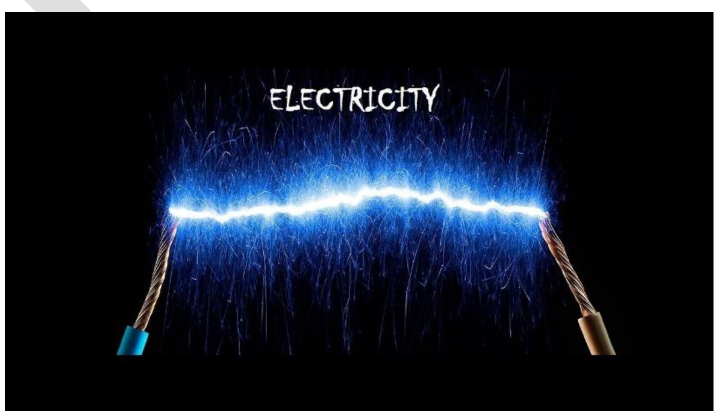
Edexcel IGCSE

Physics

CODE: (0625)

Unit 2

Electricity



2.1 Main electricity

Circuits in a home are connected by underground cables, meter, and fuse box, providing electricity to various appliances and safety devices.

Plugs and sockets in different countries look different, but the principles (rules) of electrical wiring are similar.

This is a much higher **voltage** than the **cells** and batteries used in mobile electrical appliances.

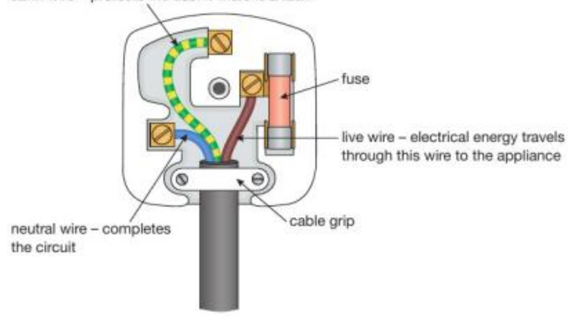


Figure 6.5 A labelled plug

If you come into direct contact with mains electricity you could receive a severe electric shock, which might even be fatal. To prevent this the outer part of a plug, called the casing, is made from plastic, which is a good **insulator.**

Connections to the circuits are made via three brass pins, as the metal brass is an excellent **conductor** of electricity.

Figure 6.5 shows the inside of a 3-pin plug used in the UK, but similar principles apply to all kinds of plug all over the world.

Safety devices

Fuses

A **fuse** is a metal wire used in plugs to prevent shocks and electrical fires. Common sizes include 3 A, 5 A, and 13 A.

Earth wires and double insultation

The metal casing of many appliances should be connected to the earth wire to prevent damage to the live wire, which can blow the fuse and turn off the circuit, causing severe electric shock.

Modern appliances with double insulation use plastic casings, insulating electrical parts. Two-wire **flex** eliminates earth wire requirement, ensuring user-untouchable appliances.

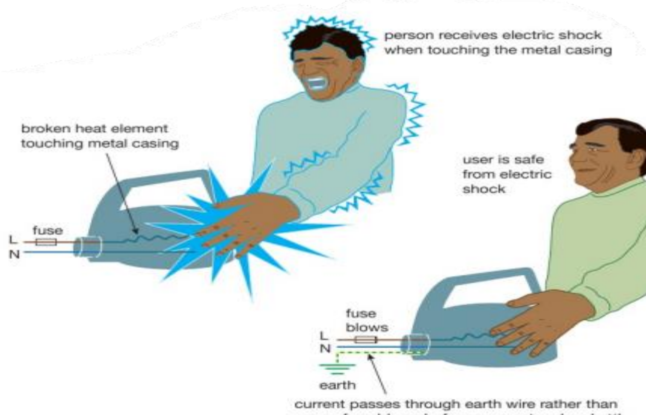
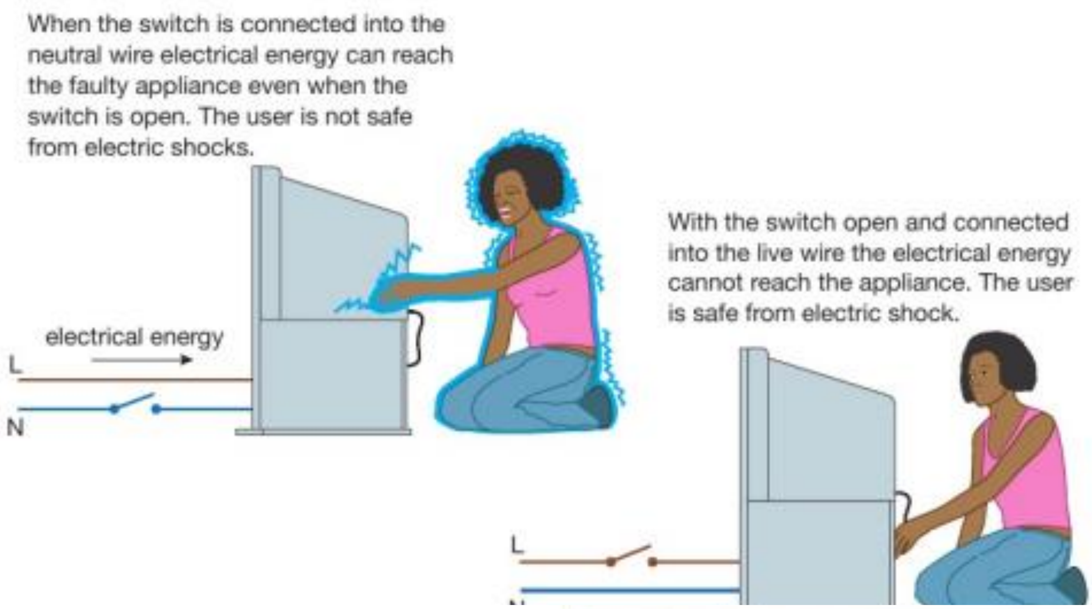


Figure 6.7 The earth wire provides protection when electrical appliances develop a fault.


Figure 6.8 This plastic kettle has double insulation which means that there is no need for an earth wire.

Switches

Switches in mains circuits should be placed in the live wire to prevent electrical energy from reaching an appliance, as placing them in the neutral wire could cause an electric shock.



▲ Figure 6.9 The switch in a circuit shc

The heating effect of current

The wiring in a house is designed to let current pass through it easily. As a result, the wires do not become warm when appliances are being used. We say that the wires have a low **resistance.**

▲ Figure 6.11 It is the heating effect of a current that is causing this bulb to glow.

we want wires (more usually called **heating elements**) to become warm.

