Edexcel Physics IGCSE

Topic 2: Electricity

Summary Notes

(Content in bold is for physics only)

EXAM PAPERS PRACTICE

Energy and voltage in circuits

Current

Current I is measured in **amperes (A)** and is the **rate of flow of charge** at a **point** in the circuit.

- The current is given by I=Q/t, where Q is measured in **coulombs (C)** and t in **seconds (s).**
- In metals, current is due to a **flow of electrons.** In solutions it can be the flow of ions. Conventional current is the rate of flow of **positive** charge - this is in the **opposite** direction to the flow of electrons because electrons are **negatively** charged.
- Current is **conserved** at a **junction** in a circuit because charge is always conserved.
- Current is measured with an **ammeter** connected in **series** with the component.

Potential difference

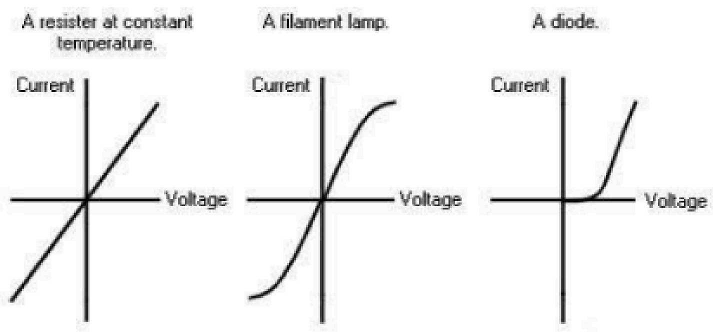
Potential difference V is measured in **volts (V where 1 V = 1 JC^{-1})** and is the **work done per unit charge** in moving **between two points** in a circuit.

- The potential difference is given by V=E/Q.
- It is measured with a **voltmeter** placed in **parallel** across the component.
- The higher the potential difference, the greater the current ($V = IR$).

Resistance

The **resistance** of a component is measured in **ohms (Ω)** and is given by the potential difference across it divided by the current through it, i.e. $R=V/I$. The greater the resistance, the harder it is for current to flow through the component.

In an **ohmic conductor** (such as a **resistor at a constant temperature**), the current is directly proportional to the voltage (i.e. it has constant resistance). In a non-ohmic conductor (such as a **filament lamp**), the resistance changes as the voltage and current changes.



In a filament lamp, this is because as the **current increases** through the filament, so does the **temperature,** which means **electrons and ions vibrate more** and **collide more, increasing resistance.**

A **thermistor** is a resistor whose resistance decreases as the **temperature** increases.
A **light dependent resistor** is a resistor whose resistance decreases as **light intensity** increases.

Electric circuits

Series:

- Components are connected **end to end** in one loop
- The **same current** flows through every component

- The **potential difference is shared** across each component - depending upon their resistance (i.e. the sum of the p.d.s across the components is equal to the total p.d. across the supply) - components with a higher resistance have a greater PD across.
- The total resistance in series is the **sum of the resistances** of each component $R_t = R_1 + R_2$ ...

Parallel:

- Components are connected to the power supply in **separate branches**
- The **current is shared** between each branch (i.e. the sum of the currents in the separate branches is equal to the current through the source) - because charge can only flow one way.
- The **potential difference** is the **same** across every branch
- Connecting lamps in parallel is advantageous because if one breaks, current can still pass through the rest.

Mains electricity

Dangers of electricity

Hazards:

- **Damaged insulation** – contact with the wire due to gaps in the insulation can cause an **electric shock** or pose a **fire hazard** by creating a short circuit.
- **Overheating of cables** – high currents passing through thin wire conductors cause the wires to heat up to very high temperatures which could **melt the insulation** and cause a **fire.**
- Damp conditions – water can conduct a current so wet electrical equipment can cause an **electric shock.**

Fuses and circuit breakers:

- A **fuse** is a thin piece of **wire** which overheats and **melts** if the **current is too high, protecting the circuit.** They have a current **rating** which should be slightly higher than the current used by the device in the circuit. The most common are 3A, 5A and 13A.
- **Circuit breakers** consist of an automatic **electromagnet** switch which **breaks the circuit** if the **current rises over a certain value.** This is better than a fuse as it can be **reset** and used again, and they operate **faster.**

Earthing metal cases:

- Earth wires create a **safe route** for current to flow through in the case of a **short circuit,** preventing electric shocks.
- Earth wires have a **very low resistance** so a strong current surges through them which breaks the fuse and disconnects the appliance.

