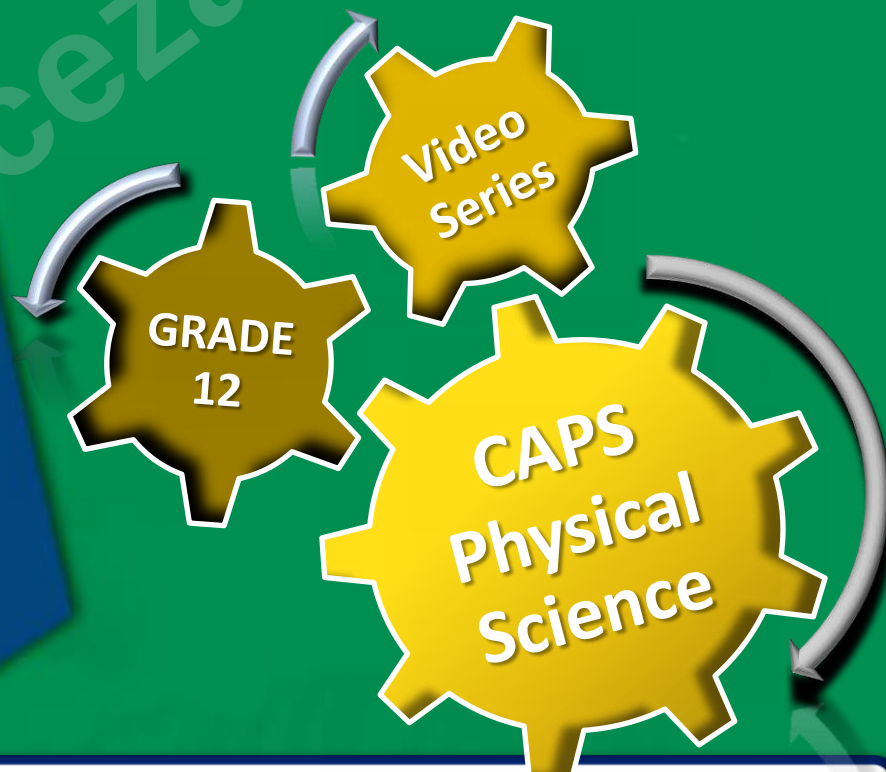
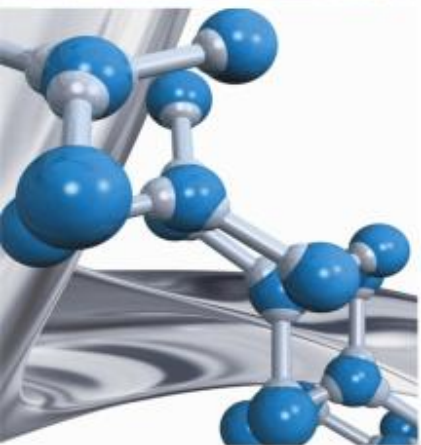




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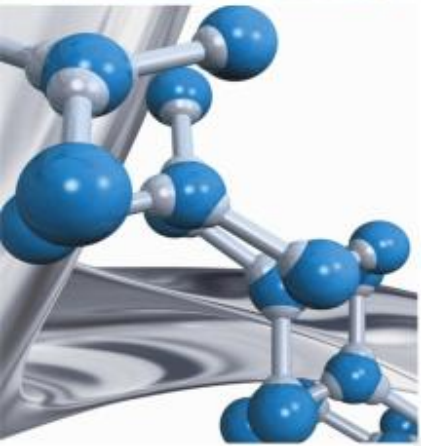


