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GCSE Physics

Edexcel Electricity, circuits and static electricity

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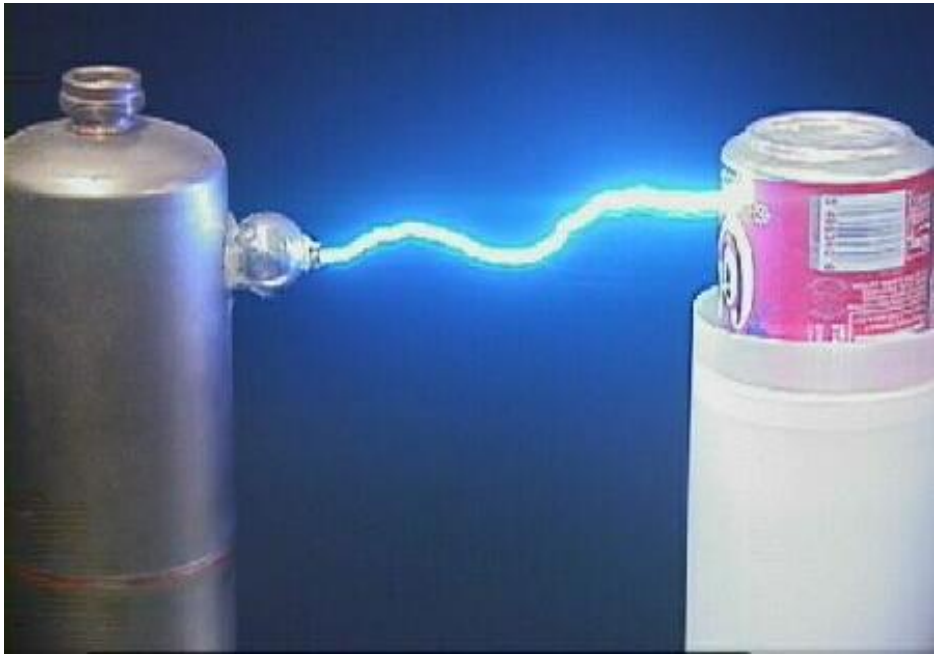
Overview
Edexcel Topic 10 ands 11

Electricity and circuits

Part 1
- Electric circuits
- Current charge and energy
- Current and potential difference

Part 2
- Resisitance
- Transferring energy
- Electrical safety

Part 3
- Static electricity



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LearnIT!
KnowIT!

Part 1

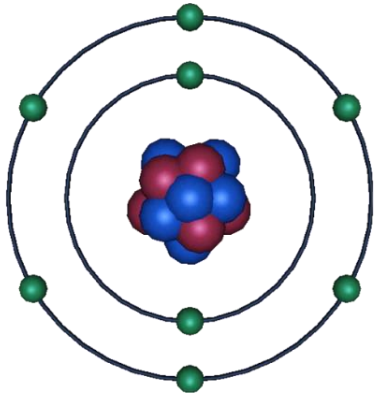
- **Electric circuits**
- **Current charge and energy**
- **Current and potential difference**

Structure of the atom - subatomic particles

- An **atom** has a positively charged **nucleus** containing **protons and neutrons**, surrounded by negatively charged **electrons in shells**.
- The nuclear radius much smaller than that of the atom and with almost all mass **of an atom** is **concentrated in the nucleus**.
- An atom contains **equal numbers of protons and electrons**.
- Atoms have **no overall electrical charge** because the number of positive protons equals the number of negative electrons.

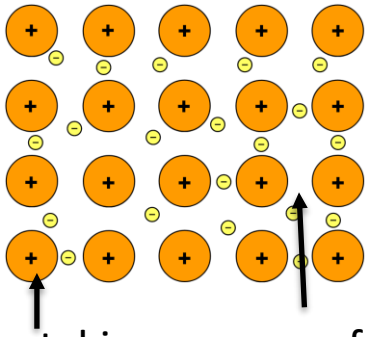
number of protons = atomic number

- All atoms of an element have the **same number of protons in the nucleus**. This number is **unique to that element**.



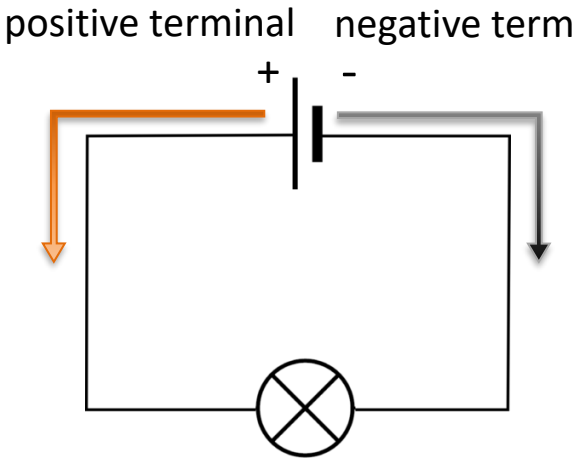
	Mass	Charge	Location
Proton	1	+ (positive)	nucleus
Neutron	1	no charge	nucleus
Electron	1/1835 negligible	- (negative)	shells

Current in metals



An **electric current flows** when **electrons** move through a **conductor**, such as a metal wire. Electricity passes through metallic conductors as **a flow of negatively charged electrons**. The electrons are **free** to move from one atom to another. We call them a **'sea of delocalised electrons'.**

Conventional current:
When working with circuits the direction of the electrical current is shown as the direction that positive charge would flow.



Electron flow:
Electrons are negatively charged particles and they transfer energy through wires as electricity from the negative terminal to the positive terminal.

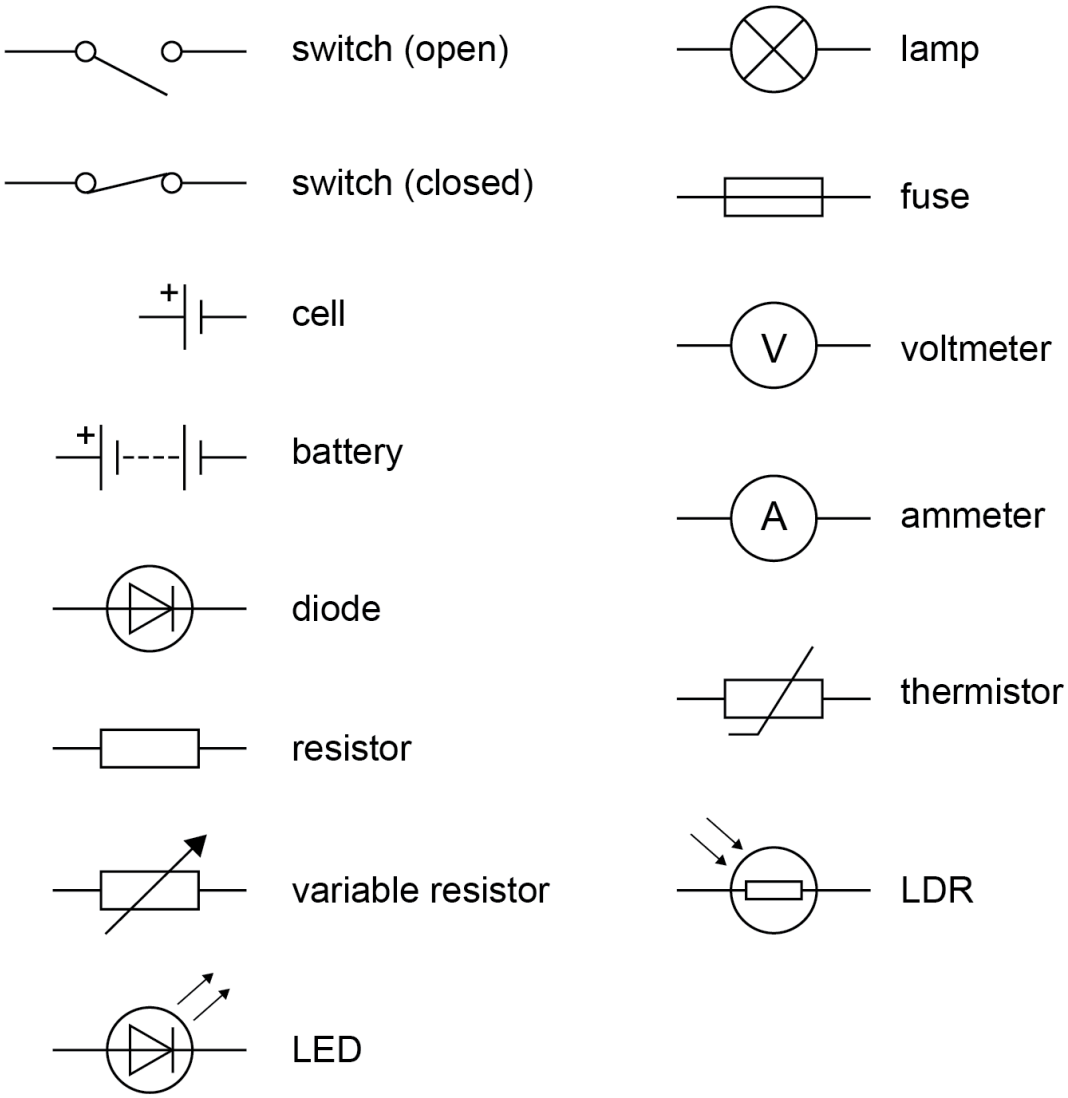
Note: Current was defined before the electron was discovered.

