Nelson Mandela Metropolitan University

for tomorrow

Video Series

GRADE 12

CAPS Physical Science

ELECTRICITY AND MAGNETISM

Lesson 1: Internal Resistance

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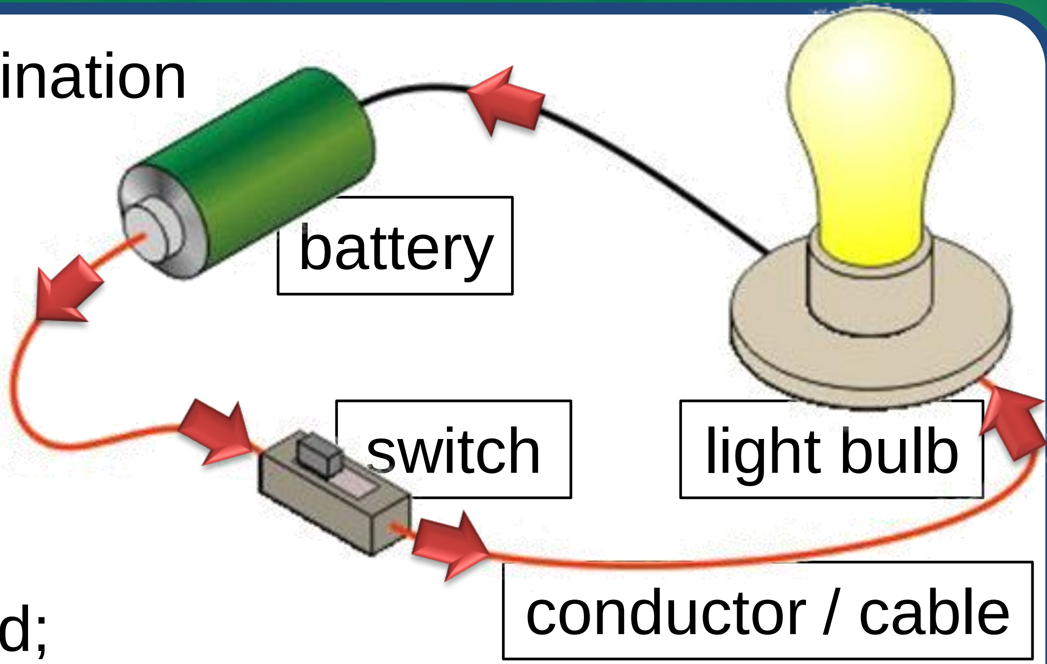
CAPS Physical Science

Electric Circuits

Electric Circuit



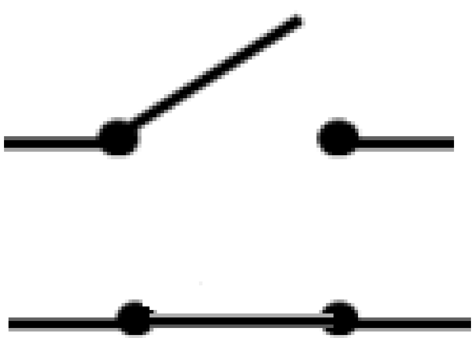
An electric circuit is a combination of electrical components connected to one another, enabling electrical charge to flow through the circuit.

For the charge to flow:

- A power source is needed;
- The circuit must be closed (completed).

Remember that when the switch is:

- *open*, the switch prevents charges from flowing since it *breaks the circuit*
- *closed*, the switch allows charges to pass through.



Unit of Charge

Charge (symbol Q) is measured in units called COULOMBS (C).

One coulomb of charge is **a very large charge**.

The charge on an electron was found to be: $q_e = 1{,}6\text{x}10^{-19}$ C.

Number of electrons constituting 1 C of charge:

$$= \frac{1\,C}{1{,}6\times10^{-19}C}$$

$$= 6{,}25 \text{ x } 10^{18}$$

$$= 6\ 250\ 000\ 000\ 000\ 000\ 000$$

LAW OF CONSERVATION OF CHARGE: The net (total) charge of an isolated system remains constant during any physical process. Charges cannot be created or destroyed.

Current

CURRENT is defined as the **RATE OF FLOW OF CHARGE**,

i.e. how much charge flows past a particular point (*flow of charge*) per unit time (*rate*).

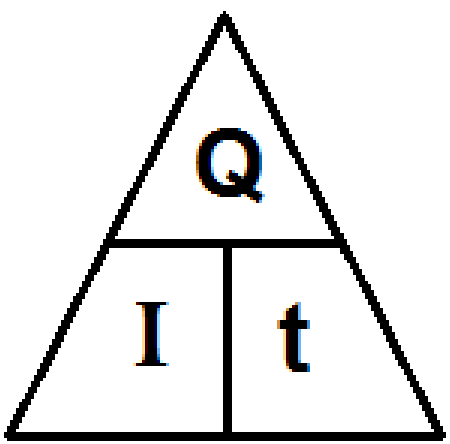
$$\textit{Electric Current} = \frac{\textit{charge flowing past a point}}{\textit{time elapsed}}$$

into symbols, as **FORMULA** $I = {}^{Q}/_{\Delta t}$

Q = charge - in coulomb (C)

I = current - in ampere (A)

Δt = time taken / elapsed



$$Q = I \times \Delta t$$

$$I = {}^{Q}/_{\Delta t} = Q \div \Delta t$$

$$\Delta t = {}^{Q}/_{I} = Q \div I$$

Direction of current is from + to –
(although current in metal conductors is actually electrons flowing from – to +)

Ammeter

ELECTRIC CURRENT is measured with an ammeter in ampere (A).

