Nelson Mandela Metropolitan University

for tomorrow

Video Series

GRADE 12

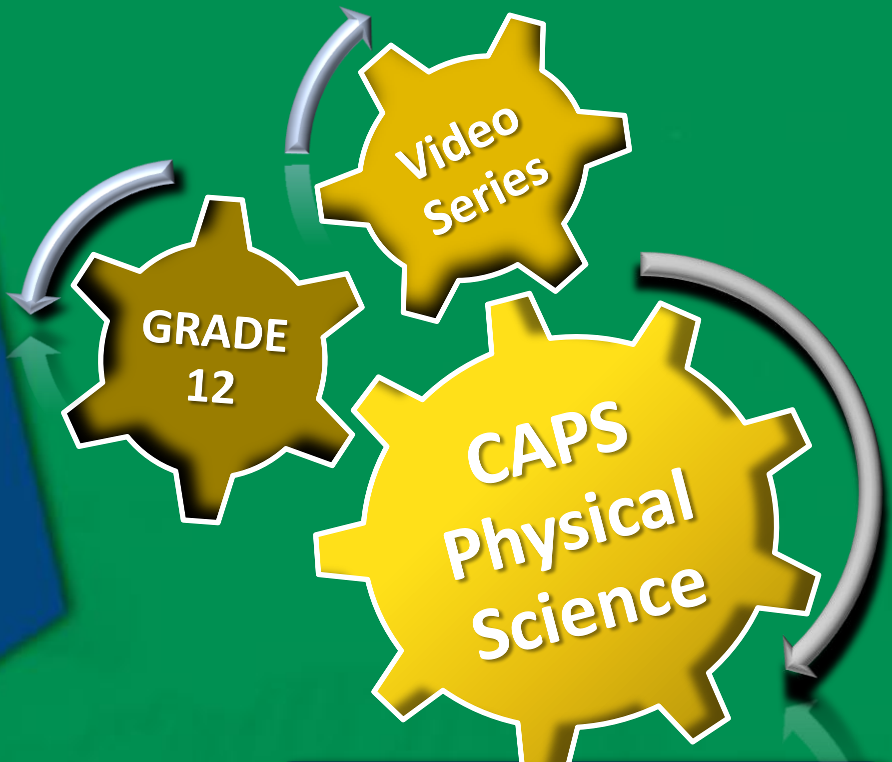
CAPS Physical Science

ELECTRICITY AND MAGNETISM

Lesson 3: Electric Circuits

Nelson Mandela Metropolitan University

for tomorrow



Electric Circuits

Class Exercise 1/1

1. A battery of **emf 24 V** and an internal resistance ***r*** is connected in a circuit

1.1. Calculate the effective resistance of the external circuit when switch **S** is closed.

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2}$$

$$\frac{1}{R} = \frac{1}{4} + \frac{1}{10+6}$$

$$\frac{1}{R} = \frac{4+1}{16}$$

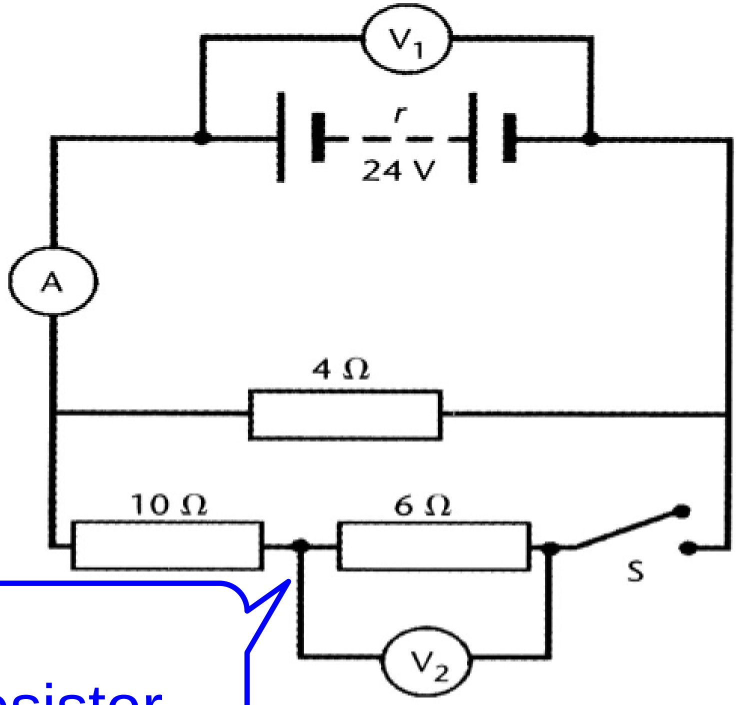