Standard Circuit Diagram Symbols

Circuit Symbols

Circuit symbols are used to clearly show components in a circuit and how they are connected.

These circuit symbols must be learnt so that you can draw them and interpret circuit diagrams that use them.

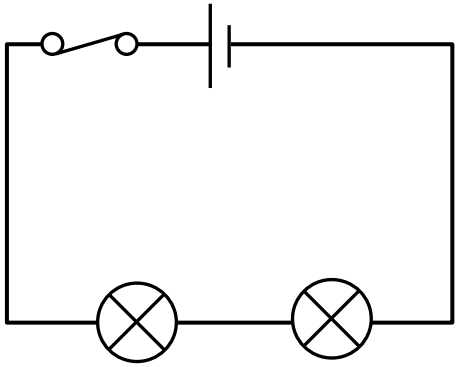


Terminology

Term	Definition
Current	The rate of flow of charge in a circuit.
Potential Difference	Also called voltage. The difference in potential between two points of a circuit. Causes a current to flow.
Charge	Charge is the amount of electricity travelling through a circuit.
Resistance	Anything that slows the flow of charge around a circuit. Resistance is usually caused by electrons colliding with ions in a material.
Series Circuit	A circuit with a single loop of wire.
Parallel Circuit	A circuit with two or more loops (branches) of wire.

Series and Parallel Circuits

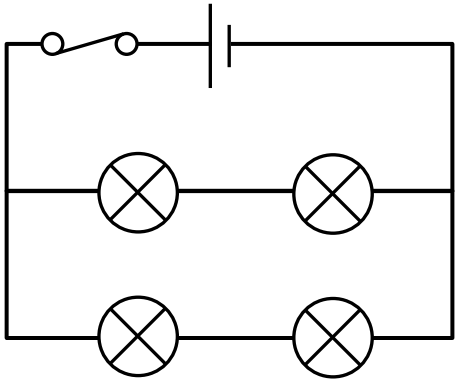
Series circuit



A **series** circuit consists of components that are **connected one after another** on the same loop of the circuit (wire). The current that flows in each component connected in series is the **same.**

If one lamp break all the lamp will go out.

Parallel circuit

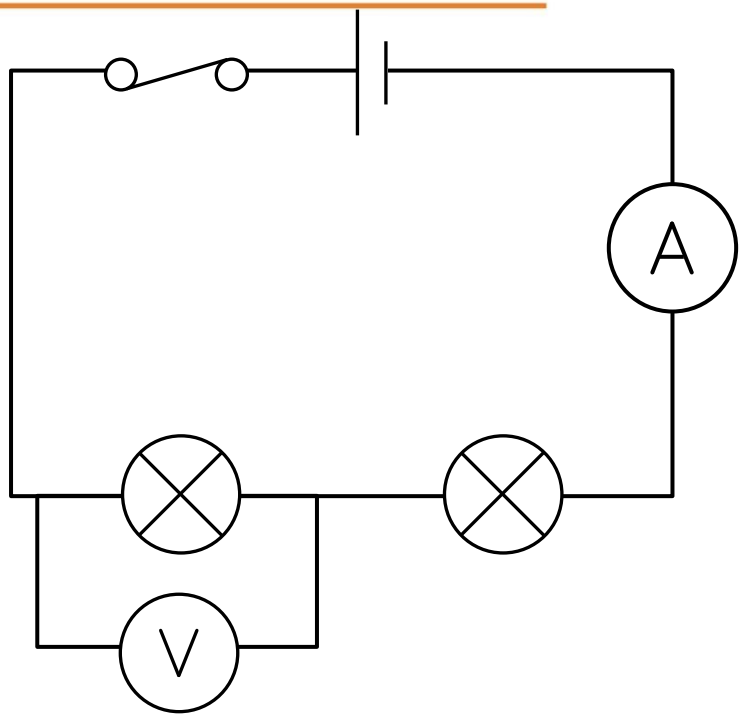


A **parallel** circuit consists of components that are **connected** on different branches of the circuit (wire). The current has **more paths** along which it can flow. The **more** branches the larger the current.

If one lamp break the other lamp will still stay on.

When a closed circuit includes a source of POTENTIAL DIFFERENCE there will be a CURRENT in the circuit

Measuring current and potential difference



Measuring current: **Electrical current** is measured in amperes usually shortened to **amps (A)** using an **ammeter**.

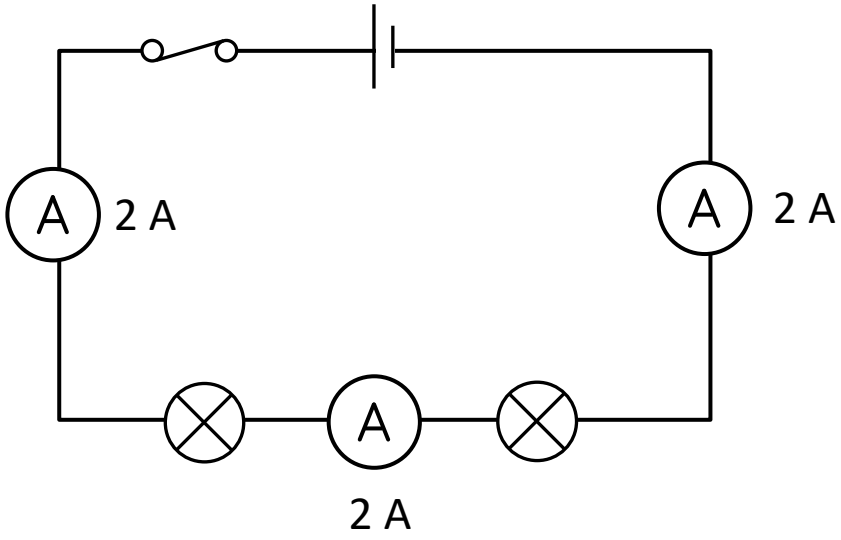
The ammeter is **always connected in series** with the **component** in the circuit to measure the current passing through it.