An ammeter is connected in series and has a very low (negligible) resistance.

Th…
be…
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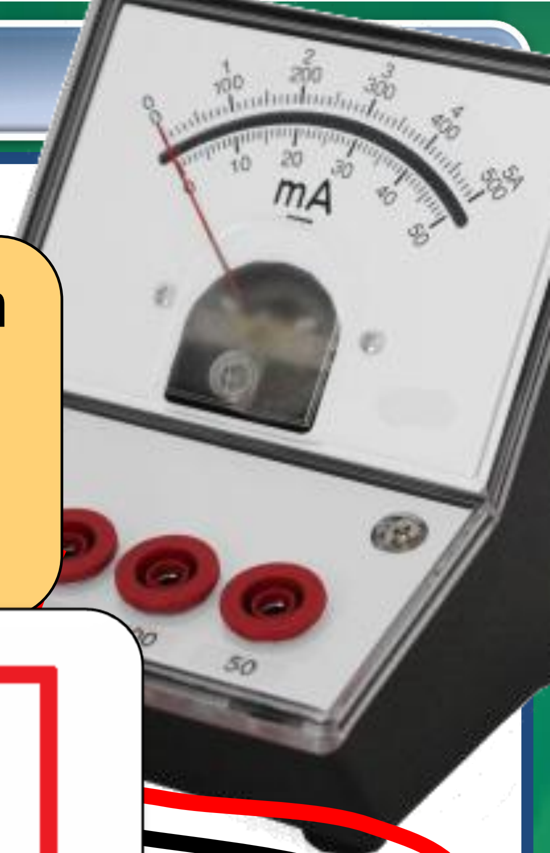
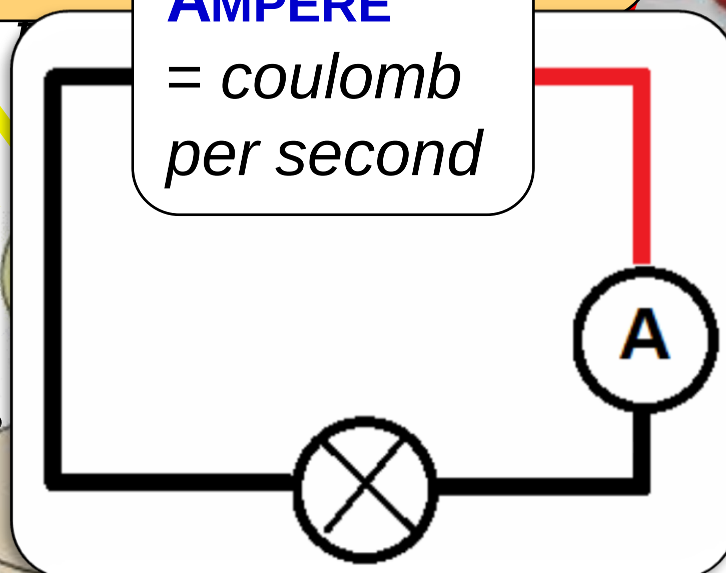
Al…
first so as not to damage t…

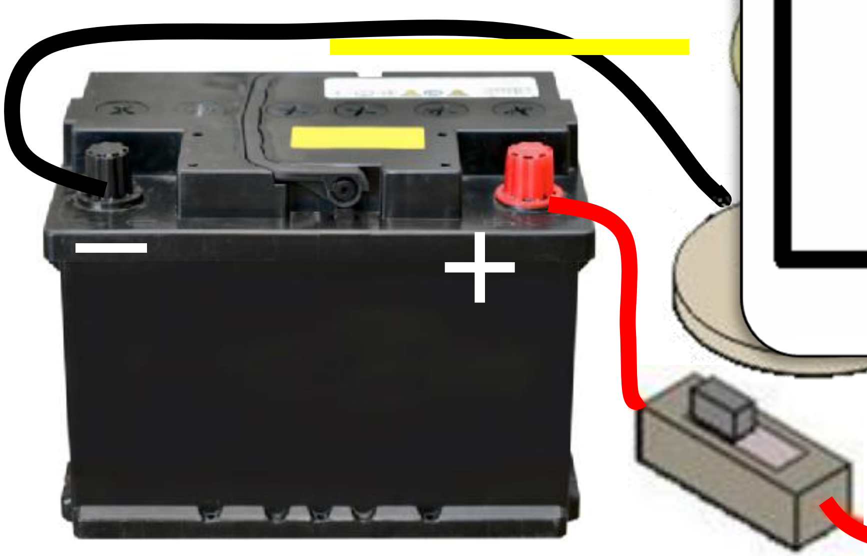
CIRCUIT DIAGRAM (A) ammeter connected in series with light bulb (including switch).