When current passes through the very thin wire **(filament)** of a traditional light bulb it becomes very hot and **glows** (shines) white. The bulb is transferring electrical energy to heat and light energy.

Electrical power

Halogen light bulbs, ranging from 50W to 70W, transfer electrical energy to heat and light, with the 70W bulb being brighter due to its higher power rating.

Calculating the total energy transferred by an appliance.

The power of an appliance (P) tells you how much energy it transfers each second. This means that the total energy (E) transferred by an appliance is equal to its power multiplied by the length of time (in seconds) the appliance is being used.

Alternative current and direct current

The voltage from the mains is a wave-like current, generating electricity at the power station. This voltage is called **alternating current (a.c.),** unlike direct current (d.c.) from batteries and cells. The voltage from the mains is different from direct current (d.c.), which is always in the same direction and has the same value. Figure 6.14 illustrates the difference between the two.

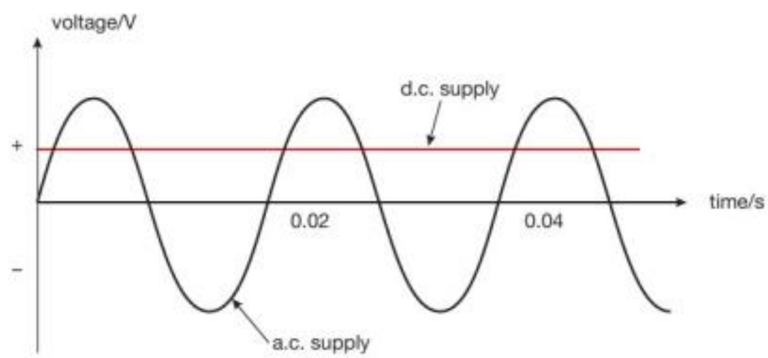


Figure 6.14 How the voltage of an a.c. supply compares with that of a d.c. supply

2.2 Current and voltage in circuits

Conductors, insulators, and electric current

In metals, some electrons are free to move between the **atoms.** Under normal circumstances this movement is random - that is, the number of electrons flowing in any one direction is roughly equal to the number flowing in the opposite direction. There is therefore no overall flow of charge.

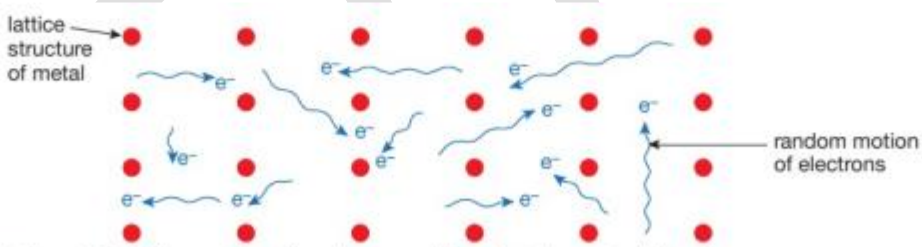


Figure 7.2a With no voltage there is an equal flow of electrons in all directions.

If, however, a cell or battery is connected across the conductor, more of the electrons now flow in the direction away from the negative terminal and towards the positive terminal than in the opposite direction. We say, 'there is now a net flow of charge'. This flow of charge is what we call an electric current.

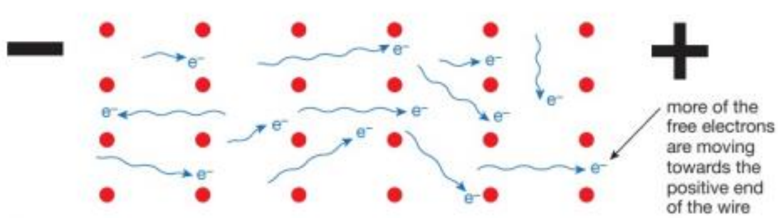


Figure 7.2b When a voltage is applied more electrons will move towards the positive.

Measuring current

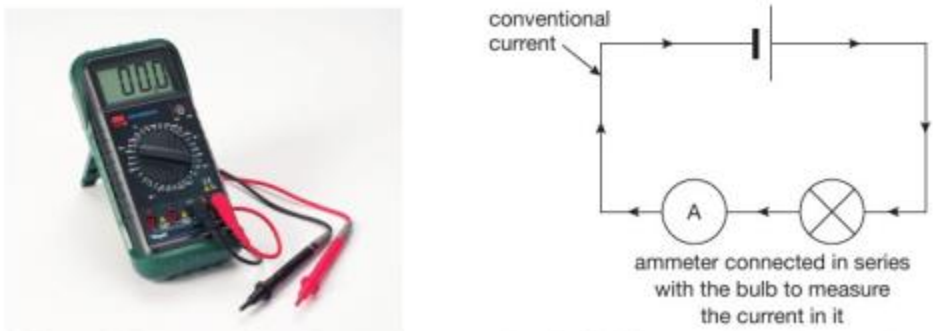


Figure 7.3 An ammeter is used to measure current in a circuit. It has a very low resistance and so has almost no effect on the current.

An ammeter measures the size of a circuit's current, which indicates the rate at which charge flows. Electric charge (Q) is measured in coulombs (C), which are larger units than mm. Amperes or amps (A) are used to measure electric current, with 1 A in a wire indicating 1 C of charge passing through the wire each second.

1 C/s = 1 A

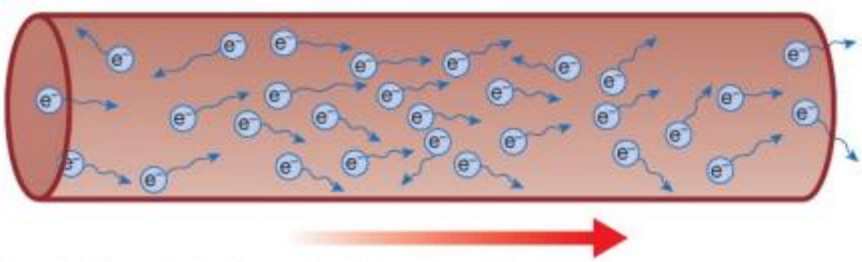


Figure 7.4 One coulomb of charge flowing each second is one amp.

Voltage

Cells or batteries act as electron pumps, transferring energy to charges. The amount of energy given is measured in volts (V). For example, a 1.5 V cell gives 1.5 J of energy to each coulomb of charge passing through it. Two 1.5 V cells pump in the same direction.

Figure 7.6 When one coulomb of charge passes through this cell it gains 1.5 J of energy.

Figure 7.7 When one coulomb of charge passes through both these cells in turn it gains 3 J of energy.

