Topic - pressure

define the term pressure in terms of force and area
recall and apply the relationship pressure = force / area to new situations or to solve related problems

- Pressure is defined as the force, F acting normally per unit area, A
- P=F/A
- SI unit: Pascal, Pa
- 1Pa = $1Nm^{-2}$

recall and apply the relationship pressure due to a liquid column = height of column × density of the liquid × gravitational field strength to new situations or to solve related problems

- Liquid pressure at a point is caused by the weight of the liquid pressing from above
- Pressure of water at given height/ depth, p = $h\rho g$
  - h= height
  - ρ = density of water
  - g = gravitational field strength
- Pressure of liquid is identical at the same level, pressure increases as depth increases
- Absolute pressure describes the actual pressure at a point ($P_{gas} + P_{liquid}$)

describe and explain the transmission of pressure in hydraulic systems with particular reference to the hydraulic press

- If pressure is applied to an enclosed liquid, the pressure is transmitted equally to all other parts of the liquid (Pascal's principle)
- $F_1 \times d_x = F_2 \times d_2$

describe how the height of a liquid column may be used to measure the atmospheric pressure

- Pressure exerted by the atmosphere at sea level = 1 atm = 1.013×10^5
- A mercury barometer uses the height of a mercury column to measure atmospheric pressure
- Atmospheric pressure = 760mm Hg
  =h x density of mercury x g
  = $0.76 \times 13.6 \times 10^3 \times 9.8$
  =1.013×10^5 Pa

describe the use of a manometer in the measurement of pressure difference

- Is used to measure difference in gas/ liquid pressure
- Pressure difference = height difference between liquid columns
- Is a simple pressure gauge in the shape of a U-tube. Typically of glass, but can be adapted with plastic tubing. It is partially filled with liquid.

Topic - kinetic model of matter

EU - The kinetic model of matter is often used in interpreting and explaining observations of matter and in predicting future observations.

Compare the properties of solids, liquids and gases

Describe qualitatively the molecular structure of solids, liquids and gases, relating their properties to the forces and distances between molecules and to the motion of the molecules

	Gas	**Solid**	**Liquid**
Properties	-No fixed shape and volume -low density -compressible	-fixed shape and volume -high density -incompressible	-fixed volume, no fixed shape -high density -incompressible
Particle arrangement	-randomly arranged and very far apart from one another -small number of particles per unit volume -this results in gases having very low densities	-closely packed together, usually in a regular pattern, occupying a minimal space -large number of particles per unit volume -this results in solids having the highest densities	-randomly arranged, with the particles slightly further apart than in solids -slightly smaller number of particles per unit volume compared to solids -this results in liquids having relatively high densities
Particle movement	-particles have very little attraction between them, and move about randomly at very high speeds. The particles occupy any available space -this explains why gases have no fixed shape or volume, and are highly compressible	-particles vibrate about fixed positions, particles are held in position by very strong attractive forces between the particles -this explains why solids have fixed volumes and shapes	-particles are free to move about within the liquid, there are attractive forces between the particles -this explains why liquids have fixed volumes, but take the shape of the container

Infer from Brownian motion experiment the evidence for the movement of molecules

The kinetic model of matter

- All matter is made up of tiny particles called atoms or molecules
- The kinetic model of matter states that the tiny particles that make up matter are always in continuous, random motion

Brownian motion

- It refers to the random motion of particles such as pollen and dust specks, suspended in fluids (e.g. air, water)
    - Air particles cannot be seen; smoke particles can be seen

- This random motion is due to the fluid particles moving about randomly and bombarding the suspended particles
- Brownian motion provides evidence for the kinetic model of matter

describe the relationship between the motion of molecules and temperature

- When the temperature is increased, the particles move faster
- When the temperature is decreased, the particles move more slowly
- In both cases, the particle movement remains random and continuous

explain the pressure of a gas in terms of the motion of its molecules

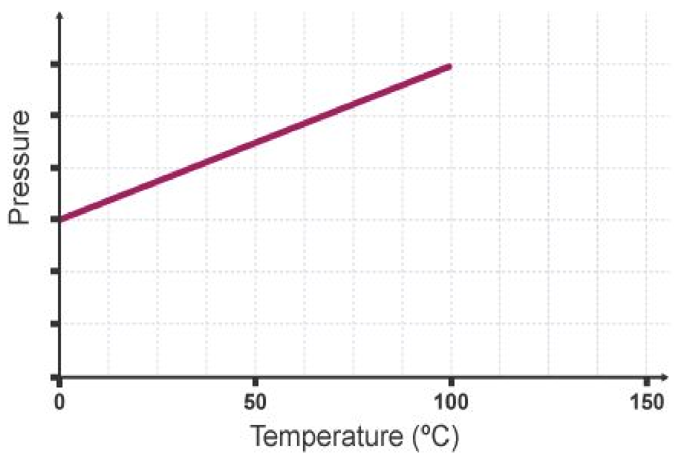
- Moving gas molecules collide with the inner wall of the container and exert a force on it
- The gas exert force per unit area, called gas pressure

recall and explain the following relationships using the kinetic model
a change in pressure of a fixed mass of gas at constant volume is caused by a change in temperature of the gas
a change in volume occupied by a fixed mass of gas at constant pressure is caused by a change in temperature of the gas
a change in pressure of a fixed mass of gas at constant temperature is caused by a change in volume of the gas

use the relationships in related situations and to solve problems

Pressure-temperature relationship of a gas ($P \propto T$)

- At a higher temperature, the air molecules have greater speeds (greater average KE)
- The air molecules will then bombard the walls of their container more forcefully and more frequently
- This causes an increase in gas pressure inside the container
- The pressure P of a fixed mass of gas is directly proportional to its temperature T (provided its volume remains constant)

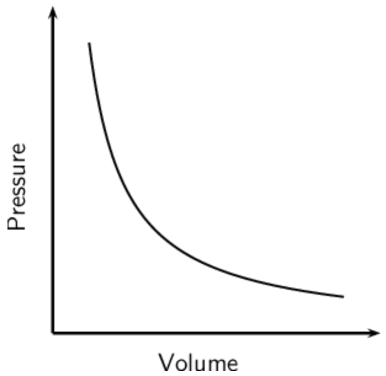


Volume-temperature relationship of a gas

- When the air is heated, the increased temperature causes the air molecules to move at higher speed

- The air molecules will then bombard the walls of their container more forcefully and more frequently, increase in gas pressure inside
- To maintain a constant pressure, the air expands and the air molecules move farther apart. As the air molecules occupy a larger volume, they collide with the walls less frequently
- The volume V of a fixed mass of gas is directly proportional to the temperature K of the gas (provided its pressure remains constant)

Pressure-volume relationship of a gas ($P \propto 1/V$)
- When the volume of the gas is decreased, the number of air molecules per unit volume increases
- The air molecules will therefore bombard the walls of the container more frequently
- This causes an increase in the force exerted on the walls of the container, and hence an increase in gas pressure
- The pressure P of a fixed mass of gas is inversely proportional to its volume V (provided its temperature remains constant)
- $P_1V_1 = P_2V_2$ (where P_1 is initial pressure, P_2 is final pressure)



Q. Explain why the dust particles are suspended in the air and do not settle to the bottom.
A. Air molecules hit the dust particles continuously in all directions randomly. Thus, dust particles are in motion constantly.

Topic - thermal properties of matter

recap of LSS
Temperature -average KE of particles
Heat - transfer of thermal energy from hot to cold region
Thermometric properties - varies with temperature
Thermal Transfer - conduction (solids), convection (fluids), radiation (all states/ vacuum)

describe a rise in temperature of a body in terms of an increase in its internal energy (random thermal energy)
- Internal energy of a body is the sum of the kinetic energy due to the motion of the molecules and the potential energy due to the intermolecular forces in the body
  - Internal energy = kinetic energy + potential energy
- Kinetic energy
  - Kinetic component of internal energy is due to the vibration of the particles
  - It is directly related to temperature (i.e. the higher the temperature, the more

vigorous)
    - In liquids and gases the kinetic energy is due to their movement instead of vibrations
    - Heat capacity

- Potential energy
    - Potential component of internal energy is due to the stretching and compressing of the interatomic or intermolecular bonds as particles vibrate
    - The amount of energy stored is dependent on the force between the particles and the distance between the particles
    - Related to change of state
    - Latent heat

- Transfer of thermal energy into a body will cause a change in the internal energy
- Change in the internal energy can affect kinetic or potential energies

define the terms heat capacity and specific heat capacity

Q. The pans are of a similar type but different size. Each pan is filled with water. They are placed on heaters having the same power. In which pan would the water boil first?

A. The smaller one. The larger pan of water needs a greater quantity of energy to cause its temperature to change by a given amount. We say that the larger pan has a greater heat capacity than the smaller one.

Heat capacity of a body

- The heat capacity of a body is the quantity of energy needed to cause its temperature to change by 1 degree celsius
- Units of heat capacity are $J^{\circ}C^{-1}$ or JK^{-1}
- Heat capacity of a body depends on
    - what substance(s) it is made of
    - masses of the different substances in the body
- The quantity of energy, Q needed to change the temperature of a body of heat capacity, C, by $\triangle T$ °C
    - $Q = C\triangle T$

Specific heat capacity of a body

- Is the quantity of energy needed to change the temperature of 1kg of the substance by 1°C or 1K
- Units of specific heat capacity are $Jkg^{-1}{}^{\circ}C^{-1}$ or $Jkg^{-1}K^{-1}$
- The quantity of energy Q, needed to change the temperature of m kg of a substance of specific heat capacity, c, by $\triangle T$ °C
    - $Q = mc\triangle T$

Solution

1. Write an expression for the heat gain by the water
2. Write an expression for the heat loss by the block
3. Assuming no heat loss to surroundings, Write an equation for heat gain equals heat

loss ($Q_{block} = Q_{water}$)

Q. Imagine you have 1kg each of iron, glass and water, and that all three samples are at 10℃. Rank them from lowest to highest temperature after 100J of energy is added to each sample.
Specific heat:
Water is 4186J/ kg℃
Glass is 837J/ kg℃
Iron is 448J/kg℃ (1kg of iron requires 448J of energy to increase T by 1℃)
A. Iron, glass, water

recall and apply the relationship thermal energy = mass × specific heat capacity × change in temperature to new situations or to solve related problems
describe melting/ solidification and boiling/ condensation as processes of energy transfer without a change in temperature

Change of state (phase)

- Matter change from one state to another
- To change the state of a substance, energy must be either supplied or removed

explain the difference between boiling and evaporation

- Boiling is the change of state from liquid to gaseous state, occurring at a fixed temperature called the boiling point

- Evaporation is the change of state of a liquid into gaseous state, at any temperature
- Evaporation causes cooling
- Rate of evaporation depends on following factors
    - Temperature
    - Surface area
    - Nature of liquid
    - Humidity of surrounding (greater humidity = greater pressure)
    - Pressure (greater pressure, lower rate of evaporation)

boiling	Evaporation
Occurs at fixed temperature	Occurs at any temperature
Occurs throughout the liquid	Occurs at the surface of the liquid
Occurs quickly	Occurs slowly
Bubbles are formed in the liquid	No bubbles formed in the liquid

define the terms latent heat and specific latent heat (both quantitative and qualitative treatments are needed)

Latent heat, L

- Latent heat is the quantity of energy absorbed to change the state of a substance without any change in temperature
- The heat which flows to or from a material without a change in temperature
- The heat will only change the structure or phase of the material e.g. melting or boiling of pure materials

Specific latent heat, l

- Specific latent heat is the quantity of energy, Q, needed to change the state of 1kg of a substance without a change in temperature
- Unit of specific latent heat is J/kg
- $Q = mL_f$ or mL_v

Latent heat of fusion, L_f → amount of energy required to change the state of a substance from solid to liquid