ELECTRICITY AND MAGNETISM

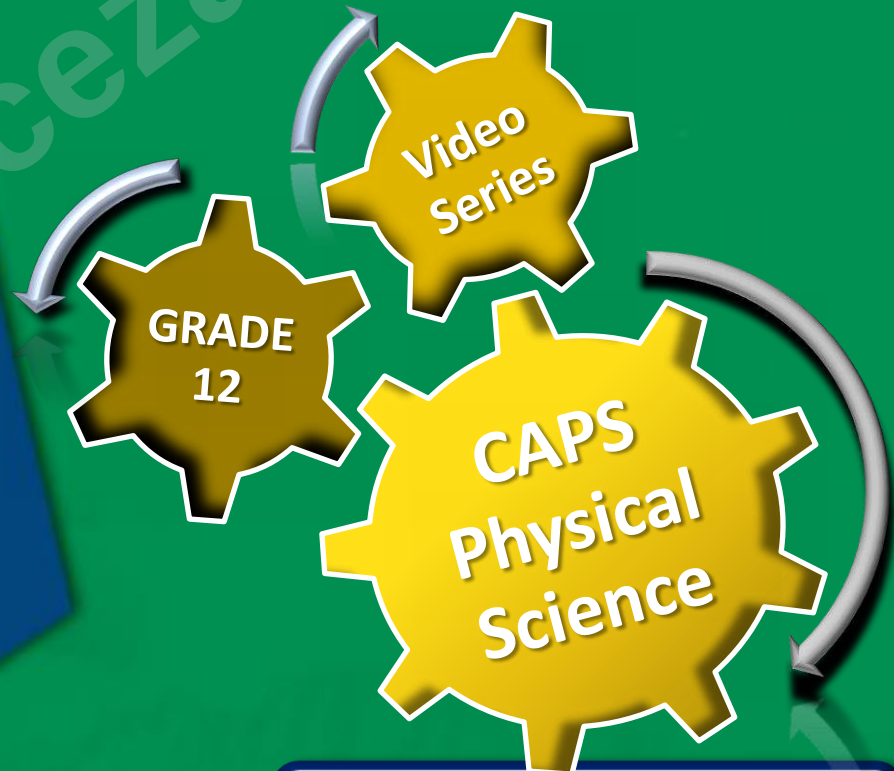
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Lesson 3: Electric Circuits

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Electric Circuits

Class Exercise 1/1

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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.

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

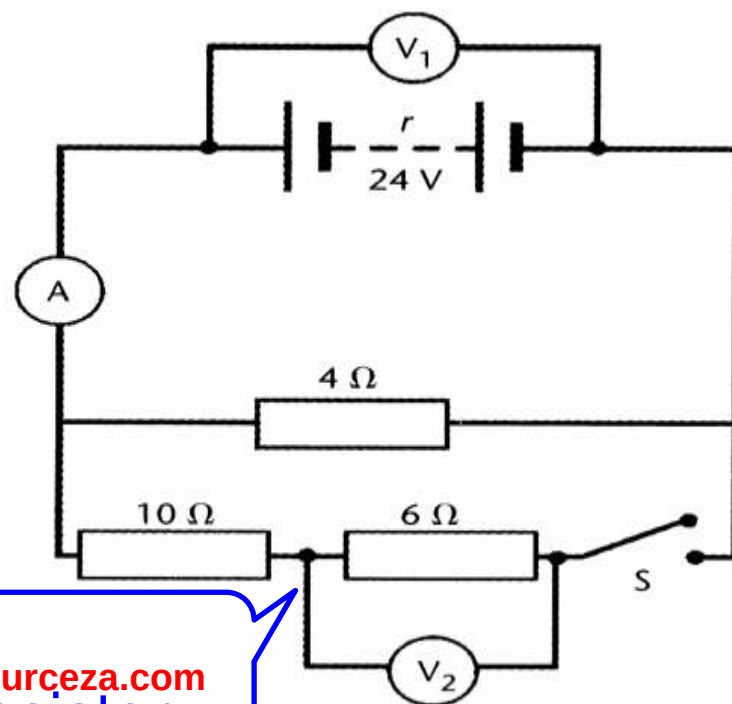
OR

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

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

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

$$\begin{aligned} R_{\text{ext}} &= \frac{R_1 R_2}{R_1 + R_2} \\ &= \frac{4 \cdot 16}{4 + 16} \\ &= 3,2 \Omega \end{aligned}$$



These two resistors are in series
 $\Rightarrow$ can be combined into one 16 Ω resistor