We can describe the relationship between the energy transferred, charge and voltage using the equation:

energy transferred, E (joules) = charge, Q (coulombs) x voltage, V (volts)
$E = Q \times V$

Measuring voltages

A voltmeter measures voltages across a component, measuring the energy given to each coulomb of charge passing through it. It is connected in parallel to the component being investigated, ensuring accurate measurement.

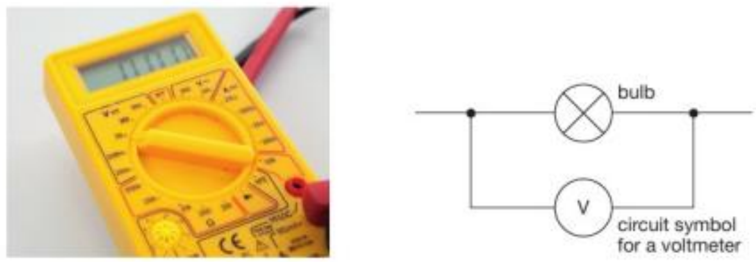


Figure 7.8 A voltmeter measures voltages across a component

Electrical circuit

When the button on the torch shown in Figure 7.9 is pressed, the circuit is complete - that is, there are no gaps. Charges can flow around the circuit and the torch bulb glows. When the button is released, the circuit becomes incomplete. Charges cease to flow, and the bulb goes out.

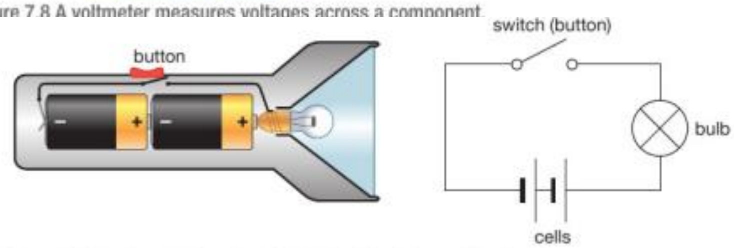


Figure 7.9 A torch contains a simple electrical circuit – a series circuit.

KEY POINT

Drawing diagrams of the actual components in a circuit is a very time-consuming and skilful task. It is much easier to use symbols for each of the components. Diagrams drawn in this way are called circuit diagrams. Figure 7.10 shows common circuit components and their symbols. You should know the common symbols but the less common ones will be given to you in the exam if you need them. Do not waste time memorising the less common ones.

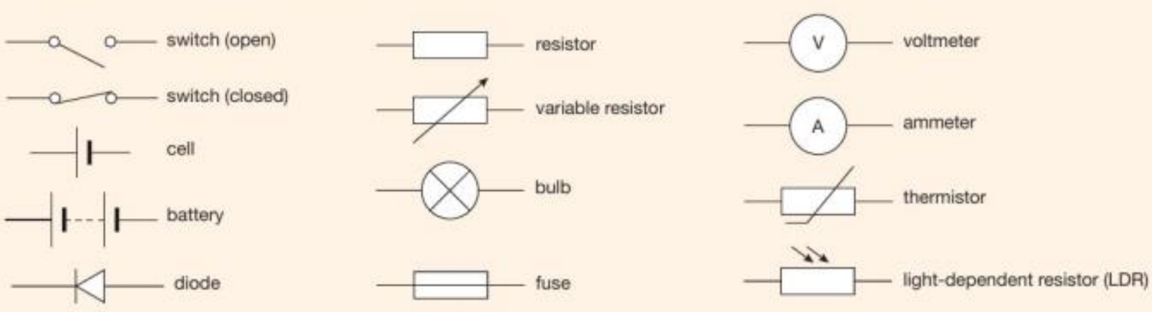


Figure 7.10 Circuit symbols

Series and parallel circuit

There are two main types of electrical circuit. There are those circuits where there are no branches or junctions and there is only one path the current can follow. These simple 'single loop' circuits are called **series circuits**.

Circuits that have branches or junctions and more than one path that the current can follow are called **parallel circuits.**

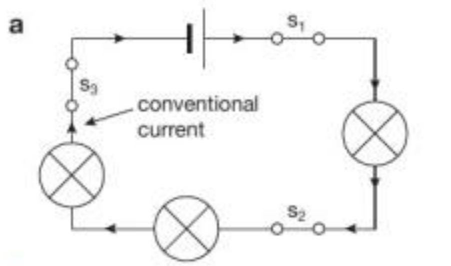


Figure 7.12a A typical series circuit. Opening any one of these switches will turn all three bulbs off.

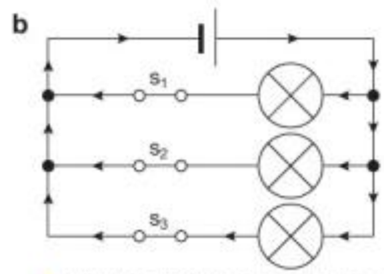


Figure 7.12b A typical parallel circuit. Opening any one of these switches will turn off just the bulb in that part of the circuit.

Series circuits and parallel circuits behave differently. This makes them useful in different situations.
In a series circuit containing bulbs:

■One switch placed anywhere in the circuit can turn all the bulbs on and off.
■If any one of the bulbs breaks, it causes a gap in the circuit and all the other bulbs will 'stop working'.
■The energy supplied by the cell is 'shared' between all the bulbs, so the more bulbs you add to a series circuit the less bright they all become.

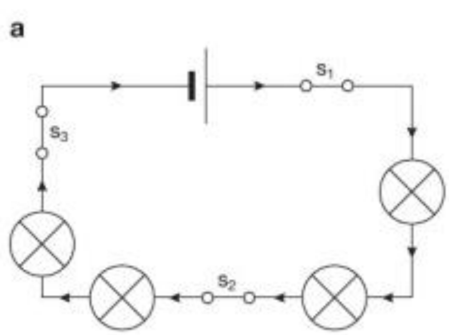


Figure 7.13a Adding an extra bulb in series will result in the bulbs shining less brightly.

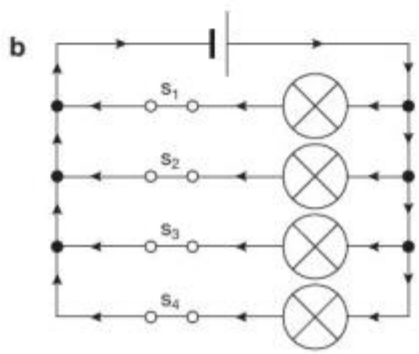


Figure 7.13b Adding an extra bulb in parallel does not affect the brightness of the other bulbs.

In a parallel circuit containing bulbs:

■Switches can be placed in different parts of the circuit to switch each bulb on and off individually, or all together.
■If one bulb breaks, only the bulbs on the same branch of the circuit will be affected.
■Each branch of the circuit receives the same voltage, so if more bulbs are added to a circuit in parallel they all keep the same brightness.