$$R = \frac{16}{5} = 3{,}2\ \Omega$$

OR

$$R_{ext} = \frac{R_1 R_2}{R_1 + R_2}$$

$$= \frac{4 \cdot 16}{4+16}$$

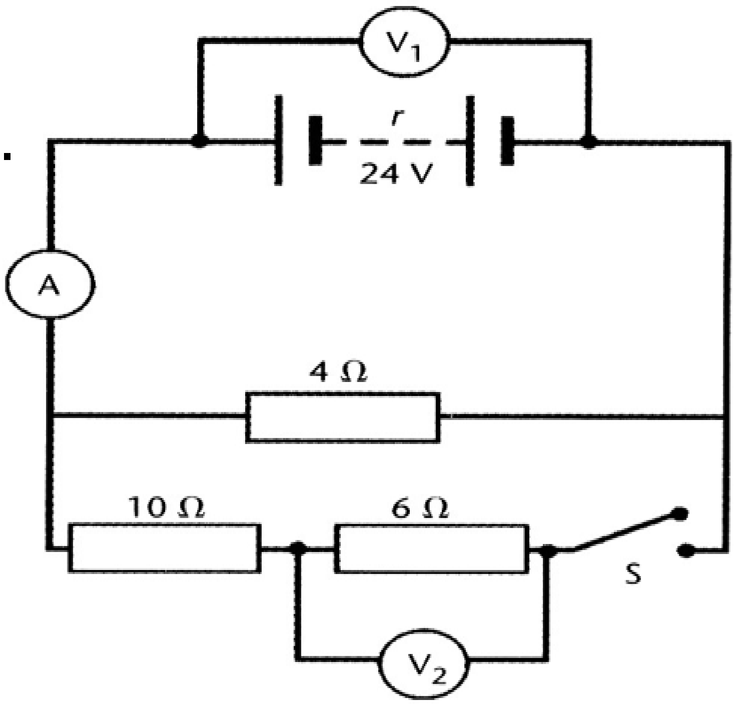
$$= 3{,}2\ \Omega$$



These two resistors are in series
⇒ can be combined into one 16 Ω resistor

Class Exercise 1/2

1.2. With switch **S** closed, the reading on the ammeter is **6,5 A**. Calculate the readings on:



1.2.1 voltmeter $\mathbf{V_1}$.

$V_1 = I_{tot} \cdot R_{ext}$

$= 6{,}5 \times 3{,}2$

$= 20{,}8$ V

1.2.2 voltmeter $\mathbf{V_2}$.

$V_{//} = V_1$ and this p.d. is divided between the 10 Ω and 6 Ω resistors (they are in series with one another) in the proportion 10 : 6 or 5 + 3.

