GCE 'O' Level Physics (6091)
Revision

Chapter 1 – Physical Quantities, Units and Measurements

Vernier Caliper

If the Vernier scale is on the right of the main scale, then the reading on the Vernier scale will be read from the left. On the other hand, if the Vernier scale is on the left of the main scale, the reading on the Vernier scale will be read from the right.

Remember this acronym: **VRRL (Vernier right, read from left)**.

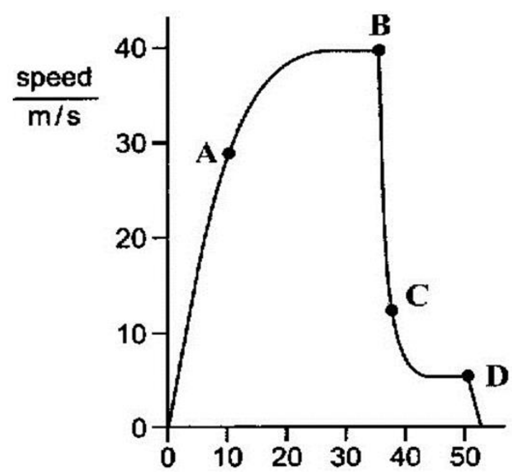
Zero Error

To obtain a correct reading of an object, take the zero error and subtract it from the measured reading. Actual reading = measured reading – zero error.

Chapter 2 – Kinematics

Terminal Velocity

Skydiving



Point A: The parachutist decelerates. The air resistance increases and the net force downwards decreases. (Acceleration decreases)

Point B: The horizontal line that passes through Point B is where the parachutist reaches terminal velocity. Here, he experiences no acceleration as the air resistance is equivalent to his weight. At Point B, he opens his parachute. He will feel a tug as there is a sudden increase in air pressure. (Acceleration decreases)

Point C: The parachutist decelerates as the large surface area of his parachute gives rise to a greater air resistance. This value is larger than the weight of the parachutist. (Constant deceleration from B to C)

Point D: The parachutist reaches a new terminal velocity.

As the parachute is opened, the air resistance increases to be more than the weight **[1]** due to the increase in surface area. The skydiver then slows down due to resultant force being negative. As he slows down, the air resistance decreases, thus the rate of deceleration decreases. **[1]** The air resistance will decrease until it is equal to his weight, making the resultant force = 0N and he moves at constant speed. The parachutist has to bend his knees upon reaching the ground as it increases the stopping duration before he comes to a complete stop, reducing the compression force.

An action-reaction pair of forces during skydiving includes the weight of the diver on Earth and the gravitational force by the Earth acting on the diver. Note that normal contact force and weight is not an action-reaction pair.

Graphical Representations

Displacement-time graphs and velocity-time graphs can have their graphical representations extended to below the x-axis since displacement and velocity are both vector quantities so their direction can be in the opposite. Your weakness during Prelims was that you forgot how to interpret displacement- and velocity-time graphs.

Non-uniform means that the rate of change is not constant, whereas uniform means that the rate of change is constant.

Object falls through the Air

When an object is released from a height with no initial terminal velocity,

- The air resistance acting on it will decrease.
- The object will experience an initial acceleration of 10m/s^2 and it will decrease overtime.
- The object's velocity will increase till it reaches terminal velocity.

<u>Chapter 3 – Dynamics</u>

Tension in Strings

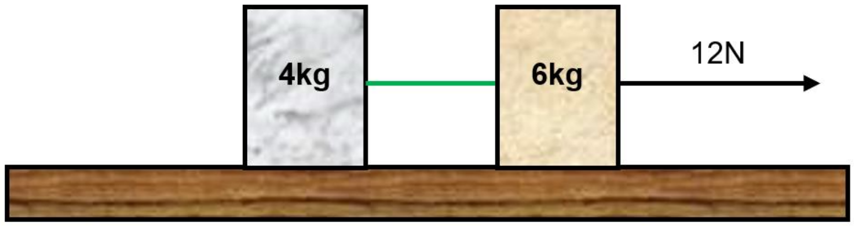
An object is suspended by strings. When tasked to draw a vector diagram of the forces on the object, they are namely tension (depends on the number of strings) and weight. The resultant force on the object is equivalent to the weight of the object.

Tension in Blocks

A boy pulls two boxes, one 4kg and another 6kg, to the right. The 4kg box is attached to the 6kg box by a string (coloured in green). The 6kg box is pulled by a 12N force to the right. **(a).** Calculate the acceleration of the 5kg box. **(b).** Calculate the magnitude of the tension in the string in the two boxes.

