4.7 Magnetism and electromagnetism

Electromagnetic effects are used in a wide variety of devices. Engineers make use of the fact that a magnet moving in a coil can produce electric current and also that when current flows around a magnet it can produce movement. It means that systems that involve control or communications can take full advantage of this.

4.7.1 Permanent and induced magnetism, magnetic forces and fields

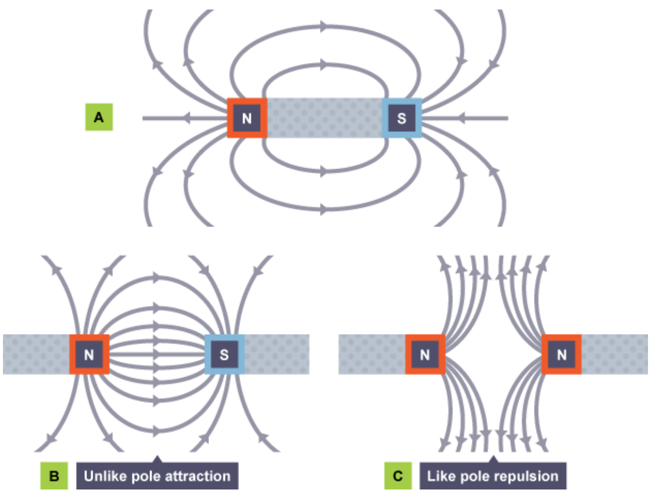
4.7.1.1 Poles of a magnet

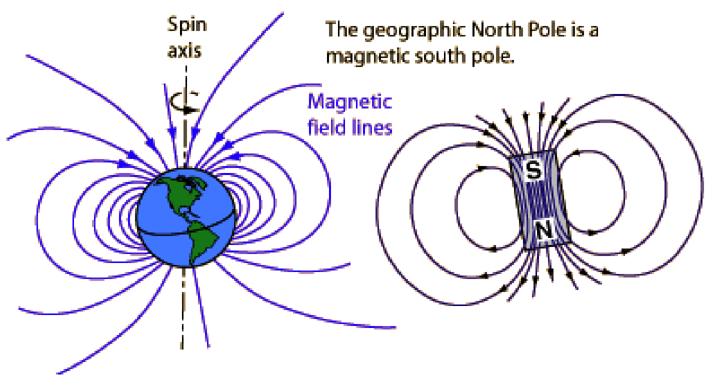
Content	Additional Comments
The poles of a magnet are the places where the magnetic forces are strongest. When two magnets are brought close together they exert a force on each other. Two like poles repel each other. Two unlike poles attract each other. Attraction and repulsion between two magnetic poles are examples of non-contact force.	You already know this.
A permanent magnet produces its own magnetic field. An induced magnet is a material that becomes a magnet when it is placed in a magnetic field. Induced magnetism always causes a force of attraction. When removed from the magnetic field an induced magnet loses most/all of its magnetism quickly. Students should be able to describe: • the attraction and repulsion between unlike and like poles for permanent magnets • the difference between permanent and induced magnets.	This is a complicated way of saying that magnetic objects become magnetised if placed in a magnetic field. If removed from a field, they stop acting like magnets. Induced magnets can only be attracted. Only permanent or electromagnets can repel.

4.7.1.2 Magnetic fields

Content	Additional notes
The region around a magnet where a force acts on another magnet or on a magnetic material (iron, steel, cobalt and nickel) is called the magnetic field. The force between a magnet and a magnetic material is always one of attraction. The strength of the magnetic field depends on the distance from the magnet. The field is strongest at the poles of the magnet. The direction of the magnetic field at any point is given by the direction of the force that would act on another north pole placed at that point. The direction of a magnetic field line is from the north (seeking) pole of a magnet to the south(seeking) pole of the magnet. A magnetic compass contains a small bar magnet. The Earth has a magnetic field. The compass needle points in the direction of the Earth's magnetic field. Students should be able to: • describe how to plot the magnetic field pattern of a magnet using a compass • draw the magnetic field pattern of a bar magnet showing how strength and direction change from one point to another • explain how the behaviour of a magnetic compass is related to evidence that the core of the Earth must be magnetic.	Learn the magnetic materials. Only two magnets can repel Remember: • Field lines never cross • The closer the field lines the stronger the field • Field lines start and end on poles. • Arrows on field lines go from north to south The fact that the south pole of the bar magnet inside the Earth is at the geographic north pole is likely to come up. See diagram below. We know this because a north pole of a compass points to the "top" of the earth. The north pole of compass would be attracted to the south pole of a bar magnet.