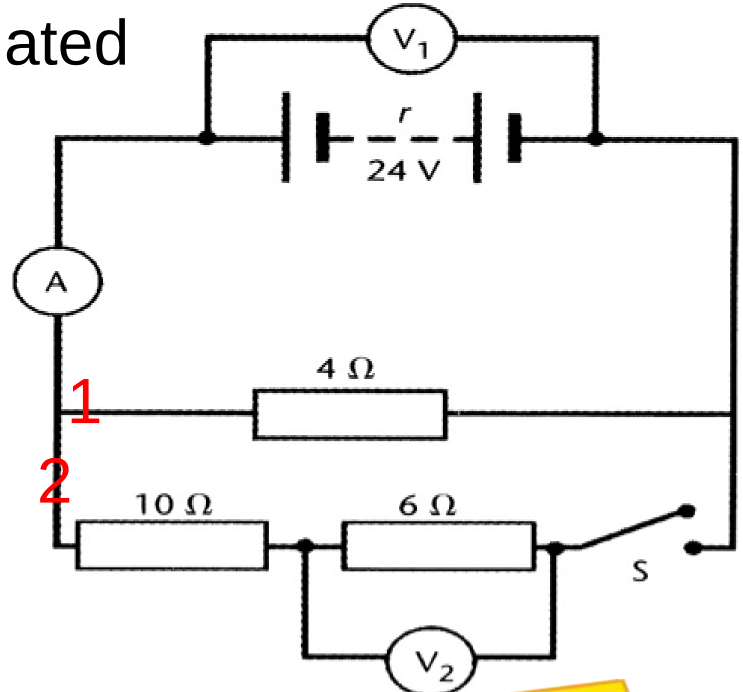
The 6 Ω resistor will draw **less** energy from the current, therefore

$V_{6\Omega} = 20{,}8 \text{ V} \times \frac{3}{8}$

$= 7{,}8$ V

Class Exercise 1/3

The reading on V_2 can also be calculated by finding the current through that branch and then using Ohm's law.



$R_{branch1} : R_{branch2}$

$4 : 16$

$1 : 4$

Therefore …

$I_{branch1} : I_{branch2}$

$16 : 4$

$4 : 1$

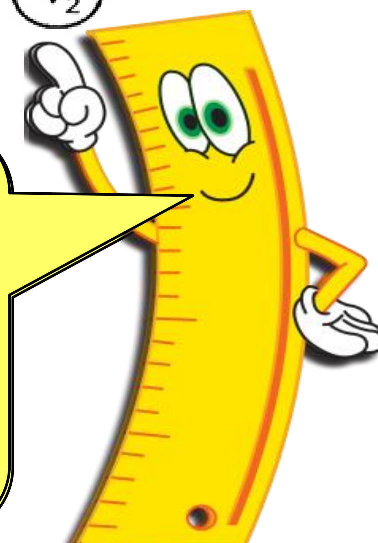
$I_{branch2} = 6,5\ A \times \frac{1}{5} = 1,$

$V_{6\Omega} = I_{6\Omega} \cdot R_{6\Omega}$

$= 1,3 \times 6$

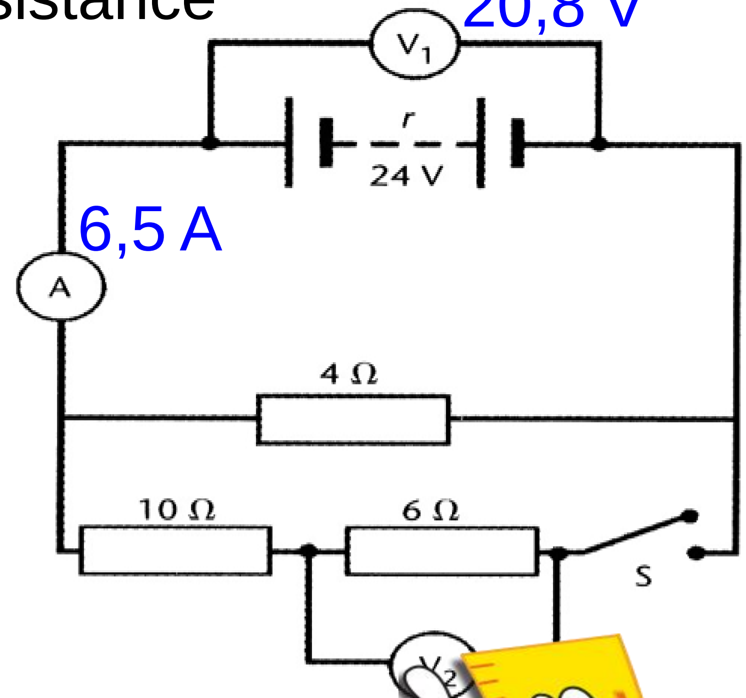
$= 7,8\ V$

Formulas are great, but very often **LOGIC** let's the penny drop!



