Science Electromagnetism Autumn Term 1

Section A: Vocabulary

alternating current (a.c.)	Current which changes direction many times each second.
alternator	A generator that produces alternating current.
carbon brush	A block of carbon that makes electrical contact between a circuit and a moving object such as a slip ring or commutator.
commutator	A device attached to the rotating coil of a generator that makes electrical contact with an external circuit. A commutator switches over the connections every half-turn of the coil so the output is a form of direct current.
core	The innermost part of something e.g. the central part of the Earth.
coulomb (C)	The unit of electric charge. One coulomb is the charge that passes a point in a circuit when there is a current of 1 ampere for 1 second.
diaphragm	A thin sheet of flexible material.
direct current (d.c)	Current that always flows in the same direction.
dynamo	A generator that uses a commutator to change its output from alternating current to direct current.

Section B:

Magnets and Magnetism

Bar magnets are permanent magnets, they will always attract magnetic materials. Bar magnets have two ends or poles, the north (or north-seeking) pole and the south (or south-seeking) pole.
Induced magnets can be made by bringing magnetic material into contact with a magnet or magnetic field.

Plotting compasses can be used to find the shape of magnetic fields by creating a series of dots at each side of the compass needle. The magnetic field of a bar magnet is 3-dmensinoal and runs from the north pole to the south pole. The filed is strongest at the poles.

Two flat magnets produce a uniform field between them.

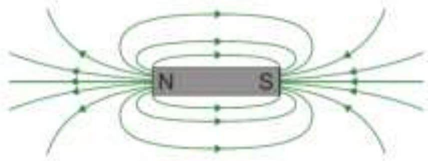
Compasses provide evidence that the earth has a magnetic field, they line up with the magnetic field lines.

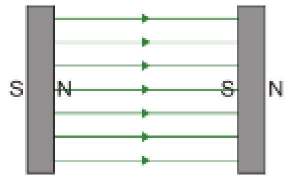
Electromagnetism

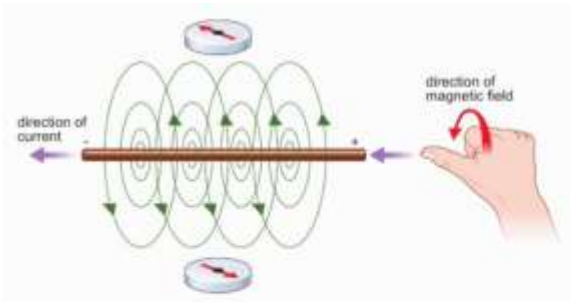
Magnetic fields are generated when current flows through a wire. The magnetic field lines are in concentric circles around the wire.
The direction of the magnetic field can be found using your right hand. Point your thumb in the direction of the current and your fingers curve in the direction of the field.

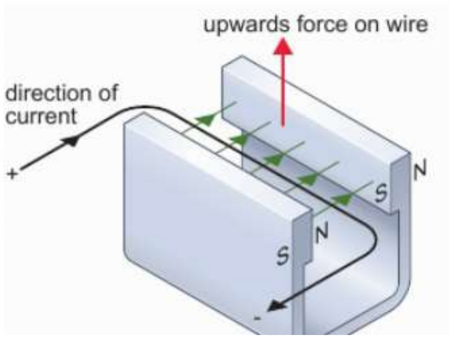
A coil of wire is called a solenoid. The overlapping magnetic fields create one large magnetic field that is very strong inside the solenoid and weaker outside of it.

Section C:









electromagnet	A magnet made using a coil of wire with electricity flowing through it.
Fleming's left-hand rule	A way of remembering the direction of the force when a current flows in a magnetic field. The thumb shows the direction of the force, the first finger shows the direction of the magnetic field (N to S) and the second finger shows the current (+ to −).
generator	A machine that produces electricity by rotating coils of wire in a magnetic field (or by rotating magnets near a coil of wire).
induce	To create. For example, a wire in a changing magnetic field has a current induced in it.
induced magnet	A piece of material that becomes a magnet because it is in the magnetic field of another magnet.
loudspeaker	A machine for converting changes in electrical current or voltage into sound waves.
magnetic field	The area around a magnet where it can affect magnetic materials or induce a current.
magnetic flux density	A way of describing the strength of a magnetic field. It is measured in teslas (T).
magnetic material	A material, such as iron, that is attracted to a magnet.
microphone	A machine for converting sound waves into changes in electrical current or voltage.