Current in a serious circuit

The size of the current in a series circuit depends on the voltage supplied to it, and the number and type of the other components in the circuit. If a second identical cell is added in series the voltage will double and so the current will also double.

In a serious circuit the current is the same in all parts; current is not used up.

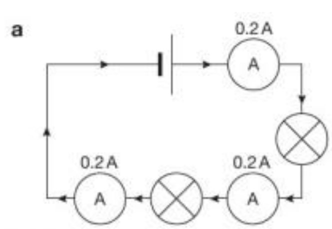


Figure 7.15a In a series circuit the current does not vary.

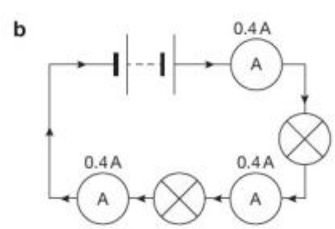


Figure 7.15b The addition of a second cell doubles the voltage applied to the circuit so the current will also double.

Current in a parallel circuit

In a parallel circuit, currents vary in different parts due to component types. The number of electrons entering and leaving a junction must always equal, as shown in Figure 7.16, where 0.6 A enters and 0.4 A leaves.

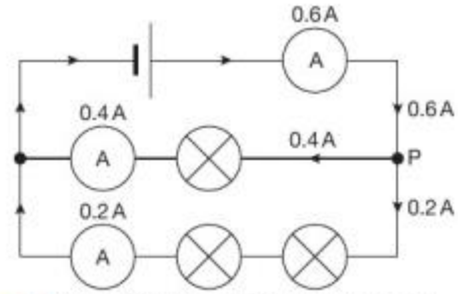


Figure 7.16 There are different currents in the different parts of a parallel circuit.

2.3 Electrical resistance

Resistance

Circuit components resist charge flow, with low resistance (connecting wires) allowing charges to pass easily, and high resistance (heat-transferring components). Resistance is measured by comparing current size and voltage applied across components, ensuring efficient charge transfer.

We measure the resistance (R) of a component by comparing the size of the current (/) in that component and the voltage (V) applied across its ends. Voltage, current and resistance are related as follows:

voltage, V (volts) = current, / (amps) x resistance, R (ohms)
V=IX R
We measure resistance in units called ohms (Ω).

Experiment to investigate how current varies with voltage for different components.

1. Set up the circuit shown in Figure 8.4.

2. Turn the variable resistor to its maximum value.

3. Close the switch and take the readings from the ammeter and the voltmeter.

4. Alter the value of the variable resistor again and take a new pair of readings from the meters.

5. Repeat the whole process at least six times.

6. Place the results in a table (see the table below) and draw a graph of current () against voltage (V).

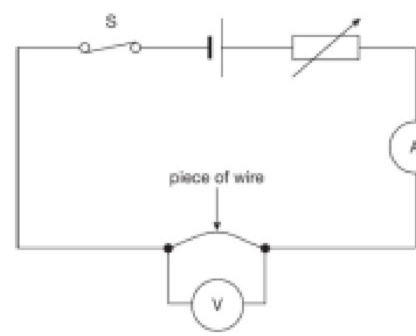


Figure 8.4 This circuit can be used to investigate the relationship between current and voltage.

Current/amps	Voltage/volts
0.0	0.0
0.1	0.4
0.2	0.8
0.3	1.2
0.4	1.6
0.5	2.0

Typical results table

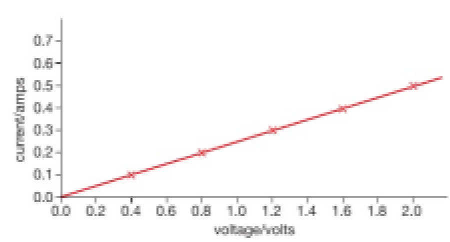


Figure 8.5 Graph of results

Current / voltage graph for a wire or a resistor

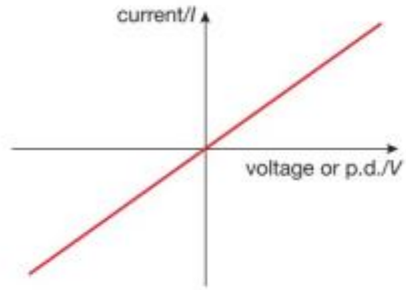


Figure 8.6

The graph is a straight line. It has a constant slope. So the resistance of this component does not change.

current / voltage graph for a filament bulb

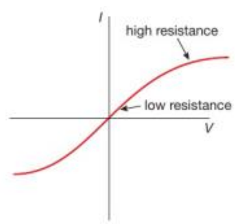


Figure 8.7

This graph is not a straight line. The resistance of the bulb changes. At higher currents and voltages the slope of the graph shows us that the resistance of the filament bulb increases – that is, as the temperature of the filament increases the current decreases.

current / voltage graph for a diode

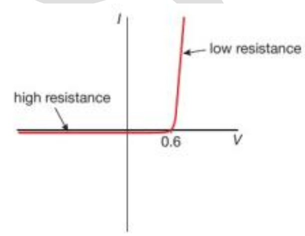


Figure 8.8

This strangely shaped graph shows that diodes have a high resistance when the current is in one direction and a low resistance when it is in the opposite direction (see page 81).

Using resistance

Fixed resistance

Fixed resistors are essential components in circuits to control current and voltage sizes. They are included in Figure 8.10 to ensure correct bulb current and voltage across it, as without them, the voltage across the bulb could cause excessive current and bulb failure.

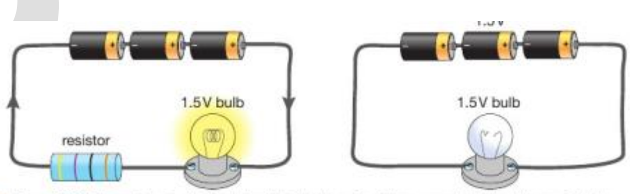


Figure 8.10 The resistor in the first circuit limits the size of the current. Without the resistor the current in the second circuit is too high and the bulb breaks.

Variable resistors

In the circuit in Figure 8.12 a variable resistor is being used to control the size of the current in a bulb. If the resistance is decreased there will be a larger current and the bulb shines more brightly.

If the resistance is increased the current will be smaller and the bulb will glow less brightly or not at all. The variable resistor is behaving in this circuit as a **dimmer switch.**

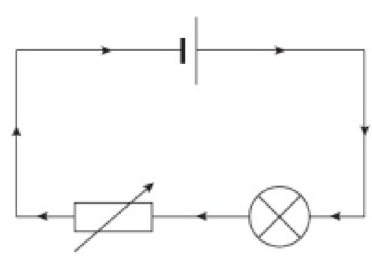


Figure 8.12 Circuit with a variable resistor being used as a dimmer switch

Special resistors

Thermistors

A **thermistor** is a resistor whose resistance changes quite a lot even with small changes in temperature.