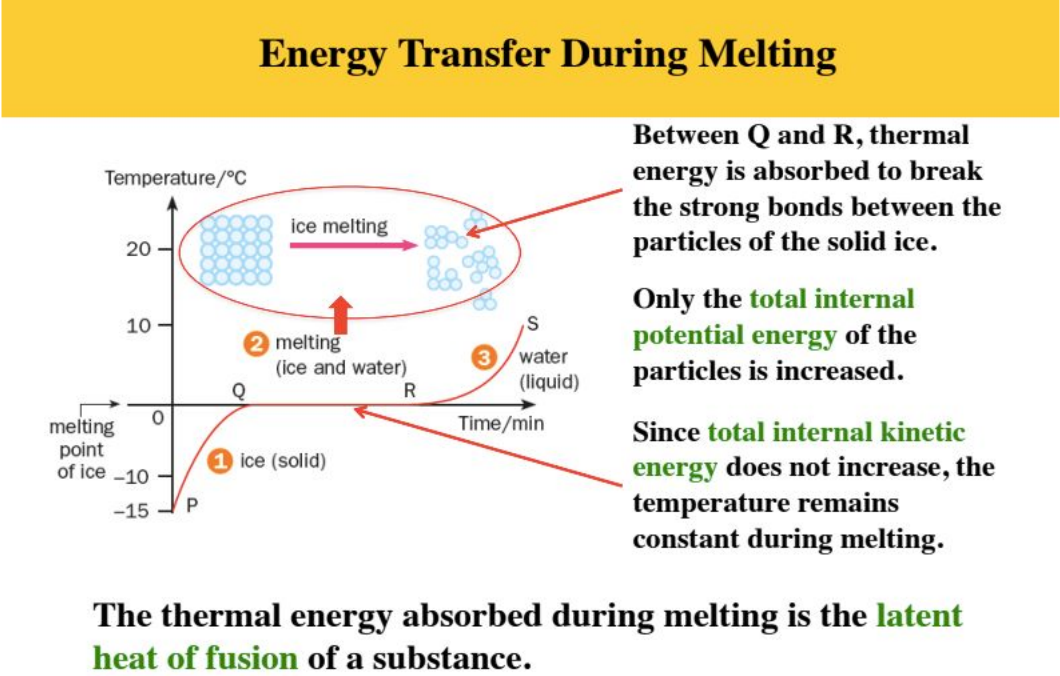
Specific latent heat of fusion, l_f → amount of energy required to change 1kg of substance from a solid (ice) to liquid (water) without changing the temperature (vice versa)

Latent heat of vaporization, L_v → amount of energy required to change the state of a substance from liquid to gas **without change in temperature**

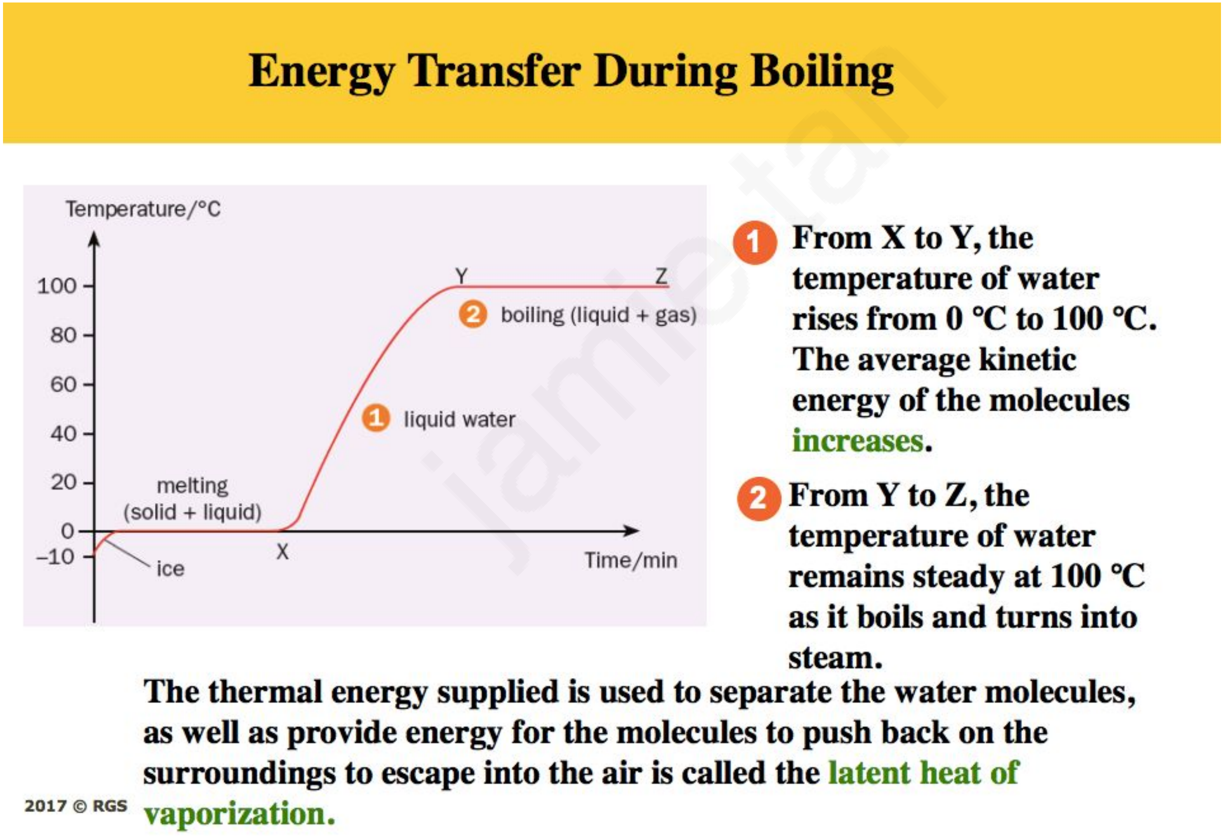
Specific latent heat of vaporization, L_v → amount of energy required to change 1kg of substance from a liquid (water) to a gas (steam) without a change in temperature (vice versa)

Energy transfer during melting

- Between Q and R, thermal energy is absorbed to break the strong bonds between the particles of the solid ice
- Only the total internal potential energy of the particles is increased
- Since the total internal kinetic energy does not increase, the temperature remains constant during melting
- The thermal energy that is absorbed during melting is called the latent heat of fusion of a substance.



Energy transfer during boiling



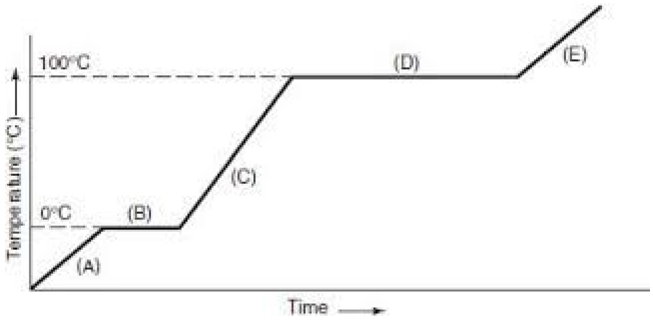
- From X to Y, the temperature of water rises from 0℃ to 100. The average kinetic energy of the molecules increases
- From Y to Z, the temperature of water remains steady at 100 as it boils and turns into steam
- The thermal energy supplied is used to separate the water molecules as well as provide energy for the molecules to push back on the surroundings to escape into the air is called the <u>latent heat of vaporization</u>

$PE_{gas} > PE_{liquid} > PE_{solid}$

Specific heat capacity of ice	2100J/kg℃
Specific heat capacity of water	4200J/kg℃
Specific latent heat of ice	336000J/kg
Specific latent heat of steam	2260000J/kg

Q. How much energy is needed to change 5g of ice to water at 20℃?
$Q = ml_f + mc\triangle T = 0.05 \times 336000 + 0.05 \times 4200 \times 20 = 2100J$

Heating curve of water



A - solid
B - solid + liquid (melting)
C - liquid
D - liquid + gas
E - gas

Overall energy change: Thermal energy → Internal energy (PE + KE)
KE component - A, C, E (change in temp, apply $Q = mc\triangle T$)
PE component - B,D (change in state, apply Q = ml)

Q. Is specific latent heat of vaporisation higher than specific latent heat of fusion?
A.More work needs to be done to overcome the atmospheric pressure for liquid molecules to escape as gas molecules and the intermolecular forces.

Topic - static electricity

state that there are positive and negative charges and that charge is measured in coulombs
state that unlike charges attract and like charges repel

Atoms

- Subatomic particles
    - Proton - positively charged sub atomic particle
    - Neutron - neutral
    - Electrons - negatively charged
- An atom typically has the same number of electrons as protons so the total charge is zero

- ○ But if the atom loses some electrons, it will be a positive ion
- ○ If the atom gains electrons it will be a negative ion

Static electricity is a collection of + charges on one surface and - charges on another surface

Law of electrostatics
- Like charges repel, unlike charges attract
- A neutral object (an uncharged conductor) will be attracted to any charged object (will be attracted to + ve and -ve charged)
- Hence, repulsion is the only true test for a charged object

Measuring electric charge
- $I = Q/t$
  - Q: charge
  - I: electric current
- SI unit for measuring electric charge: coulomb, C
- Charge of 1 proton is 1.6×10^{-19}
- Charge of 1 electron is -1.6×10^{-19}

Insulators and conductors

	Electrical insulators	Electrical conductors
Motion of charged particles	Charged particles are not free to move about	Charged particles are free to move about
Electrons	-Electrons in fixed positions -Addition or removal of electrons at any one part of the insulator does not result in the electrons in other parts of the same insulator to move -electrons are confined/ localised to the region	-Valence electrons are loosely bound -When electrons are gained/ lost by the conductors, the other electrons will flow automatically so that electron redistribution in the conductors occur -Electrons are delocalised
Method of charging	By friction	By induction/ contact
examples	Glass, perspex, silk, wool	Copper, iron, steel, graphite and fluids that contain mobile ions

show understanding that electrostatic charging by rubbing involves a transfer of electrons

Charging by friction (for insulators)
- will only work when two insulators are rubbed against each other
- the outer electrons of the cloth are scrapped off and moved on to the polythene
- How do we know which material will have electrons transferred to or removed from it?
  - The triboelectric series - a list of materials showing which have a greater tendency to

Charging

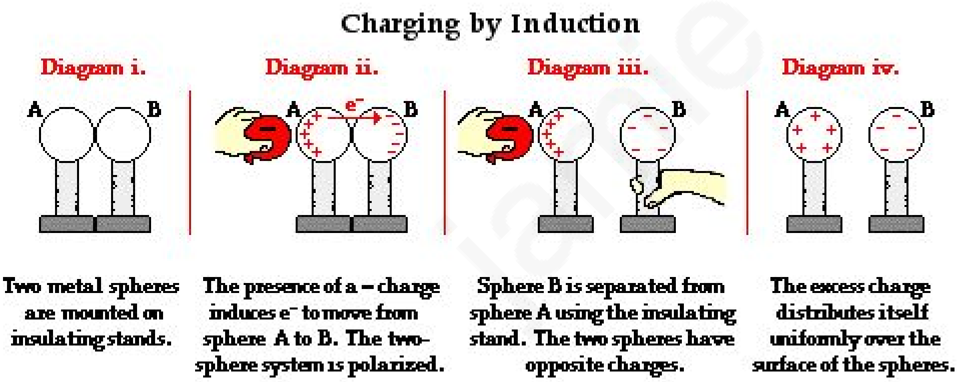
Triboelectric Series
human skin
rabbit fur
glass
human hair
nylon
sheep's wool
silk
aluminum
paper
cotton
wood
amber
Nickel, Copper, Brass, Silver, Gold, Platinum
rubber
polyester
PVC (polyvinylchloride plastic)
teflon

Under ideal conditions, if two materials are rubbed together, the one higher on the list should give up electrons and become positively charged.

describe experiments to show electrostatic charging by induction

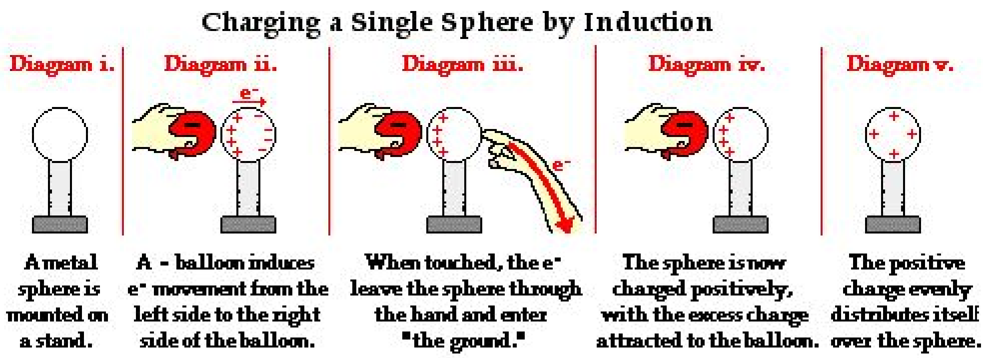
Charging by induction (for conductors) - 2 conductors

1. Place 2 conductors on insulating stands side by side such that they are touching each other
2. Bring a negatively-charged rod near (but not touching) sphere A. This causes the electrons in both metal spheres to be repelled to the far end of sphere B. Since A lost some electrons, it is positively charged and since B gained some electrons, it is negatively charged.
3. While holding the charged rod in place, pull sphere B away from sphere A
4. Remove the charged rod. A and B now have an equal number of opposite charges.