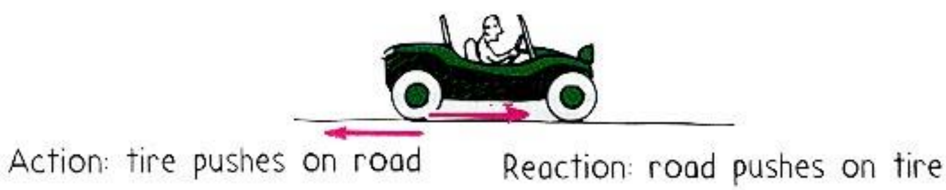
(a). The boy applies a force to pull the 6kg box. However, since the boxes are connected by a string, the total mass he has to pull is 10kg. As such, the acceleration is 1.2m/s^2.

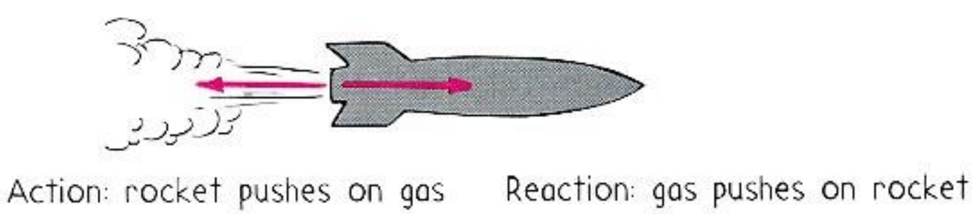
(b). *Method 1 (Make the 4kg box the subject):* Tension = 4(1.2) = 4.8N. *Method 2 (Make the 6kg box the subject):* Since the resultant force = 12N – tension (T), 12 – T = 6(1.2), T = 4.8N.



Action and Reaction Pairs

Normal reaction force and weight are not action-reaction pairs since they act on the same body. Action and reaction forces act on different bodies according to Newton's Third Law of Motion. For example, in the case of the **man driving on the road**, the action force is when the tire pushes on the road and the reaction force is when the road pushes on the tire. Note that the forces act on different bodies – the road and tire respectively.





Friction

Useful	Undesirable
• Slow down moving vehicles. • Sharpen the edges of cutting instruments. • Generate heat (i.e. matchstick).	• Wear and tear of vehicle tyres

To reduce friction, you can use ball bearings, apply lubricants (i.e. oil and grease) or design the shape of the vehicle to be streamlined.

Moving Car on a Wet Road

A moving car is travelling on a dry road. It decelerates uniformly and comes to a rest in x seconds. On a wet road, it decelerates uniformly but it will come to a rest in y seconds (where $y > x$). From F = ma, since there is less friction on the wet road, the resultant force is smaller and so is the acceleration.

Chapter 4 – Mass, Weight and Density

Mass and Inertia

Consider a heavy truck and a light ball. The heavy truck, which has more mass, thus greater inertia, is more difficult to start and stop moving but easier to continue its motion.

Chapter 5 – Turning Effect of Forces

Moments

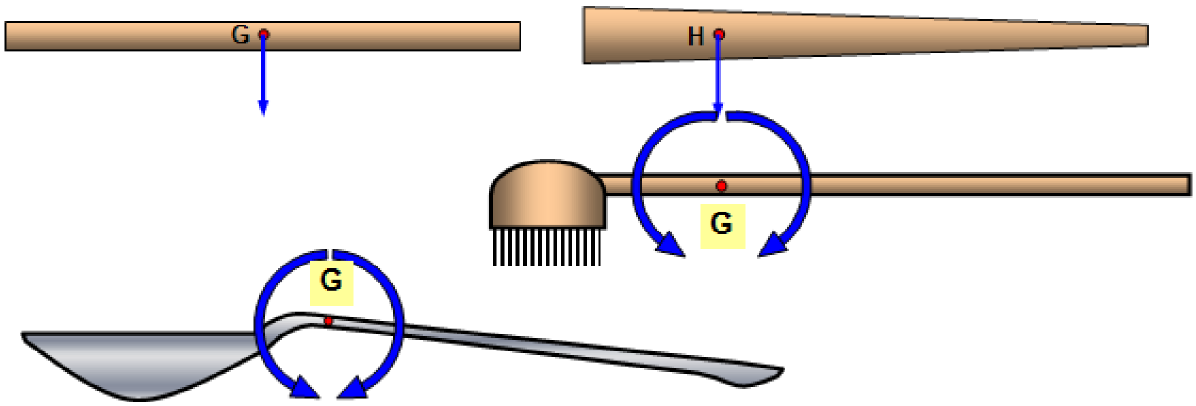
When the line of action cuts the pivot, the perpendicular distance between the line of action of the force and the pivot is 0. Moment is known as torque.