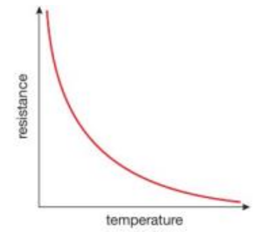


Figure 8.13 A graph showing a thermistor's decreasing resistance with increasing temperature

Light - dependent resistors. (LDRs)

A light – dependent resistor (LDR) has a resistance that change a when light is shone on it. In the dark its resistance is high but when light is shone on it its resistance decreases.

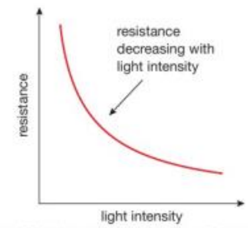


Figure 8.15 A graph showing an LDR's decreasing resistance with increasing light intensity

Diodes

Diodes are special resistors that allow charges to flow through them in one direction. They offer little resistance when connected in the right way, but high resistance when connected the opposite way, resulting in very small current.

For example, they are used in **rectifier circuits** that convert alternating current into direct current. Some diodes glow when charges flow through them. They are called **light emitting diodes (LEDs).**

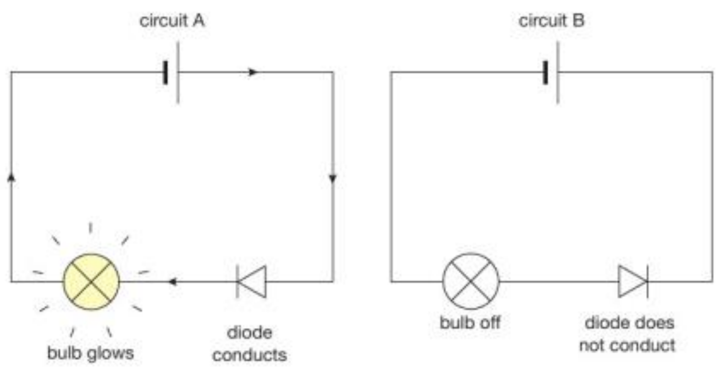


Figure 8.17 Diodes will only let charges flow one way.

2.4 Electric charge

Charges within an atom

All atoms contain small particles called protons, neutrons, and electrons. The protons are found in the centre or nucleus of the atom and carry a relative charge of +1

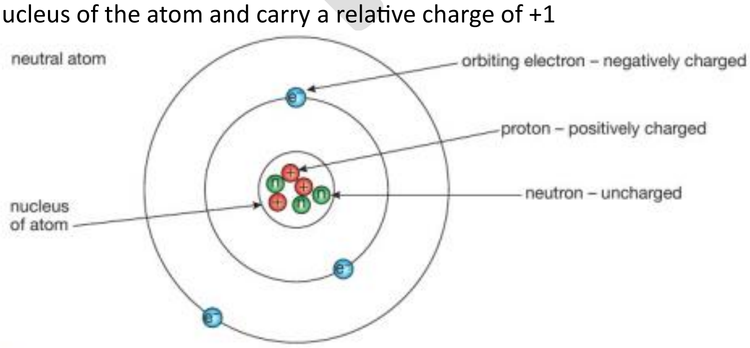


Figure 9.2 A neutral atom has the same number of negative electrons and positive protons (not to scale).

If an atom gains extra electrons, it is then **negatively charge.**

Charging materials by friction

It is possible to charge some objects simply by rubbing them together. But these objects must be made from different materials and these materials must be electrical insulators.
We can test which materials are conductors and which are insulators using the circuit in Figure 9.3.

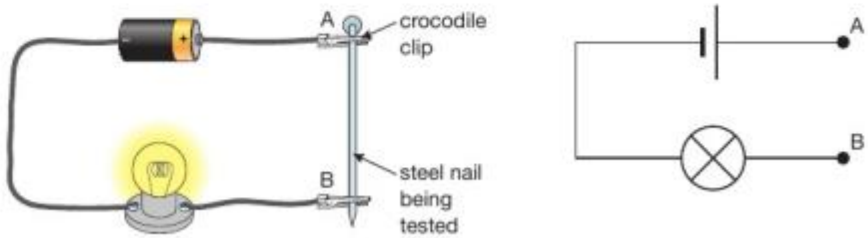


Figure 9.3 Testing circuit

Forces between charges

Charged objects can exert forces on other charged objects without being in contact with them. If the charges are similar, the objects **repel** each other. If the objects are oppositely charged, they attract each other.

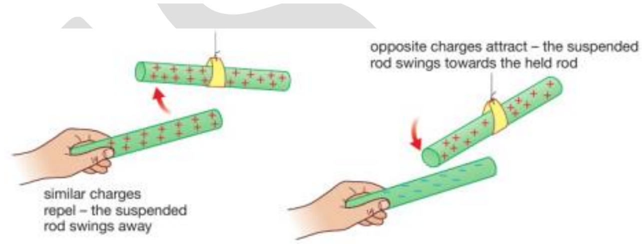


Figure 9.5 Similar charges repel and opposite charges attract.

Forces between charge and uncharged objects

The balloon experiment demonstrates that a charged object can attract an uncharged one, as the balloon sticks to a wall when held against it.

Explanation

The balloon is charged with static electricity before being brought close to a wall. The wall, uncharged, has equal positive and negative charges. As the balloon approaches the wall, some negative electrons are repelled, creating a slight positive charge.

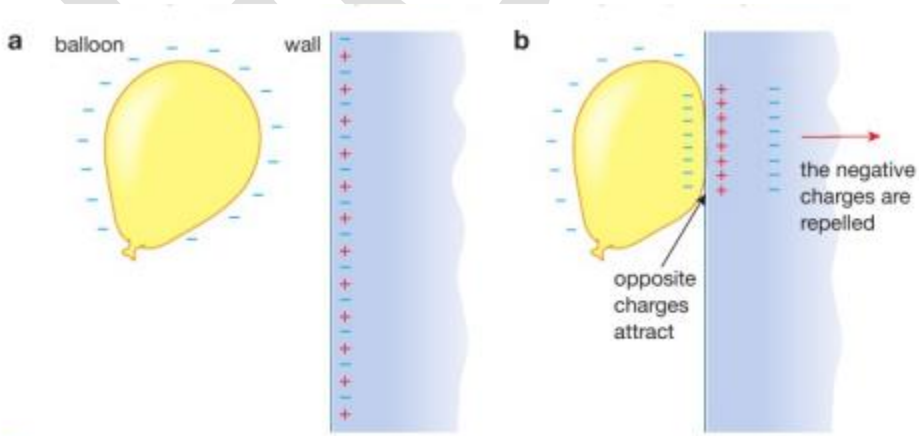


Figure 9.7 **a** The negatively charged balloon approaches the neutrally charged surface of the wall. **b** The positive charge on the surface of the wall attracts the oppositely charged balloon.