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Class Exercise 1/2

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

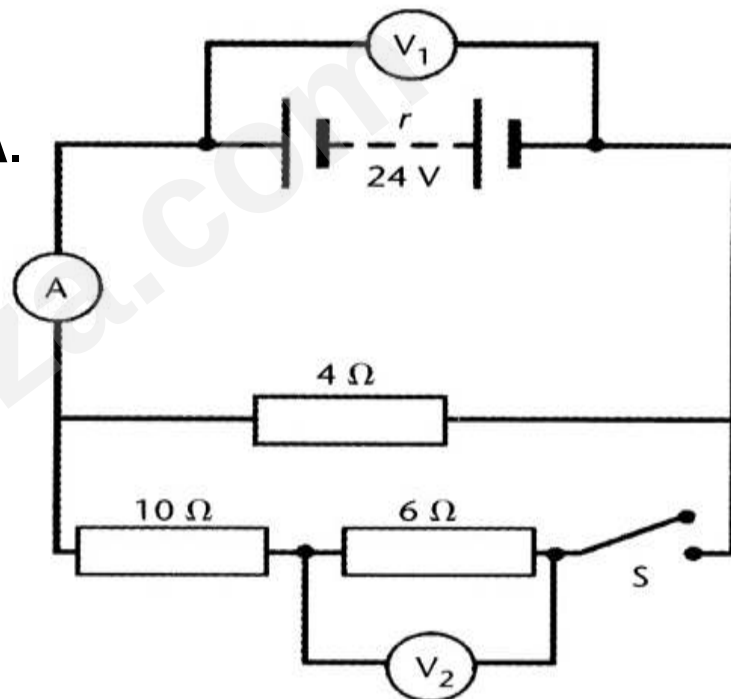
1.2.1 voltmeter V_1 .

$$\begin{aligned} V_1 &= I_{\text{tot}} \cdot R_{\text{ext}} \\ &= 6,5 \times 3,2 \\ &= 20,8 \text{ V} \end{aligned}$$

1.2.2 voltmeter V_2 .

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

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



$$\begin{aligned} V_{6\Omega} &= 20,8 \text{ V} \times \frac{3}{8} \\ &= 7,8 \text{ V} \end{aligned}$$

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Class Exercise 1/3

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

$$\begin{aligned} R_{\text{branch1}} &: R_{\text{branch2}} \\ 4 &: 16 \\ 1 &: 4 \end{aligned}$$

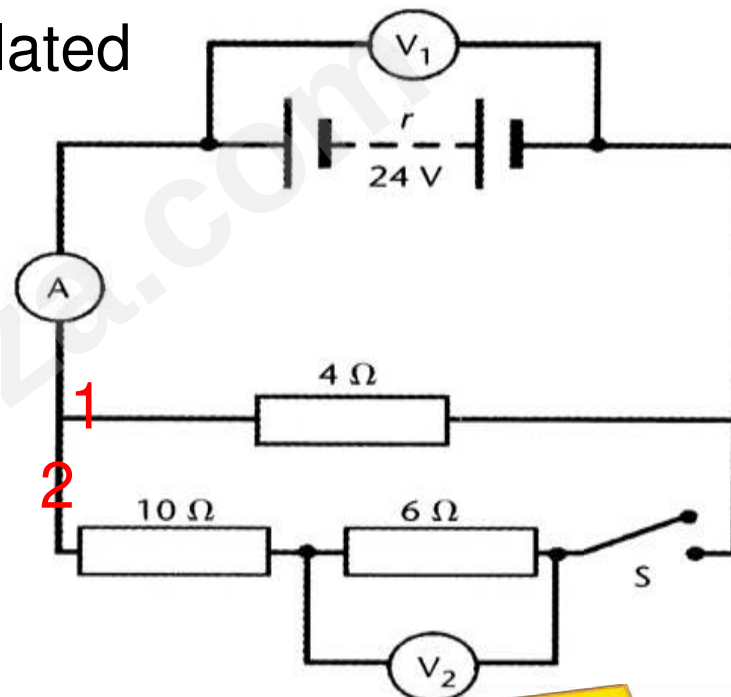
Therefore ...

$$\begin{aligned} I_{\text{branch1}} &: I_{\text{branch2}} \\ 16 &: 4 \end{aligned}$$

$$4 \div 1$$

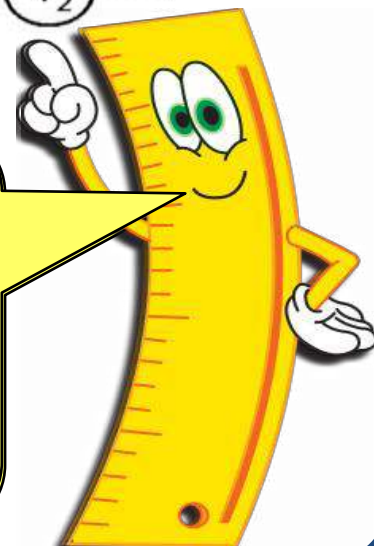
$$I_{\text{branch2}} = 6,5 \text{ A} \times \frac{1}{5} = 1,3$$

$$\begin{aligned} V_{6\Omega} &= I_{6\Omega} \cdot R_{6\Omega} \\ &= 1,3 \times 6 \\ &= 7,8 \text{ V} \end{aligned}$$