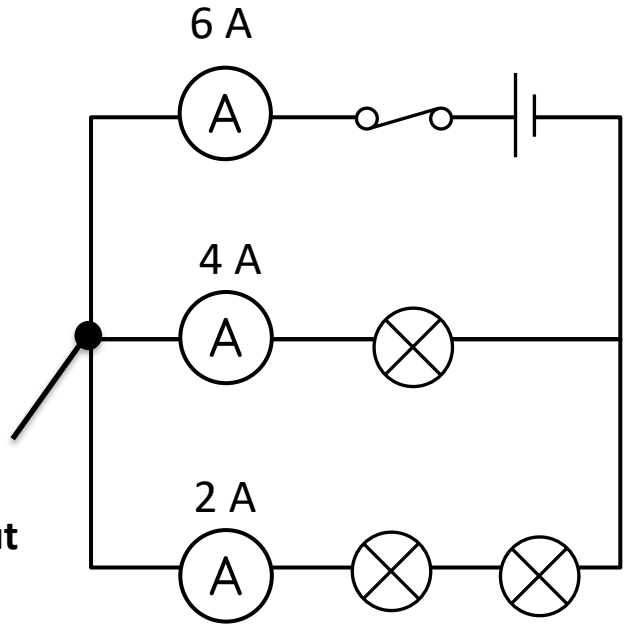
Measuring potential difference: **Potential difference** is measured in volts (V) using a **voltmeter**.

The **voltmeter** is always **connected** in **parallel** with the **component** in the circuit to measure the potential difference across it.

Note: Potential difference (voltage) is the energy transferred per unit charge passed and therefore a volt is a joule per coulomb.

Current in series and parallel circuits





At the junction:

current in = current out

6 A = 4 A + 2A

In a circuit the current stays the same, the current leaving the battery is the always **equal** to the current returning to the battery.

WE CAN SAY CURRENT IS CONSERVED.

- In a **SERIES CIRCUIT** the ammeter reading is the same in all parts on the circuit.
- In a **PARALLEL CIRCUIT** current splits at a junction and travels along the different branches. The current in the branches depend on the components on each branch. **The total amount of current entering the branch is always the same as the amount leaving the branch.**

Energy transferred

When charged particles move they form an **electric current**. Electric current is the **rate of flow of charge**. Charge is a property of a body (object) that experiences **a force in an electric field**.

Electric charge is measured in coulombs (C)

The amount of energy transferred by electrical work can be calculated using the equation:

energy transferred (J) = charge moved (C) x potential difference (V)

$$E = Q \times V$$

Using equations for energy transferred

Example:

The potential difference across a lamp is 2.5 V and 450 C of charged flowed through the lamp.

Calculate the how much energy is transferred.

Solution:

Equation: energy transferred = charge moved x potential difference

$$E = Q \times V$$

Substitution: E = 450 x 2.5

Click to reveal answer

Electrical charge and current

For electrical charge to flow through a closed circuit, the circuit must include a source of potential difference.

An electric current is the flow of electrical charge, usually electrons, around a circuit. The size of the electric current is the rate of flow of electrical charge. In a series circuit (one with a single loop of wire) the current is the same at any point of the loop.

Charge, current and time are linked by the equation:

$$\text{charge (C)} = \text{current (A)} \times \text{time (s)}$$

$$Q = I\,t$$

***Intensité** de courant*

***'I' symbol** used by*

André-Marie **Ampère**

Electrical charge and current

A current of 1.2 A flows through a wire for 5 minutes.

Work out the charge that has moved in the wire in the 5 minutes.

Solution:

Convert time into standard units: 5 minutes = 300 seconds

Equation: charge (C) = current (A) × time (s)

$$Q = I\,t$$

Substitution: Q = 1.2 x 300

Click to reveal answer

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QuestionIT!

Part 1

- Electric circuits
- Current charge and energy
- Current and potential difference

1. **Draw the circuit symbols for the following components…**
   a. A switch open and a switch closed
   b. A cell
   c. A battery
   d. A diode
   e. A resistor
   f. A variable resistor
   g. An LED (light emitting diode)
   h. A lamp
   i. A fuse
   j. A voltmeter
   k. An ammeter
   l. A thermistor
   m. An LDR (light dependent resistor)

2. Describe the difference between a series circuit and a parallel circuit.

3. What is an electric current?

4. Describe how the currents in a series circuit and a parallel circuit differ.

5.

a. Draw a circuit diagram with a bulb, a switch and a cell
b. Add two components to show how you would measure the current and potential difference.
c. Label the two components from part b.

6. State the equation that links charge flow, current and time.

7. Calculate the current in a circuit if a charge of 4 C flows in 20 seconds.

8. In a lightning bolt, a charge of 15 C flows and there is a current of 30,000 A.

   Calculate the duration of the lightning strike.

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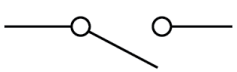
AnswerIT!

Part 1

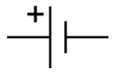
- **Electric circuits**
- **Current charge and energy**
- **Current and potential difference**

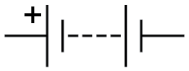
Part 1 – AnswerIT

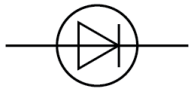
1. Draw the circuit symbols for the following components…

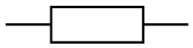
a.  switch (open)

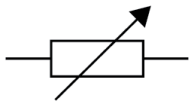
switch (closed)

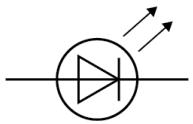
b.  cell

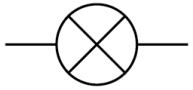
c.  battery

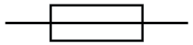
d.  diode

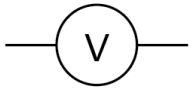
e.  resistor

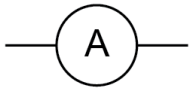
f.  variable resistor

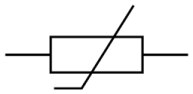
g.  LED

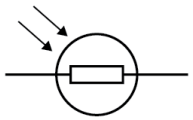
h.  lamp

i.  fuse

j.  voltmeter

k.  ammeter

l.  thermistor

m.  LDR

Part 1 – AnswerIT

2. Describe the difference between a series circuit and a parallel circuit.

- A series circuit contains only one loop of wire.
- A parallel circuit contains two or more loops (branches) of wire.

3. What is an electric current?

- An electric current is the flow of charge, usually electrons.

4. Describe how the currents in a series circuit and a parallel circuit differ.

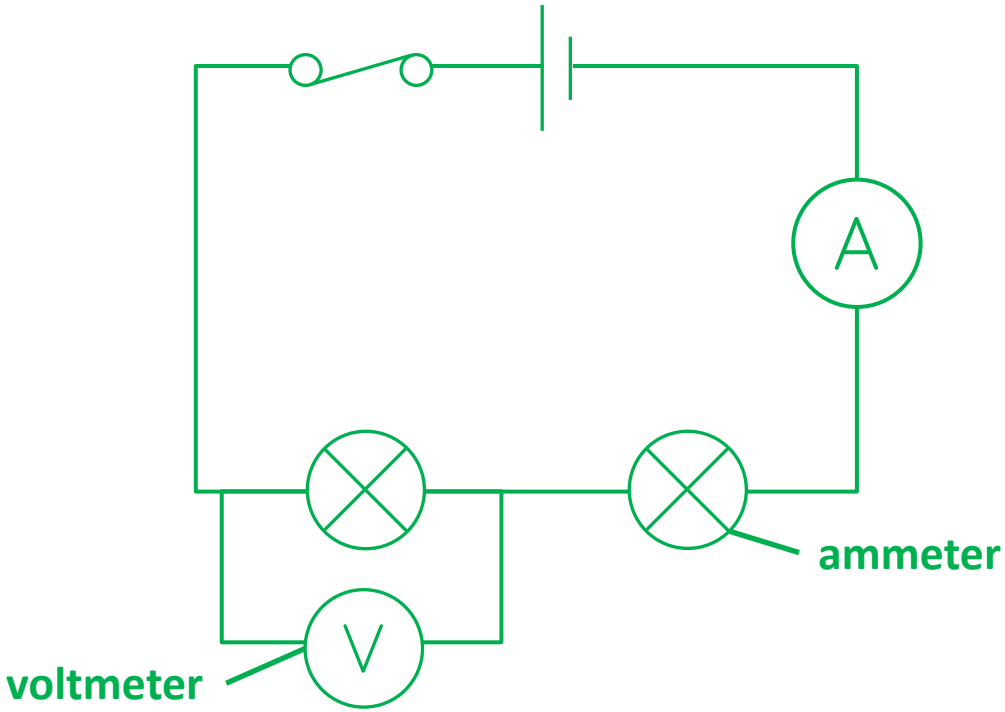
- Series circuit – same current at any point of the loop.
- Parallel circuit – the total current through the whole circuit is the sum of the currents in each loop.

