OCR (B) Physics GCSE

Chapter 3: Electric Circuits

Summary Notes

(Contents in bold is for Higher Tier Only)

P3.1 What is Electric Charge?

Charge

Around every electric charge there is an electric field; in this region of space the effects of charge can be felt; when another charge enters the field there is an interaction between them and both charges experience a force. Charge is a property of all matter:

- Positive and negative charges exist
- If a body has the same amount of positive and negative charge, they cancel out, forming a neutral body (i.e. protons and electrons in a neutral atom)
- Like charges repel
- Opposite charges attract

Electric Fields

Like magnetic fields for magnets, electric fields are for charges. They point in the direction a positive charge would go i.e. away from positive charges, and towards negative charges, at right angles to the surface.

- Stronger the charge, the more field lines present and the stronger the force felt
- Closer to the charge, the stronger the force felt

The charged objects experience a force – electrostatic force (of attraction/repulsion)

- Greater charge = greater force (e.g. a more positive object, a more negative object)
- Closer together = greater force (force is proportional to the inverse square of the distance)
- It is a non-contact force, as force can be felt even when the objects are not touching

Static Electricity (Physics only)

Insulators do not conduct electricity - their electrons cannot flow throughout the material, they are fixed. When two insulators are rubbed together:

- Electrons are transferred from one object to the other
- Forming a positive charge on one object and a negative charge on the other

Insulators become charged because the electrons cannot flow

- A positive static charge forms on object which loses electrons
- A negative static charge forms on object which gains electrons
- Which object loses/gains electrons depends on the materials involved

Sparking occurs when enough charge builds up, and the objects are close but not touching. The "spark" is when the charge jumps through the air from the highly negative object to the highly positive object, to balance out the charges

Conductors can conduct electricity - their electrons can flow, and are not fixed (they are delocalised). If conductors were rubbed, electrons will flow in/out of them cancelling out any effect, so they stay neutral.

P3.2 What Determines the Current in an Electric Circuit?

Electrical Current

Current is the flow of electrical charge. For charge to flow the circuit must be closed (no open switches) and there must be a source of potential difference (battery/cell). Greater the rate of flow of charge, greater current.

$$Q=It$$

Where Q is the charge flow, in coulombs C, I is the current, in amperes A and t is the time in seconds s. In a single closed loop, the current has the same value at any point

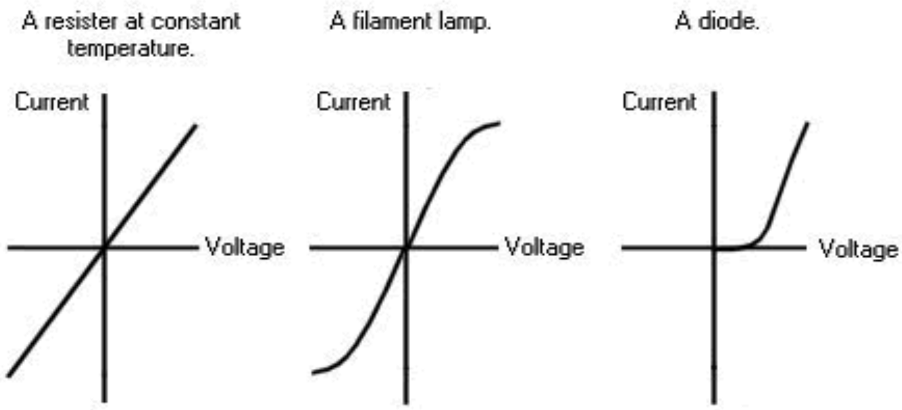
The current (I) through a component depends on both the resistance (R) of the component and the potential difference (V) across the component. Current, potential difference or resistance can be calculated using the equation:

$$V=IR$$

Where V is the potential difference in volts V, I is the current in amperes A, and R is the resistance in ohms Ω. The greater the resistance of the component the smaller the current for a given potential difference (pd) across the component.

Resistors

If the resistance is constant, an ohmic conductor, current is directly proportional to the potential difference, in this case the graph is linear. If the resistance of components such as lamps, diodes, thermistors and LDRs is not constant it changes with the current through the component, so the graph is nonlinear, for example, the resistance of a filament lamp increases as the temperature of the filament increases and the current through a diode flows in one direction only, so it has a higher resistance in the reverse direction.

