VISUAL PHYSICS ONLINE

MODULE 4.1
ELECTRICITY
DC CIRCUITS 2

Charge $q \;\; Q \;\; \Delta q \;\; \Delta Q$ [C coulomb]

Current $I \;\; i$ [A ampere]

time interval Δt [s second]

$$I = \frac{\Delta q}{\Delta t}$$

potential / **potential difference** / **voltage** / **emf**

$V \;\; \Delta V \;\; \varepsilon \;\; emf$ [V volt]

resistance R [Ω ohm]

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

energy $E \;\; E_e \;\; W$ [J joule]

$$W = P\,\Delta t$$

power P [W watt]

$$P = \frac{\Delta W}{\Delta t} = V\,I = I^2\,R = V^2 / R$$

Ohm's Law

(constant resistance and constant temperature)

$$V = I\,R \qquad I = \frac{V}{R}$$

Kirchhoff's Junction Rule

at any junction $\sum I = 0$

Kirchhoff's Loop Rule

around any loop $\sum V = 0$

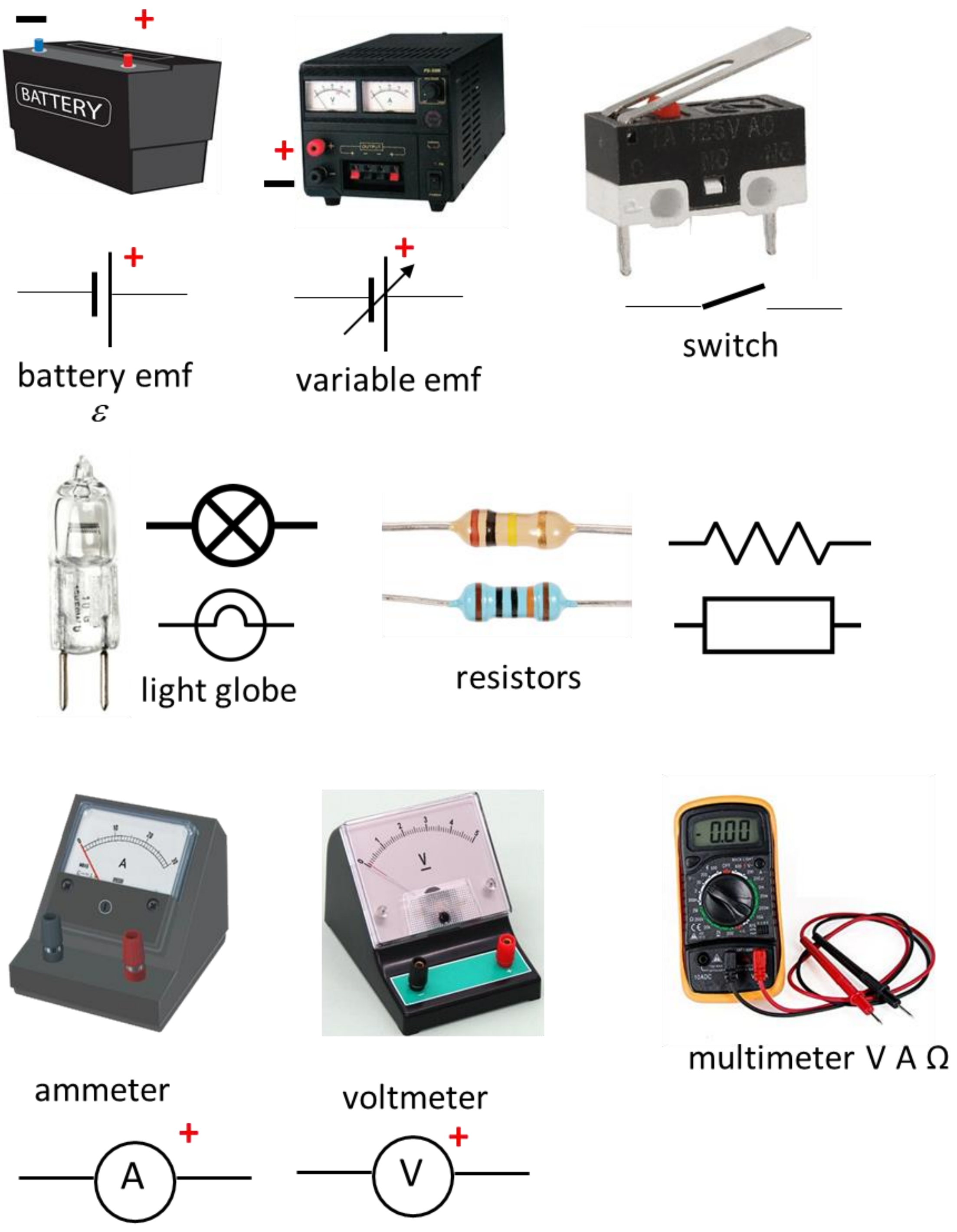
Resistors in series

$$R = R_1 + R_2 + R_3 + \ldots$$

Resistors in parallel

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$$

In a circuit many resistors can be replaced by a single equivalent resistor



Circuit Symbols

REVIEW: Electric Currents

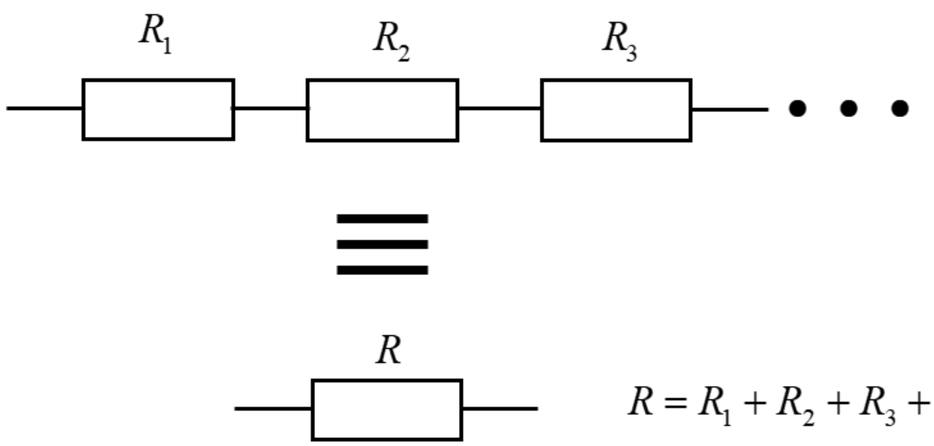