NB! Never connect an ammeter across a battery without an external …

AMPERE
= coulomb per second







…uit …
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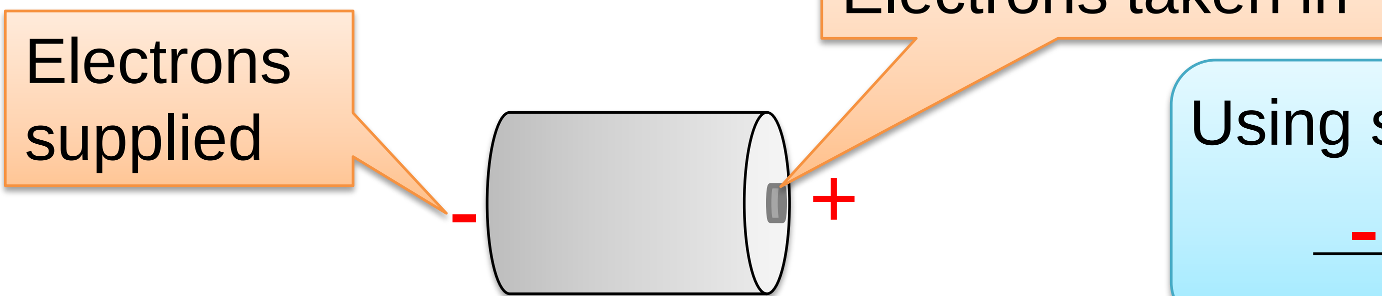
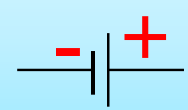
…ries,
then switch on …

Electrical E_p

The ordinary cell has 2 poles or terminals: a positive and a negative.



Using symbols:



The chemical reaction within the cell moves the electrons from the positive to the negative pole.

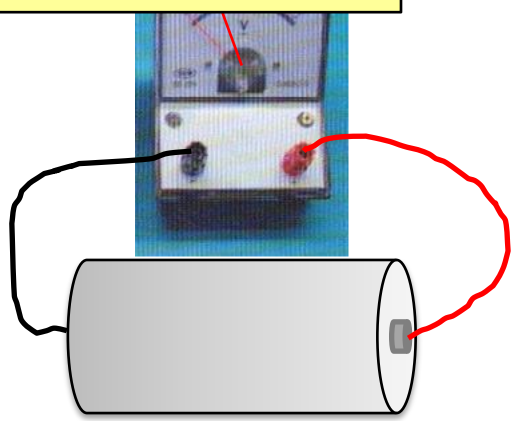
During this reaction, chemical potential energy is transformed into **ELECTRICAL POTENTIAL ENERGY**, which is supplied to the circuit.

emf

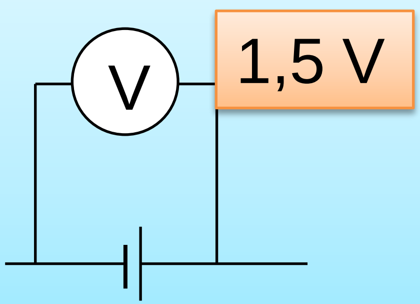
The **maximum** amount of electrical E_p being supplied per unit of charge ... led the **ELECTROMOTIVE FORCE** (e...

When th... **an external circuit**, a v... e... the cell, will ...ter the emf.

Note that the voltmeter is connected with + to + and – to - .



Using symbols:



The **voltmeter** has a **very high resistance**, blocking current from passing through it.

The emf is determined by the physical properties of the cell, such as size and chemical composition.

Potential Difference

POTENTIAL DIFFERENCE: The difference in electrical potential energy between two points in an electric field

– the work done per unit charge to move charge between the two points.

$$\text{Potential difference} = \frac{\textit{work done}}{\textit{amount of charge}}$$

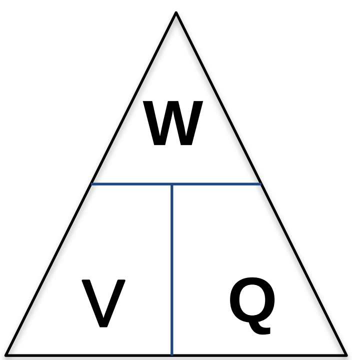
into symbols, as **FORMULA**

$$V = {}^{W}/_{Q}$$

Q = charge - in coulomb (C)

V = p.d. - in volt (V)