Class Exercise 1/4

1.3. Find the value of the internal resistance of the battery.



$$\text{emf} = I_{tot}(R + r)$$

$$24 = 6{,}5 \times (3{,}2 + r)$$

$$6{,}5r = 3{,}2$$

$$r = 0{,}49\ \Omega$$

OR

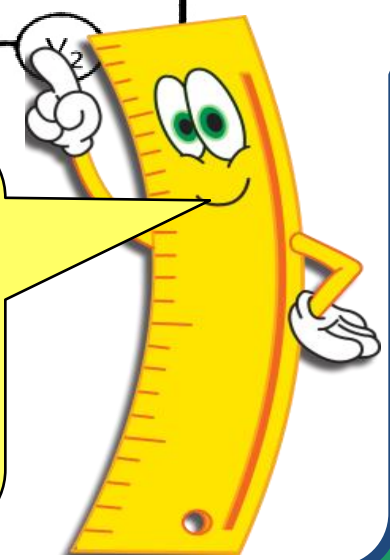
$$\text{Emf} = V_{ext} + V_{int}$$

$$V_{int} = 24 - 20{,}8$$

$$= 3{,}2\ \text{V}$$

$$r = \frac{V_{int}}{I_{int}}$$

$$= \frac{3{,}2\ V}{6{,}5\ A} = 0$$



Power

In grade 11 POWER was defined as:

POWER is the **rate** at which **electrical energy is converted** in an electrical circuit.

Symbol: P

Unit: watt (W)

$P = \frac{W}{t}$

but W = VQ, therefore

$P = \frac{VQ}{t}$ leading to $P = VI$

but $I = \frac{V}{R}$, therefore $P = \frac{V^2}{R}$

but V = IR, therefore $P = I^2R$

Power Relationships

$P = \frac{W}{t}$

$P \propto W$

Power is directly proportional to energy transferred in a constant time

⇒ If more energy is transferred in a constant time, the power increases.

$P \propto \frac{1}{t}$

Power is indirectly proportional to the time taken to transfer a constant amount of energy.

If energy is transformed in a shorter time, power increases.

$P = VI$

$P \propto V$, I constant

$P \propto I$, V constant

$P = \frac{V^2}{R}$

$P \propto V^2$, R constant

$P \propto \frac{1}{R}$, V constant

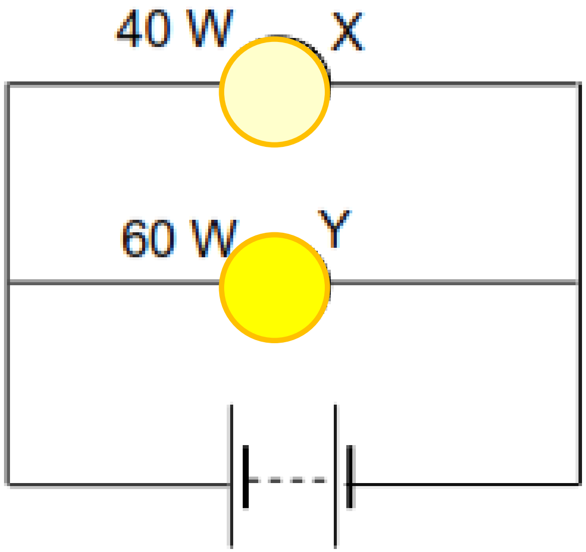
$P = I^2R$

$P \propto I^2$, R constant

$P \propto R$, I constant

Class Exercise 2/1

1. The circuit below shows two light bulbs, X and Y, connected in parallel to a battery with negligible internal resistance. The bulbs are marked 40 W and 60 W respectively.



Bulb Y glows brighter than bulb X.

1.1. How does the resistance of bulb Y compare to that of bulb X? Use an appropriate equation (or relationship) to explain your answer.