5.

a. Draw a circuit diagram with a bulb, a switch and a cell

b. Add add two components to show how you would measure the current and potential difference.

c. Label the two components from part b.



6. State the equation that links charge flow, current and time.

$$Q = I\,t$$

7. Calculate the current in a circuit if a charge of 4 C flows in 20 seconds.

- $Q = I\,t$
- $I = Q / t$ or $I = 4 / 20$
- $I = 0.2$ A

8. In a lightning bolt, a charge of 15 C flows and there is a current of 30,000 A. Calculate the duration of the lightning strike.

- $t = Q / I$
- $t = 15 / 30\,000$
- $t = 0.0005$ s or 0.5 ms

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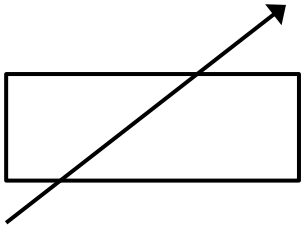
Part 2

- Resisitance
- Transferring energy
- Electrical safety

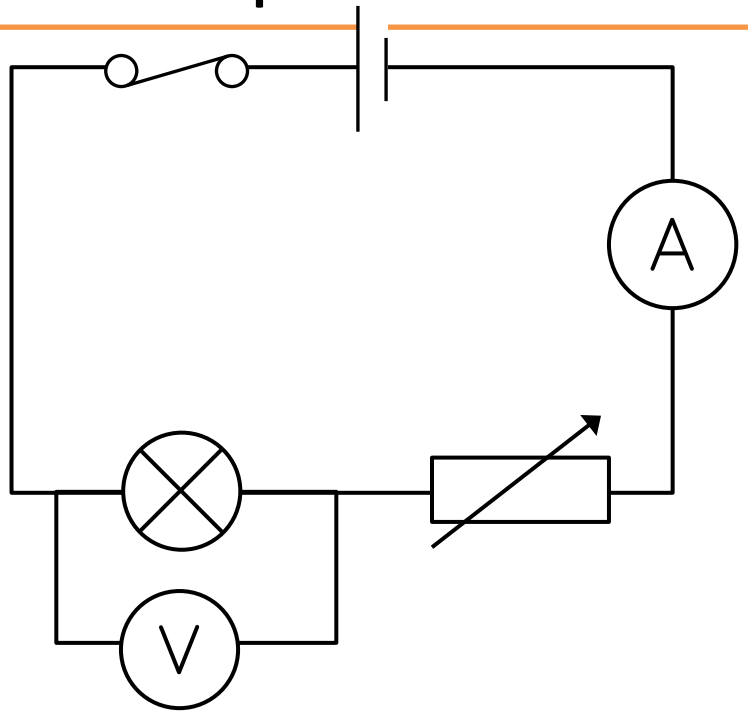
Current, Resistance and Potential Difference

- The current (*I*) through a component depends on both the resistance (*R*) of the component and the potential difference (*V*) across the component.
- The electrical resistance of an electrical conductor is a measure of the difficulty to pass a current through the conductor.
- The greater the resistance of the component, the smaller the current for a given potential difference *(V)* across the component.

connector



A **variable resistor** is a component where the resisitance changes as you slide the connector along it. It can be used to investigate how the resisitance of the lamp changes as you change the resisitance.



Current, resistance and potential difference

Current, potential difference or resistance can be calculated using the equation:

potential difference = current × resistance

$$V = I R$$

Name	Equation symbol	Unit	Unit Symbol
Potential difference	V	Volts	V
Current	I	Amp	A
Resisitance	R	Ohms	Ω

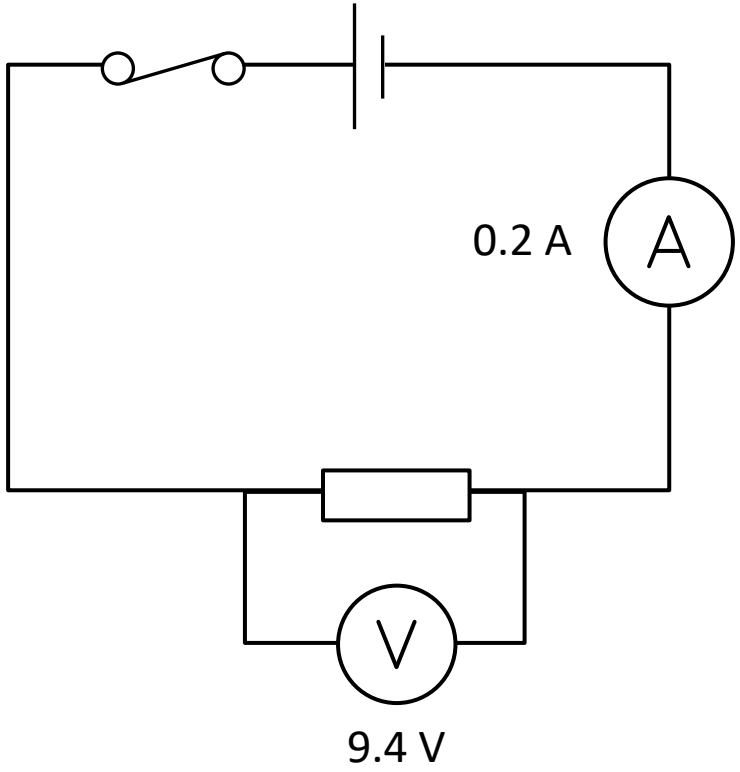
The resistance in a circuit will depend on the components used in the circuit as well as the length of wire used in the circuit. The longer the wire, the greater the resistance.

Current, Resistance and Potential Difference

Example

A resistor is placed into the circuit shown. The meter readings are shown next to each meter.

Work out the resistance.



Solution

State the equation: $V = I \times R$

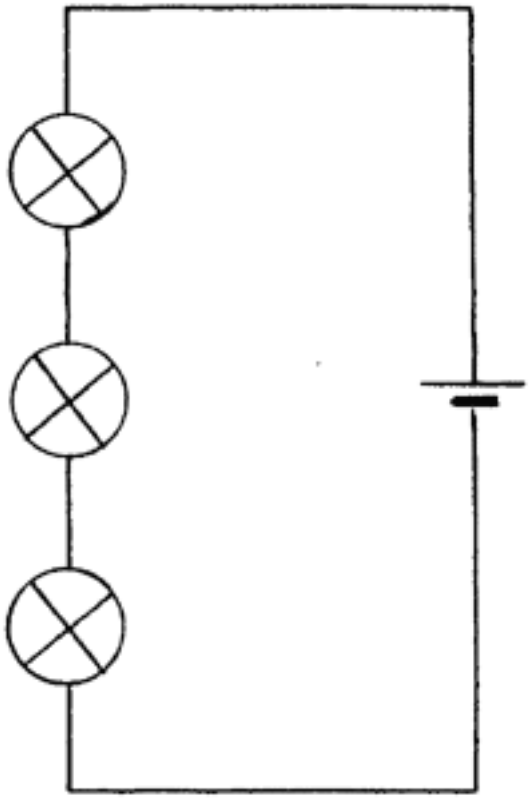
Rearrange: $R = V / I$

Substitution: $R = 9.4 / 0.2$

Answer: Click to reveal answer

Series Circuits

Series circuits consist of one loop of wire.