W = energy - in joule (J)



$$W = V \times Q$$

$$V = {}^{W}/_{Q} = W \div Q$$

$$Q = {}^{W}/_{V} = W \div V$$

Also called:
VOLTAGE

Resistance

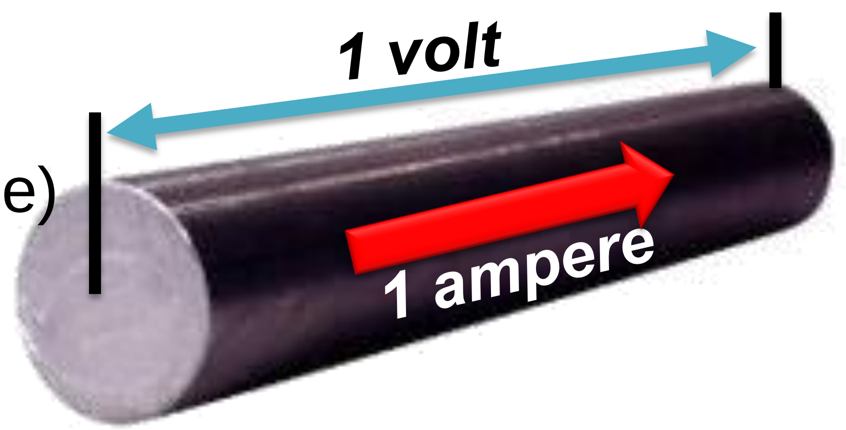
Resistance is **OPPOSITION TO** the **FLOW** of electric charge

Resistance (symbol: R) …

- is measured in **OHM (Ω)**
- the resistance across the length of the steel rod is 1 Ω (ohm) if a potential difference of 1 V (volt) is necessary to move 1 A (ampere) of charge across it.

Factors that influence the resistance of a conductor:

- Type of material
- Length (longer, more resistance)
- Width (wider, less resistance)
- Temperature (hotter, more resistance)



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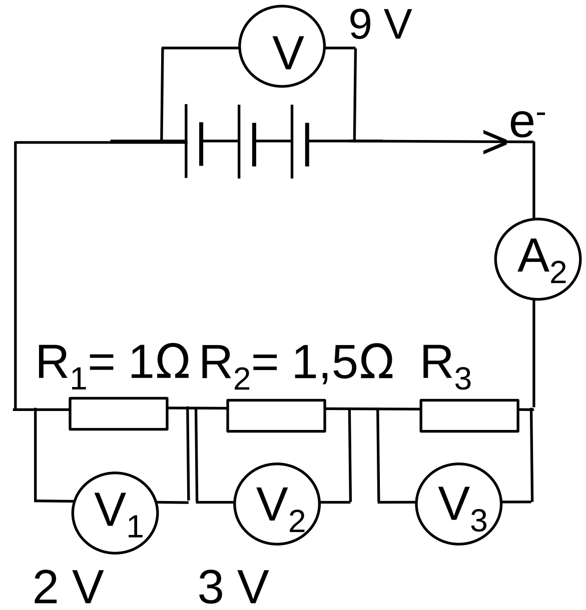
ELECTRICITY AND MAGNETISM

Class Exercise 1/1

1. Determine the resistance of R_3.



$$V_{total} = V_1 + V_2 + V_3$$

$$V_3 = 4\ V$$

$$V_1 : V_3$$
$$2\ V : 4\ V$$
$$1 : 2$$

then

$$R_1 : R_3$$
$$1 : 2$$
$$1\Omega : x$$
$$x = 2\Omega$$

OR

$$V_3 = 4\ V$$

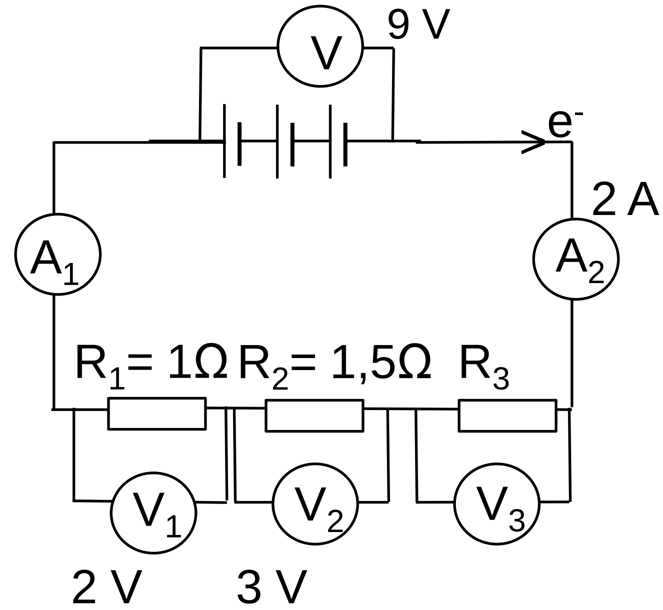
$$I_{tot} = \frac{V_1}{R_1} = \frac{2V}{1\Omega} = 2\ A$$

$$R_3 = \frac{V_3}{I_3} = \frac{4V}{2A} = 2\ \Omega$$

Series circuits are **POTENTIAL DIVIDERS**.
The **bigger the resistance**, the **greater the potential difference** over it.
Current in a series circuit **is the same** through all components.