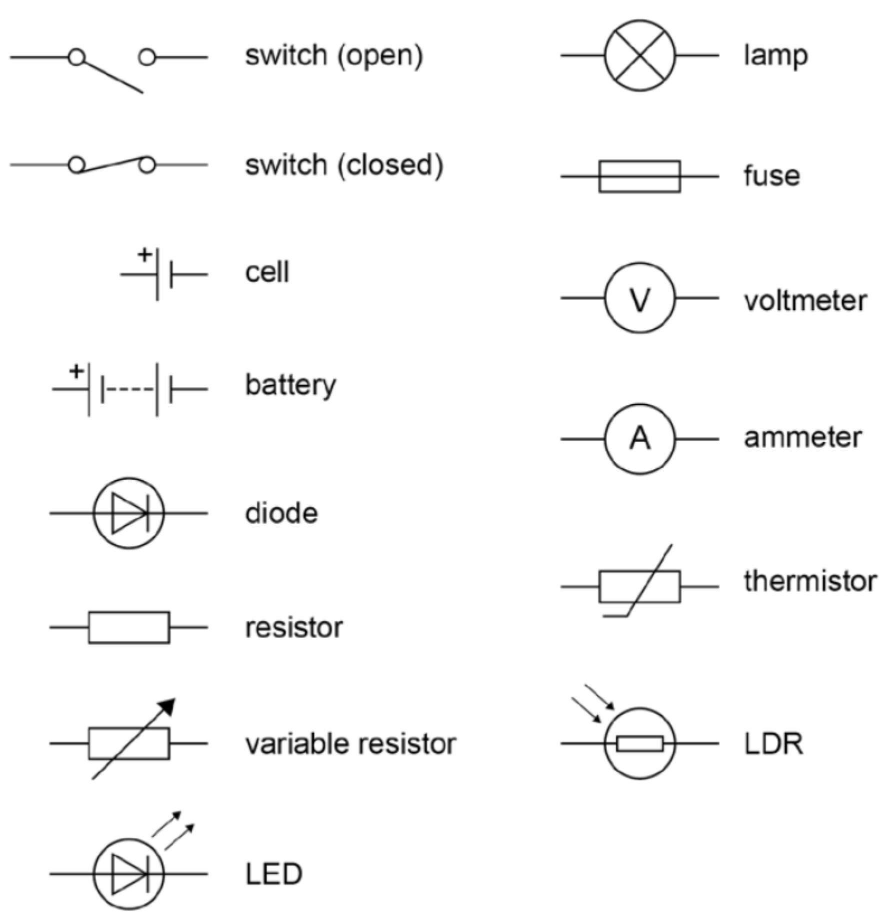


1: WordPress.com

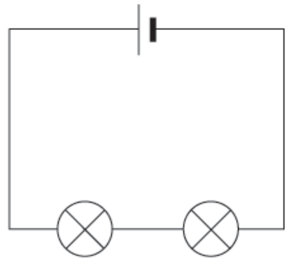
How does the resistance change?

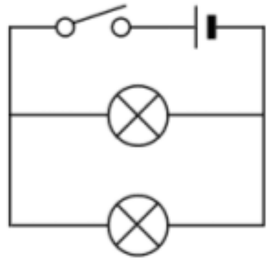
- With current
  - As current increases, electrons (charge) has more energy
  - When electrons flow through a resistor, they collide with the atoms in the resistor
  - This transfers energy to the atoms, causing them to vibrate more
  - This makes it more difficult for electrons to flow through the resistor, so resistance increases, and current decreases
- With temperature
  - Normal wires - See above, the same process occurs as atoms vibrate when hot
  - Thermistor
    - In hotter temperatures the resistance is lower
    - These are often used in temperature detectors/thermostats
- With light
  - LDR (Light Dependent Resistor)
    - The greater the intensity of light, the lower the resistance
    - So the resistance is greatest when it is dark
    - These are used in automatic night lights.
- With voltage
  - Diodes
    - Diode allows current to flow freely in one direction
    - In the opposite direction, it has a very high resistance so no current can flow

Circuit Symbols



P3.3 How do Series and Parallel Circuits work?





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Series and Parallel Circuits

- Series Circuits
  - Closed circuit
  - Current only follows a single path

- Parallel Circuits
  - Branched circuit
  - Current splits into multiple paths

Series

In a series circuit, components are connected end to end, all the current flows through all the components and you can only switch off all components at once.

Potential difference is shared across the whole circuit

PD of power supply=sum of PD across each component

Current is the same through all parts of the circuit

Current at one point=current at any other point

Total Resistance is the sum of the resistance in each component

Resistance of two components is bigger than just one of them, because the charge has to push through both of them when flowing round the circuit

Parallel

In a parallel circuit, components are connected separately to the power supply, current flows through each one separately and you can switch each component off individually.