Charging by induction (for conductors) - single conductor

1. Bring a positively charged glass rod near a metal conductor on an insulating stand. The free electrons in the metal are drawn towards the end near the positively-charged glass rod.
2. Without removing the glass rod, earth the positively-charged end of the metal conductor by touching it with your hand. Free electrons move from earth to the conductor, neutralising the positive charges on that end of the conductor
3. With the glass rod still in place, remove your hand from the conductor. This stops the earthing process
4. Remove the glass rod. The electrons redistribute themselves throughout the conductor, it is now negatively charged.



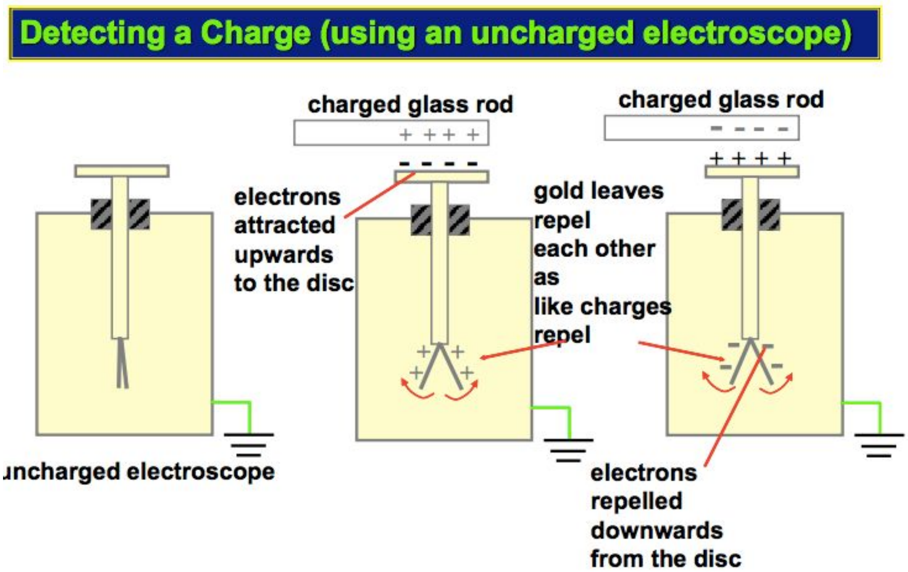
Discharging

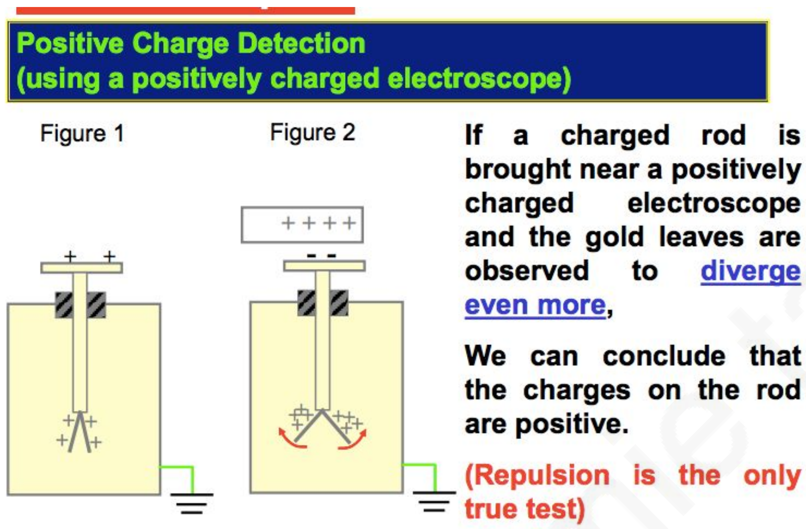
- Discharging is the process in which a charged body is removed of excess charges from it
- When a charged body is discharged, it is said to be neutralised
- Discharging an insulator
    - A charged insulator can be discharged by passing it quickly over a flame
    - The air above a flame consists of many ions (both positive and negative)
    - Ions present in the flame will be attracted and transferred to the charged insulator
    - These ions will neutralise the charges in the insulators, thus discharging them
    - The hot gases in the flame are ionised (ionised is opposite of discharged)

- Discharging a conductor - earthing
    - To discharge a conductor, you only need to touch it
    - This is known as earthing
    - When conductor is earthed, the excess electrons will flow out of the conductor, through the body, to the earth OR electrons flow into the conductor

The electroscope

- Used to test for the presence of a charge
- Test the sign of a charge (positive or negative)





describe an electric field as a region in which an electric charge experiences a force
draw the electric field of an isolated point charge and recall that the direction of the field lines gives the direction of the force acting on a positive test charge
draw the electric field pattern between two isolated point charges

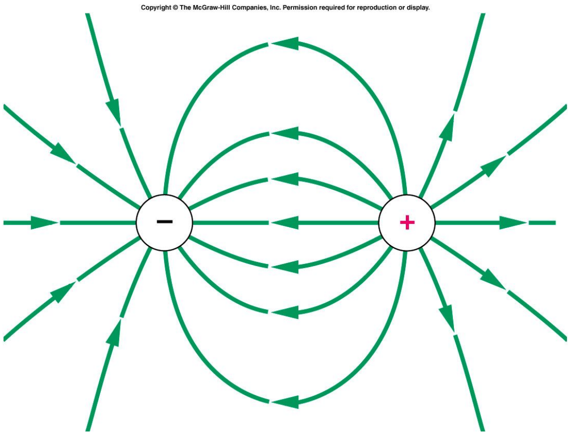
Electric fields

- An electric charge has an electric field around it
- An electric field is the region where an electric force is exerted on any electric charge placed within the influence of the electric field
- Electric fields are represented by field lines (imaginary)

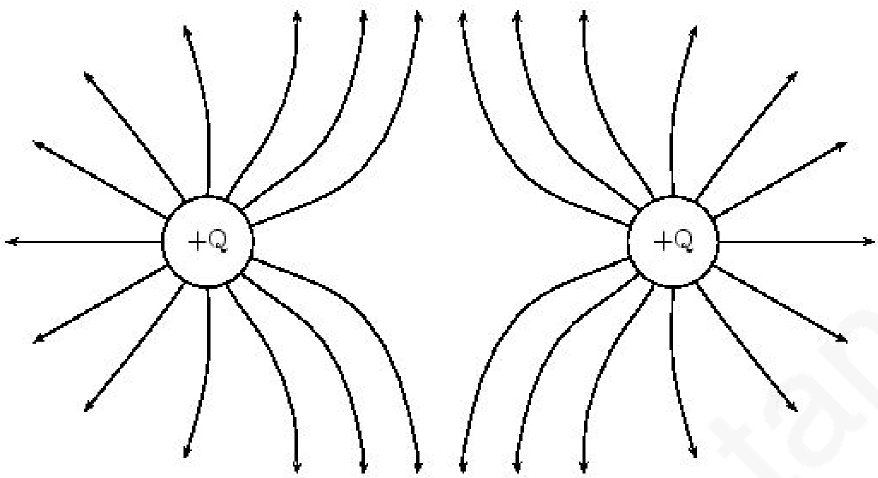
Direction

- Electric field direction is drawn from a positive charge to a negative charge
- Electric field lines (also known as electric flux) do not touch each other
- An electric field line represents the path a small positive charge would move in the electric field

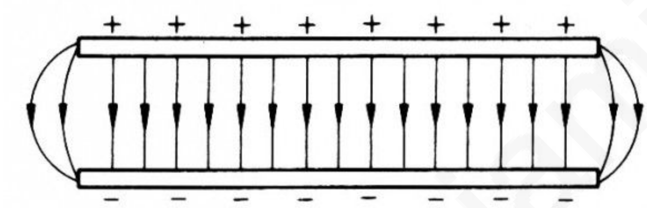
Field around 2 unlike charges



Field around 2 positive charges



Field between 2 charged plates



describe examples where electrostatic charging may be a potential hazard
describe the use of electrostatic charging in a photocopier, and apply the use of electrostatic charging to new situations

Potential hazards of electrostatic charging

- Lightning
    - Is caused by charging (friction) between water droplets and air molecules
    - When the charge built up is large enough, the air will ionise, allowing the charge to discharge to the ground
    - A lightning conductor provides a path to the ground for electrons

- Fires and explosions
    - Charge can build up on many objects such as planes and petrol tankers
    - If not discharged carefully, a spark (similar to that produced by lightning) can start a fire or cause an explosion

Uses of electrostatic charging

- Spray painting
    - To ensure even coat of paint
    - To increase efficiency and reduce paint usage
    - Paint particles and the car body are given opposite charges
- Photocopier

Topic - Current of electricity

state that current is a rate of flow of charge and that it is measured in amperes
distinguish between conventional current and electron flow
recall and apply the relationship charge = current × time to new situations or to solve related problems

Electric current

- An electric current is formed by **moving charges**
- An electric current is a measure of the **rate of flow** of electric charge through a given cross-section of a conductor
- I = Q/t
    - I = current (in Ampere)
    - Q = charge (in Coulombs)
    - t = time (in seconds)
- SI unit of electric current is the ampere (A)

Conventional current and electron flow

- Before the discovery of electrons, scientists believed that electric current was caused by the movement of positive charges
- Although the idea was later proven wrong, the idea remains. This movement of positive charges is called conventional current
- Electric current is actually caused by the flow of electrons from the negative to positive terminal

Measure of electric current

- We make use of an ammeter to measure current
- The ammeter should be connected <u>in series</u> to the circuit

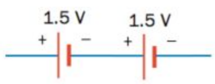
define electromotive force (e.m.f.) as the work done by a source in driving a unit charge around a complete circuit
calculate the total e.m.f. where several sources are arranged in series
state that the e.m.f. of a source and the potential difference (p.d.) across a circuit component is measured in volts

define the p.d. across a component in a circuit as the work done to drive a unit charge through the component

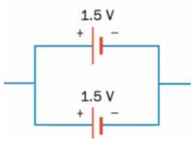
Electromotive force (e.m.f.)

- Of an electrical energy source is defined as work done by a source in driving a unit charge around a complete circuit
- (source) chemical potential energy → electrical potential energy to drive all charges around the complete circuit
- $\mathcal{E}$=W/Q
  - $\mathcal{E}$ = e.m.f. Of electrical energy source (in V)
  - w = work done (amount of non-electrical energy converted to electrical energy) (in J)
  - Q = amount of charge (in C)
- SI unit is V (volts) or J/C

Arrangement of cells

- When cells are arranged in series, the resultant e.m.f. is the sum of all the e.m.f. of the cells
  - $V = V_1 + V_2 + V_3 \ldots$
  - 

- When cells are arranged in parallel, the resultant e.m.f. is equal to that of a single cell
  - $V = V_1 = V_2$



What is potential difference

- The potential difference (p.d.) across a component in an electric circuit is the work done to drive a unit charge through the component
- V = W/ Q
  - V = pd across a component (in V)
  - W = Work done/ amount of electrical energy converted to other forms (in J)
  - Q = amount of charge (in C)
- SI unit is Volt (V) or J/C

How do we measure e.m.f. or potential difference?

- We make use of voltmeter to measure e.m.f. or pd
- The voltmeter should be connected in parallel with the electrical source/ component
  - Positive terminal to positive terminal; negative terminal to negative terminal

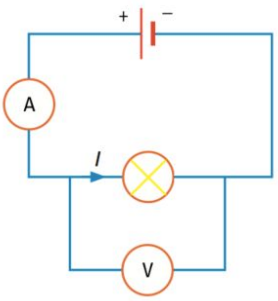
EMF	Potential difference
Associated with an electrical energy source	Associated with 2 points in an electrical circuit (across a component)
It is the work done by the source in driving a unit charge around a complete circuit	It is the work done to drive a unit charge through 2 points

state the definition that resistance = p.d. / current
apply the relationship R = V/I to new situations or to solve related problems
describe an experiment to determine the resistance of a metallic conductor using a voltmeter and an ammeter, and make the necessary calculations
recall and apply the formulae for the effective resistance of a number of resistors in series and in parallel to new situations or to solve related problems
recall and apply the relationship of the proportionality between resistance and the length and cross-sectional area of a wire to new situations or to solve related problems
state Ohm's Law
describe the effect of temperature on the increase on the resistance of a metallic conductor
sketch and interpret the I/V characteristic graphs for a metallic conductor at constant temperature, for a filament lamp and for a semiconductor diode

What is resistance?