Centre of Gravity

The centre of gravity of an object is the point through which the entire weight of the object appears to act.

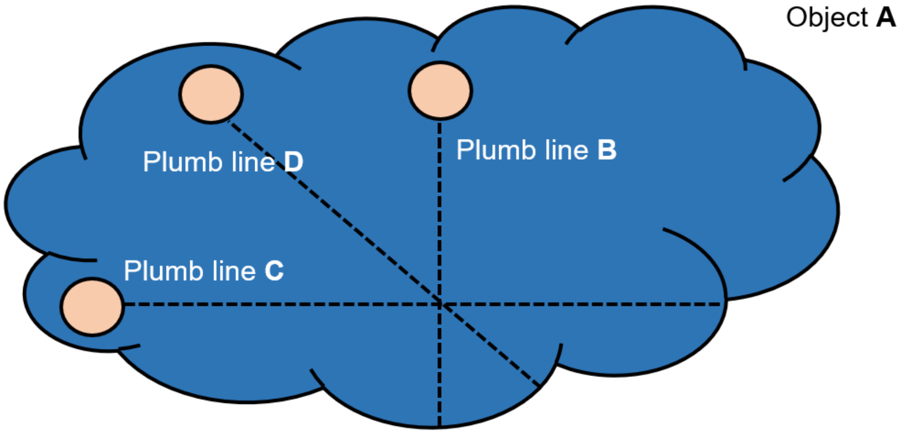
Non-Uniform Objects

A good example of a non-uniform shape is a broom or a spoon. The mass on either side of their centre of gravity is not equal – the distribution of this mass must be allowed for. An object will only balance in equilibrium if the point of balance is directly below the centre of gravity. There is no resulting turning moment.



Determining the Centre of Gravity of a Non-Uniform Object

Suppose you have an irregular object, **A**. To determine the centre of gravity, attach a pin at the top of the object and allow the object to suspend freely. Draw a plumb line **B** vertically downwards. Rotate the object, allow it to suspend freely and draw a plumb line **C** vertically downwards. Then repeat this process for as many points as you want. The point of intersection between plumb lines **B**, **C** and **D** is the centre of gravity.



Stability

To increase a body's stability, we can:

- Lower its centre of gravity
- Increase the area of its base

Tightrope

When a person holds a long rod while standing on a tightrope, he will generally hold it below his waist. This is to lower the whole body's centre of gravity, increasing his stability.

<u>Chapter 6 – Pressure</u>

Hydraulic Systems

A hydraulic system works by using liquids under pressure. It makes use of 2 properties of liquids.

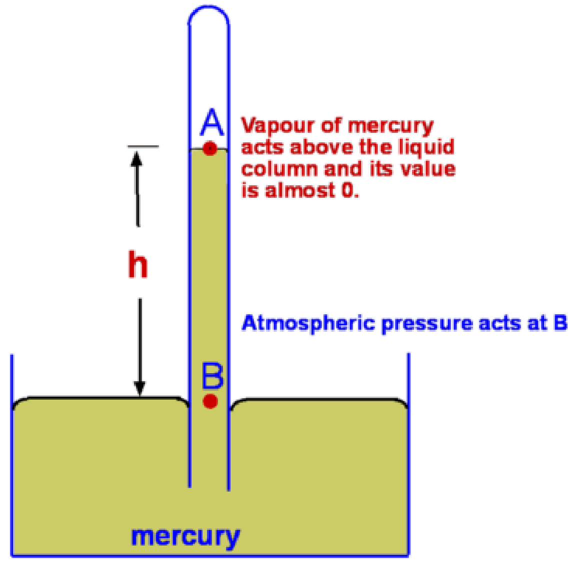
- Liquids are incompressible.
- If pressure is applied to an enclosed liquid, the pressure is transmitted to all parts of the liquid.

Oil is generally used as the liquid in hydraulic systems since oil is incompressible. This creates a force pressing on the piston. Air is not used since it is compressible. Pressure exerted on the piston will not be fully transmitted, resulting in a greater force required to obtain the same force as compared to using oil.