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

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Class Exercise 1/4

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

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

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

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

$$r = 0,49 \Omega$$

OR

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

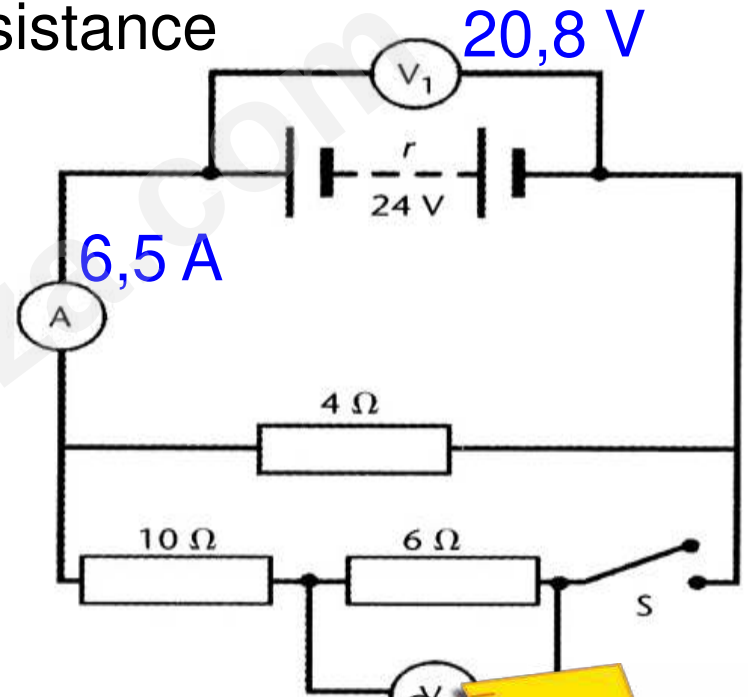
$$V_{\text{int}} = 24 - 20,8$$

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

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

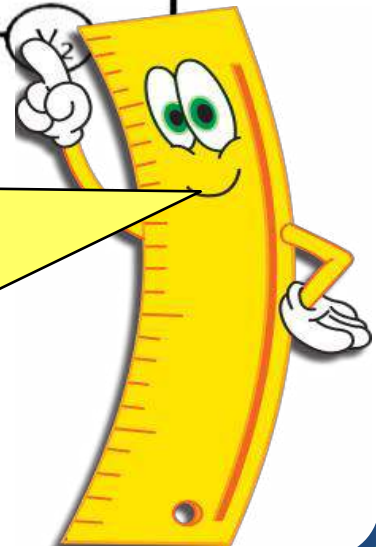
$$= \frac{3,2 \text{ V}}{6,5 \text{ A}} = 0,49 \Omega$$

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Most of the time, there are more than one path to take.

Use your LOGIC!



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

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

but $V = IR$, therefore

$$P = VI$$

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

$$P = I^2R$$

Power Relationships

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

$$P \propto W$$

Power is directly proportional to energy transferred in a constant time
 $\Rightarrow$ 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.

$$P = VI$$

$$P \propto V, I \text{ constant}$$

$$P \propto I, V \text{ constant}$$

$$P = I^2R$$

$$P \propto I^2, R \text{ constant}$$

$$P \propto R, I \text{ constant}$$

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

$$P \propto V^2, R \text{ constant}$$

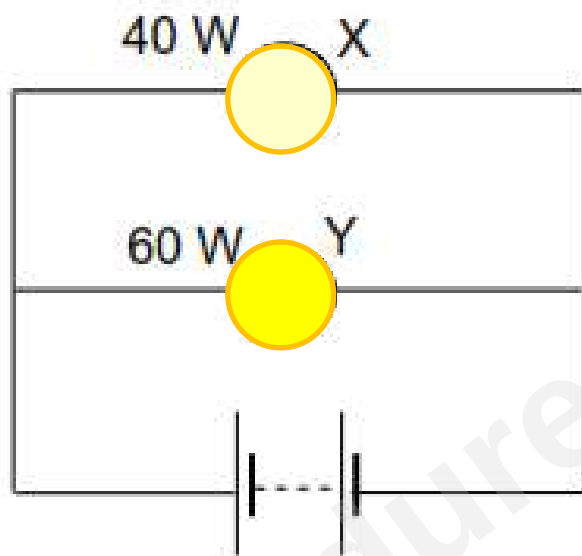
$$P \propto \frac{1}{R}, V \text{ constant}$$

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Class Exercise 2/1

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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:

$$V_Y = V_X \text{ (V is constant – parallel V)}$$

But, $P_Y > P_X$ (given)

$$\therefore \frac{V^2}{R_Y} > \frac{V^2}{R_X}$$

$$\therefore R_Y < R_X$$

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Class exercise 2/2

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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.