Uses of static electricity

Electrostatic paint spraying

Electrostatic spraying is a more efficient method for painting an awkwardly shaped object like a bicycle frame. The process involves charging paint drops with the same charge, repelling and spreading out a thin spray. The metal bicycle frame, with a wire attached to an electrical supply, attracts the paint, making it easier to reach corners and other hard-to-reach areas.

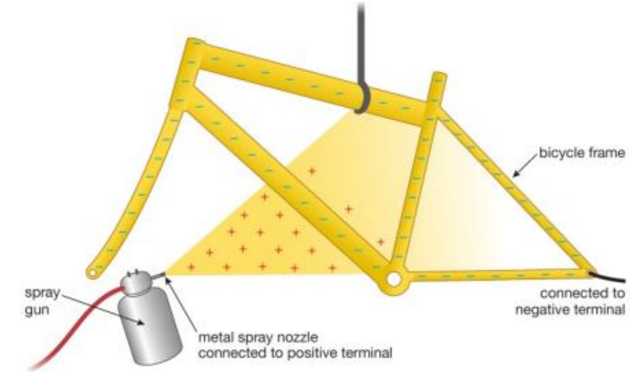


Figure 9.11 The positive paint is attracted to all parts of the negatively charged object.

Inkjet printers

Modern inkjet printers use electrostatic forces to direct fine ink drops onto paper. Each spot is charged, causing it to fall between deflecting plates. The plates change hundreds of times per second, forming pictures and words on the paper as needed.

Figure 9.12 An inkjet printer

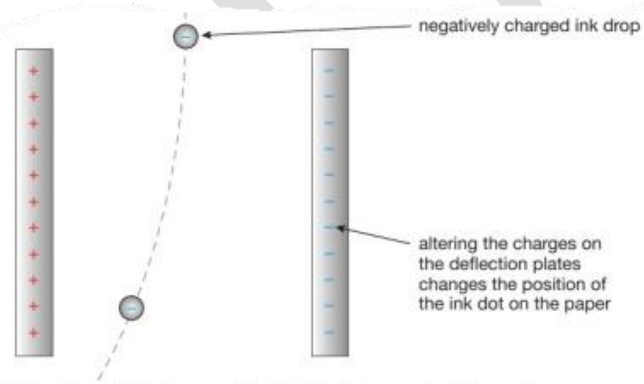


Figure 9.13 The charged ink drops are deflected into the correct position on the paper.

Photocopiers

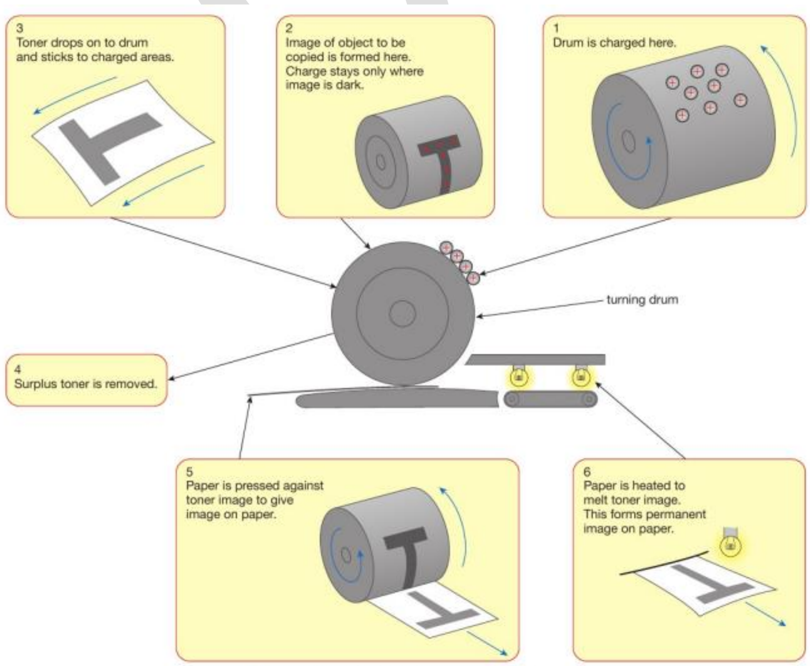


Figure 9.14 Static electricity is used in photocopiers.

Electrostatic precipitations

Heavy industrial plants like steel-making furnaces and coal-fired power stations emit large amounts of smoke, causing health issues and building damage. Electrostatic precipitators can help remove these pollutants from the smoke.

Smoke rises a chimney through highly charged wires, attracting ash and dust particles. These particles stick to metal earthed plates, releasing cleaner smoke into the atmosphere. When the plates are covered with dust and ash, they are tapped hard, and the dust and ash fall into collection boxes. In a large coal-fired power station, 50-60 tonnes of dust and ash can be removed each hour.

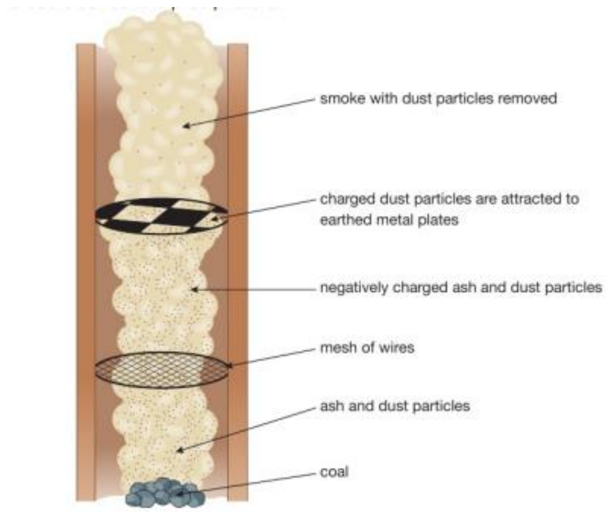


Figure 9.16 Electrostatic precipitators help to cut down the amount of pollution released into the atmosphere.

Problems with static electricity

Static electricity can be a disadvantage in aircraft due to friction, causing them to become charged. After landing, charges can escape to earth as sparks, potentially causing an explosion during refueling. To address this, planes should be earthed with a conductor immediately and before fuel transfer to prevent sparks causing fires or explosions. This is especially important for fuel tankers on roads.