You need to be able to draw these diagrams. including the Earth one. Remember the arrows! They will get you a mark.

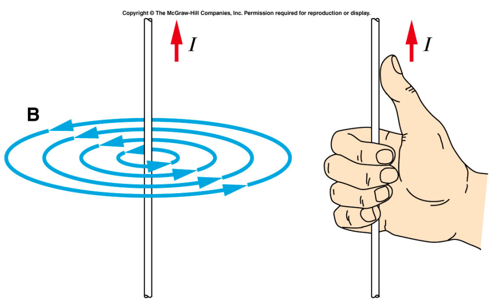


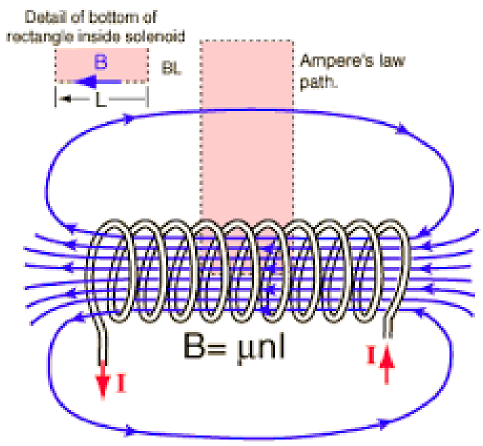


4.7.2 The motor effect

4.7.2.1 Electromagnetism

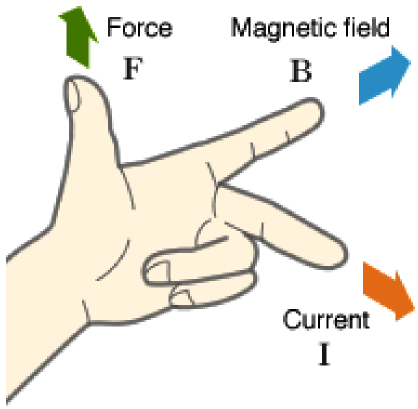
Content	Additional notes
When a current flows through a conducting wire a magnetic field is produced around the wire. The strength of the magnetic field depends on the current through the wire and the distance from the wire. Shaping a wire to form a solenoid increases the strength of the magnetic field created by a current through the wire. The magnetic field inside a solenoid is strong and uniform. The magnetic field around a solenoid has a similar shape to that of a bar magnet. Adding an iron core increases the strength of the magnetic field of a solenoid. An electromagnet is a solenoid with an iron core. Students should be able to: • describe how the magnetic effect of a current can be demonstrated • draw the magnetic field pattern for a straight wire carrying a current and for a solenoid (showing the direction of the field) • explain how a solenoid arrangement can increase the magnetic effect of the current. (Physics only) Students should be able to interpret diagrams of electromagnetic devices in order to explain how they work.	Any wire, any current and there is a magnetic field around it. You need to be able to draw arrows on the field lines. Note the hand on the diagram below. A solenoid is just an electromagnetic without the iron bar. Again, you need to be able to draw the diagram. Note that field lines are close together through the middle, therefore that is where the field is strongest. The magnetic effect is demonstrated using the kicking wire i.e. putting a piece of wire that is free to move in a magnetic field, then putting a current through it. it will move.





The standard electromagnetic device diagrams are the electric bell, the loud speaker and the electric relay switch. However, make sure you understand how they work, not just learn it, because you could easily get something that you haven't seen before. They all work on the principle that a circuit is closed, which makes current flow in the electromagnet. This will then attract something and something else will happen!

