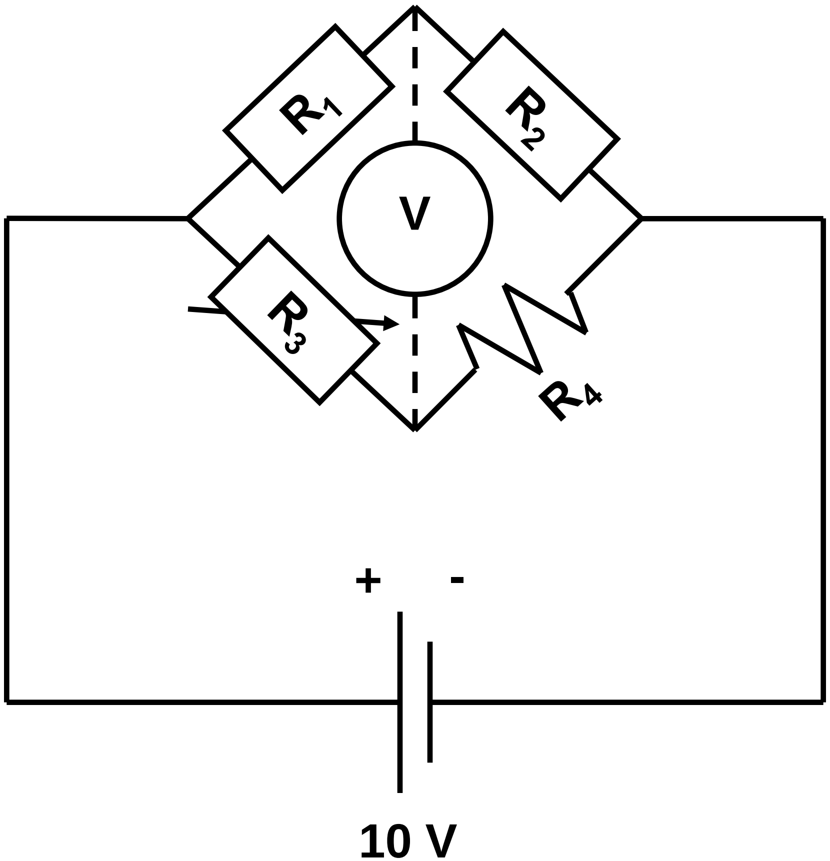
In order for the voltmeter to read zero, the ratio of the resistances in branch 1 must equal that in branch 2.

The ratio in branch 1 is 1:1 & branch 2 is 10:R_4.

R_4 must therefore equal 10 Ω

Wheatstone bridge 1

- This is a wheatstone bridge circuit
- A variant of it is present in most arterial pressure transducers