Revision questions

1)A kitchen has a water supply, an electricity supply and electric lighting.
There are several electrical appliances in the kitchen including a toaster, a kettle, a clothes iron, a microwave oven, and a dishwasher.
Discuss three hazards of using electricity in this kitchen.

2) A student has two computer hard drives.
One is black and one is white.
The student places the white hard drive on top of the black one as shown in photograph A.

The student connects both hard drives to a computer so that they receive the same amount of electrical power.
The temperature of the hard drives rises as they work.
The student then rearranges the hard drives so that the black one is on top as shown in photograph B.

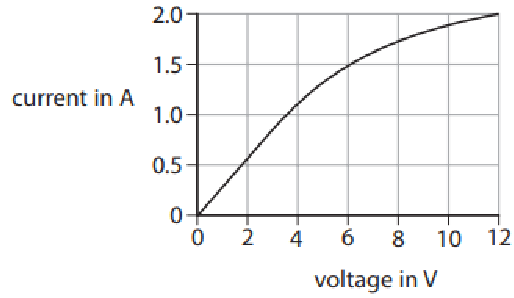
The hard drives are still working, but their temperature is lower than before.

Photograph A

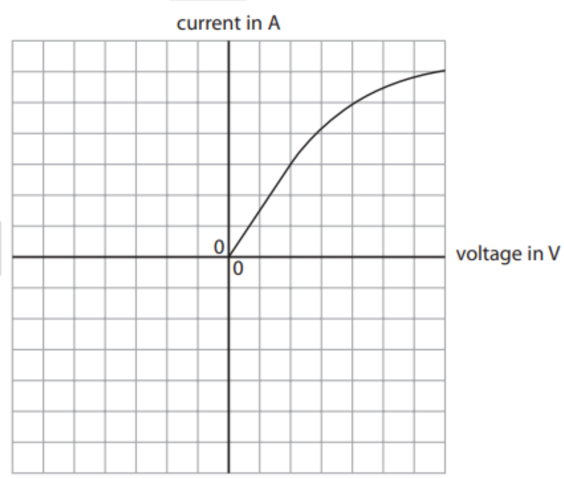
Photograph B

Explain why the hard drives work at a lower temperature when the black one is on top.

3) (a) A student investigates the resistance of a lamp.
(i) The student uses a circuit that contains an ammeter, a battery, a lamp, and a voltmeter to determine the resistance of the lamp. Draw a circuit diagram to show how he should connect the apparatus.
(ii) State the relationship between voltage, current and resistance.
(iii) The student obtains this graph for a filament lamp
Calculate the resistance of the lamp when the voltage is 6.0 V. Give the unit.

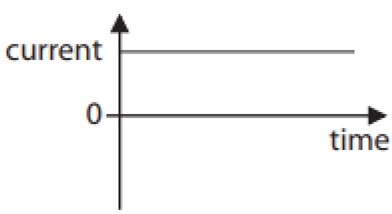


(iv) The student reverses the battery connections and then repeats his measurements. On the axes below, sketch the graph that he would obtain. Part of the graph has been done for you.

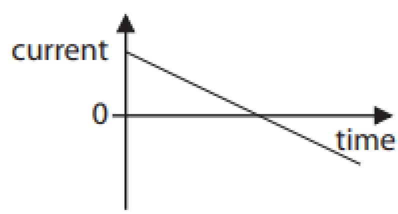


(b) The student replaces the filament lamp with a light emitting diode (LED). He notices that there is no current in the diode when the battery is reversed. He replaces the battery with an a.c. supply.

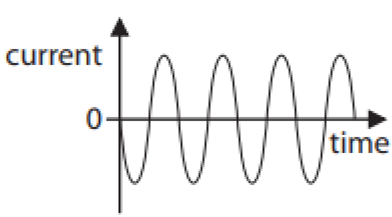
Which graph shows how the current in the diode varies with time?



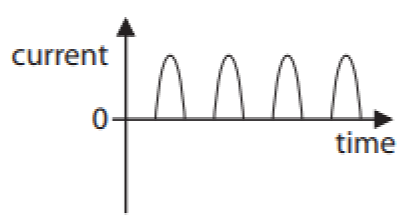
☒ **A**



☒ **B**

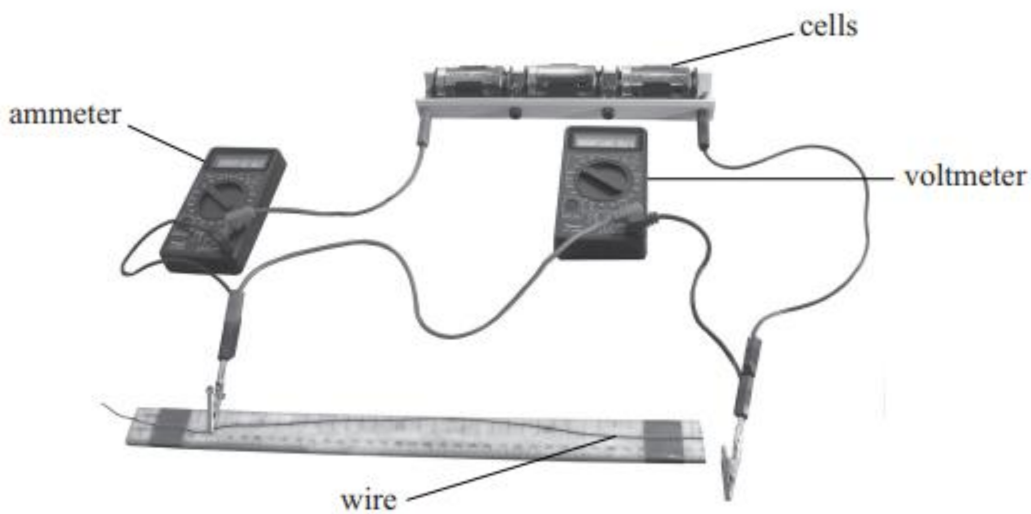


☒ **C**



D ☒

4) A student investigates how the resistance of a wire depends on its length. The photograph shows the circuit that the student uses.



(a) Draw a circuit diagram to show how the components in the photograph are connected
(b) (i) Complete the table by naming the key variables in this investigation.

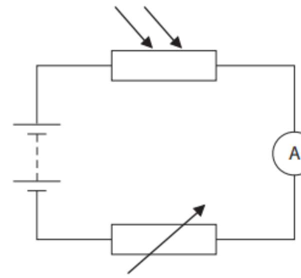
independent variable	
dependent variable	

(ii) Describe the method the student should use for this investigation
(c) The table shows the student's measurements.