In parallel:

$V_Y = V_X$ (V is constant – parallel V)

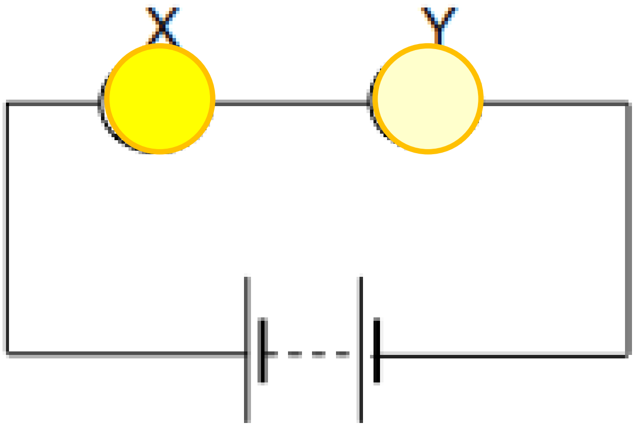
But, $P_Y > P_X$ (given)

$$\therefore \frac{V^2}{R_y} > \frac{V^2}{R_x}$$

$\therefore R_Y < R_X$

Class exercise 2/2

1.2. During an experiment a learner connects these two bulbs in series to the same power supply as before.
He observes that bulb X now glows brighter than bulb Y.
Use an appropriate equation (or relationship) to explain his observation.



In series:

$I_Y = I_X$ (I constant in series circuit)

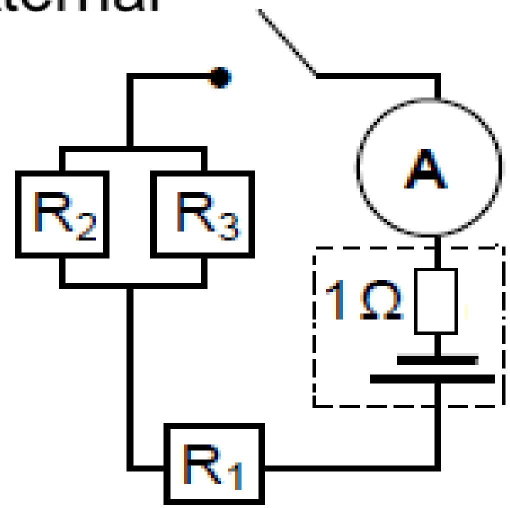
$I^2R_Y < I^2R_x \quad (R_Y < R_x)$

$P \propto R$ (with I constant)

$\therefore P_Y < P_X$

Class exercise 2/3

2. In the electrical circuit, the battery has an emf of 6 V and an internal resistance of 1 Ω. The total external resistance of the circuit is 9 Ω.



2.1. Calculate the current in R_1 when the switch is closed.

I_{tot} passes through R_1

$$I_{tot} = \frac{emf}{R_{tot}} = \frac{6V}{(9+1)\Omega} = 0{,}6\ A$$

2.2. Calculate the p.d. across the battery when the switch is closed. Explain your answer.

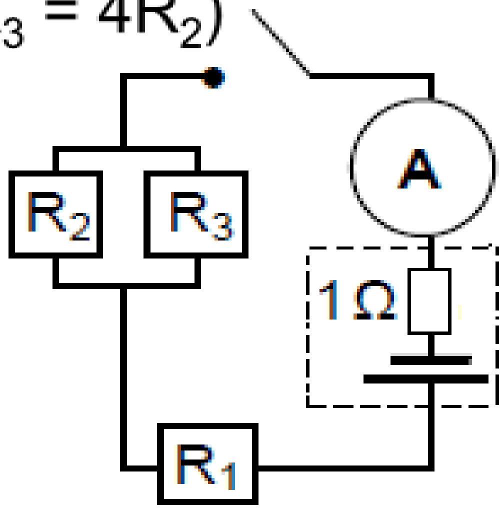
$$V_{load} = emf - V_{int}$$
$$= emf - I_{int} \times r$$
$$= 6\ V - 0{,}6\ A \times 1\ \Omega = 5{,}4\ V$$

When the battery has to supply energy to charges, some of the energy is used to overcome internal resistance.