Measuring Pressure using a Barometer

Mercury Barometer

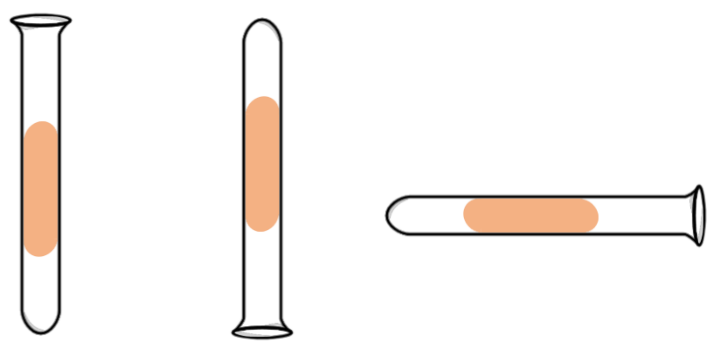
Atmospheric pressure can be measured using a mercury barometer. It can be made with a tube about 1.0m long. The glass tube is sealed at one end and is filled to the top with mercury. The tube is then turned upside down in a trough of mercury.



The mercury level in the tube drops until it is about 760mm vertically above the mercury level in the trough. The atmospheric pressure is measured in terms of 'millimetres of mercury' or mm Hg. For example, the atmospheric pressure at sea level is 760mm Hg or 100kPa. The space above the mercury column is a vacuum.

The height of the column is measured from the top of the trough to the top of the mercury column. As we travel down the barometer, the pressure in the mercury column increases since according to the formula ρ = pgh, when h increases, the pressure of the mercury increases.

Mercury Test Tube

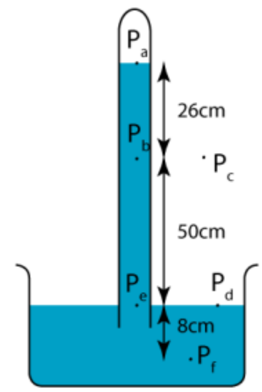


Consider **Case 1 (left)**, **Case 2 (centre)** and **Case 3 (right)**. The blobs of mercury are not moving. It is given that the atmospheric pressure is 760mm Hg. Calculate the pressure of the trapped air in all 3 cases.

The blob of mercury in **Case 1** has a pressure of 25mm Hg. In **Case 2**, another sample of a blob of mercury has a pressure of 35mm Hg. In **Case 3**, the sample of a blob of mercury has a pressure of 30mm Hg.

It's important that the blobs of mercury are not moving. This implies that the blob is in equilibrium.

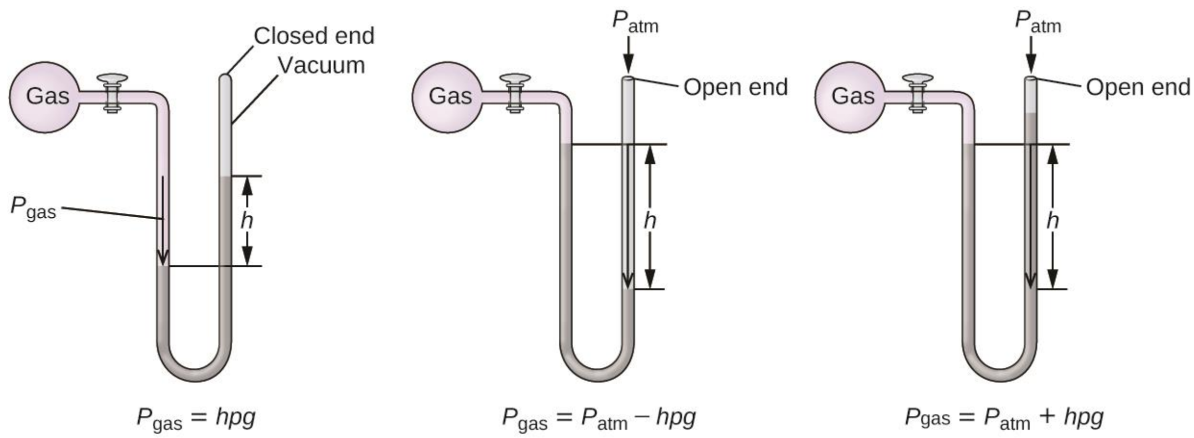
At **Point A**, the pressure is 0cm Hg. At **Point B** and **Point C**, the pressure at each point is 26cm Hg since they are at the same height. At **Point E** and **Point F**, the pressure at each point is 76cm Hg. At **Point F**, the pressure is 84cm Hg.