- The resistance of a component is the ratio of the potential difference across the component to the current flowing through the component
- R = V/ I
    - R = resistance of a component (in Ω)
    - V = p.d. Across a component (in V)
    - I = current flowing through component (in A)
- SI unit is the ohm (Ω)
- Without resistance, there will be a short circuit
- Resistance is a measure of how difficult it is for an electric current to pass through a material
- It is the property of the material that restricts the movement of free electrons in the material

Circuit for measuring resistance



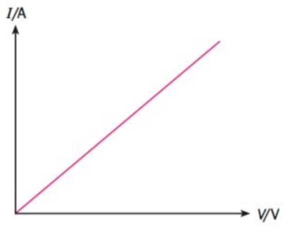
- The ammeter is connected in series with the bulb
- The voltmeter is connected in parallel with the bulb

What are resistors

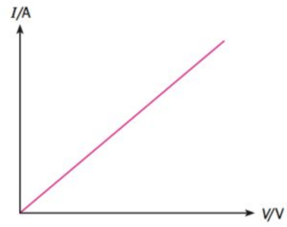
- A resistor is a conductor in a circuit that is used to control the size of the current flowing in a circuit
- There are 2 types of resistors - fixed resistors and variable resistors (rheostats)

Ohm's law

- Ohm's law states that the current passing through a metallic conductor is **directly** proportional to the potential difference across it, provided that physical conditions remain **constant**
- I ∝ V
    - Where I = current
    - V = potential difference



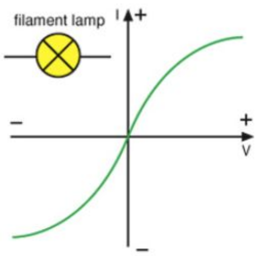
Ohmic conductors (fixed resistors)

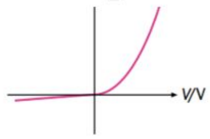


- Ohmic conductors are conductors that obey Ohm’s law
    - The I-V graph of an ohmic conductor is a straight line that passes through origin

Non-Ohmic conductors (variable resistors)

- They do not obey Ohm’s law and their resistance R can vary
- Their I-V graphs are not straight lines, which means the ratio V/I is not a constant





diode

Resistivity

- Other than temperature, the resistance R of a conductor also depends on
    - Its length (longer length, higher resistance)
    - Its cross sectional area A
    - The material it is made of (ie resistivity ρ)
- R = ρl/ A
- ρ = RA/ l
- SI unit of resistivity is the ohm meter (Ω m)

- Different materials have different resistivities
- Resistivity is a property of the material and it is independent of the dimensions of the material
- The lower the resistivity of a material, the better it is at conducting electricity

Topic - Direct Current Circuits

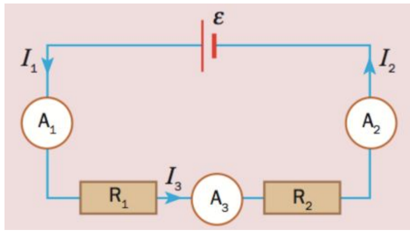
draw circuit diagrams with power sources (cell, battery, d.c. supply or a.c. supply), switches, lamps, resistors (fixed and variable), variable potential divider (potentiometer), fuses, ammeters and voltmeters, bells, light- dependent resistors and thermistors

state that the current at every point in a series circuit is the same and apply the principle to new situations or to solve related problems.
state that the sum of the potential differences in a series circuit is equal to the potential difference across the whole circuit and apply the principle to new situations or to solve related problems.

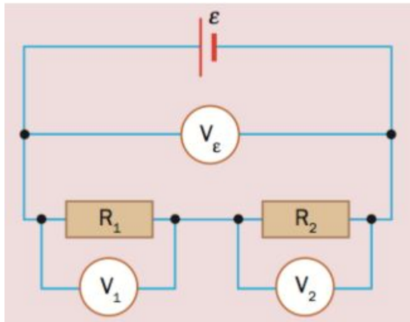
state that the current from the source is the sum of the currents in the separate branches of a parallel circuit and apply the principle to new situations or to solve related problems
state that the potential difference across the separate branches of a parallel circuit is the same and apply the principle to new situations or to solve related problems
recall and apply the relevant relationships, including R = V/I and those for current, potential differences and resistors in series and in parallel circuits, in calculations involving a whole circuit
describe the action of a variable potential divider (potentiometer)
describe the action of thermistors and light-dependent resistors and explain their use as input transducers in potential dividers
solve simple circuit problems involving thermistors and light-dependent resistors

In a series circuit

- The components are connected one after another in a single loop
- There is only one path through which electric current can flow



- All ammeters give the same readings
  - $\mathbf{I_1 = I_2 = I_3}$
  - This is because the same current flows into and out of the resistor

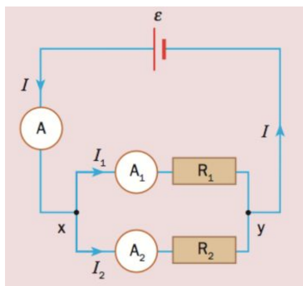


- Potential difference across the whole circuit is equal to the sum of the potential difference across the 2 resistors
  - Voltmeters are connected in parallel to the components they are measuring
  - $\mathbf{V_\varepsilon = V_1 + V_2 + V_3 \ldots}$

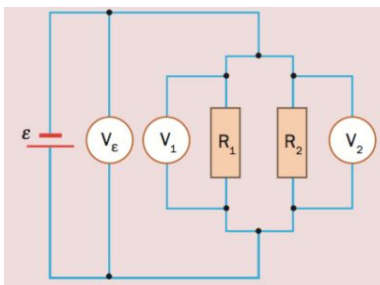
- The effective resistance R is the sum of all the resistances
  - $\mathbf{R_T = R_1 + R_2 + R_3 \ldots}$
- The effective resistance is always greater than the largest resistance

Parallel circuit

- The components are connected to the e.m.f in 2 or more loops
  - More than 1 path for current to flow

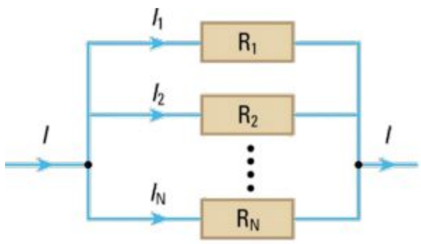


- The current flowing from the cell splits at junction x and rebombines at junction y
  - The ammeter reading on A is equal to the **sum** of the readings on ammeters A_1 and A_2
  - $\mathbf{I = I_1 + I_2}$



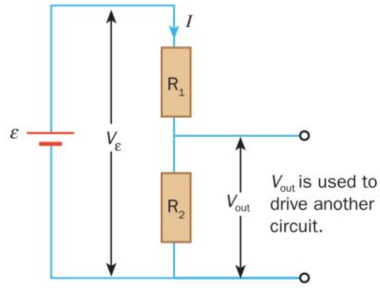
- The potential difference V_E across the whole circuit is equal to the potential difference across each branch
  - $\mathbf{V_\varepsilon = V_1 = V_2}$

- The reciprocal of the effective resistance of resistors in parallel, 1/R, is the sum of the reciprocal of all the individual resistances
  - **$1/ R_T = 1/R_1 + 1/R_2$ ...**
  - The effective resistance is always smaller than the smallest individual resistance



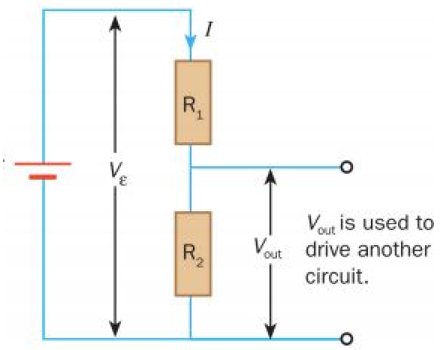
Potential Dividers

- A potential divider is a line of resistors connected in **series**, used to provide a **fraction** of the voltage of a source to another part of the circuit
- **$V_{out} = (R_2/ R_1 + R_2) \times V_\varepsilon$**

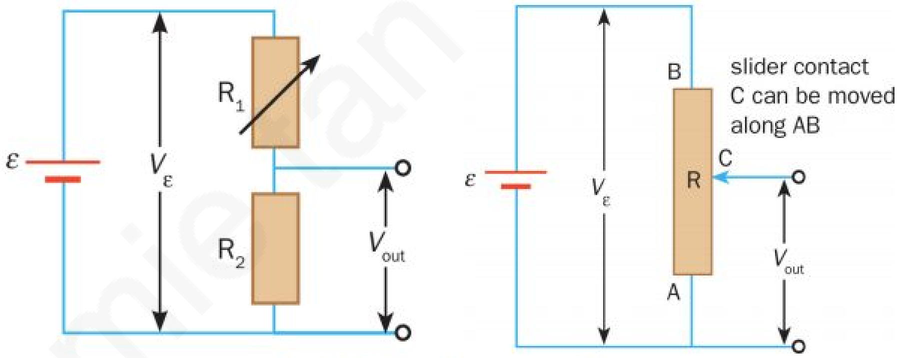


Variable potential dividers

- we can vary the value of V_{out} by changing the resistance of the resistors R_1 and R_2
- To do this, we can change the fixed resistors, or we can make use of variable resistors

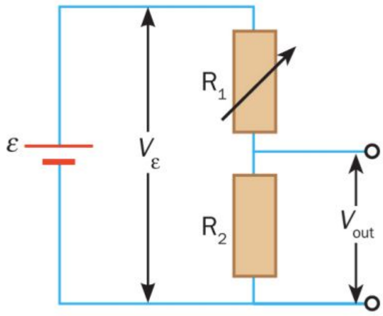


potential divider made with fixed resistors

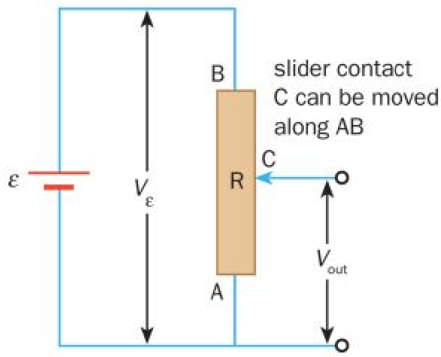


potential dividers made with variable resistors

- Type 1 - using a rheostat
  - A rheostat is a variable resistor that is connected at **2 terminals**
  - Since $V_{out} = $ **$(R_2/ R_1 + R_2) \times V_\varepsilon$**
    - when R_1 is increased, V_{out} decreases
    - When R_1 is decreased, V_{out} increased

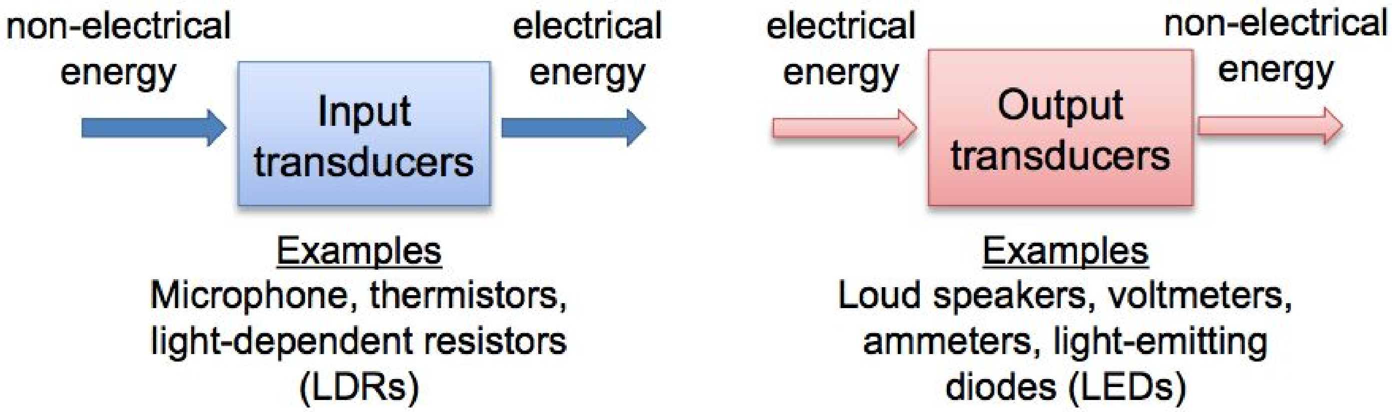


- Type 2 - Using a potentiometer
  - A potentiometer is a variable resistor that is connected at three terminals.
  - In the diagram, contact C is the sliding contact.
  - Since resistance is proportional to length for a fixed cross-sectional area, the position of the slider determines the ratio of resistance of AC to BC.