Solenoids (and electromagnets) are temporary magnets as they are only magnetic when current is flowing through the wire.

Magnetic forces and motors (H)

When a wire carrying current is placed between two magnets, a force is experienced. The force is greatest when current and magnetic field are perpendicular. Fleming's left-hand rule helps predict the direction of the force.

The size of the force is proportional to the size of current, magnetic field strength and length:

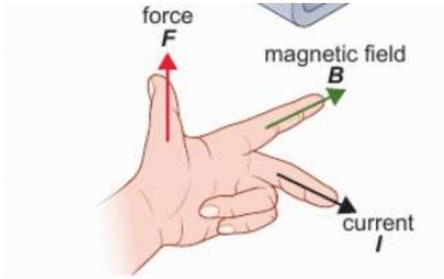
force on conductor carrying current at right angles to magnetic field (N) = magnetic field strength (N/A m or T) × current (A) × length (m)

Electric motors use coils of wire in a magnetic field to produce a turning effect. A split ring is used to keep the motor rotating in a single direction; every half turn, the current changes direction to keep the force going one way.

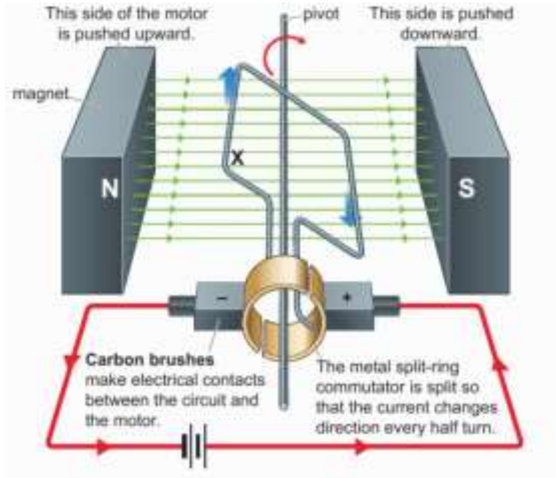
Electromagnetic induction (H)

A changing magnetic field direction can induce a potential difference in a wire, resulting in a current. Generators use a coil of wire that rotates inside a magnetic field. The rotation generates voltage in the wire which is connected to an external circuit. This generate A.C. current and is how electricity is generated at power stations.

Microphones and speakers (H)



B Fleming's left-hand rule. The direction of the current is from + to -.



motor effect	The force experienced by a wire carrying a current that is placed in a magnetic field.
national grid	The system of wires and transformers that distributes electricity around the country.
permanent magnet	A magnet that is always magnetic, such as a bar magnet.
potential difference (p.d.)	The difference in the energy carried by electrons before and after they have flowed through a component. Another term for voltage.
power	The amount of energy (in joules, J) transferred every second. It is measured in watts (W).
primary coil	The coil in a transformer to which the electricity supply is connected.
secondary coil	The coil in a transformer where the changed voltage is obtained.
slip ring	Metal rings connected to the rotation coil in a generator. They make electrical contact with an external circuit.
solenoid	A coil of wire with electricity flowing in it. Also called an electromagnet.
split-ring commutator	A device attached to the rotating coil of a motor that makes electrical contact with an external circuit. A commutator switches over the connections every half-turn of the coil.

Sound waves cause variation in air pressure. In a microphone, this causes a coil of wire to move backwards and forwards past a permanent magnet causing variation in current.

In speakers, a variation in current causes a coil of wire and a diaphragm to move backwards and forwards changing air pressure and creating sound waves.

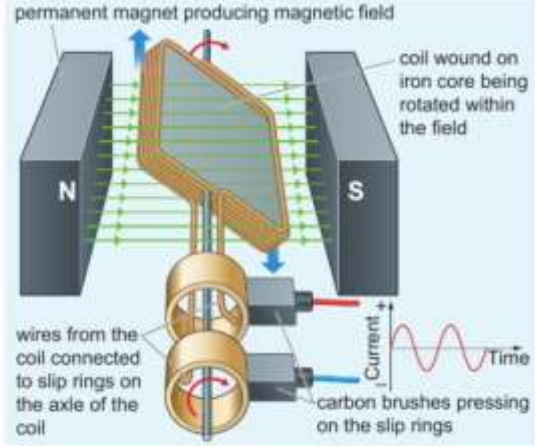
The national Grid
Electricity is generated in power stations and transported around the country at very high voltage (400kV) The higher voltage means there is lower current in the cables reducing the amount of energy lost by heating.
Transformers change the current and voltage at different places in the country so that industry have a higher voltage (11kV or 33kV) whilst schools, offices and homes have a safer 24V supply.