Why is a Water Barometer not used?
The glass tube has to be much longer since water has a much lower density than mercury.

Why does a Balloon inflate?
Suppose you pump air into a balloon. The amount of molecules per unit volume increases, thus the pressure of the air molecules increases (frequency of effective collisions increases). The molecules will exert more force on the inner surface of the balloon. This means that the net force exerted by the air molecules in the balloon is greater than the force exerted by the atmospheric pressure, causing the balloon to expand, thus inflate.

Measuring Pressure using a Manometer
A manometer consists of a U-tube containing a liquid. It is used to measure gas pressure.



Consider 3 cases. **Case 1:** Other end of the manometer is closed, **Case 2:** Atmospheric pressure is larger than the pressure of the gas and **Case 3:** Atmospheric pressure is smaller than the pressure of the gas.

Case 1: Only the gas exerts a pressure on the liquid in the manometer. With the value of the difference in the height level between the left arm and right arm, the pressure of the gas can be calculated.

Case 2: The other end of the manometer is open. The atmospheric pressure exerts pressure on the right arm and the gas exerts pressure on the left arm. According to the diagram, we can infer that the atmospheric pressure is larger than the pressure exerted by the gas.

Case 3: The other end of the manometer is open. The atmospheric pressure exerts pressure on the right arm and the gas exerts pressure on the left arm. According to the diagram, we can infer that the atmospheric pressure is smaller than the pressure exerted by the gas.

How do gas molecules create a pressure?

Gas contains many molecules. They are in random motion at fast speeds and collide with one another frequently. Due to these many effective collisions, they exert a force on the liquid in the manometer.

Chapter 7 – Work, Energy and Power

Gravitational Potential Energy

When talking about gravitational potential energy, the height, h, refers to the vertical distance the object travels. Remember that it has nothing to do with the diagonal height. In examinations, given a right-angled triangle, one can easily solve for the vertical height using the Pythagorean Theorem.

Work Done

As work done is defined as the product of the force and the distance travelled in the direction of the force, it suggests that the distance is parallel to the direction of the force.

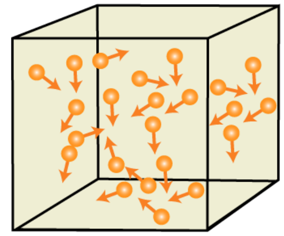
Ball rolling down a Hill

A classic example of the principle of energy conservation would be a ball rolling down a hill. Since the ball is at its peak at the top of the hill, we can say that the ball possesses maximum gravitational potential energy and 0 kinetic energy. This is only applicable if the ball is at rest at the peak.

However, if a force is applied initially and the ball rolls down a hill at a certain speed, that ball already possesses some kinetic energy. In this case, the kinetic energy and gravitational potential energy will be converted to kinetic energy upon contact with the ground surface and some sound and thermal energies as well. The conversion to thermal energy is due to friction with the ground.

Chapter 8 – Kinetic Model of Matter

Brownian Motion



Brownian Motion is the haphazard movement of microscopic particles suspended in a fluid due to the uneven bombardment of the suspended particles by the molecules of the fluid.

Robert Brown's Experiment

The random motion of the smoke particles was the result of smoke particles being hit by the unseen, fast-moving air molecules. Brownian Motion provides evidence for the continuous movement of molecules. The 'moving points of light' Brown observed were the reflected light from the smoke particles colliding with air molecules.

Behaviour of Gases

In this section, we will study a 'breakdown' of the ideal gas equation PV = nRT, and apply it to molecular behaviour in gases. The following table summarises the key points required.

	Pressure-temperature	**Volume-temperature**	**Pressure-volume**
Constant	Volume	Pressure	Temperature
Relationship	Direct	Direct	Inverse
Explanation	Increasing temperature → molecules move faster and hit the walls more frequently.	Increasing temperature → molecules move faster, hit the walls more frequently. Volume increases to reduce the rate of collisions.	Volume decreases → no. of gas molecules per unit vol. increases. Rate of collisions increases.