4.7.2.2 Fleming's left-hand rule (HT only)

Content	Additional notes
When a conductor carrying a current is placed in a magnetic field the magnet producing the field and the conductor exert a force on each other. This is called the motor effect. Students should be able to show that Fleming's left-hand rule represents the relative orientation of the force, the current in the conductor and the magnetic field. Students should be able to recall the factors that affect the size of the force on the conductor.	 Remember: Force Fields are a Current topic of research! It has to be your left hand!
For a conductor at right angles to a magnetic field and carrying a current: $force = magnetic\ flux\ density \times current \times length$ [$F = B\,I\,l$] force, *F*, in newtons, N magnetic flux density, *B*, in tesla, T current, *I*, in amperes, A (amp is acceptable for ampere) length, *l*, in metres, m	You are given this equation! Put the numbers in and rearrange. Watch your units. Easy marks. The equation also tells you what makes the force stronger. Remember that the length is the length that is actually in the magnetic field.

4.7.2.3 Electric motors (HT only)

Content	Additional notes
A coil of wire carrying a current in a magnetic field tends to rotate. This is the basis of an electric motor. Students should be able to explain how the force on a conductor in a magnetic field causes the rotation of the coil in an electric motor	Make sure you actually understand how the motor works. The slip rings are important. Without them the motor would not spin, just oscillate. Check your revision guide for details.

4.7.3 Induced potential, transformers and the National Grid (physics only) (HT only)

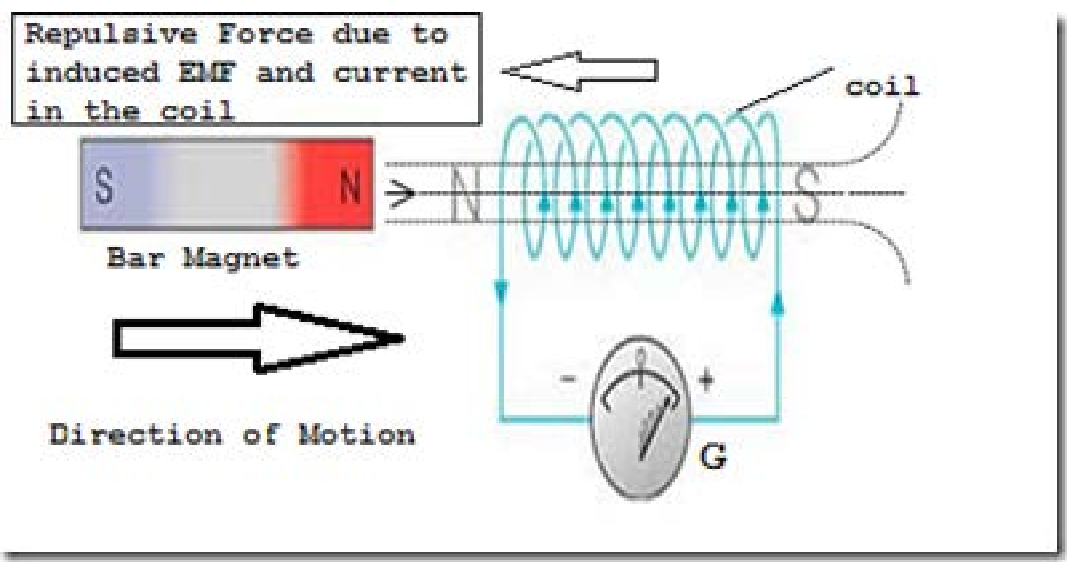
4.7.3.1 Induced potential (HT only)

Content	Additional notes
If an electrical conductor moves relative to a magnetic field or if there is a change in the magnetic field around a conductor, a potential difference is induced across the ends of the conductor. If the conductor is part of a complete circuit, a current is induced in the conductor. This is called the generator effect. An induced current generates a magnetic field that opposes the original change, either the movement of the conductor or the change in magnetic field. Students should be able to recall the factors that affect the size of the induced potential difference/induced current. Students should be able to recall the factors that affect the direction of the induced potential difference/induced current. Students should be able to apply the principles of the generator effect in a given context.	Don't let the word "induced" worry you. It just means made, sort of. However, you must use the word "induced" in all answers. It is usually underlined on the mark scheme. This is undeniably a tricky bit. The questions they ask won't actually be very difficult, I don't think. Learn the facts below and you should get most of them.