REVIEW: DC Circuits 1

Resistors in series

What is the equivalent resistance of any number of resistors in series?

In a **series circuit**, the different components follow one after the other and there is just one loop for the current to follow and the current is the same at all points.

Equivalent resistance means that a number of resistors can be replaced by a **single resistor** such that it does not change the current drawn from the sources of electrical energy or the emf of the sources.



$$R = R_1 + R_2 + R_3 + \dots$$

From Kirchhoff's Junction (Current) rule, the same current must pass through each resistor and therefore, the potential drop across each resistor is

$$V_1 = I\,R_1 \quad V_2 = I\,R_2 \quad V_3 = I\,R_3 \quad \ldots$$

In the equivalent circuit, the potential drop across the equivalent resistor is

$$V = I\,R$$

Applying Kirchhoff's Loop (Voltage) Rule, we must have

$$V = V_1 + V_2 + V_3 + \ldots$$

$$I\,R = I\,R_1 + I\,R_2 + I\,R_3 + \ldots$$

Hence,

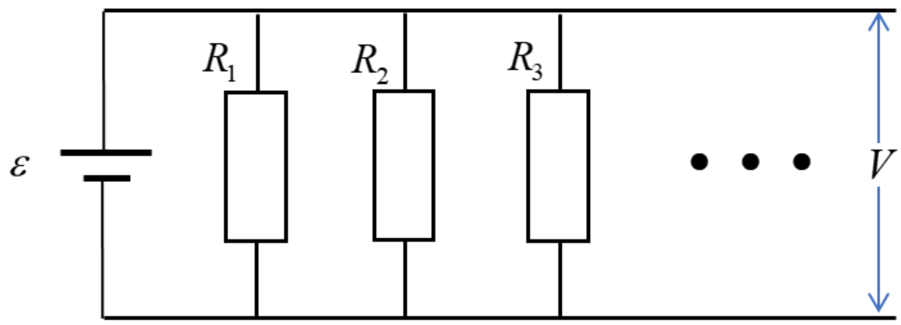
$$R = R_1 + R_2 + R_3 + \ldots$$ **resistors in series**