Transducers

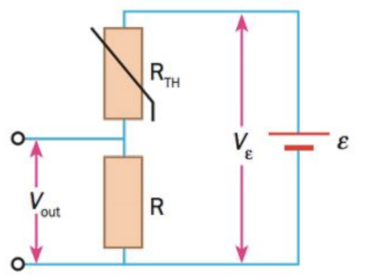
- Transducers are electronic devices that convert energy from one form to another
- Two types: input transducers and output transducers



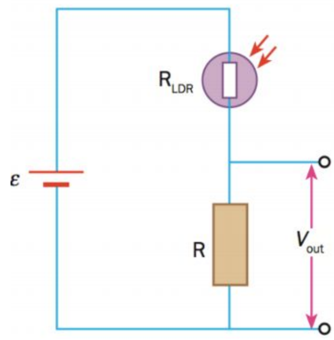
Input transducers

- Input transducers are **electronic devices that convert non-electrical energy to electrical energy.**
  - Input transducers are electronic devices that respond to changes in the physical environment
  - They can be used in potential dividers to vary output voltages, they allow electronic devices to respond to changes in the environment.

- E.g. Thermistors
  - A thermistor is a device whose resistance varies with **temperature**
  - When the resistance of the common resistor R_{TH} decreases, V_{out} increases.
  - Thermistors can be used for temperature control and measurement



- E.g. Light-Dependent Resistors (LDRs)
  - The resistance R_{LDR} of a light-dependent resistor decreases with increasing light intensity
  - when R_{LDR} decreases, V_{out} increases
  - LDRs can be used in devices that measure light intensity and in automatic street lights.

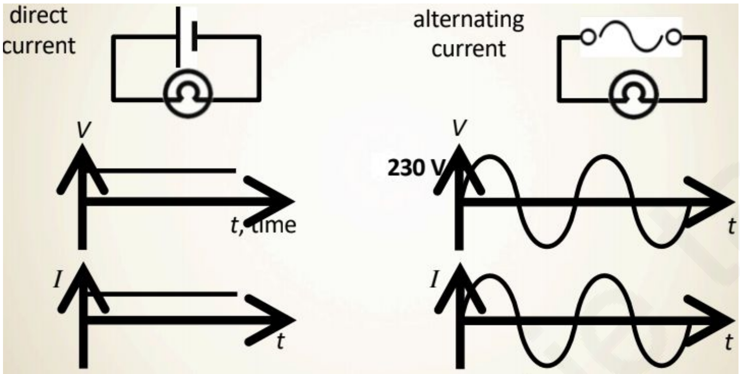


Topic - Practical Electricity

describe the use of the heating effect of electricity in appliances such as electric kettles, ovens and heaters
recall and apply the relationships P = V I and E = V I t to new situations or to solve related problems
calculate the cost of using electrical appliances where the energy unit is the kW h
compare the use of non-renewable and renewable energy sources such as fossil fuels, nuclear energy, solar energy, wind energy and hydroelectric generation to generate electricity in terms of energy conversion efficiency, cost per kW h produced and environmental impact.
state the hazards of using electricity in the following situations: damaged insulation, overheating of cables, damp conditions
explain the use of fuses and circuit breakers in electrical circuits and of fuse ratings
explain the need for earthing metal cases and for double insulation
state the meaning of the terms live, neutral and earth
describe the wiring in a mains plug
explain why switches, fuses, and circuit breakers are wired into the live conductor

Electrical energy supply and safety

- Electrical energy is supplied to homes in the form of alternating current



- Some appliances come with power adaptors to convert a.c. to d.c.

- Why transmit a.c. at high voltages?
    - Transmitting at high voltage result in less power loss in cable
        - $P_{\text{loss in cable}} = I^2r$ where r is resistance of transmission cable
            - $P_{\text{supply by power station}} = IV$ (derivation)
        - P_{supply} is largely determined by user and taken to be constant
            - V increased → I decreased → P_{loss} decreased
    - Voltage can be step up (increased) or step down (decreased) easily for a.c.

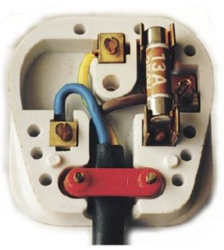
Electrical energy consumption

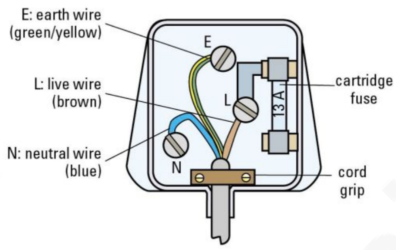
- **P = VI**
  = I^2R
  =V^2/R
- Amount of electricity consumed is measured by the number of kilowatt-hours (kWh) of electrical energy consumed
    - Energy (in kWh) = Power (kW) x time (h)
    - 1kWh = 1000W x 60 min x 60s = 3600000 J

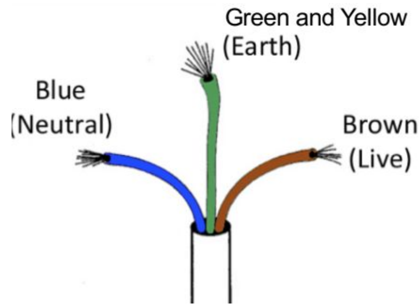
Safety features in home circuits

- Circuit breakers

- Switch off the electrical supply in a circuit when large currents flow through them
    - Without circuit breakers, a surge of current can damage home appliances or start a fire
    - Connected to live wires, so that when there is a current surge, they will trip and cut off the current to the appliances
    - Can be reset by switching them on again
- Fuses
    - If excessive current flows in the appliance, the fuse blows, breaking the circuit and isolates the appliance with the fault, so that overheating does not damage it
    - Fuse of an electrical appliance should have a **rated value that is slightly higher** than the current the electrical appliance draws
    - Fuse should be connected to the live wire so that current to the appliance will be cut off
    - Same function as a circuit breaker, but fuses should be replaced after they blow
- Switches
    - Designed to break or complete an electrical circuit
    - Fitted to the live wire
    - If an electrical fault causes the metal casing of an appliance to be at high voltage, a switch on the live wire is able to disconnect the voltage supplied to the metal casing
- Three-pin plugs







    - components - live wire, earth wire, neutral wire, fuse, cord grip
    - Live wires (brown or red) - connected to a high voltage (230V) and delivers current to the appliance. Circuit breakers, fuses and switches are fitted to live wires.
    - Neutral wires (blue) - completes the circuit by providing a return path to the supply for the current. Usually at 0V.
    - Earth wires (green and yellow) - low-resistance wires, usually connected to the metal casing of appliances to prevent electric shocks
    - Fuse - safety device added to an electrical circuit to prevent excessive current flow
    - Cord grip - secures the cord to the plug
- Earthing
    - Large current flows to the ground through the earth wire, which has a much lower resistance than the person, so the person does not get an electric shock
    - The flow of the large current from the live wire through the metal casing to the earth creates a short circuit. The sudden surge in current exceeds the rated value of the fuse, so the fuse is blown and the circuit is opened, electricity supply to the appliance is cut off

- Double insulation
    - Safety feature that can replace the earth wire (for two-pin plugs - live and neutral)
    - Two levels of insulation

1. Electric cables are insulated from the internal components of the appliance
2. The internal components are insulated from the external casing (plastic)

Dangers of electricity

- Damaged insulation
  - Wires that carry electricity from the voltage supply to electrical appliances are wound together to form cables
  - These cables are enclosed by insulating materials such as PVC or rubber
  - The insulating materials can become worn with time, and expose the conducting wires inside
  - The exposed conducting wires can cause electric shocks if touched
- Overheating of cables
  - Overloaded power sockets - when a power socket is overloaded with many appliances, an unusually large current flows through the wires
  - Use of inappropriate wires
    - The resistance of a conducting wire is inversely proportional to its cross-sectional area, a thin wire has a higher resistance and generates more heat, compared to a thick one
    - Thin wires are used for electrical appliances that need less power, such as lamps
    - Thick wires are used for appliances that need more power such as kettles
- Damp conditions
  - Water in contact with the uninsulated electrical wires provides a conducting path for current
  - Large currents cause burns, uncoordinated contraction of the heart or death\

Uses of heating effect of electricity

- Electrical energy converted to thermal energy via heating elements
  - Electric kettles - water is heated by conduction and convection
  - Electric irons - metal base is heated by conduction
  - Electric radiator - air is heated by radiation and convection

compare the use of non-renewable and renewable energy sources such as fossil fuels, nuclear energy, solar energy, wind energy and hydroelectric generation to generate electricity in terms of energy conversion efficiency, cost per kW h produced and environmental impact.

Topic - magnetism

state the properties of magnets
describe induced magnetism
describe electrical methods of magnetisation and demagnetisation
draw the magnetic field pattern around a bar magnet and between the poles of two bar magnets
describe the plotting of magnetic field lines with a compass
distinguish between the properties and uses of temporary magnets (e.g. iron) and permanent magnets (e.g. steel)

Magnetic materials

- Magnetite consists of an iron oxide
- Natural magnet attracts certain materials
  - Cobalt
  - Nickel

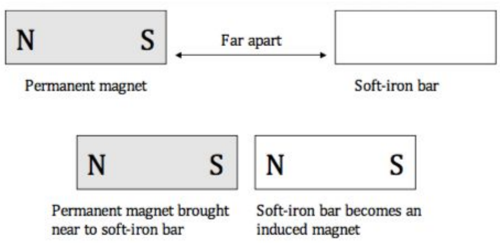
  - Iron
  - Steel
  - Alloys of any of the above

Non-magnetic materials
- Natural magnet cannot attract other materials such as
  - Copper, brass, wood, plastics

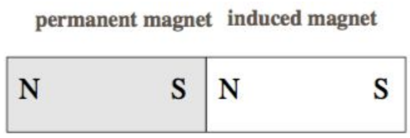
Properties of magnets
- All magnets exhibit the following properties
  1. Attract magnetic materials
  2. They have 2 magnetic poles
     a. The north and south seeking poles
     b. These are the strongest parts of the magnets

  3. A free suspending magnet will come to a rest with one end pointing towards the earth's north pole, the other end pointing towards the earth's south pole. (attract opp ends) Hence, a magnet can be used as a compass for navigational purposes.
  4. Law of magnetic poles
     a. Like poles repel, unlike poles attract
     b. Repulsion is the only true test for polarity

Magnetic Induction
- When a non-magnetised magnetic material is brought near to (or touches) a magnet, the material itself will become a weak magnet. This is called induced magnetism (which means the material has magnetism induced in it)
- An opposite pole is always induced



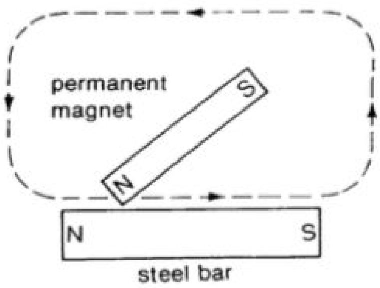
- If placed sufficiently near to each other, attraction occurs between the permanent and induced magnet
  - Induced magnetism in magnetic materials is the reason that these non-magnetised objects are able to be attracted to magnets



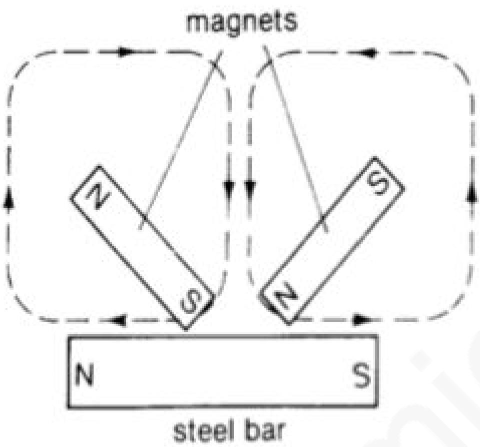
Magnetic domain theory
- If a piece of magnet is dropped broken into 2 or more pieces, each piece still behaves like a magnet, it is **able to exhibit all the properties of a magnet**
- All original magnet is made up of many tiny magnets, all lined up with the same magnetic orientation (i.e. all of the tiny magnets have their N-pole facing the same direction)
- A few adjacent tiny magnets are usually aligned in the same magnetic orientation
  - This group of tiny magnets pointing in the same direction form a magnetic domain
- In an unmagnetised object made of magnetic material, magnetic domains do not have the same magnetic orientation