Double insulation:

- Appliances with **double insulation** have either **plastic casings** completely covering their electrical components, or have been designed so that the earth wire **cannot touch** the metal casing, preventing them from giving an electric shock.

Electrical transfer of energy

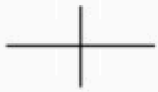
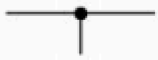
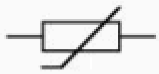
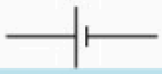
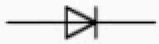
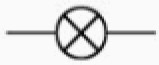
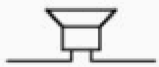
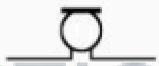
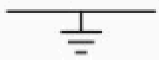
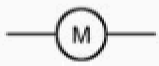
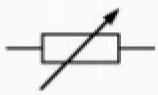
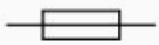
Energy, measured in **joules (J)**, is transferred from **chemical** energy in the **battery** to **electrical** energy used by **circuit components** and then to the **surroundings.**

- The **power** of a component is measured in **watts (W)** and is given by P=IV (by using V=IR, this can be shown to be equivalent to $P=I^2R$ and $P=V^2/R$). Using this equation, the energy transferred is given by E=IVt.

Alternating current and direct current

In a **direct current,** the current only flows in **one direction** whereas in an **alternating current,** the current continuously **changes direction.**

Mains electricity is an alternating current (a.c.) whereas the current supplied by a **cell or battery** is direct current (d.c.).

Description	Symbol	Description	Symbol
Conductors crossing with no connection		Heater	
Junction of conductors		Thermistor	
Open switch		Light-dependent resistor (LDR)	
Cell		Diode	
Battery of cells		Light-emitting diode (LED)	
Power supply (DC)		Lamp	
Power supply (AC)		Loudspeaker	
Transformer		Microphone	
Ammeter		Electric bell	
Voltmeter		Earth or ground	
Fixed resistor		Motor	
Variable resistor		Generator	
		Fuse/circuit breaker	

Electric charge

Charge is measured in coulombs, C. There are **positive** and **negative** charges; **opposite** charges **attract** and **like** charges **repel.**

- Atoms are composed of protons, electrons and neutrons. Protons have a charge of **+1**, electrons have a charge of **-1** and neutrons have a charge of **0**.
- Charging a body involves the **addition** or **removal** of **electrons -** charging atoms creates ions.
- **Conductors** such as **metals** allow electrons to flow through them whereas **insulators** such as **plastics** impede the flow of electrons.
  - When two insulators are **rubbed** together, friction causes electrons to move from one to the other and they become charged. The material that loses electrons becomes **positively charged** and the material that gains electrons becomes **negatively charged**.
  - The **magnitude** of the charge on each material is equal, since they lose/gain the **same number** of electrons.
  - For example, when a **rod** is rubbed with a **cloth,** electrons are transferred from the rod onto the cloth and the rod becomes positively charged.

The charges cannot move within the insulator so they build up - this is known as **static electricity**.

Consequences of static electricity can be seen in a number of phenomena.

- Lightning:
  - Electrostatic charge can build up on clouds due to **friction**.
  - When this charge becomes large enough, the clouds **discharge** through the air to the earth. This results in **lightning**.
- Charged balloon on a wall:
  - A positively charged balloon will stick to a wall if moved close enough.
  - Positive charges in the wall are **repelled by the balloon** and move to other parts of the wall. This leaves a **negative charge** on the area of the wall closest to the balloon.
  - The **attraction** between the **negatively charged wall** and the **positively charged balloon** makes the balloon stick.
- Comb picking up bits of paper:
  - Rubbing a comb against an **insulator** will cause it to pick up an electrostatic charge due to the **transfer of electrons**.
  - The charge on the comb **repels** like-charged in the paper, leaving the paper closest to the comb with an electrostatic charge **opposite to the comb**.
  - This end of the paper is then **attracted** to the comb.

Electrostatic phenomena caused by the movement of electrons have many useful applications but also pose many risks.