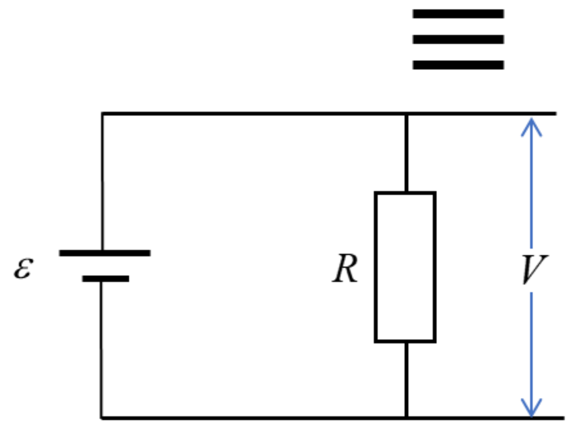
The greater the number of resistors in series, then the larger the resistance value.

Resistors in parallel

What is the resistance of a number of resistors in parallel?

Consider a number of resistors connected in parallel and their equivalent resistance





$$R = \frac{1}{1/R_1} + \frac{1}{1/R_2} + \frac{1}{1/R_3} + \ldots$$

Kirchhoff's Loop (voltage) Rule: the same potential difference V must exist across each resistor in parallel, so,

$$V = I_1 R_1 \quad V = I_2 R_2 \quad V = I_3 R_3 \quad \ldots$$

In the equivalent circuit, the potential drop is

$$V = I R$$

Applying Kirchhoff's Junction (current) Rule: we must have

$$I = I_1 + I_2 + I_3 + \dots$$

$$I = \frac{V}{R} \quad I_1 = \frac{V}{R_1} \quad I_2 = \frac{V}{R_2} \quad I_1 = \frac{V}{R_3} \quad \dots$$

Therefore,

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} + \dots$$

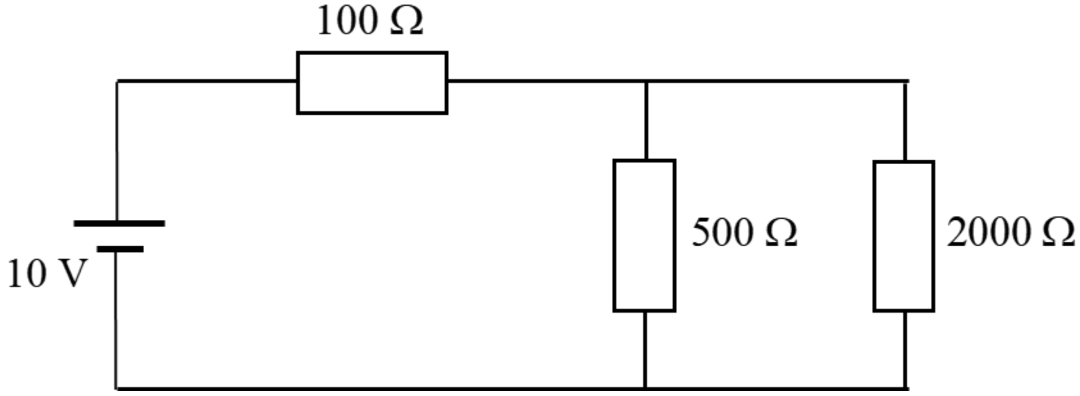
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$ do **not** use this form of the equation

$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots}$$ **use this equation for resistors in parallel**

Adding more resistors in parallel reduced the total resistance value.

Example

For the circuit shown below, find the current through each resistor.