Length of wire in cm	Voltage in V	Current in A	Resistance of wire in Ω
20	4.5	3.6	1.3
40	4.5	1.8	2.5
60	4.5	1.2	3.8
80	4.5	0.9	5.0
100	4.5	0.7	

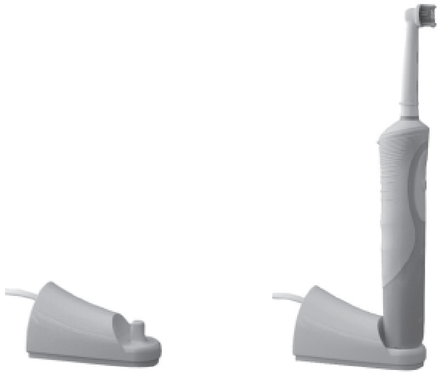
(i) State the equation linking voltage, current and resistance.
(ii) Complete the table by calculating the missing value of resistance

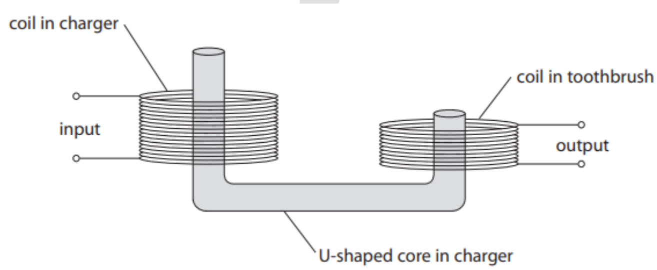
5) The resistance of a Light Dependent Resistor (LDR) is affected by the amount of light that shines on it.
A student investigates this relationship using the circuit shown.



(a) (i) The student uses a voltmeter to measure the voltage across the LDR. Add this voltmeter to the circuit diagram.
(ii) Explain how the student can work out the resistance of the LDR using this circuit

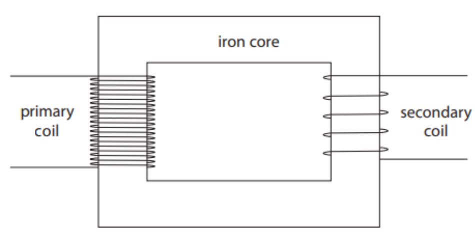
6) The photographs show how an electric toothbrush fits on its charger. The charger and the toothbrush each have a coil of wire inside them. The diagram shows how the two coils are linked by a U-shaped core.





This arrangement of core and coils acts as a transformer that reduces voltage.
(a) (i) Name the type of transformer that reduces voltage.
(ii) Explain why the core is made of a soft magnetic material, such as iron.
(b) (i) State the equation linking the input (primary) and output (secondary) voltages and the turns ratio of a transformer.
(ii) The transformer has 520 primary turns and 30 secondary turns. The input voltage to the transformer is 44 V. Calculate the output voltage.
(c) (i) The alternating current in the transformer has a frequency of 27 000 Hz. The toothbrush vibrates at the same frequency when it is being charged. Explain why these vibrations cannot be heard.
(ii) A circuit in the toothbrush delivers regular pulses of direct current. There is a pulse every 1.5 ms. Calculate the frequency of the pulses.

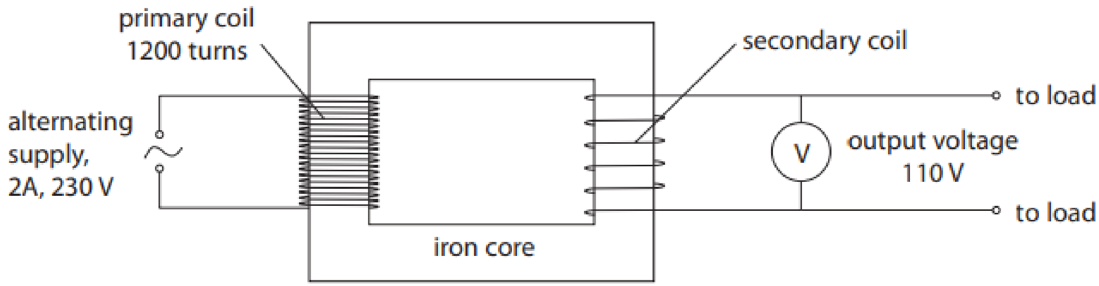
7) The diagram shows parts of a transformer



(a) The input voltage to the transformer is 230 V a.c.
The output of the transformer is 25V a.c.
There are 100 turns on the secondary coil.
(i) Name the type of transformer shown in the diagram.
(ii) State the equation linking input (primary) voltage, output (secondary) voltage, primary turns, and secondary turns.
(iii) Calculate the number of turns on the primary coil
(b) Explain how a transformer works.
In your answer, you should include the reasons for using,

- Two coils
- The iron core.
- An alternating supply

8) The diagram shows a transformer that is 100% efficient.



(a) (i) State the equation linking input power and output power for the transformer.
(ii) Calculate the output current of the transformer
(b) (i) State the equation linking input voltage, output voltage and turns ratio for the transformer.
(ii) Calculate the number of turns on the secondary coil of the transformer
(c) Explain how a transformer works. In your answer, you should include the reasons for using,

- Two coils
- The iron core.
- An alternating supply

9) Diagram 1 shows a machine used for demonstrating electrostatics

When the handle is turned, the dome becomes positively charged.
(i) In terms of electron movement, give a reason why the metal dome becomes positively charged.
(ii) When the handle is turned for 15 s the dome gains 0.50 J of energy in its electrostatic store as it becomes charged.
The voltage between the dome and the earth is 120 KV.
Calculate the mean charging current during this time.
b) The metal dome is discharged.
A thin metal case is then placed on top of the metal dome, as shown in Diagram 2.
(i) When the handle is turned, the thin metal case moves upwards away from the dome.
Explain why the thin metal case starts to move upwards.
(ii) Explain why the metal case reaches a maximum height above the metal dome.

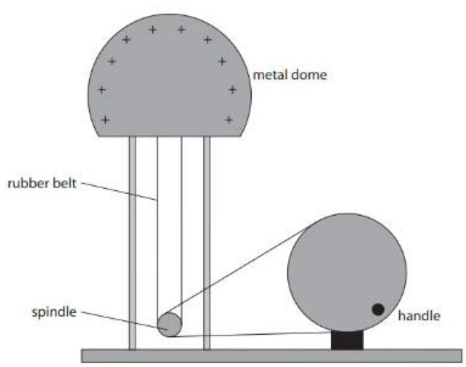


Diagram 1

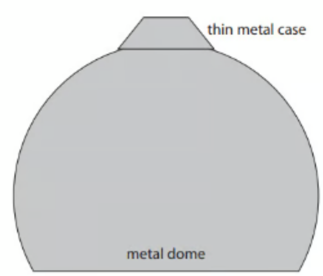


Diagram 2