Class Exercise 1/2

2. Name advantages and disadvantages of series circuits.



Advantages:

- More cells in series provide more energy to charges and increase the current.

Disadvantages:

- If one cell is flat or one bulb / resistor blown, the current is interrupted.
- All lights (resistors) must be turned on or off at once.
- More resistors in series increase the total resistance and decrease the current.

Class Exercise 1/3

4. Find the equivalent resistance in this circuit.

$$\frac{1}{R_p} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$$

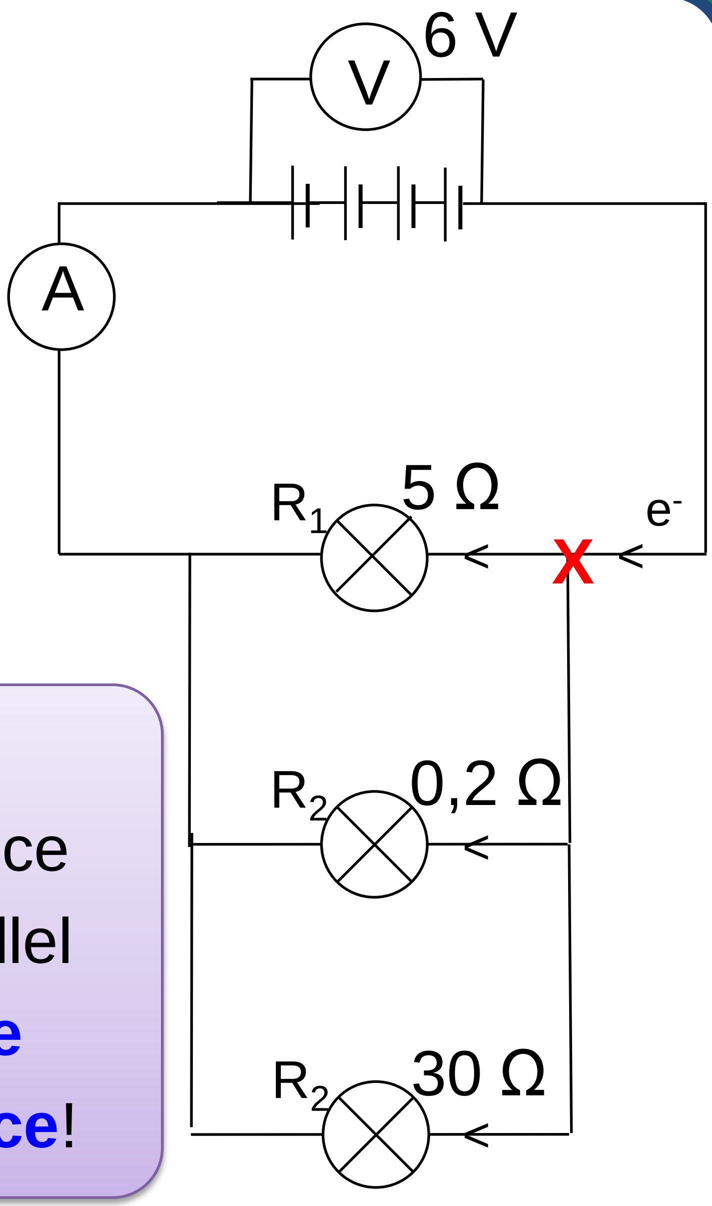
$$= \frac{1}{5\Omega} + \frac{1}{0{,}2\Omega} + \frac{1}{30\Omega}$$