Chapter 9 – Temperature

Types of Thermometers

Thermometer	Thermometric Property	Advantages
Liquid-in-glass	Volume of liquid column	• Portable • Cheap and affordable • Does not need a power supply
Resistance	Electrical resistance	• Very accurate • High sensitivity • Able to measure a wide range of temperature
Thermocouple	e.m.f	• Able to measure a wide range of temperature • Able to measure temperatures that change rapidly due to quick response

Internal Energy

Defined as the combination of the total kinetic energy and potential energy of the molecules in a body.

	Melting	**Boiling**	**Freezing**	**Condensation**
Potential energy	Increases		Decreases	
Kinetic energy	Constant			

Calibration for Liquid-in-glass Thermometer

To mark the fixed points in an uncalibrated thermometer, conduct the following two experiments:

- Dip the thermometer into a trough of pure melting ice and mark the ice point (0°C) on it.
- Dip the thermometer into boiling water and mark the steam point (100°C) on it. Make the mark when the temperature is steady.

On the Celsius scale, the interval between the ice point and the steam point is divided into 100 equal divisions for easy reading. Each portion is equal to one degree Celsius (°C).

Chapter 10 – Transfer of Thermal Energy

Conduction

Thermal energy is transferred through a medium from one particle to another via molecular vibrations and collisions.

For all solids, conduction takes place when thermal energy is transferred from one particle to the next. When one end of the rod is heated, the atoms gain more energy and vibrate faster. These atoms collide with their less energetic neighbours. Some of their energy is transmitted to these neighbouring atoms, which in turn gain kinetic energy. In this way, thermal energy is passed along the rod by the vibrating atoms.

Convection

Thermal energy is transferred through the movement of a heated liquid or gas.

Air Conditioner

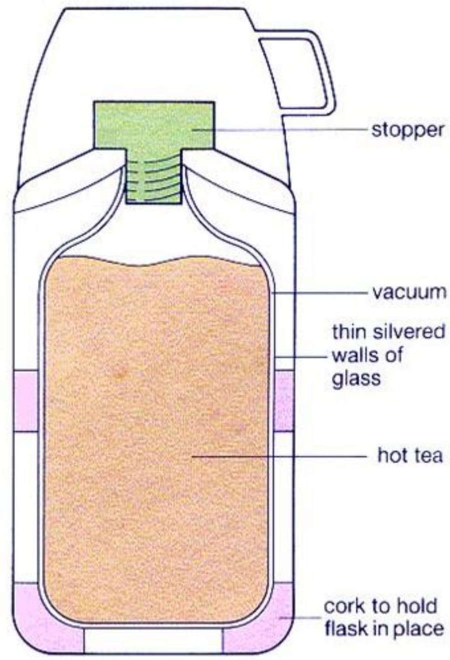
You turn on the air-conditioner (which should ideally be at the top of the room). The warm air at the bottom heats up and becomes less dense. The air rises to the top of the room. The cool air emitted from the air-conditioner becomes denser and sinks. It occupies the void which was once occupied by the warm air. This creates a convection current through the idea 'hot air rises and cold air sinks'. The continuous cycle of convection currents ensures that the room is kept cool.

Radiation
Thermal energy is transferred via electromagnetic waves.

Effect of Surface Texture and Colour on Radiation

- Black is the best emitter and absorber of thermal energy, followed by white then silver.
- Dull surfaces are better emitters than shiny surfaces.
- Rough surfaces are better emitters than smooth surfaces.

Application of Radiation – Vacuum Flask
The purpose of a vacuum flask is to keep hot liquids hot and cold liquids cold. The transfer of thermal energy in or out of the flask must be minimised.



Type of transfer	Components
Conduction	• Stopper, vacuum
Convection	• Vacuum
Radiation	• Silvered walls

The silvered walls reduce radiation as they reflect infra-red radiation from hot fluids back into the flask and from the external surroundings away from the flask.

Since a vacuum flask is used to keep hot things hot and cold things hold, the interior which is designed to hold hot water is shiny. Shiny surfaces are poor absorbers of radiation. This reduces heat loss to the surrounding via radiation.

A Cold Winter Night
In cities which experience cold winters, some homeless people who sleep along the street cover themselves with newspaper to minimise heat loss from the body via conduction and convection.

Conduction	Heat is transferred due to contact with the newspaper.
Convection	It is a cold city, the cold air will sink.
Radiation	No transfer via this mean as it is not in a vacuum.