Potential difference is the same across all branches

PD of power supply=PD of each branch

Because charge can only pass through any one branch, current is shared between each of the branches

Current through source=sum of current through each branch

Total resistance is less than the branch with the smallest resistance. Two resistors in parallel will have a smaller overall resistance than just one. Because charge has more than one branch to take, so only some charge will flow along each branch

Potential Difference

When electric charge flows through a component (or device), work is done by the power supply and energy is transferred from it to the component and/or its surroundings. Potential difference measures the work done per unit charge.

$$V = \frac{W}{Q}$$

Where V is the Potential Difference in volts ,V, W is the work done in Joules, J, and Q is the charge in coulombs, C.

P3.4 What determines the Rate of Energy Transfer in a Circuit?

Power

Power rating of an appliance shows the power it uses in Watts, so greater power rating means it uses more energy.

Power is defined as the rate at which energy is transferred or the rate at which work is done:

$$P = IV$$

The power P, is in watts, I, the current, is in Amperes, A, W the potential difference, in volts, V.

Step-Up Transformers

The National Grid uses transformers to step down the current for power transmission. Transformers change the potential difference. The power output from a transformer cannot be greater than the power input, due to the conservation of energy, therefore if the current increases, the potential difference must decrease.

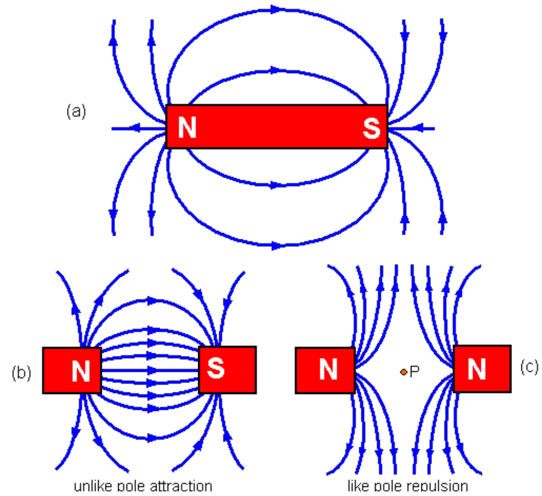
$$P_{loss} = I^2R$$

The power loss, P, is in watts, I, the current, is in Amperes, A, R the resistance, in Ohms. From this it is apparent that transmitting power with a lower current through the cables results in less power being dissipated during transmission and thus a higher efficiency.

P3.5 What are Magnetic Fields?

Magnetic Fields

- Field Lines point from North to South
- Strength decreases with distance from the magnet
- Direction always points to north pole and away from south pole, at any point
- Use Plotting Compasses
- Small compasses which show the direction of the magnetic field at a certain point



2: schoolphysics.co.uk

Magnets have a North and South Poles where same Poles repel and opposite poles attract.

Permanent Magnets always magnetic, always have poles.
Induced Magnets are "magnetic" materials but do not have fixed poles.These can be made into temporary magnets by 'stroking' them with a permanent magnet. (e.g. Iron, Nickel, Cobalt)

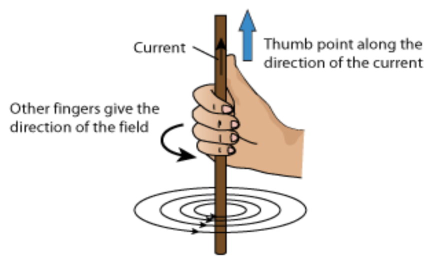
Earth's Magnetic Core

The Earth's core is magnetic, and creates a large magnetic field around the Earth. We know this because a freely suspended magnetic compass will align itself with the earth's field lines and point North.

A compass is effectively a suspended Bar Magnet, with its own north pole lining up with Earth's 'North pole'
However this cannot be right, as like poles repel
So in fact, Earth's magnetic pole above Canada is a magnetic South Pole! (and the geographic south pole is close to the Magnetic North Pole)

Current

- Current produces a magnetic field around the wire
- The direction is dictated by the "right hand grip rule"
- Plotting compasses on a piece of paper through which a wire is pierced shows this



Right Hand Grip Rule

Strength of Magnetic Field

- Greater current, stronger magnetic field
- Greater distance from wire, weaker field