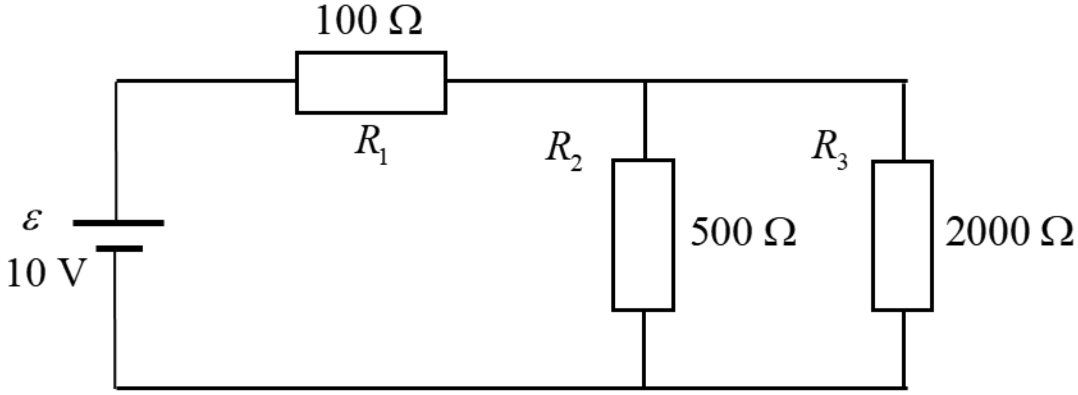


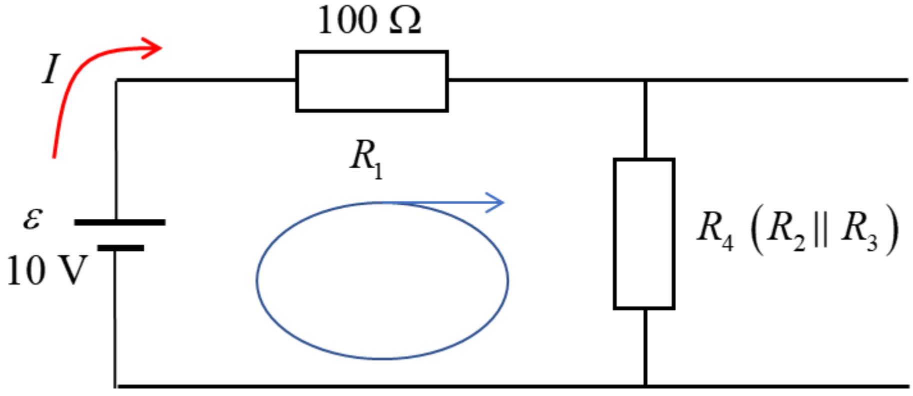
Solution

Draw the circuit and label each component.

Replace the parallel combination with its equivalent resistor and redraw the circuit.

Apply Ohm's Law and Kirchhoff's Rules.





$\varepsilon = 10\ \text{V} \quad R_1 = 100\ \Omega \quad R_2 = 500\ \Omega \quad R_3 = 2000\ \Omega$

$R_4\ \left(R_2 \parallel R_3\right)$

$$R_4 = \frac{1}{1/R_2 + 1/R_2} = \frac{1}{1/500 + 1/2000}\ \Omega = 400\ \Omega$$

Let the current be in a clockwise sense and traverse the circuit loop also in a clockwise sense.

Kirchhoff's Junction (current) Rule

$$I_1 = ?\ \text{A} \quad I_2 = ?\ \text{A} \quad I_3 = ?\ \text{A} \quad I_4 = ?\ \text{A}$$

$$I = I_1 = I_4 \qquad I = I_2 + I_3$$

Kirchhoff's Loop (voltage) Rule

$$V_1 = ?\ \text{V} \quad V_2 = ?\ \text{V} \quad V_3 = ?\ \text{A} \quad V_4 = ?\ \text{A}$$

$$V_4 = V_2 = V_3 \qquad \varepsilon = V_1 + V_4$$

$$\varepsilon = V_1 + V_4 = I\left(R_1 + R_4\right)$$

$$I = \left(\frac{10}{100 + 400}\right)\ \text{A} = 0.020\ \text{A}$$

Using Ohm's Law, the potential differences across the parallel combination and resistor #1 are

$$V_4 = I\,R_4 = \left(0.020\right)\left(400\right)\text{V} = 8.00\ \text{V}$$

$$V_1 = \varepsilon - V_4 = \left(10 - 8\right)\ \text{V} = 2.00\ \text{V}$$

The currents through resistors #2 and #3 are

$$V_4 = I_2\, R_2 = I_3\, R_3$$

$$I_2 = \frac{V_4}{R_2} = \left(\frac{8}{500}\right)\ \text{A} = 0.016\ \text{A}$$

$$I_3 = \frac{V_4}{R_3} = \left(\frac{8}{2000}\right)\ \text{A} = 0.004\ \text{A}$$

Check

$$I_2 + I_3 = \left(0.016 + 0.004\right)\ \text{A} = 0.020\ \ \text{A} = I = I_1$$

as expected

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http://www.physics.usyd.edu.au/teach_res/hsp/sp/spHome.htm