R_1 – Known resistance

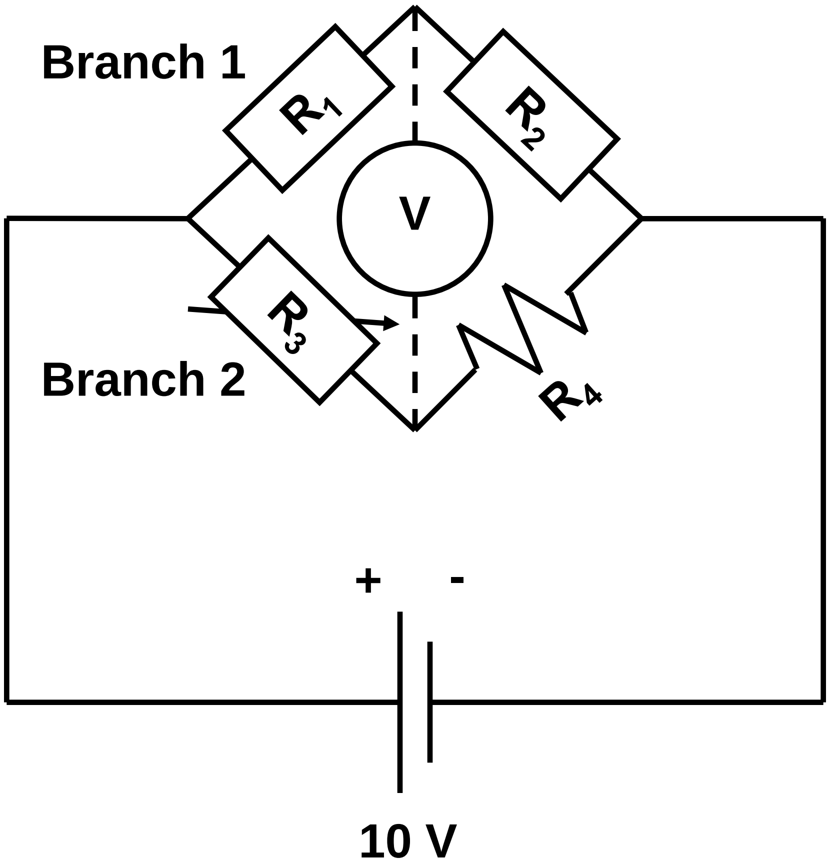
R_2 – Known resistance

R_3 – Variable resistance which can be adjusted until V reads 0

R_4 – Unknown resistance which varies according to the tension of the resistance wire in the strain gauge

Wheatstone bridge 2

- In a wheatstone bridge, the ratio of the resistances in branch 1 (R_1:R_2) is fixed
- The ratio of resistances in branch 2 (R_3:R_4) is adjusted using a variable resistor (R_3) until the ratio equals that in branch 1
- At that point, the voltmeter reads 0 and the unknown resistance (R_4) can be calculated as described on the next few slides