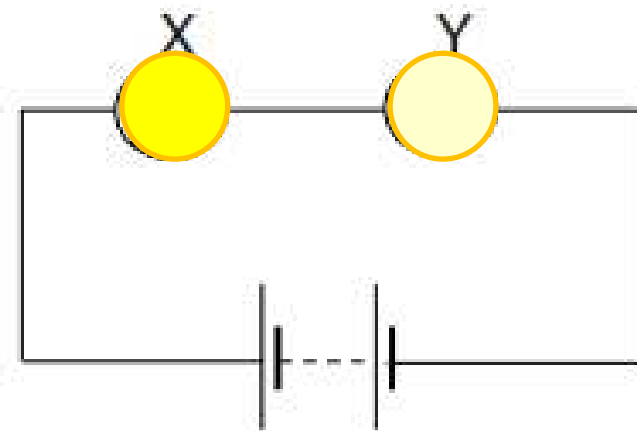
In series:

$$I_Y = I_X \text{ (I constant in series circuit)}$$

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

$$P \propto R \text{ (with I constant)}$$

$$\therefore P_Y < P_X$$



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Class exercise 2/3

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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

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

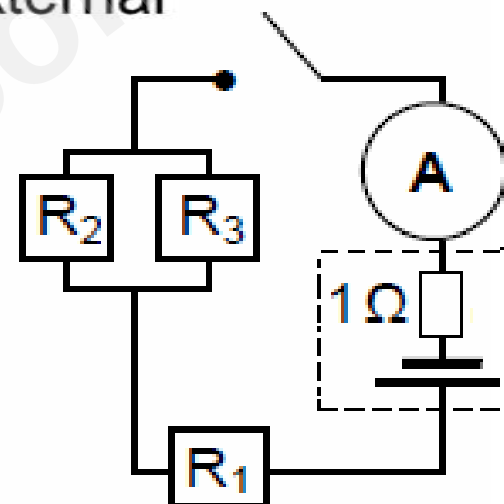
2.2. Calculate the p.d. across the battery when the switch is closed. Explain your answer.

$$V_{\text{load}} = emf - V_{\text{int}}$$

$$= emf - I_{\text{int}} \times r$$

$$= 6 \text{ V} - 0,6 \text{ A} \times 1 \Omega = 5,4 \text{ V}$$

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



Class exercise 2/4

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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 .

$$P_1 = I_1^2 R_1$$

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

$$R_1 = 5 \Omega$$

$$R_3 = 4R_2, \text{ therefore } I_2 = 4I_3$$

$$I_2 = \frac{4}{5} \times 0,6 \text{ A}$$
$$= 0,48 \text{ A}$$

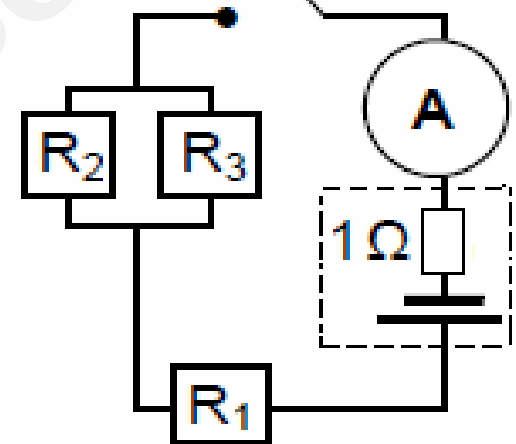
$$V_2 = V_{\text{load}} - V_1$$

$$P_1 = V_1 I_1$$

$$V_1 = \frac{1,8 \text{ W}}{0,6 \text{ A}}$$
$$= 3 \text{ V}$$

$$V_2 = V_{\text{load}} - V_1$$
$$= 5,4 \text{ V} - 3 \text{ V}$$
$$= 2,4 \text{ V}$$

$$R_2 = \frac{V_2}{I_2}$$
$$= \frac{2,4 \text{ V}}{0,48 \text{ A}} = 5 \Omega$$



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Class exercise 2/5

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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 .