Methods of magnetisation
- Making a material permanently magnetic is called magnetisation

- Stroking (single-touch)
  - Note the polarities of both the permanent magnet and steel bar that is to be magnetised
  - This form of magnetism gained is weak but permanent

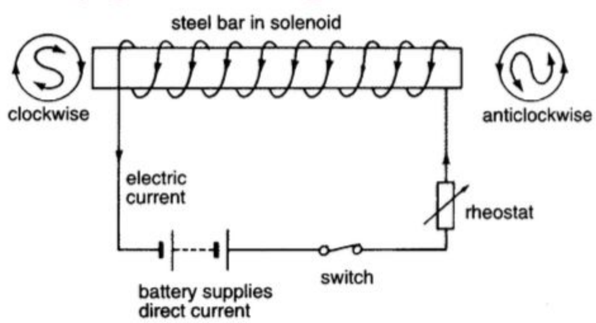


- Stroking (double-touch)
  - 2 permanent magnets are used
  - Note the polarities of both the permanent magnets and their induced end of the steel bar
  - This form of magnetism gained is weak but permanent



- Heating and hammering
  - A magnet can be made by first placing a steel bar in a magnetic field, then heating it to a high temperature and then finally hammering it as it cools
  - This can be done by laying the magnet in a north-south direction in the earth's magnetic field
  - Magnet produced is weak but permanent

- Use of an electrically-generated magnetic field of a solenoid
  - Place the steel object inside a coil of wire (a solenoid)
  - Pass a direct current (d.c.) through the solenoid for a few seconds
  - A magnetic field is produced on the solenoid
  - The steel rod is now placed inside a magnetic field, when the current is turned off, the steel rod is magnetised
  - The polarity of the newly formed magnet can be determined using the right-hand grip rule OR taking a look at which the d.c. is flowing at each end
    - If the direction of flow is anti-clockwise, the end is North pole

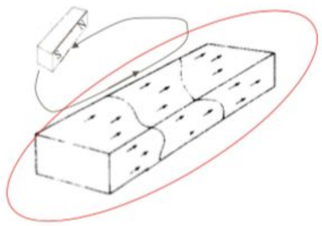


- If the direction of flow is clockwise, the end is South pole

  - To increase strength of magnet, increase number of turns/ increase current (by increasing batteries)
  - This form of magnetism gained is strong and permanent

Magnetic saturation

- No matter how long you continue to magnetise it, the magnet can no longer become stronger as all initial magnetic domains are already aligned in the same orientation

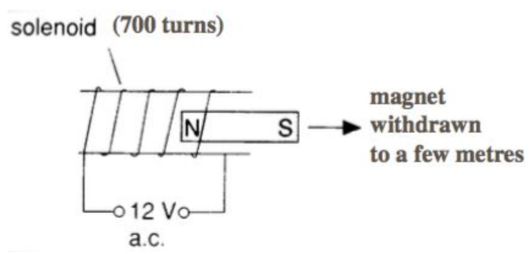


Methods of demagnetisation

- The process of weakening a magnet’s strength (removing magnetism)
- When some magnetic domains are no longer in the same magnetic orientation as the rest of the domains, the magnet’s strength weakens and the magnet is completely demagnetised

- Heating and hammering
  - Heat a magnet
    - strongly heating a magnet cause atoms of the magnet to vibrate vigorously when heated, causing the magnetic domains to lose their alignment
  - Then hammer it as it is allowed to cool in the absence of a magnetic field (facing east-west direction)
    - hammering a magnet placed in the east-west direction alters the alignment of the magnetic domains, causing the magnet to lose its magnetism

- Electrically-generated magnetic field of a solenoid
  - Place magnet in a solenoid in the east-west direction
  - Pass an altering current (a.c.) through the solenoid (not through magnet)
  - Slowly remove the magnet from the solenoid with the a.c. supply still on. Remove to a great distance
  - Repeat the procedure for as many times as it is necessary. Each time it is done, the magnet’s strength weakens

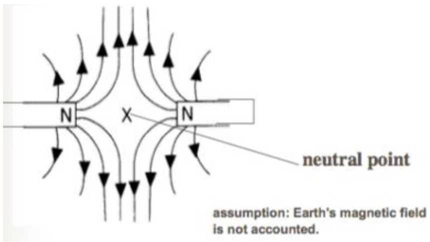


Magnetic fields

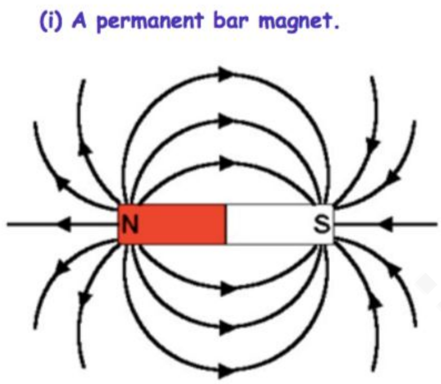
- A magnetic field is the region where a magnetic force is exerted on any magnetic objects placed within the influence of the field
  - Showing the magnetic field using iron filings
    - One method is to observe the shape of the magnetic field is by sprinkling iron filings onto a piece of paper placed on top of the magnet
  - Plotting compass
    - A compass is simply a thin magnet or magnetized iron needle balanced on a pivot.

- The needle will rotate to point toward the opposite pole of a magnet
    - Exit the north poles, enter the south poles
- More sensitive that iron filings

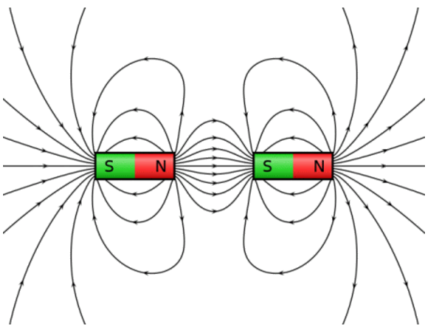
Magnetic field lines
- Magnetic field lines are imaginary and represent the direction of the magnetic field
- Magnetic field lines are also known as lines of force because if magnetic objects are placed in the region of the field lines, the magnetic objects will experience a magnetic force directed along the same lines
- By convention, the magnetic field line is the path along which an imaginary 'free' N pole
- Neutral point
    - Whenever a point in space has no magnetic field or
    - The magnetic field due to one magnet cancels out that due to another magnet



Examples of magnetic fields
- A permanent bar magnet



- 2 opposite poles facing each other



- 2 like poles facing each other

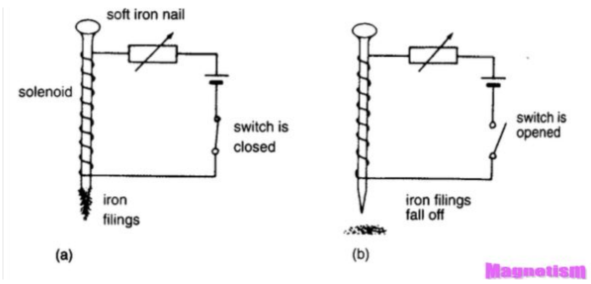
Properties of field lines
- Lines always start and end on the magnet
- The lines travel from the N-pole to the S-pole
- The lines never cross or touch each other

- The closer the lines the stronger the field (more magnetic field lines do not necessarily mean stronger magnetic field)

Magnetic properties of iron and steel
1. Iron is easily magnetised, whereas steel is NOT easily magnetised
2. Iron is easily demagnetised, whereas steel is NOT easily demagnetised
3. Iron is thus known as a soft magnetic material (easily magnetised and easily demagnetised)
4. Steel is however known as a hard magnetic material (difficult to magnetise and difficult to demagnetise)
5. Iron is thus used in making electromagnets and steel is thus used in making permanent magnets

Use of permanent magnets
- The galvanometer
- Refrigerator doors

Uses of electromagnets
-removal of scrap metals, speakers, electric-bell



1.what do you observe about the field lines drawn in general?
Magnetic field lines exit the north pole of a magnet and enter the south pole of a magnet. The field lines do not cross, a neutral point appears when 2 similar poles of the magnet are facing each other

2.why do you think there are places unaffected by the magnetic field?
The magnetic field due to one magnet cancels out that due to another magnet i.e. there is no magnetic field, its in the centre of a magnetic shield

3. Given a weak magnet field, which would you choose to trace the field - a plotting compass or iron filings?
A plotting compass ,as it is more sensitive than iron filings

Topic - Electromagnetism

draw the pattern of the magnetic field due to currents in straight wires and in solenoids and state the effect on the magnetic field of changing the magnitude and/or direction of the current
describe the application of the magnetic effect of a current in a circuit breaker
describe experiments to show the force on a current-carrying conductor, and on a beam of charged particles, in a magnetic field, including the effect of reversing
- **the current**
- **the direction of the field**

deduce the relative directions of force, field and current when any two of these quantities are at right angles to each other using Fleming's left- hand rule
describe the field patterns between currents in parallel conductors and relate these to the forces which exist between the conductors (excluding the Earth's field)
explain how a current-carrying coil in a magnetic field experiences a turning effect and that the effect is increased by increasing
-the number of turns on the coil
-the current
discuss how this turning effect is used in the action of an electric motor
describe the action of a split-ring commutator in a two-pole, single-coil motor and the effect of winding the coil on to a soft-iron cylinder

Magnetic fields due to current

- A conductor carrying an electric current produces a magnetic field

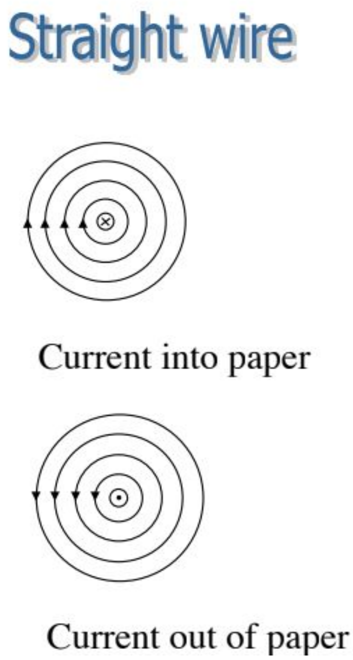
Direction of magnetic field

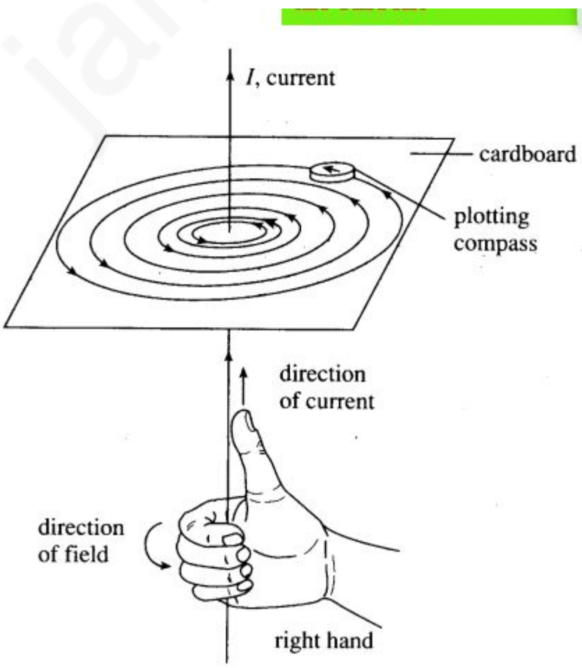
- Use your right hand
- Wrap your fingers around the wire such that the thumb is pointing in the direction of current
- The other four fingers will represent the direction of magnetic field

Right hand grip rule

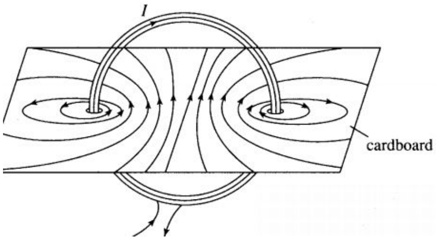
magnetism	electromagnetism
Tells polarity of solenoid thumb - north fingers - direction of current in coil	Tells direction of magnetic field thumb - current direction fingers - direction of magnetic field