For components connected in series:

- **there is the same current through each component**
- **the total potential difference of the power supply is shared between the components**
- **the total resistance of two components is the sum of the resistance of each component.**

$$R_{total} = R_1 + R_2$$

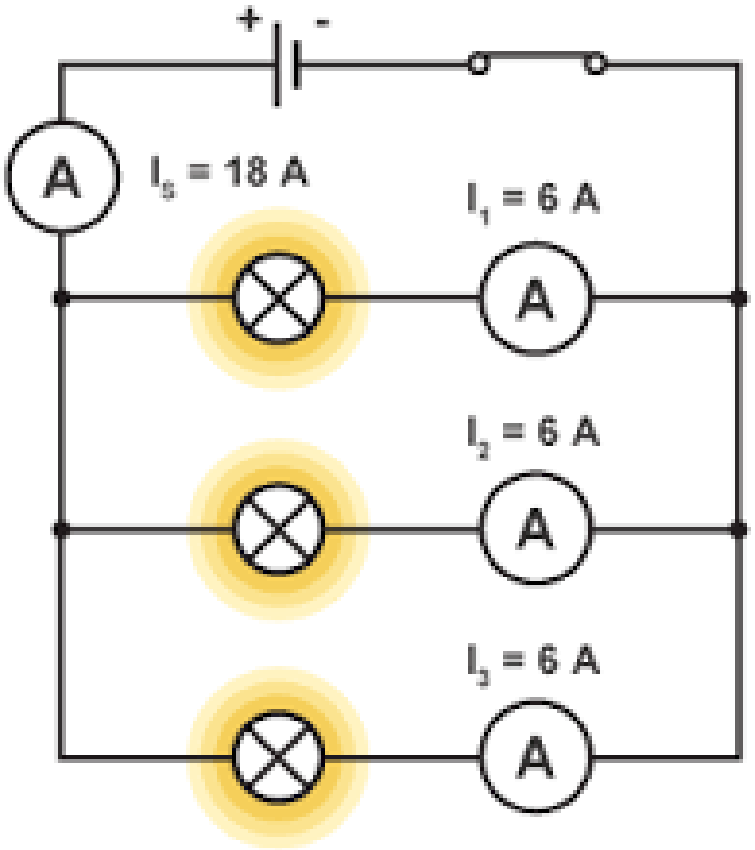
resistance, *R*, in ohms, Ω

Parallel Circuits

Parallel Circuits consist of two or more loops (branches) of wire.

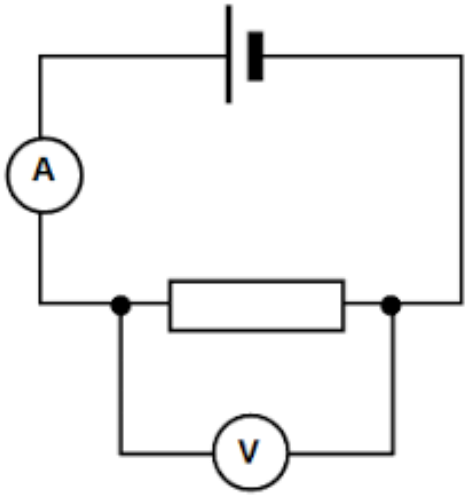
For components connected in parallel:

- **the potential difference across each component is the same**
- **the total current through the whole circuit is the sum of the currents through the separate components on each loop (branch)**
- **the total resistance of two resistors is less than the resistance of the smallest individual resistor.**



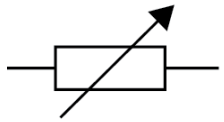
Measuring Resisitance:

To measure the resistance of an electrical component the following circuit needs to be set up…



By measuring the current, using the ammeter, and the potential difference, using a voltmeter, the resistance can be found from…

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



The electrical component tested can be changed from the resistor shown to any other electrical component.

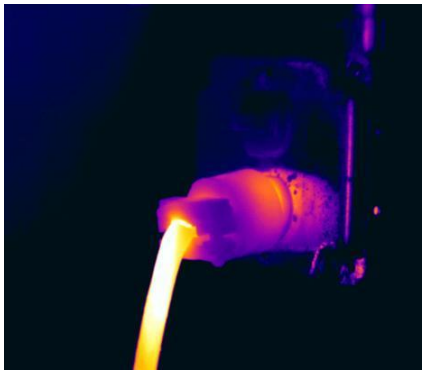
To get a range of potential differences and currents a variable resistor can be added into the circuit or the input potential difference changed.

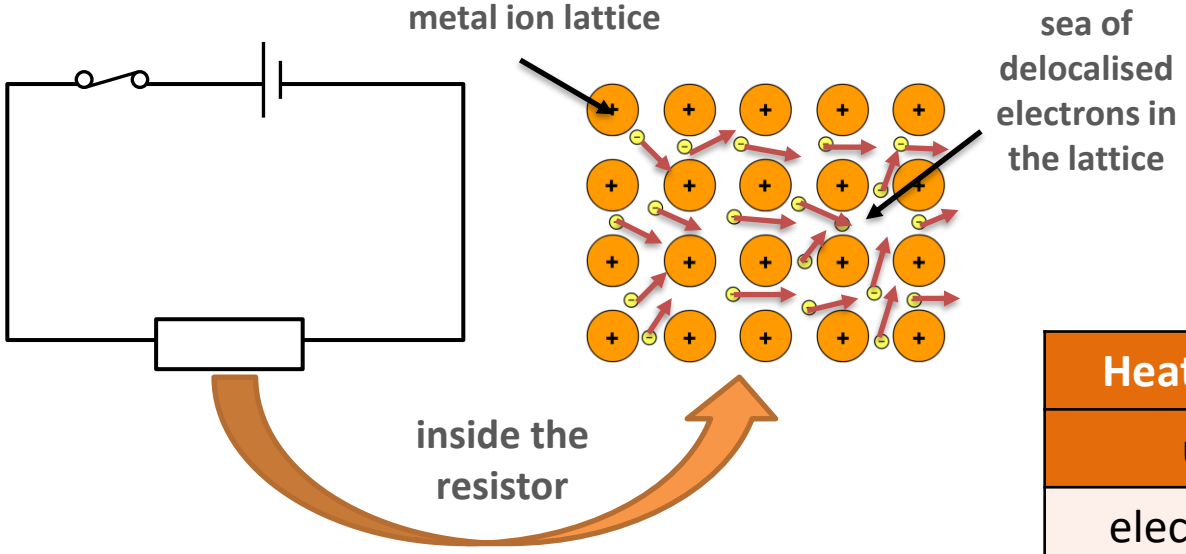
Name	Equation symbol	Unit	Unit Symbol
Potential difference	V	Volts	V
Current	I	Amp	A
Resisitance	R	Ohms	Ω

Transferring energy

Electrical energy is spread out or **dissipated** as **thermal energy** to the surroundings when an electrical current **does work** against electrical resistance. All electrical circuits have **some resistance** this is because when electrical energy is passed through a resistor it does **work** against it.

Below is an infra red thermal image it shows how a plug heats up when current passes through it.





The **energy transfer** is a result of **collisions** between the **free moving electrons** and the **metal ions** in the lattice when a current is applied. **Energy transfers** in circuits can be **reduced** by using **low resisitance wires.**

Heating effect of electrical current	
useful	**not useful**
electric ovens	computers
electric kettles	televisions
hairdryers	chargers
electric fires	plugs

Energy transferred

The amount of energy transferred can be calculated using the equation:

energy transferred = current × potential difference × time

$$E = I \times V \times t$$

Name	Equation symbol	Unit	Unit Symbol
energy transferred	E	Joules	J
current	I	Amps	A
potential difference	V	Volts	V
time	t	seconds	s

Energy transferred

Example:
A 6V battery supplies a current of 0.5 A to a lamp for 3 minutes

Work out the energy transferred to the lamp.