Chapter 11 – Thermal Properties of Matter

Differences between Boiling and Evaporation

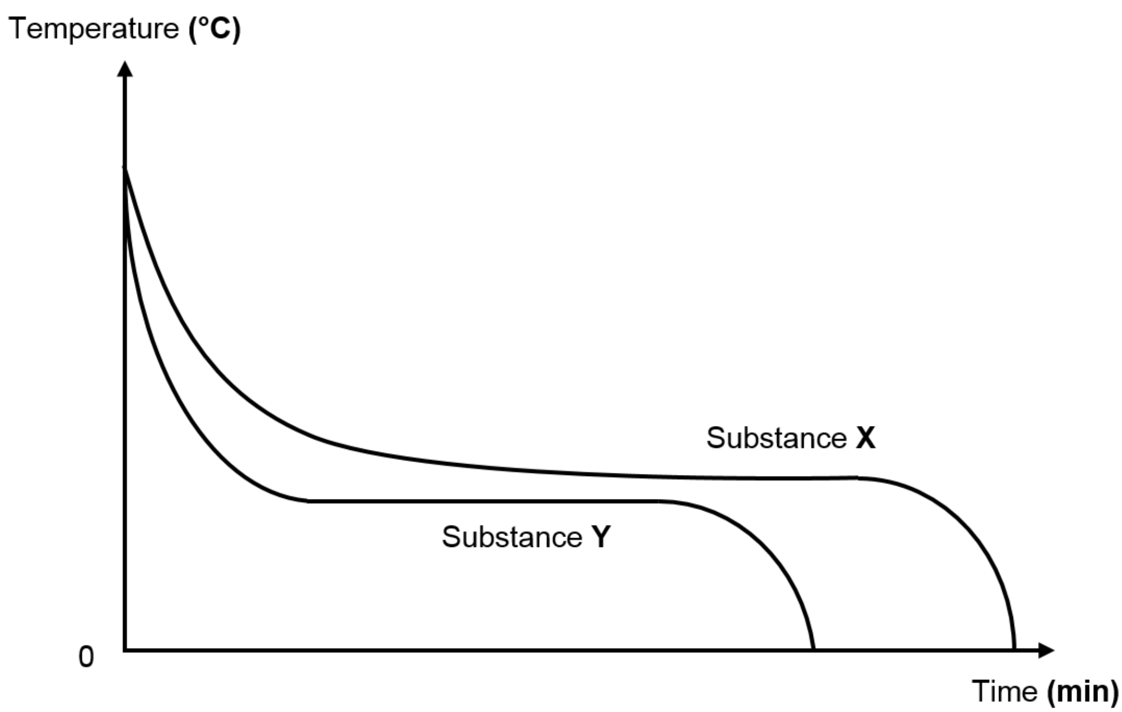
Boiling	Evaporation
• Occurs throughout the liquid • Bubbles are formed • Relatively fast process • Occurs at a fixed temperature	• Occurs on the surface of the liquid • No bubbles formed • Relatively slow process • Occurs at any temperature between the melting and boiling points of the substance

Heat Capacity

The base of a frying pan should be made of a material which has a high specific heat capacity. The pan will heat up quicker. Materials which have higher specific heat capacities are better conductors of thermal energy.

Graphs related to Latent Heat and Specific Heat Capacity

The diagram below shows two substances, **X** and **Y**, which are cooled down at the same temperature and all physical conditions are the same.



X has a higher specific heat capacity since its temperature falls at a slower rate, thus it needs more energy to be lost. **Y** has a higher specific latent heat of fusion as it takes a longer time to change its state from liquid to solid. More thermal energy is lost.

Proportion can also be used to illustrate this. From $Q = mc\Delta\theta$, since $\Delta\theta$ of **X** is smaller, c of **X** is larger. From $Q = ml_f$, since Q of **Y** is larger, l_f of **Y** is larger.

Chapter 13 – Light

Reflection

Object and Image Distance Application

A person runs at a velocity of x cm/s to a large mirror. The distance between the object (him) and his image will decrease at a rate of $2x$ cm/s, considering the change in distance on the real plane and virtual plane.