Straight wire

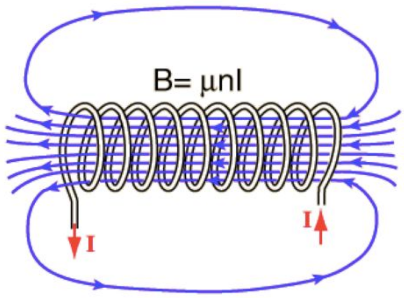




A flat circular coil



A solenoid



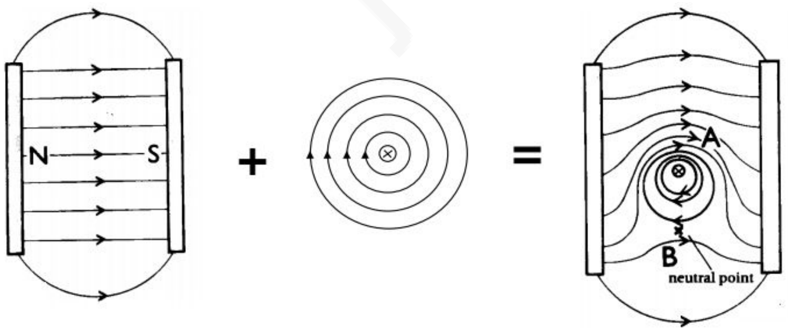
- The magnetic field is concentrated into a nearly uniform field in the center of a long solenoid. The field outside is weak and divergent, the magnetic field inside is stronger.
- When a current flows in a solenoid, the magnetic field pattern produced is identical to that of a bar magnet
- Hence the solenoid has poles just like a bar magnet

Magnetic field strength in a solenoid

- Can be increased by
  - Increasing the current flowing through the solenoid
  - Increasing the number of turns per unit length of the solenoid
  - Placing a soft iron core within the solenoid

Force on a current- carrying conductor in a magnetic field

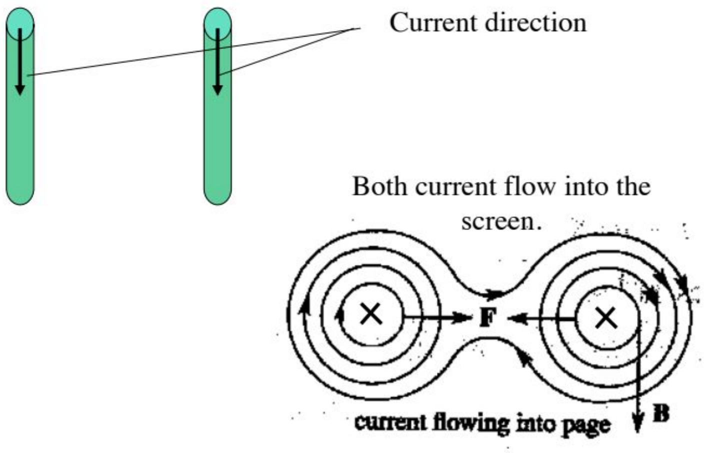
- When a current-carrying conductor is placed in a magnetic field, the conductor experiences a force. This effect on the conductor is called the motor effect.
- At A, the magnetic fields produced by the current-carrying wire and by the magnetic poles act in the same direction, reinforcing each other
- At B, since the magnetic field of the current-carrying wire is in the opposite direction to that due to the magnetic poles, the combined magnetic field is weaker
- The difference between the magnetic field strength at A and at B results in a net force acting on the wire. The force acts towards the weaker field.



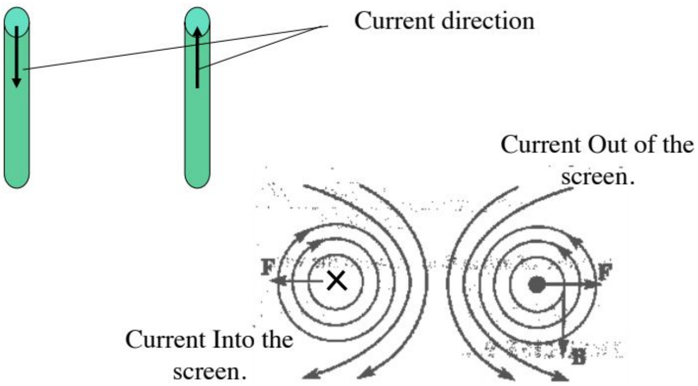
- Flemings left hand rule
  - F - Force (thumb)
  - B - Magnetic field (index finger)
  - I - Current (middle finger)

Force on parallel current-carrying conductors

- Currents in the same direction attract each other



- Currents in opposite directions repel

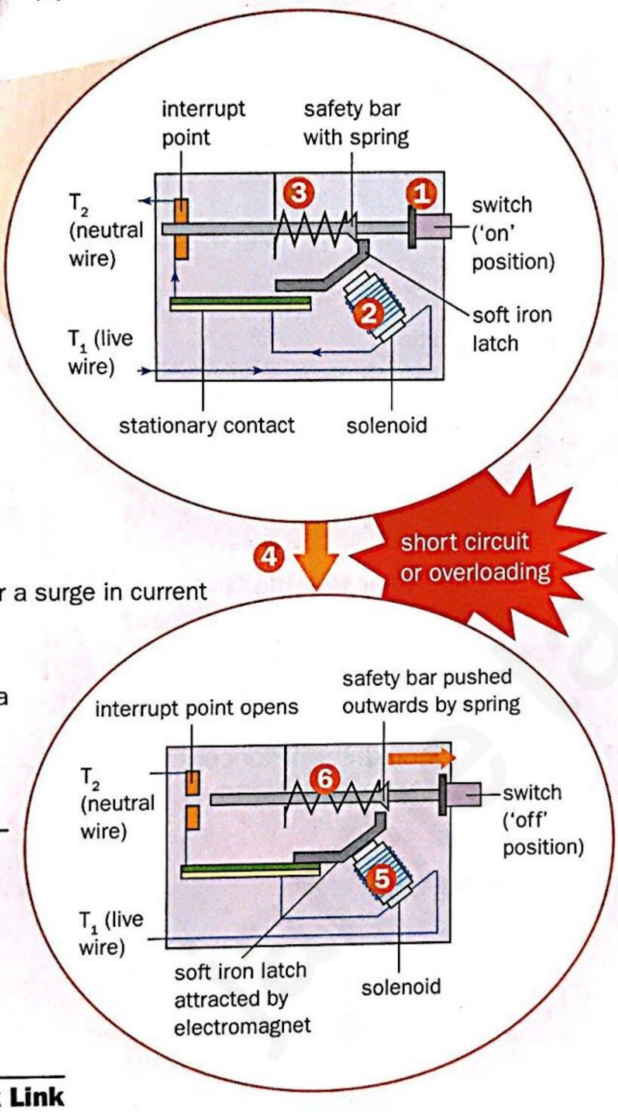


Circuit breakers - an application of electromagnetism

Circuit breakers — an application of electromagnetism

A circuit breaker (Figure 21.10) is a safety device that switches off the electrical supply when there is excessive current flow. Figure 21.11 shows how an electromagnet inside the circuit breaker enables it to work.

▲ **Figure 21.10**
A circuit breaker



▶ **Figure 21.11** How a circuit breaker works

1. When the switch is in the 'on' position, current flows from T_1 to T_2 through the solenoid and stationary contact.
2. When the current is below the limit (e.g. less than 20 A), the magnetic field of the solenoid is not strong enough to attract the soft iron latch.
3. The safety bar stays in position and the interrupt point remains closed. Current flows normally through the circuit.
4. A short circuit or overloading can cause a surge in current (e.g. more than 20 A).
5. The larger current causes the solenoid to become a strong electromagnet that can attract the soft iron latch.
6. This releases the spring, which pushes the safety bar outwards such that the switch is in the 'off' position and the interrupt point is open. There is a break in the circuit and current no longer flows through it.

Link

You learnt about the function of circuit breakers in Chapter 19.

Practical Book Link

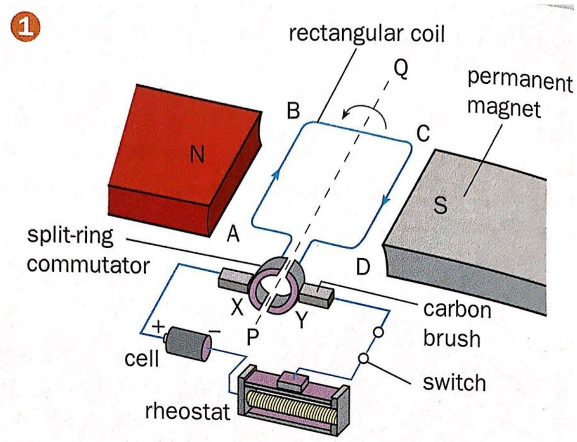
Experiment 18
How do we investigate the effect of current size on electromagnetic strength?

After the fault has been identified and repaired, we can reset the circuit breaker by pushing the switch to the 'on' position. This closes the interrupt point and sets the circuit breaker back to default mode, as shown in Figure 21.11(a).

Direct current motor

- Electrical energy → mechanical energy

1

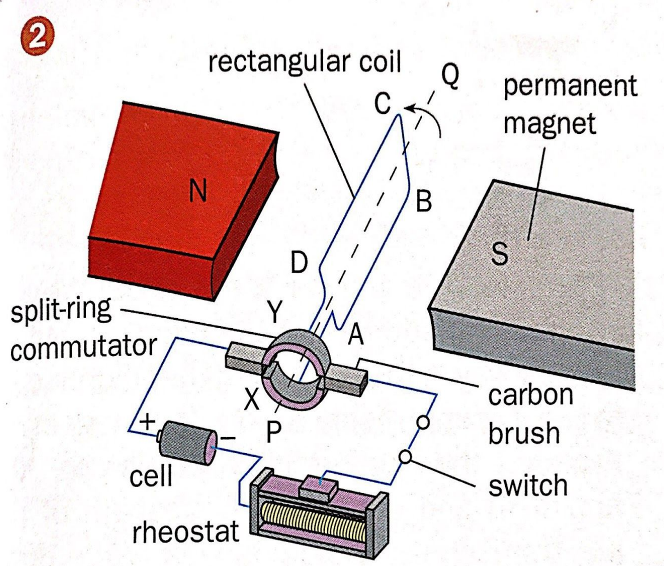


Structure of a d.c. motor:

1. A **rectangular wire coil** ABCD is mounted on an axle (represented by the dotted line PQ) that allows it to rotate about PQ.
2. The coil and the axle are positioned in between the poles of a **permanent magnet**.
3. The ends of coil ABCD are connected to a **split-ring commutator** XY. The commutator rotates with the coil.
4. **Two carbon brushes** press lightly against the commutator.

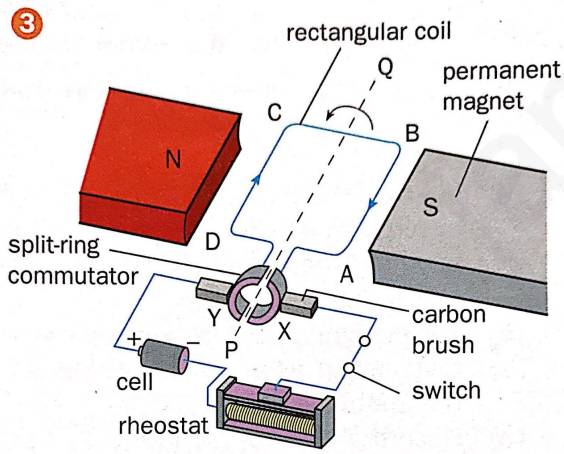
Using Fleming's left-hand rule, we know that a downward force acts on wire section AB, and an upward force on wire section CD. The coil thus rotates anticlockwise about PQ until it reaches a vertical position.

2



- When the coil is in the vertical position, the current is cut off because the split ring commutator XY is not in contact with the carbon brushes.
- The momentum of the coil, however, carries it past the vertical position.

3



- The direction of the currents flowing through wire sections AB and CD is now reversed. An upward force now acts on AB, and a downward force acts on CD.
- Hence, the coil continues to rotate in the anticlockwise direction.