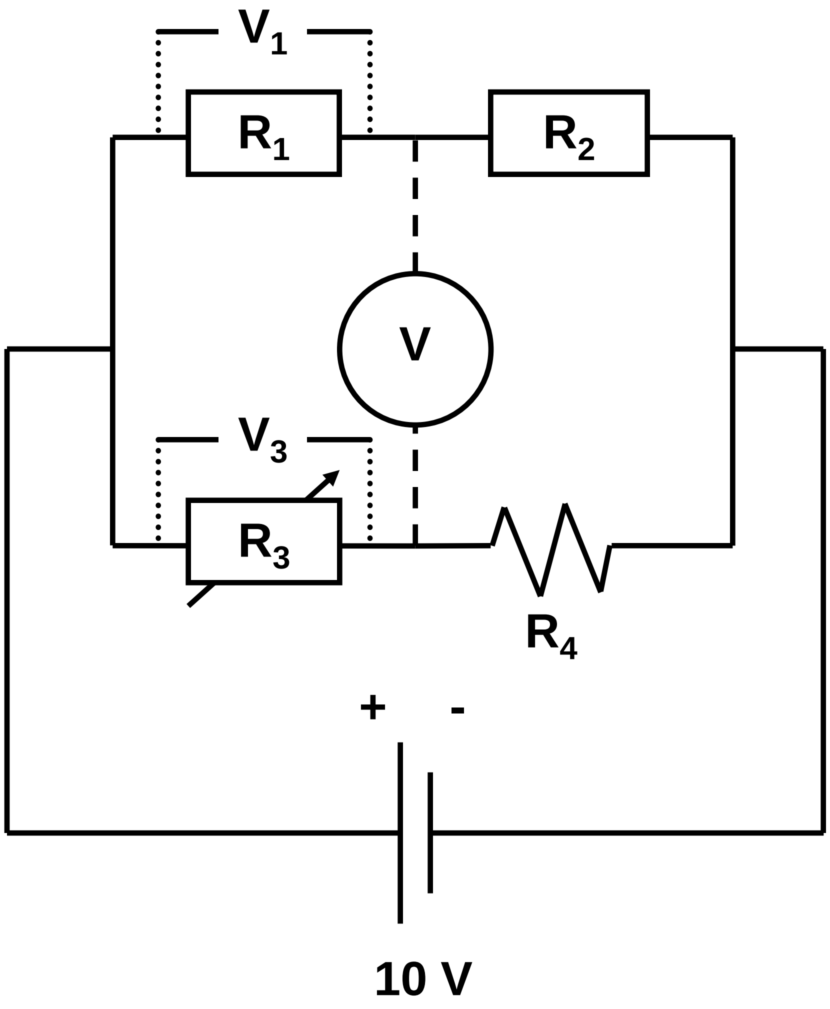
R_1 – Known resistance

R_2 – Known resistance

R_3 – Variable resistance which can be adjusted until V reads 0

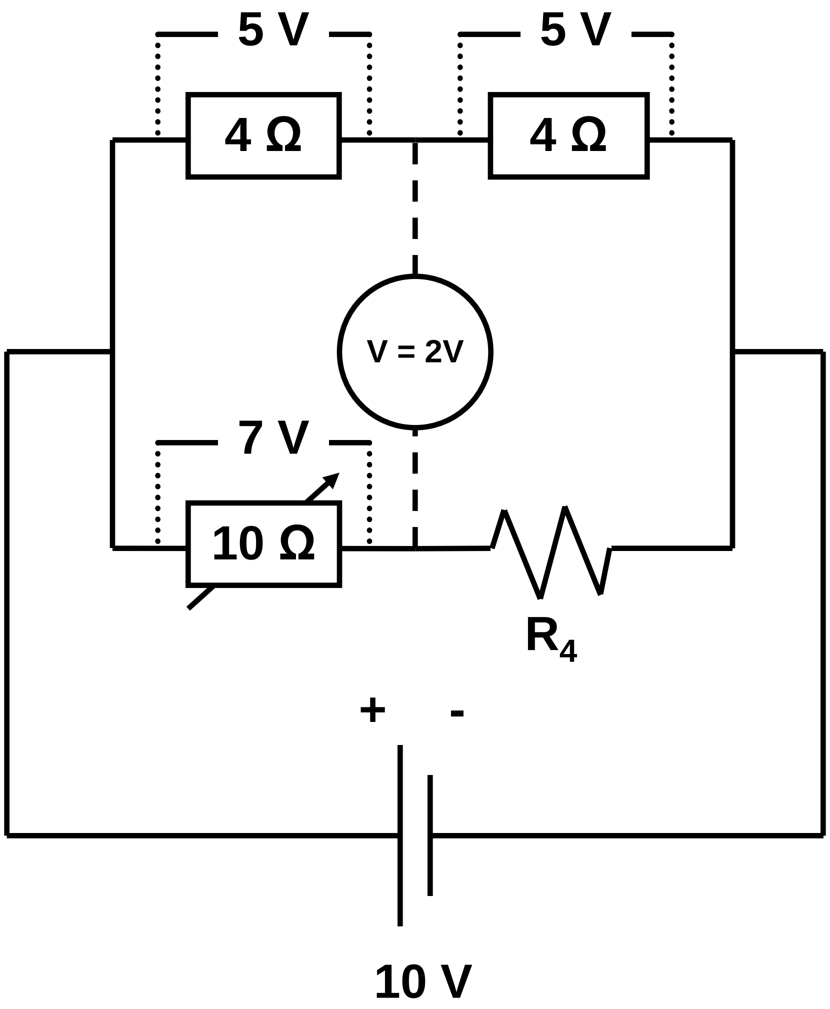
R_4 – Unknown resistance which varies according to the tension of the resistance wire in the strain gauge

Wheatstone bridge 3



- In the early resistor examples, we first calculated the total resistance and used that to work out the voltages across each resistor
- In the Wheatstone bridge, this approach is not possible because R_4 is unknown
- Instead, the ratio of R_1:R_2 and R_3:R_4 is used