- Dangers of electrostatic charges include:
  - Static charges pose a risk of **electric shock**. If a person touches an object with a large amount of static charge, electrons will flow through the person's body to the **earth**.
  - When **fuelling aircraft and tankers,** if enough charge builds up on the vehicle or pump it can create a **spark.** This can ignite the fuel and cause a **fire or explosion.** For safety, an *earthing* wire can be attached so that the charge instead flows into the earth.
- Safety measures when using electrostatic charges include:
  - **Earthing** involves offering electrons an **alternative pathway** to the earth.

  - This prevents too much electrostatic charge form **building up** on the surface of an insulator. Less electrostatic charge **reduces the risk** of electric shock, or the harm it can cause.
- Uses of electrostatic charges include:
  - In an **inkjet printer,** droplets of **ink** are **charged** and pass between **two charged metal plates,** one of which has a positive charge and the other a negative charge. The droplets are attracted to the plate with the opposite charge and repelled by the plate with the same charge and **deflected** towards a specific place on the paper.

  - In a **photocopier,** the image of a document is projected onto a **positively charged plate;** where light falls onto the plate, the charge leaks away. **Negatively charged toner particles** are attracted to the remaining positive areas. Paper is then placed over the plate and the toner is transferred to it, making the photocopy.

Current, Voltage, and Resistance

Current is the flow of electric charge in a circuit, typically carried by electrons. It is defined as the amount of charge passing through a point in a circuit per unit of time and is given by:

$$\text{Current}(I) = \frac{\text{Charge}(Q)}{\text{Time}(t)}$$

Current is a scalar quantity, and its SI unit is the **ampere (A)**.

Voltage, also known as potential difference, is the amount of energy transferred per unit charge between two points in a circuit. It is given by:

$$\text{Voltage}(V) = \frac{\text{Energy transferred}(E)}{\text{Charge}(Q)}$$

The SI unit of voltage is the **volt (V)**, and it is a scalar quantity.

Resistance is the opposition to the flow of current in a conductor. It is given by **Ohm's Law**:

$$V = IR$$

Where V is the voltage, I is the current, and R is the resistance. Resistance depends on factors such as material, length, cross-sectional area, and temperature of the conductor. Its SI unit is the **ohm (Ω)**.

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Series and Parallel Circuits

Series Circuits have components connected end-to-end, forming a single path for current. In a series circuit:

- The current is the same at every point.
- The total voltage is the sum of the individual voltages across each component.
- The total resistance is the sum of individual resistances:

$$R_{\text{total}} = R_1 + R_2 + R_3 + \dots$$

Parallel Circuits have components connected across common points, creating multiple paths for the current. In a parallel circuit:

- The voltage across each branch is the same.
- The total current is the sum of the currents in each branch.
- The total resistance is given by:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$$

Series circuits are commonly used in devices where the current must flow through every component, while parallel circuits are used in household wiring to allow independent control of devices.

Electric Power and Energy

Electric Power is the rate at which electrical energy is transferred by an electric circuit. It is calculated using:

$$P = IV$$

Where P is power, I is current, and V is voltage. The SI unit of power is the **watt (W)**.

Electrical Energy consumption is typically measured in **kilowatt-hours (kWh)**, where 1 kWh is the energy consumed by a 1 kW device running for 1 hour. The formula for electrical energy is:

$$E = Pt$$

Where E is the energy, P is the power, and t is time in hours.

Electrical Safety and Hazards

Electricity poses risks like shocks, fires, and damage to appliances if not handled safely. Electrical safety devices include:

- **Fuses**: Protect circuits by breaking the connection when excessive current flows through them.
- **Circuit breakers**: Automatically cut off the current in case of overload or short circuits.
- **Earthing**: Ensures that excess current is safely discharged into the ground.
- **Double insulation**: Prevents contact with live parts in electrical appliances.

Safety measures like using insulated tools, turning off the main power before repairs, and avoiding water near electrical devices help minimize hazards.

Static Electricity

Static Electricity is the buildup of electric charge on the surface of materials due to the transfer of electrons, often through friction. Unlike current electricity, static charges remain stationary until discharged.

- **Charging by friction** occurs when two insulating materials are rubbed together, transferring electrons from one to the other.
- **Attraction and repulsion**: Objects with opposite charges attract each other, while objects with like charges repel.

Practical applications of static electricity include:

- **Electrostatic precipitators**: Used to remove dust particles from smoke.
- **Photocopiers**: Use static charge to transfer toner onto paper.

Dangers of static electricity include the risk of sparks that can ignite flammable substances, as seen in lightning strikes or when handling fuels.