Solution:

Convert time into standard units: **3 minutes = 180 seconds**

Equation:

energy transferred = current × potential difference × time

$$E = I \times V \times t$$

Substitution: **E = 0.5 x 6 x 180**

Click to reveal answer

Energy transferred

Energy transferred by an electrical circuit depends upon the time taken.

Power is the energy transferred by electrical devices per second and it is measured in watts(W), 1W is a transfer 1 joule per second.

Electrical power can be calculated using the equation:

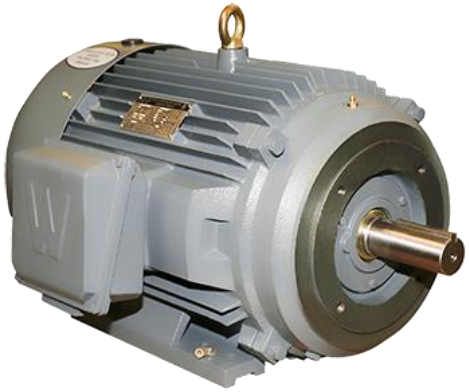
$$\text{power} = \frac{\text{energy transferred}}{\text{time taken}}$$

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

Name	Equation symbol	Unit	Unit Symbol
Energy transferred	E	Joules	J
Power	P	Watts	W
Time	t	Seconds	s

Energy Transfers in Everyday Appliances

Example:
An electric motor transfers 600 kJ of energy in 2 minutes.



Work out the power rating of the electric motor.

Solution:

Conversion into standard units: E = 600 kJ x1000 = 600 000 J
t = 2 minutes = 120 s

State the equation: $P = \frac{E}{t}$

Substitution: P= 600 000/120

Click to reveal answer

Electrical power

Power: When electrical appliances are connected into a circuit **energy** is transferred to the appliance. The rate at which energy is transferred to the appliance is the **power** rating of the appliance.

To calculate the power of an electrical component:

electrical power (W)= potential difference (V) x current (A)

$$P = V I$$

An alternative equation for calculating power is:

power = current squared x resistance

$$P = I^2 R$$

Name	Equation symbol	Unit	Unit Symbol
power	P	watts	W
potential difference	V	volts	V
current	I	amp	A
resisitance	R	ohms	Ω

Electrical power

Example:

A microwave oven is powered by mains electricity at 230 V. The microwave oven has a power rating of 800 W.

Calculate the current flowing in the microwave oven.

Solution:

State the equation: $P = VI$

Rearrange: $I = P / V$

Substitution: $I = 800 / 230$

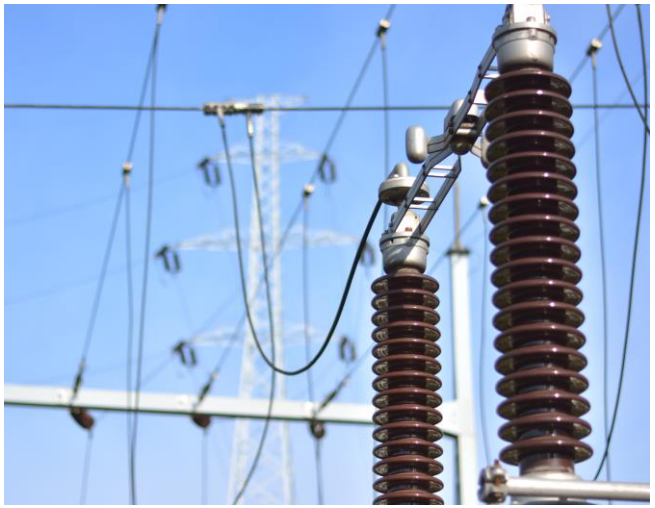
Click to reveal answer

Electrical power

Example:

An overhead powerline is 100 miles long and carries a current of 400 A. The powerline has a resistance of 27.5 Ω.

Calculate the power loss in the 100 mile length of powerline.



Solution:

State the equation: $P = (I)^2 \times R$

Substitution: $P = (400)^2 \times 27.5$

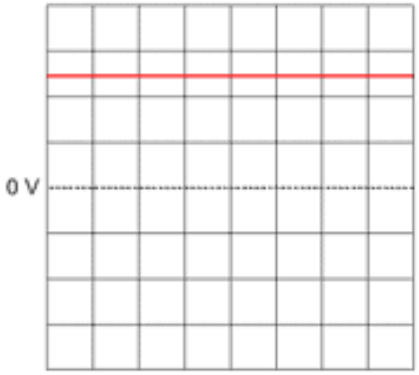
Click to reveal answer

Therefore the power loss in the overhead powerline is: 4.4 MW per 100 miles of cable.

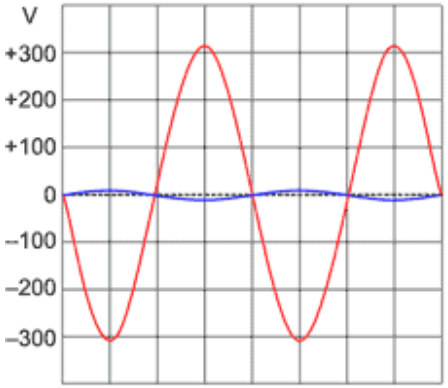
Direct and alternating potential difference

A direct potential difference will produce a direct current (dc) (a current in which the charge carriers move in one direction only). Batteries are dc.

An alternating potential difference will produce an alternating current (ac) (a current in which the charge carriers move backwards and forwards).
Mains electricity is ac.



A direct pd does not go below 0 V

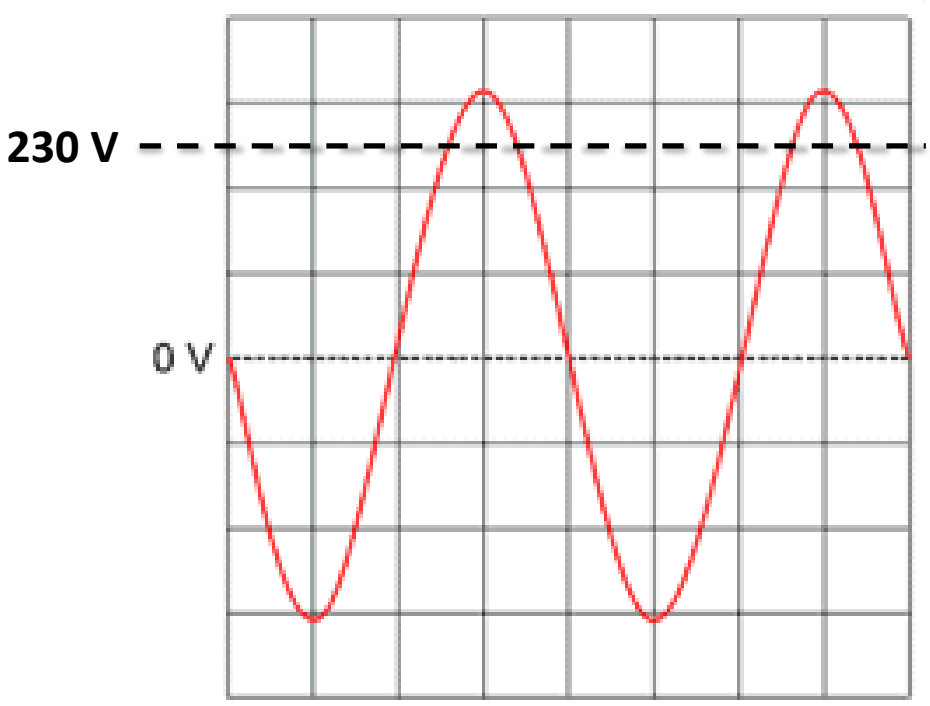


An alternating pd goes below 0 V

In different domestic devices, energy is transferred from batteries and the a.c. mains to the energy of motors and heating devices

Mains electricity supply

In the UK, mains electricity is supplied at approximately 230 V, 50 Hz ac.