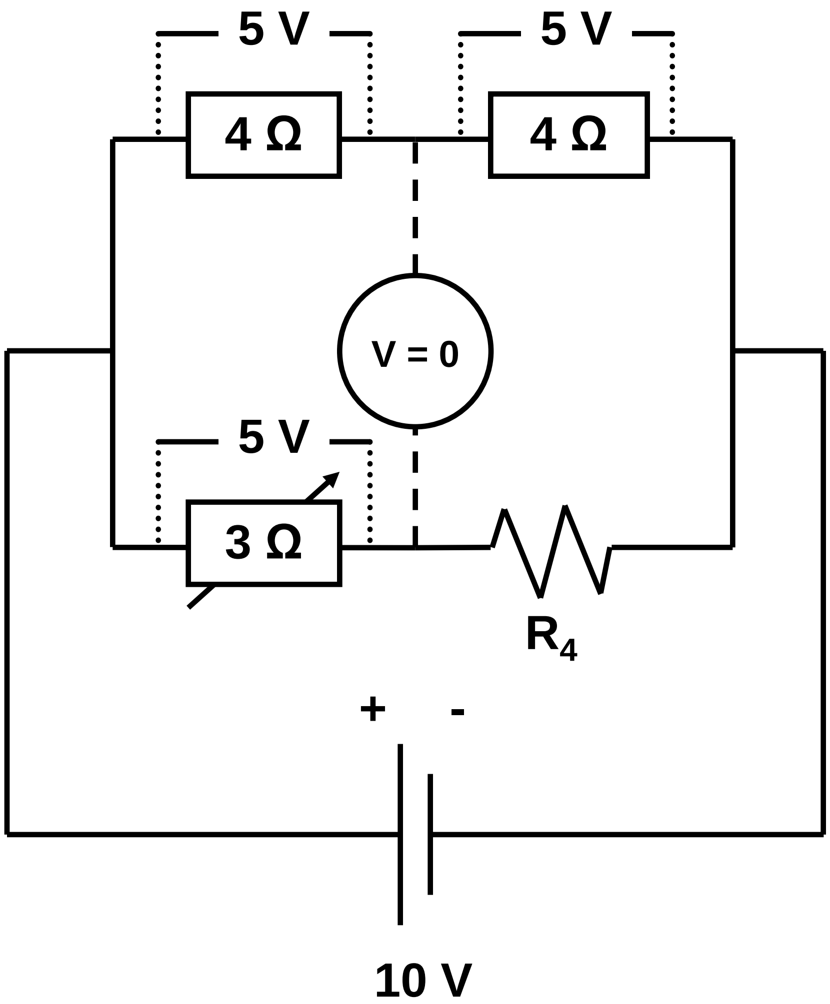
Wheatstone bridge 4



In the following wheatstone bridge circuit, the voltmeter initially reads 2 volts.

In order to find out the unknown resistance of R_4, the resistance of R_3 is adjusted until the voltmeter reads 0.