$$P_1 = I_1^2 R_1$$

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

$$R_1 = 5 \Omega$$

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

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

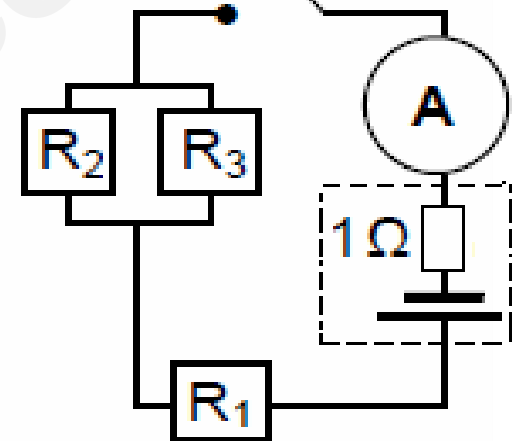
$$9 \Omega = 5 \Omega + \frac{R_2 + 4R_2}{R_2 \cdot 4R_2}$$

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

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

$$R_2 = 50$$

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Class exercise 2/6

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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)

$$P = VI$$

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

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

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

$$W = P \cdot \Delta t$$

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

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

$$\text{Cost} = 0,46 \text{ kWh} \times \text{R } 1,47/\text{kWh}$$

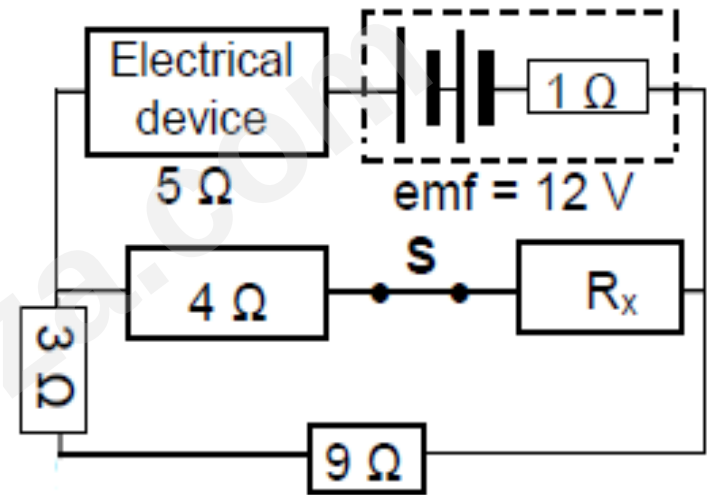
$$= \text{R } 0,68$$

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Class exercise 2/7

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



- 4.1. Explain, in words, the meaning of an emf of $12\ \text{V}$.
The maximum amount of energy that the battery can supply is $12\ \text{J}$ per coulomb of charge.
- 4.2. Calculate the current that passes through the electrical device.

$$P = I^2 R$$

$$5\ \text{W} = I^2 \times 5\ \Omega$$

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$$I = 1\ \text{A}$$

Class exercise 2/8

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4.3. Calculate the resistance of resistor R_x .

$$\begin{aligned} V_{\text{ext}} &= \text{emf} - V_{\text{int}} \\ &= 12 \text{ V} - (1 \text{ A} \times 1 \Omega) \\ &= 11 \text{ V} \end{aligned}$$

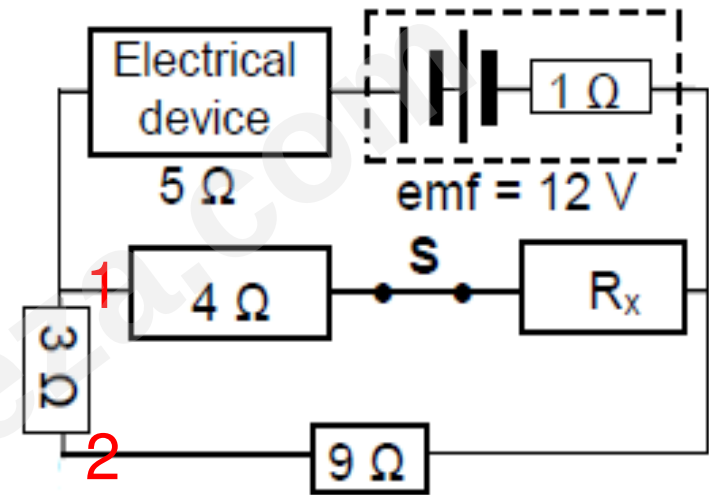
$$\begin{aligned} V_p &= V_{\text{ext}} - V_{\text{device}} \\ &= 11 \text{ V} - (1 \text{ A} \times 5\Omega) \\ &= 6 \text{ V} \end{aligned}$$