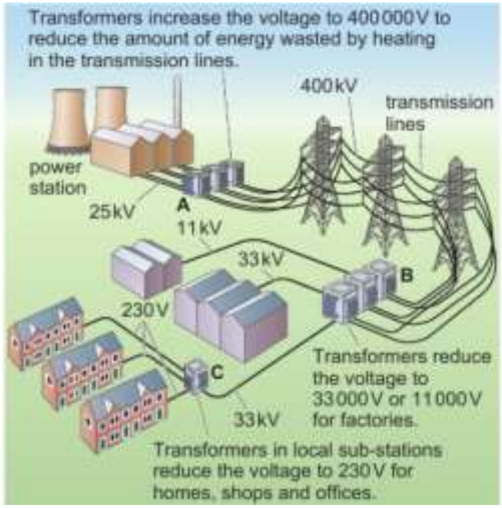
The transformers used to step-up or step-down the voltage are essentially two separate coils of wire around an iron core. The primary coil induces a current in the secondary coil.

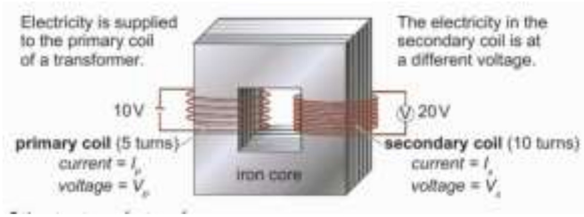
The number of coils in the transformer to induce the desired step change can be calculated using:

$$\frac{\text{potential difference across primary coil}}{\text{potential difference across secondary coil}} = \frac{\text{number of turns in primary coil}}{\text{number of turns in secondary coil}}$$

Transformers and energy transferred







step-down transformer	A transformer that reduces the voltage.
step-up transformer	A transformer that increases the voltage.
temporary magnet	A magnet that is not always magnetic, such as an electromagnet or an induced magnet.
tesla (T)	The unit for magnetic flux density, also given as newtons per ampere metre (N/A m).
transmission lines	The wires (overhead or underground) that take electricity from power stations to towns and cities.
voltage	The difference in the energy carried by electrons before and after they have flowed through a component. Another term for potential difference.

Current is the measure of coulombs per second and potential difference is the energy transferred by each coulomb of charge. The energy transferred per second, the power, is given by:

$$\text{electrical power (W)} = \text{current (A)} \times \text{potential difference (V)}$$

As energy cannot be created or destroyed, power transferred to the primary coil is the same as power transferred away from the secondary coil, assuming no energy wasted by heating. The potential difference and current in the coils are related by:

$$\text{potential difference across primary coil (V)} \times \text{current in primary coil (A)} = \text{potential difference across secondary coil (V)} \times \text{current in secondary coil (A)}$$

(H) The worked calculations show how to calculate the energy wasted when transmitting power. This can be used to explain why it is more efficient to transmit at higher voltages (i.e. 400kV)

power (W) = $\frac{\text{energy transferred (J)}}{\text{time taken (s)}}$, $P = \frac{E}{t}$

electrical power (W) = current (A) × potential difference (V), $P = I \times V$

electrical power (W) = current squared (A)^2 × resistance (Ω), $P = I^2 \times R$

Worked example W2

An electricity substation supplies 2 MW of power to a small housing estate. Electricity is sent to the substation along cables with a resistance of 0.08 Ω. The supply is at 230 V. Calculate the energy wasted every hour.

Current required: $I = \frac{P}{V}$

$= \frac{2 \times 10^6\ \text{W}}{230\ \text{V}}$

$= 8.7 \times 10^3\ \text{A}$

Power transferred by heating in the wires to the substation: $P = I^2 \times R$

$= (8.7 \times 10^3\ \text{A})^2 \times 0.08\ \Omega$

$= 6.05 \times 10^6\ \text{W}$

Energy transferred per hour: $E = P \times t$

$= 6.05 \times 10^6\ \text{W} \times 3600\ \text{s}$

Energy wasted $= 2.18 \times 10^{10}\ \text{J}$