Wheatstone bridge 5



The voltmeter reads 0 when R_3 = 3 Ω

$$\text{Voltage } V_1 = \frac{4}{4+4} \times 10 = 5 \text{ volts}$$

$$\text{Voltage } V_3 = \frac{3}{3+R_4} \times 10$$

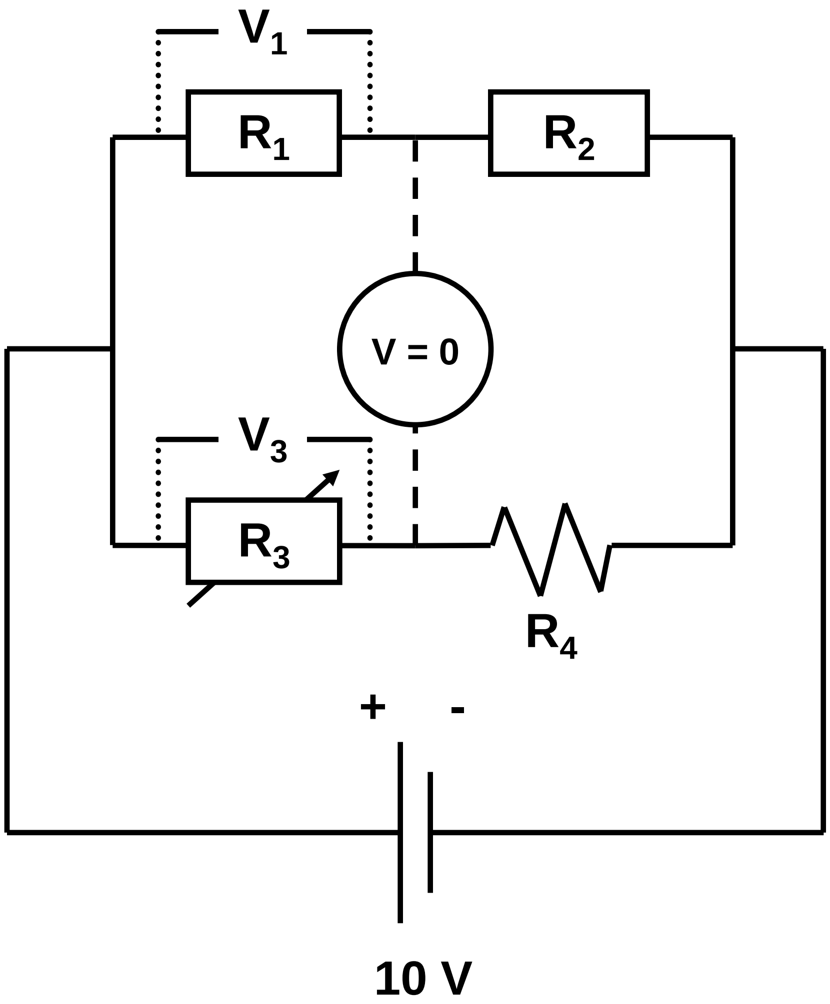
When the voltmeter reads 0,

$$V_1 = V_3$$

$$\frac{3}{3+R_4} \times 10 = 5$$

$$R_4 = 3\Omega$$

Wheatstone bridge 6

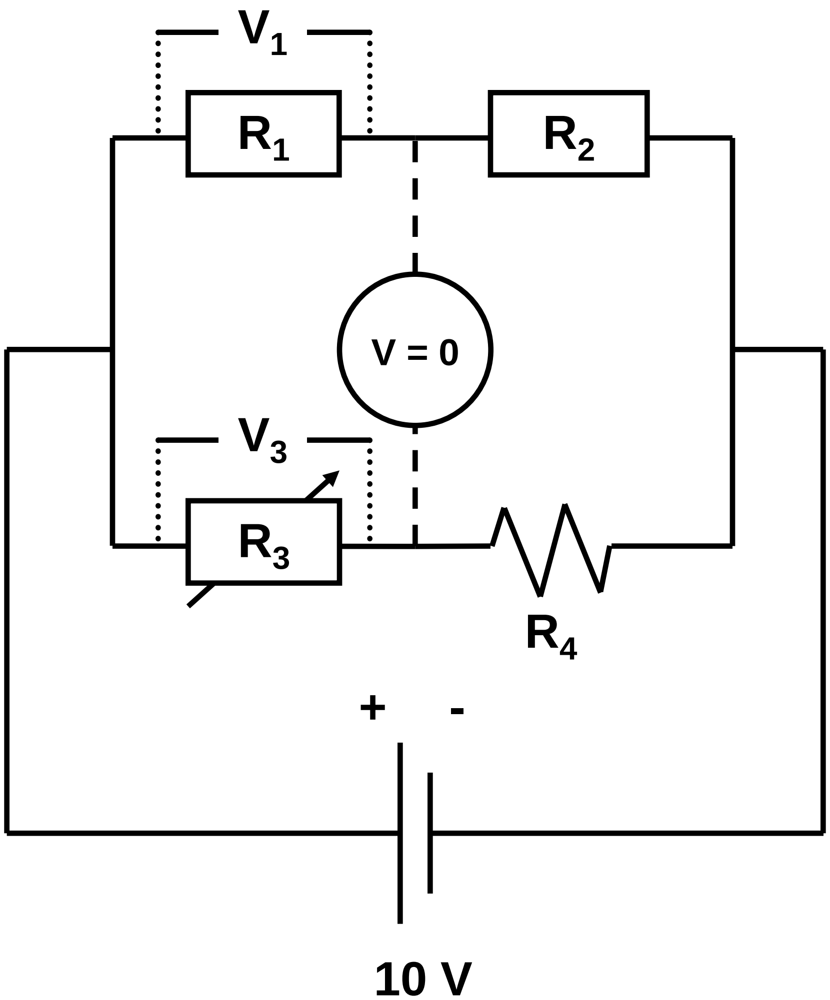


Expressing this relationship in terms of symbols:

$$V_1 = \frac{R_1}{R_1 + R_2} \times 10$$

$$V_3 = \frac{R_3}{R_3 + R_4} \times 10$$

Wheatstone bridge 7



When voltmeter reads 0,

$$V_1 = V_3$$

$$\frac{R_1}{R_1 + R_2} \times 10 = \frac{R_3}{R_3 + R_4} \times 10$$

$$R_1(R_3 + R_4) = R_3(R_1 + R_2)$$

$$R_1 R_4 = R_3 R_2$$

$$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$

Recognise this equation?!