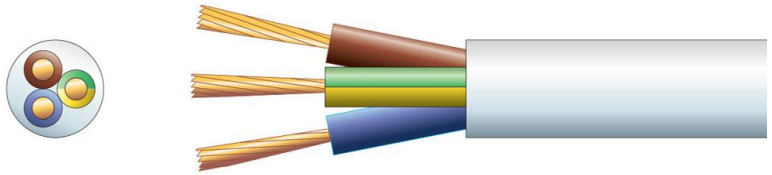


- **The mains supply does change slightly, which is why your lights at home may get a bit brighter or dimmer at various times.**

- **Lights usually dim when a commercial starts on TV during a big show, as lots of people get up to put the kettle on and so demand increases.**

Wiring in the home

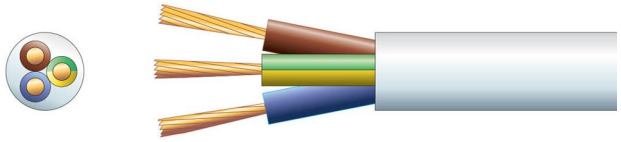
Most electrical appliances are connected to the mains using three-core electrical cable.



Name	Colour	Function
live	brown	Carries alternating potential difference from the supply.
neutral	blue	Completes the circuit.
earth	yellow/green	Safety wire to stop appliance becoming live.

Wiring in the home… continued

- The potential difference between the live wire and earth (0 V) is about 230 V.
- The neutral wire is at, or close to, earth potential (0 V).
- The earth wire is at 0 V,
- The earth wire only carries a current if there is a fault.



The live wire may be dangerous when a switch in the mains circuit is open as a person could complete the circuit to ground (0 V) themselves and therefore get electrocuted as the current will flow through them.

Any connection between the live wire and earth can cause a current to flow. This can potentially cause:

- electrical fires, if the current is too high
- or electrocution, if a person is making the connection.

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QuestionIT!

Part 2

- Resisitance
- Transferring energy
- Electrical safety

Part 2 - QuestionIT

1. What is electrical resisitance?

2. In a circuit if you keep the potential difference the same what will happen to the current as you increase the resistance?

3. Write the equation that links, potential difference, current and resisitance.

4. A current of 0.05A flows through an electrical device with a resisitance of 240 Ω. Calculate the potential difference.

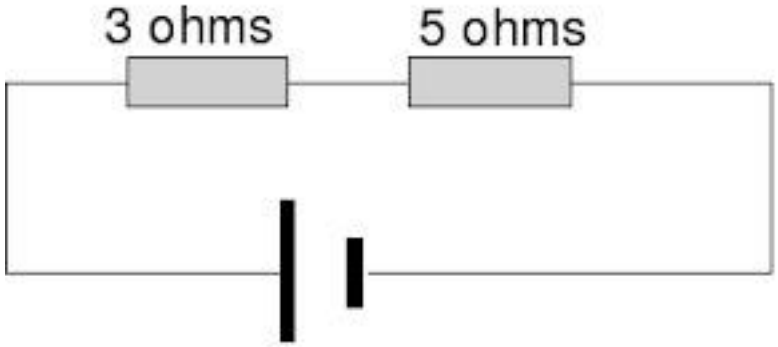
5. A lamp has current of 1.2 A flowing through it and a potential difference of 72 V electrical device with a resisitance of 240 Ω. Calculate the potential difference.

Part 2 - QuestionIT

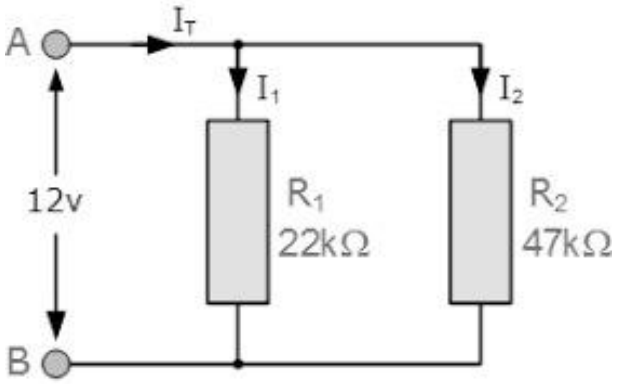
11. Describe how the currents in a series circuit and a parallel circuit differ.

12. Draw a fully labelled series circuit that contains a switch, a battery and two lamps.

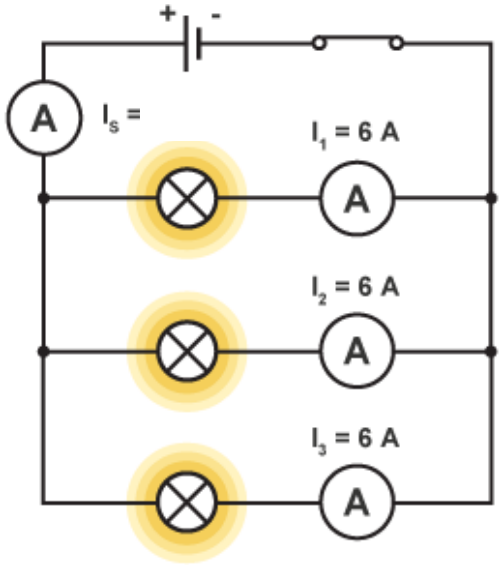
13. Calculate the resistance of the resistors in series shown in the diagram below.



14. Two resistors are placed in parallel as shown in the diagram below.
Why will the maximum resistance of the circuit be less than 22 kΩ?



15a) What is the current in the main branch (I_s) of the circuit shown?



15b) The cell in the circuit above supplies a potential difference of 9 V to the circuit.
What is the potential difference across each lamp? Explain your answer.

Part 2 - QuestionIT

16. Describe three ways that electrical appliances can transfer electrical energy.

17. Why do electrical devises heat up when they are switched on?

18. Write the equation that links energy transfer, time, current and potential difference.

19. A 12 V battery supplies a current of 1.2 A to a lamp for 130 seconds.
    Calculate the energy transferred.

20. State the equation that links power, energy transferred and time. Include equation symbols and units.

21. State the equation that links power, potential difference and current. Include equation symbols and units.

22. State the equation that links power, current and resistance. Include equation symbols and units.

Part 2 - QuestionIT

23. What does a.c stand for?

24. What does d.c stand for?

25. Give an example of where a.c is used.

26. Give an example of where d.c is used.

27. Describe the difference between an alternating potential difference and direct potential difference. You may draw a sketch graph to help answer the question.

28. What is the frequency and potential difference of mains electricity in the U.K?

29. Copy and complete the table below for the wire in three core electrical cable.

Name	Colour	Function
Live		
Neutral		
Earth		

30. Explain why a live wire may be dangerous even when a switch in the mains circuit is open.

AnswerIT!

Part 2

- Resisitance
- Transferring energy
- Electrical safety

Part 2 - AnswerIT

1. What is electrical resisitance?

- How difficult it is for current to pass through an electrical conductor

2. In a circuit if you keep the potential difference the same what will happen to the current as you increase the resistance?

- The current will decrease

3. Write the equation that links, potential difference, current and resisitance.

- potential difference = current × resistance
- $V = I R$

4. A current of 0.05A flows through an electrical device with a resisitance of 240 Ω. Calculate the potential difference.