Class exercise 2/4

The power dissipated in resistor R_1 is 1,8 W. The resistance of resistor R_3 is 4 times that of resistor R_2. ($R_3 = 4R_2$)

2.2. Calculate the resistance of resistor R_2.



$P_1 = I_1^2 R_1$

$1{,}8\ W = (0{,}6\ A)^2 \times R_1$

$R_1 = 5\ \Omega$

$R_3 = 4R_2$, therefore $I_2 = 4I_3$

$I_2 = \frac{4}{5} \times 0{,}6\ A$

$= 0{,}48\ A$

$V_2 = V_{load} - V_1$

$P_1 = V_1 I_1$

$V_1 = \frac{1{,}8W}{0{,}6A}$

$= 3\ V$

$V_2 = V_{load} - V_1$

$= 5{,}4\ V - 3\ V$

$= 2{,}4\ V$

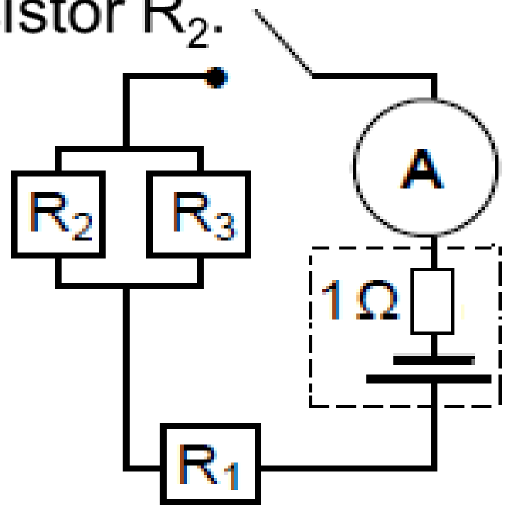
$R_2 = \frac{V_2}{I_2}$

$= \frac{2{,}4V}{0{,}48A} = 5\ \Omega$

Class exercise 2/5

OR The power dissipated in resistor R_1 is 1,8 W. The resistance of resistor R_3 is 4 times that of resistor R_2. ($R_3 = 4R_2$)

2.2. Calculate the resistance of resistor R_2.



$$P_1 = I_1^2 R_1$$

$$1{,}8\ \text{W} = (0{,}6\ \text{A})^2 \times R_1$$

$$R_1 = 5\ \Omega$$

$$R_{ext} = R_1 + R_p$$

$$R_{ext} = R_1 + \frac{R_2 + R_3}{R_2 \cdot R_3}$$

$$9\ \Omega = 5\ \Omega + \frac{R_2 + 4R_2}{R_2 \cdot 4R_2}$$

$$\frac{5R_2}{4(R_2)^2} = 4\ \Omega$$

$$\frac{5}{4R_2} = 4\ \Omega$$

$$R_2 = 5\Omega$$

Class exercise 2/6

3. A hair dryer operates at a potential difference of 240 V and a current of 9,5 A. It takes a learner 12 minutes to completely dry her hair. Eskom charges energy usage at R1,47 per unit. Calculate the cost of operating the hairdryer for the 12 minutes. (1 unit = 1 kW·h)