$$\begin{aligned} I_{\text{branch2}} &= \frac{V_p}{R_{\text{branch2}}} \\ &= \frac{6 \text{ V}}{12 \Omega} \\ &= 0,5 \text{ A} \end{aligned}$$

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

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

$$R_x = 8 \Omega$$

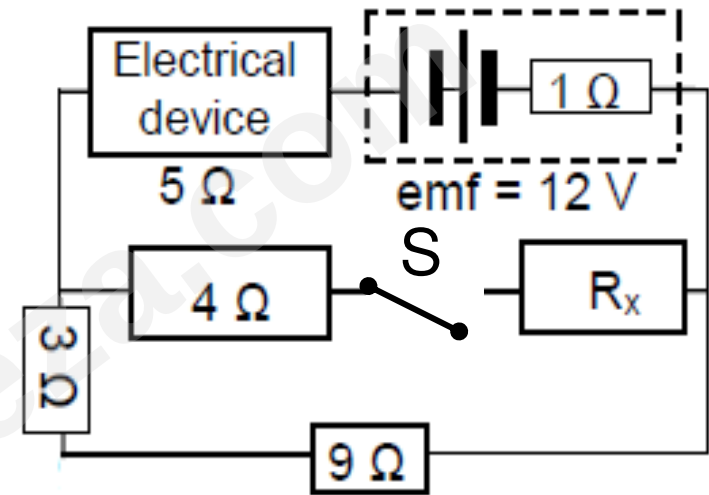


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Class exercise 2/9

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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

$\Rightarrow I_{\text{tot}}$ will decrease

and therefore P_{device} will decrease.

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

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Class exercise 2/10

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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?

$$\begin{aligned} R &= \frac{V}{I} \\ &= \frac{6\text{ V}}{66 \times 10^{-3}\text{ A}} \\ &= 90,91\ \Omega \end{aligned}$$

$$\begin{aligned} R &= \frac{V}{I} \\ &= \frac{9\text{ V}}{75 \times 10^{-3}\text{ A}} \\ &= 120\ \Omega \end{aligned}$$

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.

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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

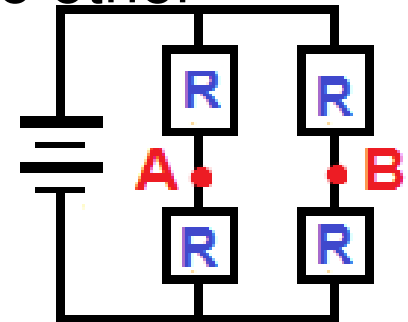
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7. This circuit has four identical resistors. Suppose that a wire is added to connect points A and B. What is the current through this resistor and how will it affect the current through and p.d. across the other resistors?

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.



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Key Concepts 1

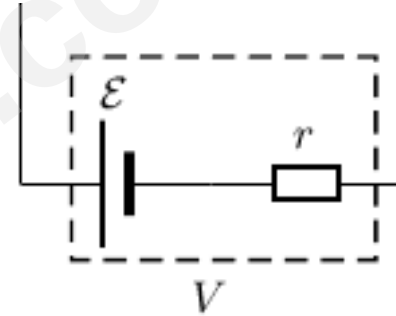
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OR

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

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

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



emf = terminal potential difference + “lost volts”

$$\text{Emf} = IR + Ir = I(R + r)$$

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

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Key Concepts 2

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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

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

but $V = IR$, therefore

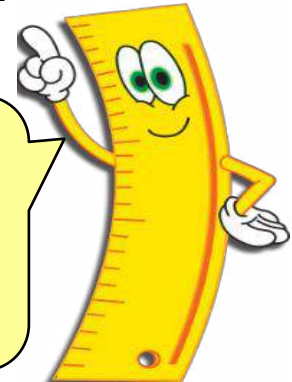
$$P = VI$$

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

$$P = I^2R$$

- **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



PhiniseD