$$= \frac{6}{30\Omega} + \frac{150}{30\Omega} + \frac{1}{30\Omega}$$

$$\frac{1}{R_p} = \frac{157}{30\Omega}$$

$$\frac{R_p}{1} = \frac{30\Omega}{157}$$

$R_p = 0{,}19\ \Omega$

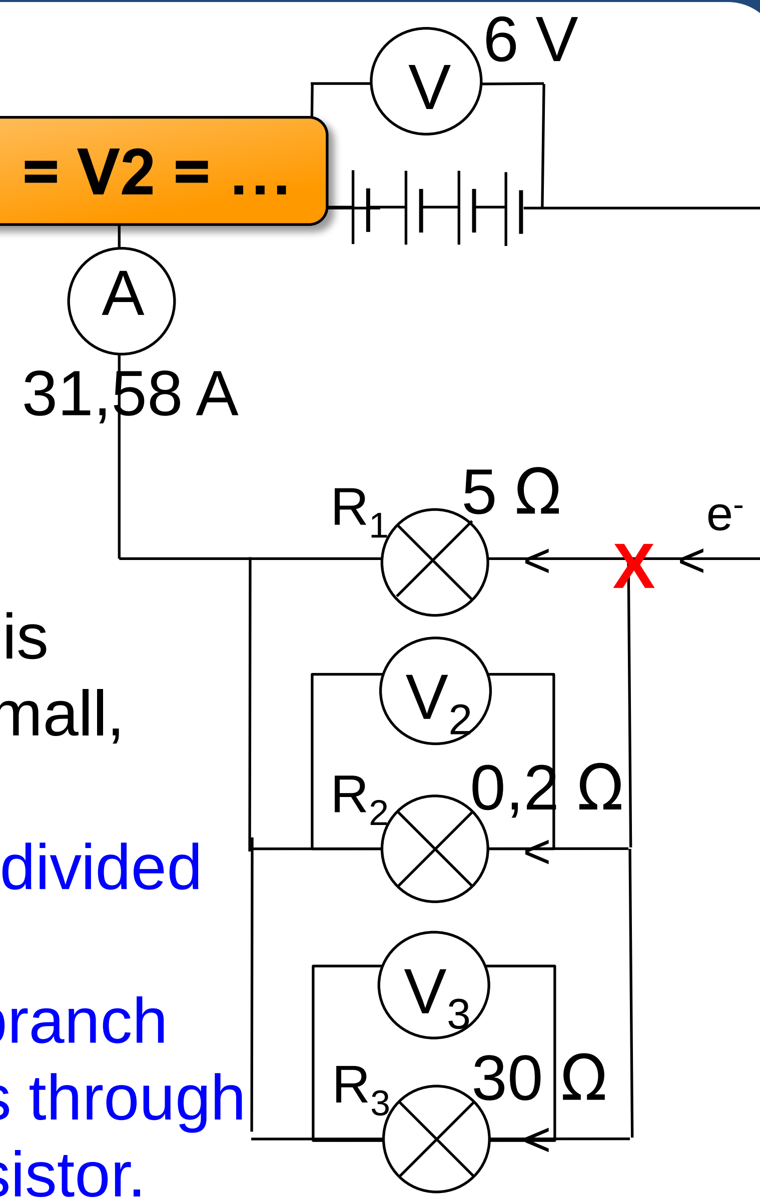


Note that the equivalent resistance of resistors in parallel is **smaller than the smallest resistance**!

Class Exercise 1/4

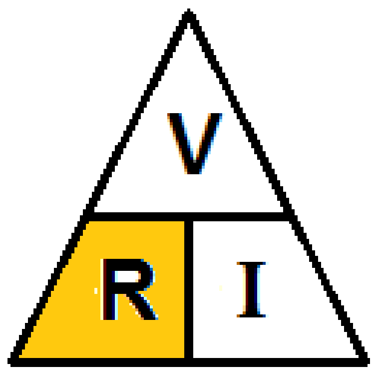
5. Give the readings on V_2 and V_3.
   Explain your answer.
   V_2 = 6 V and V_3 = 6V
   Potential difference is the same over all parallel components.

V_{total} = V1 = V2 = …



6. Determine the current through resistor R_3.

$$I_3 = \frac{V_3}{R_3} = \frac{6V}{30\Omega} = 0{,}2\text{ A}$$



why this
is so small,
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rent is divided

The smallest branch current passes through the biggest resistor.

Parallel circuits are **current dividers**.

Class Exercise 1/5

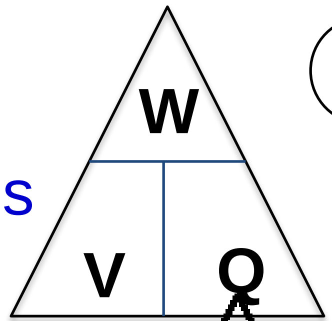
8. Determine how much energy is transferred to bulb R_3 in 4 minutes.