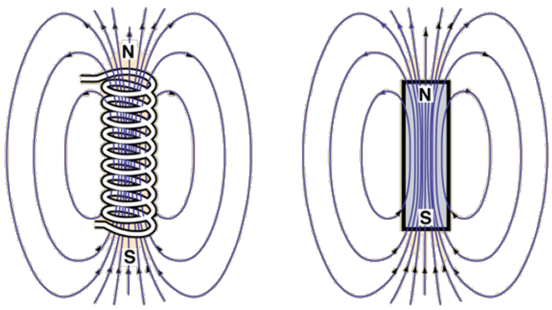
Solenoid

- Magnetic field shape is similar to a bar magnet
- It enhances the magnetic effect as coiling the wire causes the field to align and form a giant single field, rather than lots of them all perpendicular to the direction of the current

- Having an iron core in the centre increases its strength as it is easier for magnetic field lines to pass through than air

Factors that affect the strength:

- Size of current
- Length
- Cross sectional area
- Number of turns (coils)
- Using a soft iron core



3: hyperphysics.co.uk

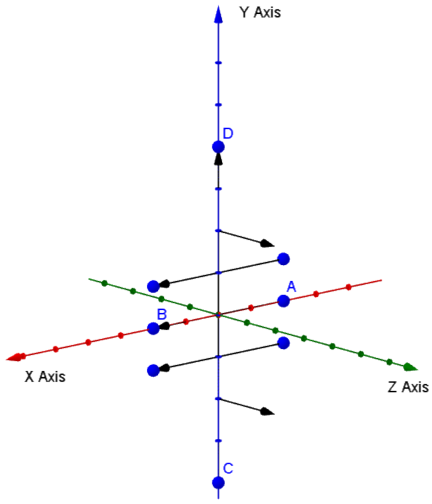
Loudspeakers

- **The setup is identical, working in reverse**
- **The current flows into the coil**
- **The magnetic field from magnet and from current interact, causing the coil to move**
- **The cone therefore moves**
- **Producing pressure variations, making sound**

P3.6 How do Electric Motors Work?

The Motor Effect

- Two magnets will interact, feeling a magnetic force of attraction/repulsion.
- So a magnet and a wire will also exert a force, as the two magnetic fields (generated by the magnet and the current in the wire) will also interact
- The magnetic field around a wire is circular, but the magnetic field between two magnets is straight
- When the two interact, the wire is pushed away from the field between the poles (at right angles to the wire direction and the field direction)

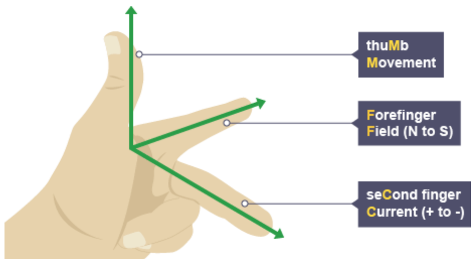


To visualise

- Fixed permanent magnets have field lines along the x axis, as the magnets are at A and B and the field lines are shown
- Wire is along y axis, where current is moving up from C to D
- The force felt on the wire is at right angles to both the direction of the current and magnetic field lines, along the z axis

Fleming's Left-Hand Rule

- Each direction is 90° to each other
- Use this to work out the unknown factor out of the three (usually the direction of the force felt)
- Remember current is conventional current, which moves in opposite direction to the electrons



4: BBC.co.uk

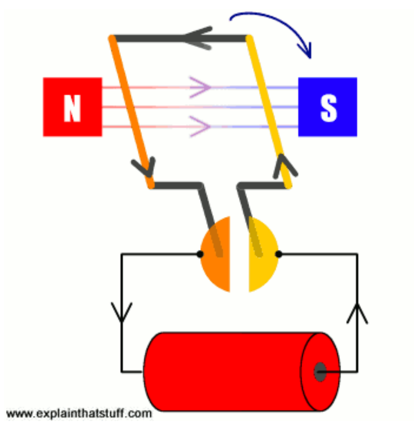
Force on a current-carrying conductor can be calculated as followed:

$$F = BIL$$

Where Magnetic Flux Density, B, is measured in Tesla and it is the number of flux lines per metre squared. F, the Force in Newtons [N], I, the current in Amperes [A] and L, the length in metres [m].

How Electric Motors work

- Knowledge of structure is not required
- Permanent Magnets lie in fixed positions
- In between, a coil of current-carrying wire lies on an axis
    - Force on one side moves that side up
    - Force on the other side (where current is flowing in opposite direction) moves down
    - This can be verified using Fleming's Left-Hand Rule
- Hence it rotates