- $V = I R$
- $V = 0.05 \times 240$
- $V = 12$ V

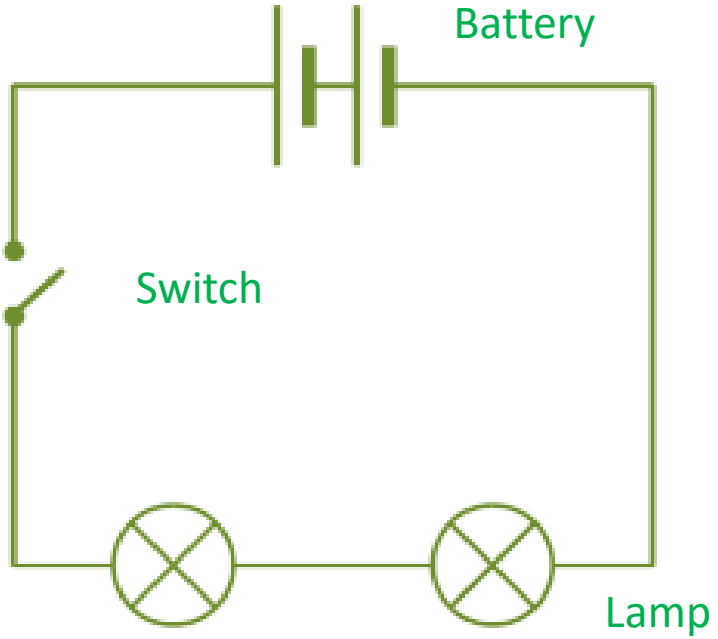
5. A lamp has current of 1.2 A flowing through it and a potential difference of 72 V electrical device with a resisitance of 240 Ω. Calculate the potential difference.

- $V = I R$
- $R = V/I$
- $R = 72/1.2$
- R = 60 Ω

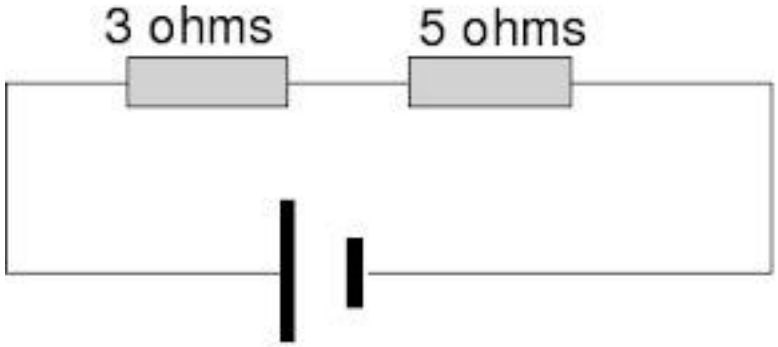
11. Describe how the currents in a series circuit and a parallel circuit differ.

- Series circuit – same current at any point of the loop.
- Parallel circuit – the total current through the whole circuit is the sum of the currents in each loop.

12. Draw a fully labelled series circuit that contains a switch, a battery and two lamps.

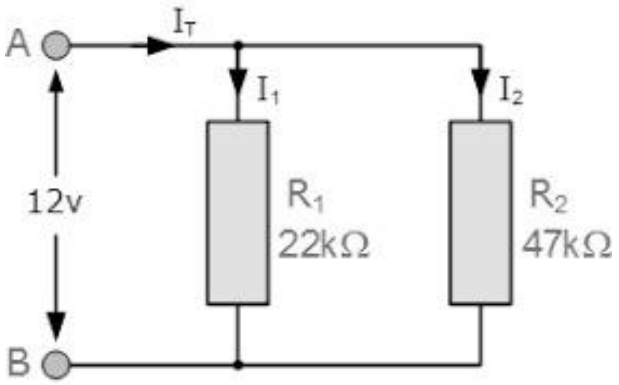


13. Calculate the resistance of the resistors in series shown in the diagram below.



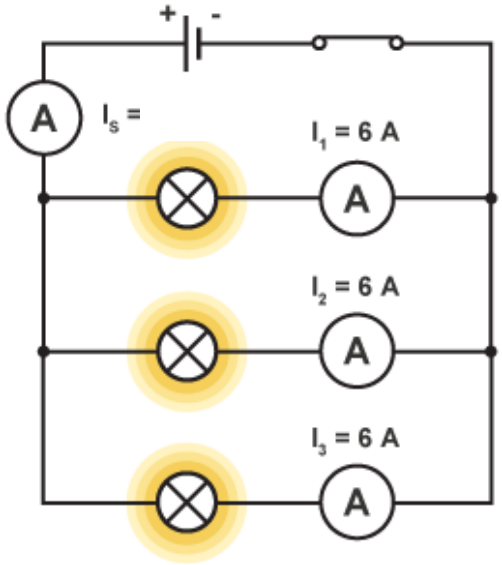
- $R_{total} = R_1 + R_2$
- 8 Ω

14. Two resistors are placed in parallel as shown in the diagram below.
Why will the maximum resistance of the circuit be less than 22 kΩ?



- It will be ***less than*** 22 kΩ because the total resistance of two resistors in parallel is less than the resistance of the smallest individual resistor.
- The smallest individual resistor is 22 kΩ.

15a) What is the current in the main branch (I_s) of the circuit shown?



- 18 A
- As 6 + 6 + 6 = 18

15b) The cell in the circuit above supplies a potential difference of 9 V to the circuit.
What is the potential difference across each lamp? Explain your answer.

- 9 V
- As the potential difference across each lamp is the same in a parallel circuit.

16. Describe three ways that electrical appliances can transfer electrical energy.

- motors converting electrical energy into kinetic energy
- lightbulbs converting electrical energy into light energy
- electric heaters converting electrical energy into heat energy.

Allow any other sensible ideas

17. Why do electrical devises heat up when they are switched on?

- They heat up as a result of collisions between the free moving electrons and the metal ions in the lattice when a current is applied

18. Write the equation that links energy transfer, time, current and potential difference.

- energy transferred = current × potential difference × time
- $E = I \times V \times t$

19. A 12 V battery supplies a current of 1.2 A to a lamp for 130 seconds. Calculate the energy transferred.

- $E = I \times V \times t$
- $E = 1.2 \times 12 \times 130$
- 1872 J

20. State the equation that links power, energy transferred and time. Include equation symbols and units.

- power = $\frac{\text{energy transferred}}{\text{time taken}}$ $P = \frac{E}{t}$

21. State the equation that links power, potential difference and current. Include equation symbols and units.

- power = potential difference x current
- P = V I

22. State the equation that links power, current and resistance. Include equation symbols and units.

- power = (current)^2 x resistance
- P = I^2 R

Name	Unit	Unit Symbol
Energy transferred	joules	J
time	seconds	s
power	watts	W
potential difference	volts	V
current	amp	A
resisitance	ohms	Ω

23. What does a.c stand for?

Alternating current

24. What does d.c stand for?

Direct current

25. Give an example of where a.c is used.

Mains electricity

26. Give an example of where d.c is used.

Batteries

27. Describe the difference between an alternating potential difference and direct potential difference. You may draw a sketch graph to help answer the question.

- An alternating potential difference will go from positive to negative repeatedly
- Producing an alternating current in a circuit.
- A direct potential difference will stay either positive or negative, but not change sign
- Producing a direct current in a circuit.

Part 2 - AnswerIT

28. What is the frequency and potential difference of mains electricity in the U.K?

Frequency 50Hz

Potential difference 230V

29. Copy and complete the table below for the wire in three core electrical cable.

Name	Colour	Function
Live	Brown	Carries alternating potential difference from the supply.
Neutral	Blue	Completes the circuit.
Earth	Yellow/Green	Safety wire to stop appliance becoming live.

30. Explain why a live wire may be dangerous even when a switch in the mains circuit is open.

A person could complete the circuit to ground getting electrocuted.