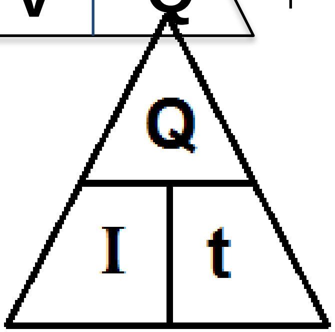
$W_3 = V_3 \cdot Q_3$

$= V_3 \cdot I_3 . \Delta t$

$= 6\ V \times 0{,}2\ A \times\ 240\ s$

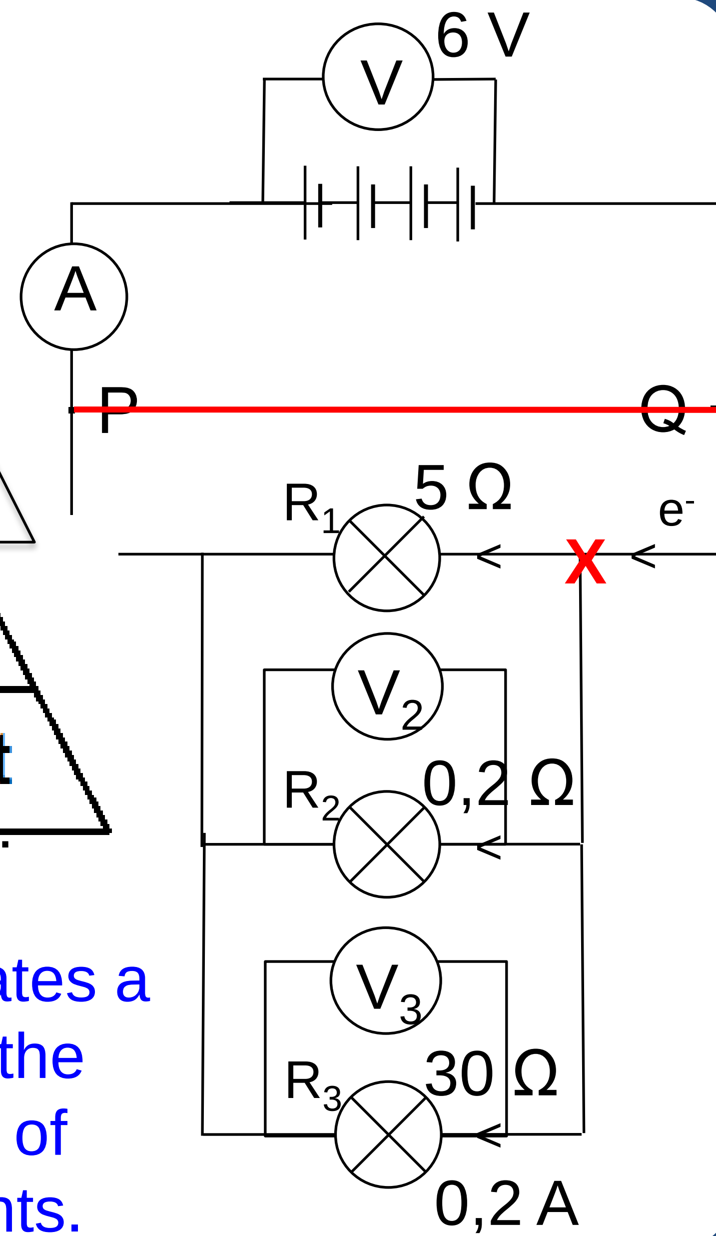
$= 288\ J$





9. What will happen to the bri
the lamps if a conducting w
connected between point
Explain.

All lamps would die, since PQ creates a **short cut / short circuit**, causing the current to flow through PQ instead of through the other circuit components.



Class Exercise 1/6

10. Give advantages and disadvantages of parallel circuits.

Advantages:

- The equivalent resistance of parallel resistors is smaller than the smallest individual resistance and therefore increases the current.
- If a cell is flat or a resistor / bulb is blown, the current can still continue.
- Lights (resistors) can be turned on or off individually.
- Cells in parallel last longer, since each cell only have to supply a part of the charges with energy.

Disadvantage:

- Cells in parallel do not provide the unit charge with more energy.

Class Exercise 1/7

11. Determine the total resistance in the circuit.

$$\frac{1}{R_p} = \frac{1}{R1} + \frac{1}{R2}$$

$$= \frac{1}{2\Omega} + \frac{1}{2\Omega}$$

$$= \frac{2}{2\Omega}$$

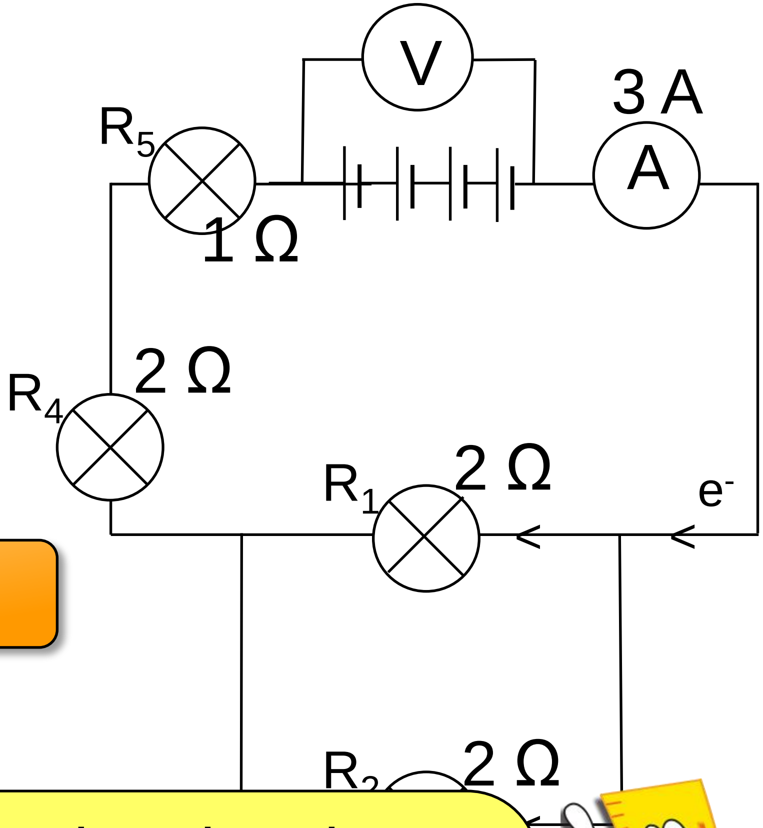
$$\frac{R_p}{1} = \frac{2\Omega}{2}$$

$R_p = 1\ \Omega$

$$R_{total} = R_p + R_4 + R_5$$

$= 1+2+1$

$= 4\ \Omega$



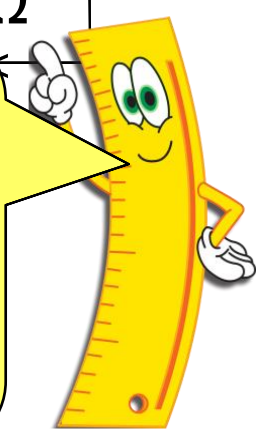
10. Determine the readi

$V_{tot} = I_{tot} \times R_{tot}$

$= 3\ A \times 4\ \Omega$

$= 12\ V$

Remember that the equivalent resistance of 2 identical resistors in parallel = half of each resistance.