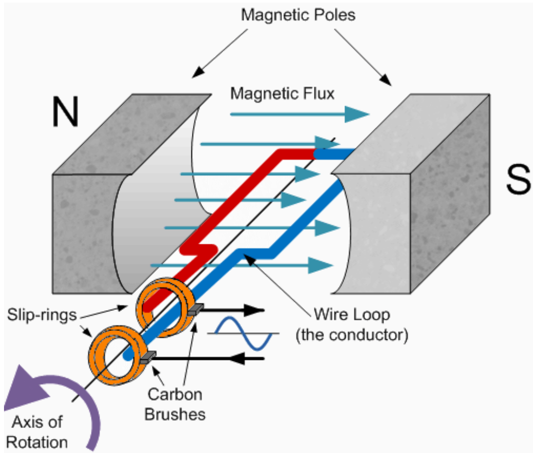
P3.7 What is the Process inside an Electric Generator? (Physics only)

Electromagnetic Induction (Physics only)

- When there is a relative **movement between a conductor and a magnetic field**, a potential difference is induced across the conductor.
- This happens if the **magnetic field changes** as well
- A current flows if the conductor forms a complete circuit.
- This current will produce its own magnetic field, which **oppose the change inducing it**

How Electric Generators work (Physics only)

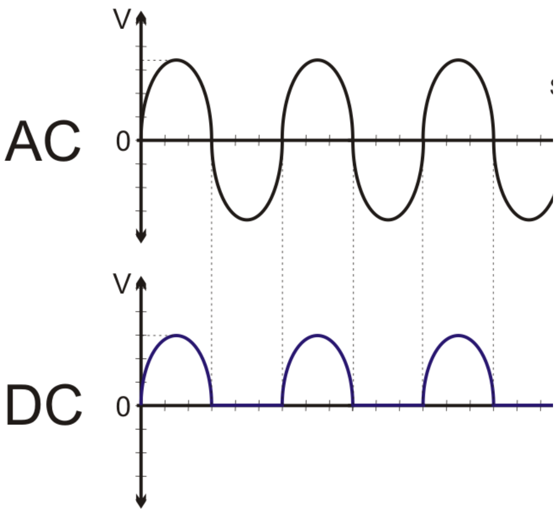
- Same setup as a **motor**, with a coil of wire able to rotate between two permanent magnets
- A **turbine spins turning the coil of wire**
- The movement of the wire causes the wire to **cut through the magnetic field**
- It experiences a **change in magnetic field**
- This creates a **potential difference**
- If the coil of wire is connected to a complete circuit, an alternating current (AC) will flow – this is a basic **alternator**, as shown above



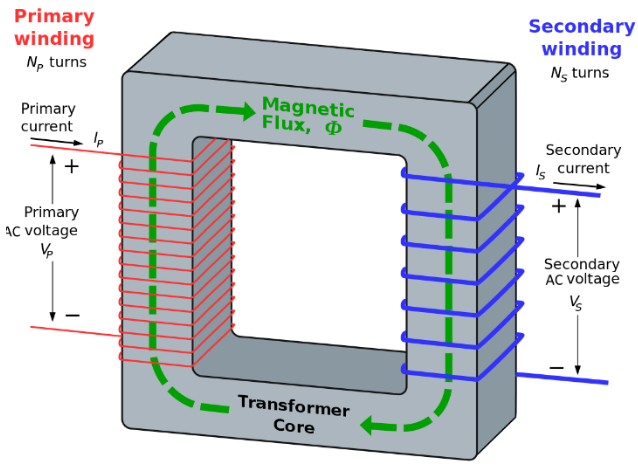
5: electronics-tutorials.com

- **Direct current** (DC) current is produced if the ends, A and D in diagram above, are connected to a **split ring commutator**
- This reverses the current each **half-rotation** so current remains positive – this system is called a **dynamo**

AC produced by Alternator and DC produced by Dynamo:



Transformers (Physics only)



- AC in first coil creates a changing magnetic field
- This changing magnetic field cuts through the secondary coil
- This induces a current in the secondary coil
  - Which is also AC
  - If primary current was DC, magnetic field it produces will be constant, not inducing anything in the secondary coil
- More coils on secondary: Step up transformer, as voltage will be increased, as changing field will cut through more of the secondary wire inducing a larger PD
- Fewer coils on secondary: Step down transformer, as smaller PD induced on secondary

For a 100% efficient transformer:

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

Where N_p is the number of turns on primary coil, N_s, is the number of turns on secondary coil. V_p is the potential difference across primary coil, V_s is the potential difference across secondary coil. I_p is current across primary coil and I_s is the current across secondary.

How Dynamic Microphones Work (Physics only)

- They produce a current which is proportional to the sound signal
- Fixed magnet is at the centre, and the coil of wire around the magnet is free to move
- Pressure variations in the sound waves cause the coil to move, and as it moves current is induced in the coil (because it cuts the magnetic field)
- This current is then sent to a loudspeaker