- A commutator reverses the direction of the current in the coil every half a revolution. This occurs whenever the commutator changes contact from one brush to the other to ensure that the coil will always turn in one direction

A simple two-pole DC electric motor

- A simple motor has six parts

- Armature or rotor
- Commutator
- Brushes
- Axle
- Field magnet
- DC power supply of some sort

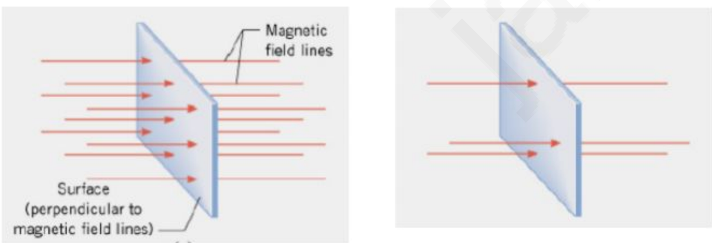
Topic - Electromagnetic Induction

deduce from Faraday's experiments on electromagnetic induction or other appropriate experiments:
that a changing magnetic field can induce an e.m.f. in a circuit
that the direction of the induced e.m.f. opposes the change producing it
the factors affecting the magnitude of the induced e.m.f.
describe a simple form of a.c. generator (rotating coil or rotating magnet) and the use of slip rings (where needed)
sketch a graph of voltage output against time for a simple a.c. generator
interpret displays of waveforms, p.d.'s and time intervals to solve related problems
describe the structure and principle of operation of a simple iron-cored transformer as used for voltage transformations
recall and apply the equations $V_P / V_S = N_P / N_S$ and $V_P I_P = V_S I_S$ to new
situations or to solve related problems (for an ideal transformer)
describe the energy loss in cables and
deduce the advantages of high voltage transmission

Magnetic flux

- The magnetic flux density, B, is a measure of the **strength** of the magnetic field in a particular region of a space
- It has the unit tesla (T)
- The magnetic flux density is very high if many lines pass through a given area

The magnetic flux is proportional to the number of magnetic field lines that pass through a surface.



Electromagnetic Induction

- Electromagnetic induction is the process through which an induced e.m.f. Is produced in a conductor due to a **changing** magnetic field
  - If you move a magnet through a loop of wire (or any conductor), an electric current flows in that wire. The current also flow if the loop is moved over a stationary magnet.

Faraday's law

- States that the **magnitude** of the induced e.m.f. In a circuit is directly proportional to the **rate of change** of magnetic flux in the circuit
  - The faster the speed of magnet/ wire, the greater the e.m.f

How to increase magnitude of induced e.m.f?

- Increasing speed at which the magnet moves with respect to the solenoid
- Increasing the no. of coils in the solenoid
- Increasing strength of magnet
- Introducing a soft iron core into the solenoid

Lenz's law

- States that the **direction** of the induced e.m.f. and hence the induced current in a closed circuit, is always such that its magnetic effect **opposes the change** producing it

Q. When magnet is held stationary at the end of the coil, the galvanometer is not deflected. Why?
A. The rate of change of magnetic flux is 0, according to faraday's law of electromagnetic induction, there is no induced emf

Q.When magnet is moved towards solenoid, the galvanometer is deflected towards A. Why?
A. According to Lenz's law, the induced current will be in the direction such that its magnetic effect opposes the change producing it, hence induced current will produce a north pole to repel the north pole of the magnet.

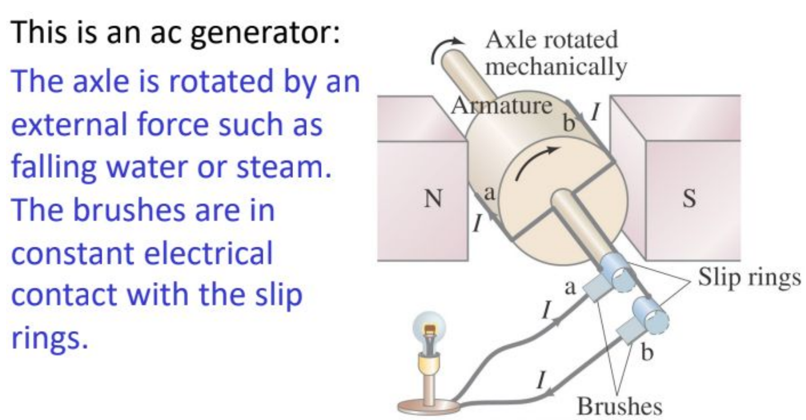
Q. The faster the motion of the magnet towards the solenoid, the larger the deflection of the galvanometer needle. Why?
A. At a greater speed, rate of change of magnetic flux is higher, according to Faraday's law, higher current produced.

Q. Why is the angle of deflection not constant?
A. the rate of change in magnetic flux linking the conductor is not constant. (There is maximum flux cutting coil when the magnet is moving the fastest, there is no change in flux cutting by the coil when the magnet is momentarily at rest at the highest and lowest position.)

Induced current in a straight conductor

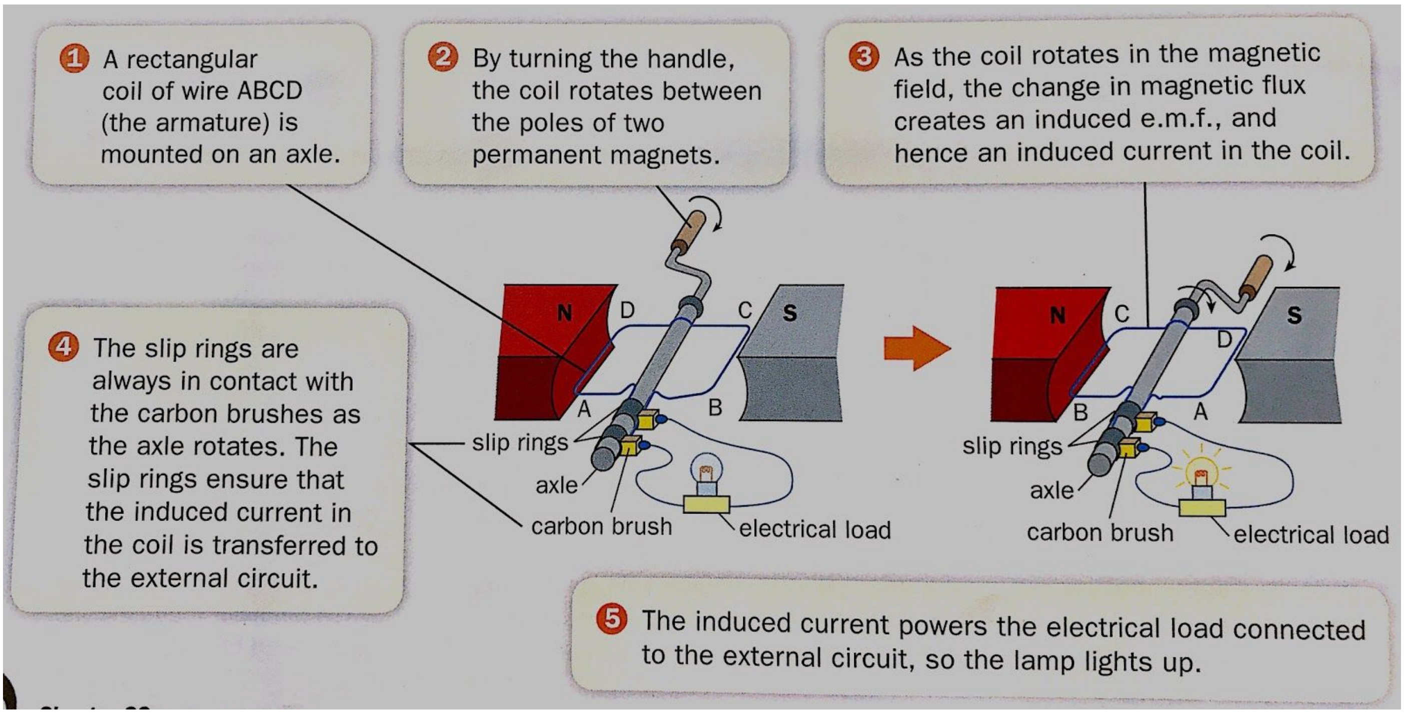
- Direction of the induced current in the straight conductor can be deduced by Fleming's right hand rule

The AC generator



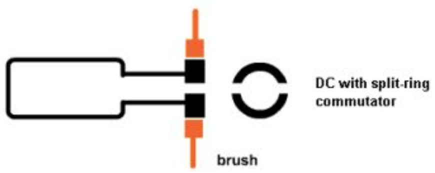
- Mechanical energy → electrical energy
- Parts of a generator
  - Slip rings → ensure that induced current in the coil is transferred to external circuit

- ○ Brushes → ensure electrical connection between brushes and stationary circuit



Voltage output of an A.C. generator

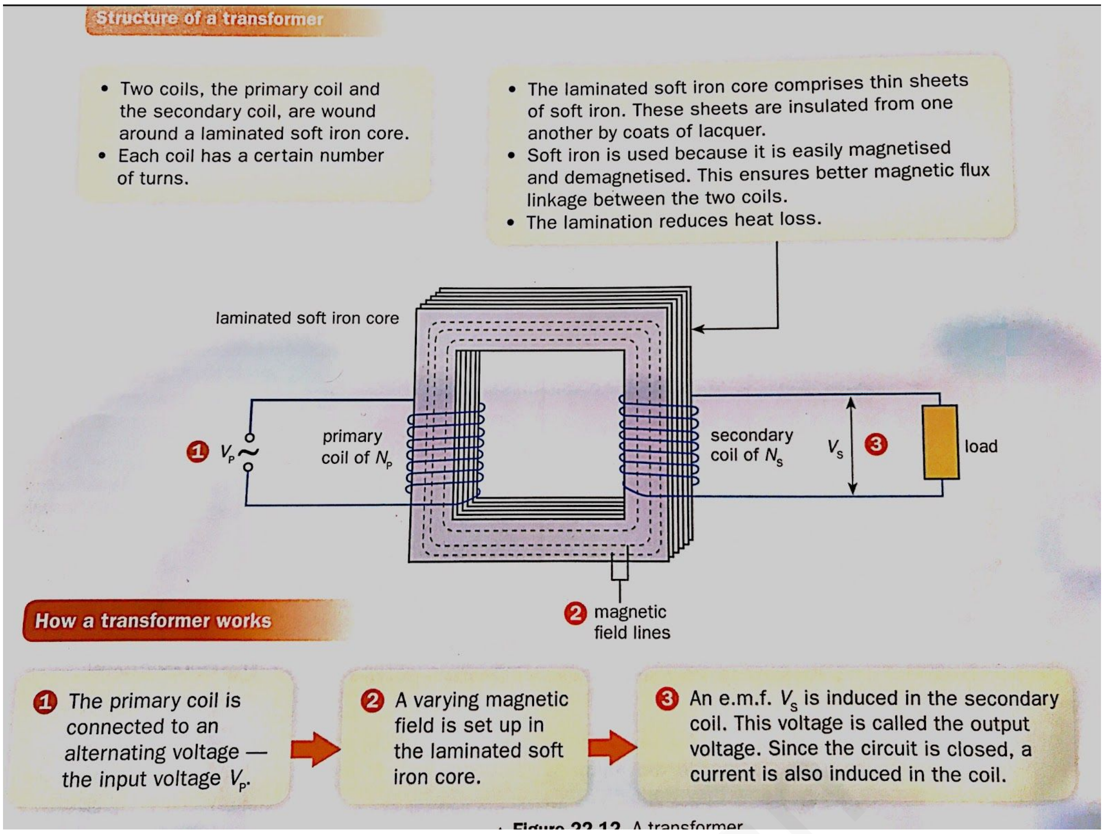
- Rate at which coil cuts magnetic lines of forces is greatest when coil is horizontal → induces maximum e.m.f.
- When coil is vertical, rate at which coil cuts magnetic lines of forces is least → induces minimum e.m.f

D.C. motor	A.C. generator
Electrical energy → mechanical energy	Mechanical energy → electrical energy
“Induced” force	Induced current
Fleming’s left hand rule to determine direction of force	Fleming’s right hand rule to determine direction of induced current
Split ring  External circuit always receive current in the same direction	Slip ring  Current in external circuit flows in alternating direction
D.C. source in external circuit	A.C. output in external circuit (electrical load)

Transformer

- Is a device which is used to convert high alternating voltage to a low alternating voltage and vice versa
- Transformer works on the principle of mutual induction of two coils. When current in the primary coil is changed the flux linked to the secondary coil also changes. Consequently an EMF is induced in the secondary coil

- Consists of a primary coil and a secondary coil



Step-up transformer

- Turns in secondary coil > turns in primary coil
- Ns > Np

Step-down transformer

- Turns in primary coil > turns in secondary coil
- Np > Ns

For an ideal transformer

- $\frac{secondary\ output\ voltage}{primary\ input\ voltage} = \frac{Vs}{Vp} = \frac{Ns}{Np}$
- $\frac{Ns}{Np}$ is called the turns ratio ($\frac{Np}{Ns}$ is not turn ratio!)
- $V_pI_p = V_sI_s$

Transformers and transmission of power

- Transformers work only if the current is changing. Electricity is transmitted as AC as it is easy to convert to change between high and low voltages.