$P = VI$

$= 240\ \text{V} \times 9{,}5\ \text{A}$

$= 2\ 280\ \text{W}$

$= 2{,}28\ \text{kW}$

$W = P \cdot \Delta t$

$= 2{,}28\ \text{kW} \times \frac{12}{60}\text{h}$

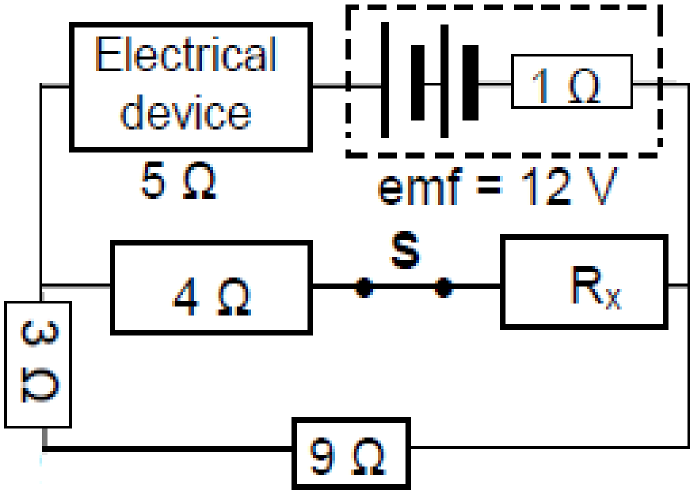
$= 0{,}46\ \text{kWh}$

Cost = 0,46 kWh x R 1,47/kWh

= R 0,68

Class exercise 2/7

4. The circuit shown is used to obtain the desired potential difference for an electrical device to function. The resistance of the device is 5 Ω.
   When switch S is closed as shown, the device functions at its maximum power of 5 W.



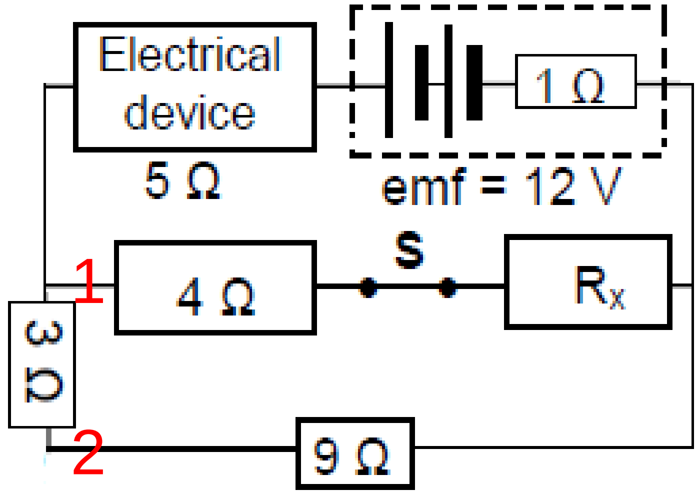
4.1. Explain, in words, the meaning of an emf of 12 V.
The maximum amount of energy that the battery can supply is 12J per coulomb of charge.

4.2. Calculate the current that passes through the electrical device.

$$P = I^2R$$
$$5\ W = I^2 \times 5\ \Omega$$
$$I = 1\ A$$

Class exercise 2/8

4.3. Calculate the resistance of resistor $\mathbf{R_x}$.



$$V_{ext} = emf - V_{int}$$
$$= 12\ V - (1\ A \times 1\ \Omega)$$
$$= 11\ V$$

$$V_p = V_{ext} - V_{device}$$
$$= 11\ V - (1\ A \times 5\Omega)$$
$$= 6\ V$$

$$I_{branch2} = \frac{V_p}{R_{branch2}}$$
$$= \frac{6\ V}{12\ \Omega}$$
$$= 0{,}5\ A$$

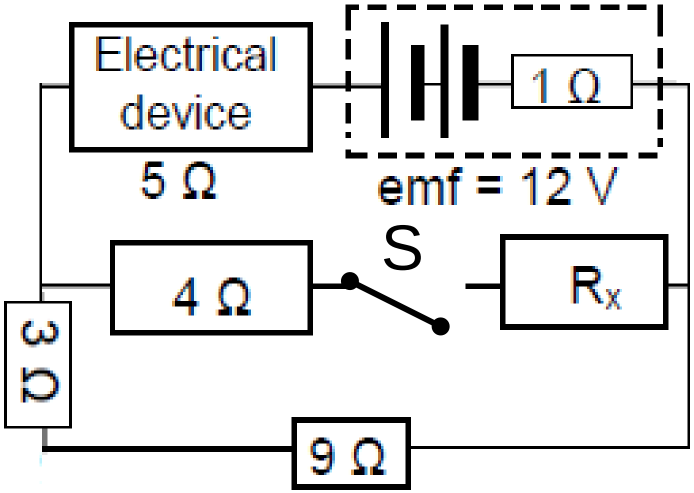
$\Rightarrow I_{branch1} = 0{,}5\ A$

$\therefore R_{branch1} = 12\ \Omega$

$R_x = 8\ \Omega$

Class exercise 2/9

4.4. Switch S is now **opened**. Will the device still function at maximum power? Write down YES or NO. Explain the answer (without calculations).