Induced current gets bigger if:

- the conductor moves faster through the field
- the field is stronger

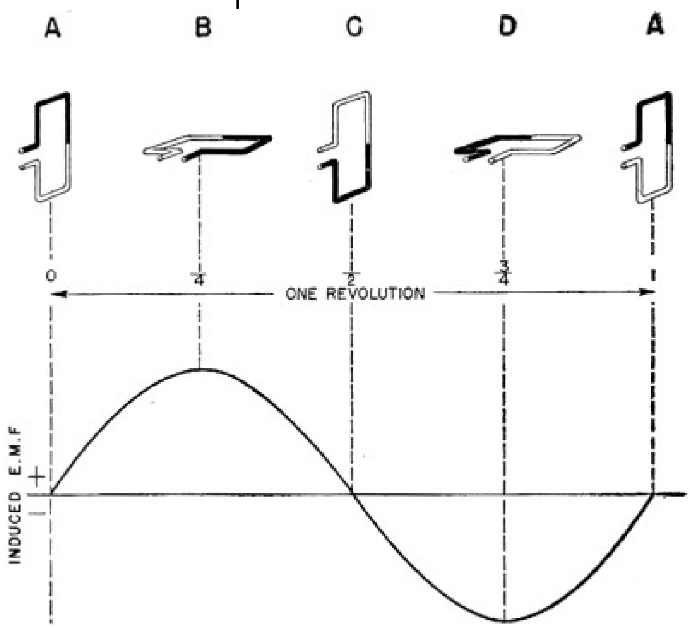
Direction of current is called Lenz's law. There are lots of videos on YouTube. Watch them till you get it.



4.7.3.2 Uses of the generator effect (HT only)

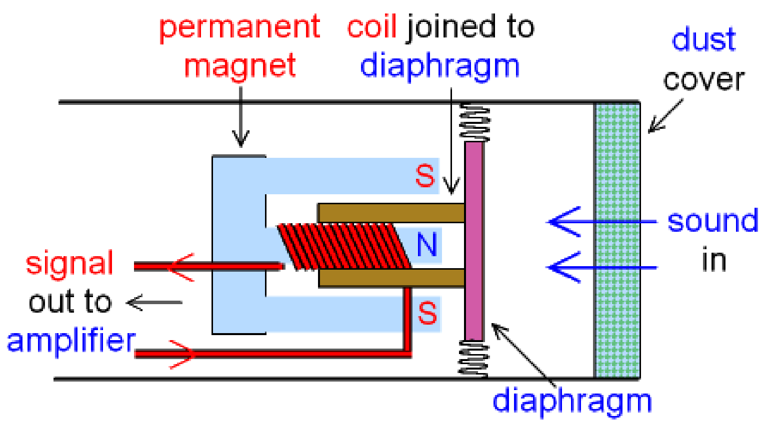
Content	Additional notes
The generator effect is used in an alternator to generate ac and in a dynamo to generate dc. Students should be able to:	
• explain how the generator effect is used in an alternator to generate ac and in a dynamo to generate dc • draw/interpret graphs of potential difference generated in the coil against time.	

This diagram says it all.
The amount of current generated depends on the direction the sides of the coil is moving with respect to the magnetic field lines.
If the side of the coil is moving parallel to the field lines then no current is generated.
Maximum current is when the sides of coil are moving perpendicularly to the field lines.



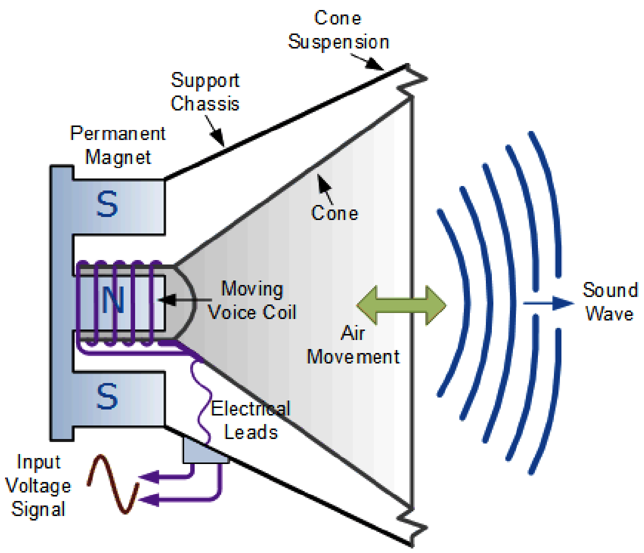
4.7.3.3 Microphones (HT only)