Key Concepts 1

Serie circuits are **POTENTIAL DIVIDERS**.

Parallel circuits are **CURRENT DIVIDERS**.

Resistance of circuit components are influenced by:

- Type of metal
- Length
- Width
- Temperature

CURRENT is defined as the **RATE OF FLOW OF CHARGE**.

$$I = Q/\Delta t$$

POTENTIAL DIFFERENCE: The work done per unit charge to move a unit charge between two points.

$$V = W/Q$$

RESISTANCE is the measure of the potential difference needed per unit of current passing through the resistor.

$$R = V/I$$

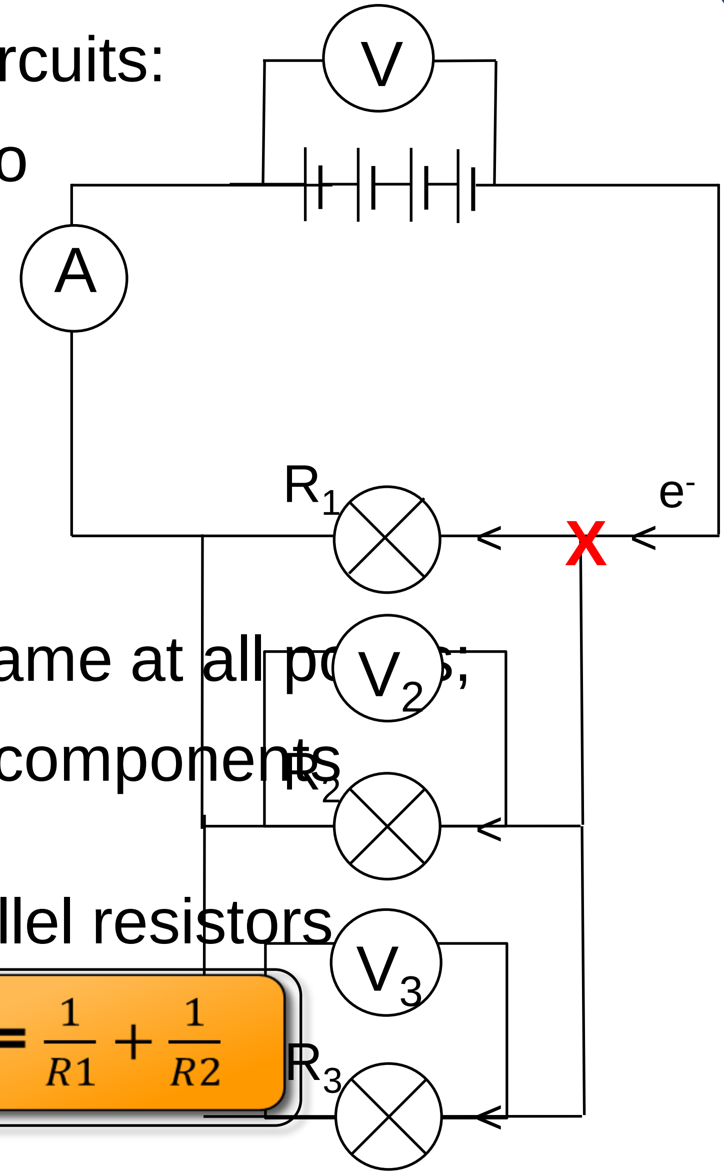
Key Concepts 2

When doing calculations on electric circuits:

- Always pair information according to the applicable resistor, e.g.

$$I_3 = \frac{V_3}{R_3} \qquad I_{tot} = \frac{V_{tot}}{R_{tot}}$$

- Remember that
  - current in a series circuit is the same at all points;
  - p.d. is the same over all parallel components



Series resistors

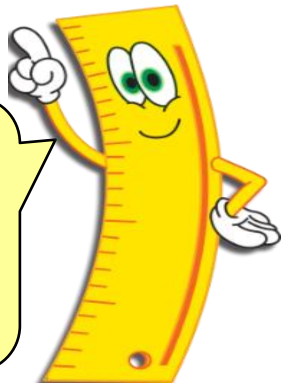
$$R_{total} = R_p + R_4 + R_5$$

Parallel resistors

$$\frac{1}{Rp} = \frac{1}{R1} + \frac{1}{R2}$$

- **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 2: Internal Resistance



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