R_{tot} will increase since all resistors are now in series

$\Rightarrow I_{tot}$ will decrease

and therefore P_{device} will decrease.

No, the device will no longer function at maximum power.

Class exercise 2/10

5. A lamp draws a 66 mA current when connected to a 6,0 V battery. When a 9,0 V battery is used, the lamp draws 75 mA.

   Does the lamp obey Ohm's law?

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

$= \frac{6\ V}{66 \times 10^{-3} A}$

$= 90{,}91\ \Omega$

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

$= \frac{9\ V}{75 \times 10^{-3} A}$

$= 120\ \Omega$

When a conductor obeys Ohm's law, the proportion V/I will be constant.

This is not the case in this scenario

⇒ the lamp does not obey Ohm's law.

Class exercise 2/11

6. Why is there a difference in equivalent resistance between three resistors connected in series and the same three resistors connected in parallel?

   In series, the length of resisting components are increased.

   The longer a resistor, the greater its resistance.

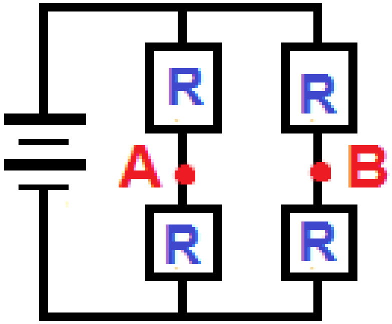
   In parallel, the width of the resisting part of the circuit is increased.

   The wider a resistor, the smaller its resistance.

Class exercise 2/12

7. This circuit has four identical resistors. Suppose that a wire is added to connect points A and B.

   What is the current through this resistor and how will it affect the current through and p.d. across the other resistors?



Since the resistors are identical, point A and B are at the same potential.

There is no potential difference between points A and B

⇒ NO current will flow through the wire and the current through and p.d. across the other resistors will be unchanged.

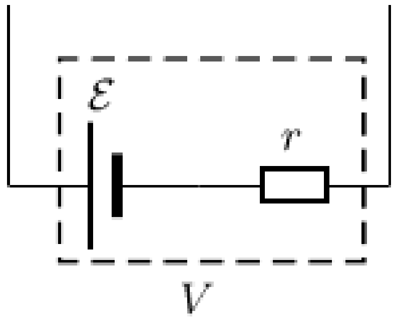
Key Concepts 1

$$\text{Emf} = V_{internal} + V_{external}$$

OR

$$\varepsilon = V_{internal\ resistance} + V_{load}$$

$$V_{external} = \text{Emf} - V_{internal}$$



emf = terminal potential difference + "lost volts"

Emf = IR + Ir = I(R + r)

You must be able to apply the principles represented by these formulas in different electrical circuits!

Key Concepts 2

Power is the **rate** at which **electrical energy is converted** in an electrical circuit.

Symbol: P

Unit: watt (W)

$P = \frac{W}{t}$ but W = VQ, therefore

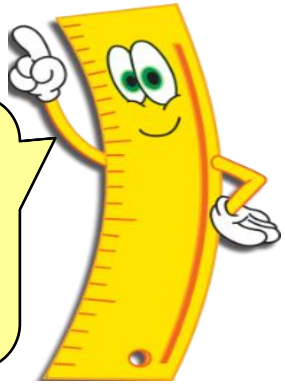
$P = \frac{VQ}{t}$ leading to $P = VI$

but $I = \frac{V}{R}$, therefore $P = \frac{V^2}{R}$

but $V = IR$, therefore $P = I^2R$

- **Memorise** the various definitions
- **Review** the exercises you had difficulty with …
- and do some **additional exercise** …
  - as given in your **workbooks** that accompany this video series or from your school textbook

Continue your learning by watching the **next video lesson** in this series:
Lesson 1: Electrical Machines



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