Content	Additional notes
Microphones use the generator effect to convert the pressure variations in sound waves into variations in current in electrical circuits. Students should be able to explain how a moving-coil microphone works.	This is the opposite of the loud speaker. The sound wave makes the diaphragm move, which makes the coil move in the magnetic field which induces a current in the circuit.



4.7.2.4 Loudspeakers (physics only) (HT only)

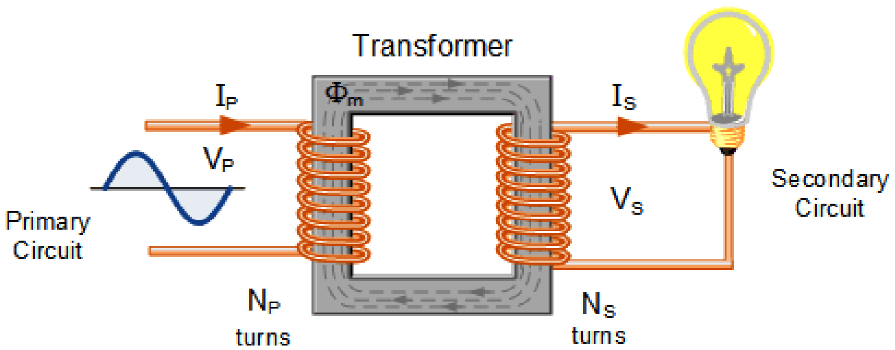
Content	Additional notes
Loudspeakers and headphones use the motor effect to convert variations in current in electrical circuits to the pressure variations in sound waves. Students should be able to explain how a moving-coil loudspeaker and headphones work	The music comes through as a complex electrical signal. Sometimes +ve sometimes -ve etc. This means that the current in the coil is changing in the same way that the sound is. If the current is changing, then the strength of the magnetic field is changing, so the force is changing. So a rapidly changing current makes quick vibrations therefore a loud sound etc.



Headphones work in the same way, just smaller.

4.7.3.4 Transformers (HT only)

Content	Additional notes
A basic transformer consists of a primary coil and a secondary coil wound on an iron core. Iron is used as it is easily magnetised. Knowledge of laminations and eddy currents in the core is not required. The ratio of the potential differences across the primary and secondary coils of a transformer V_p and V_s depends on the ratio of the number of turns on each coil, n_p and n_s.	You get loads of marks for being able to deal with this equation so make sure that you can. You don't have to learn it. Loads of past paper questions available on transformers and they are all the same. Read the mark schemes. If you don't understand how transformers work then learn one of the mark schemes.
$\left[\frac{v_p}{v_s} = \frac{n_p}{n_s} \right]$ potential difference, V_p and V_s in volts, V In a step-up transformer $V_s > V_p$ In a step-down transformer $V_s < V_p$ If transformers were 100% efficient, the electrical power output would equal the electrical power input.	
$V_s \times I_s = V_p \times I_p$ Where $V_s \times I_s$ is the power output (secondary coil) and $V_p \times I_p$ is the power input (primary coil). power input and output, in watts, W Students should be able to: • explain how the effect of an alternating current in one coil in inducing a current in another is used in transformers • explain how the ratio of the potential differences across the two coils depends on the ratio of the number of turns on each • calculate the current drawn from the input supply to provide a particular power output	You might have to combine this equation with the one above in a longer calculation. Both equations have voltage in them. Again, it is important to use the word **induced** whenever possible.
• apply the equation linking the p.d.s and number of turns in the two coils of a transformer to the currents and the power transfer involved, and relate these to the advantages of power transmission at high potential differences.	Remember that it is the voltage that is induced. If there is a complete circuit then a current will flow. If not, there is still a voltage induced.



The magnetic field in the iron core changes as the current changes. This means that the field lines are cutting through the secondary coil, thus inducing a voltage.