Total Internal Reflection and Critical Angle

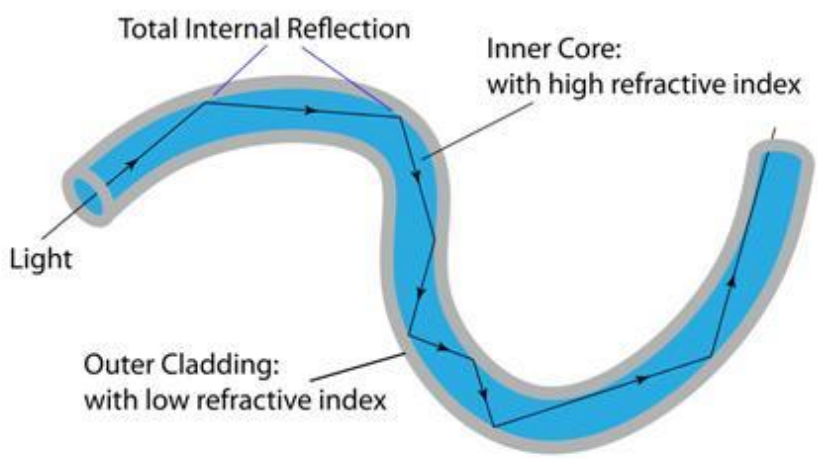
The critical angle is defined as the angle of incidence in the optically denser medium for which the angle of refraction in the optically less dense medium is 90°.

For total internal reflection to occur, two conditions must be satisfied:

- The light ray must travel from an optically denser medium to an optically less dense medium.
- The angle of incidence must be greater than the critical angle.

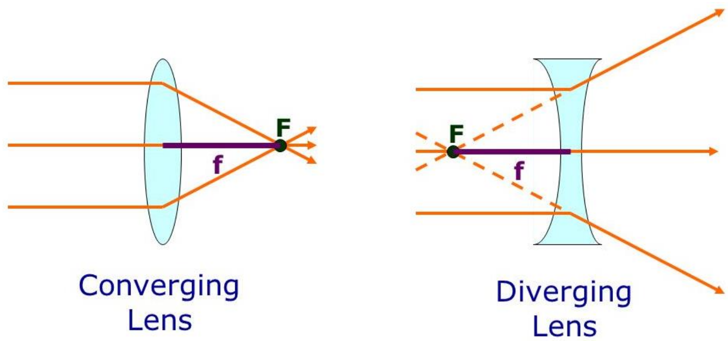
Application of Total Internal Reflection – Fibre Optics

An application of total internal reflection is in fibre optics where 'light pipes' are used to transmit light from one place to another. A light ray entering the pipe comes out of the pipe because of total internal reflection from the ides.



Converging and Diverging Lenses

A converging lens is thicker in the centre and thinner at the sides but a diverging lens is thinner in the centre and thicker at the sides. Converging lenses are known as convex lenses and diverging lenses are known as concave lenses.



When manufacturing spectacle lens, to correct short-sightedness, a divergent lens must be used. On the other hand, to correct long-sightedness, a convergent lens must be used.

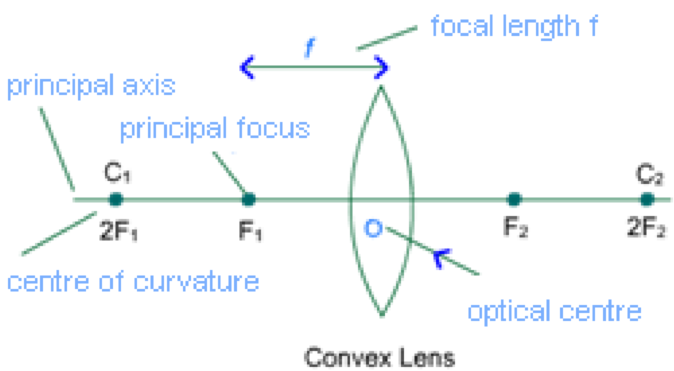
Lens Terminology

The focal length, f, of a lens is the distance between its optical centre, C, and principal focus, F.

Ray Diagrams for Thin Converging Lens

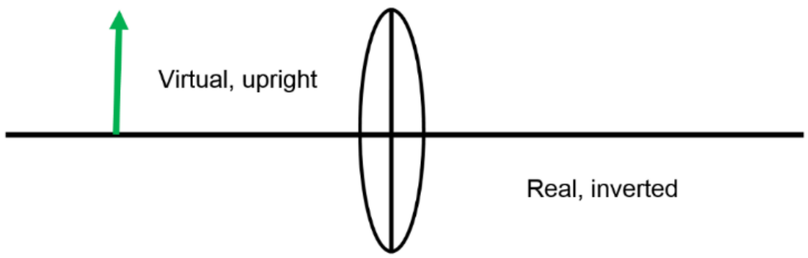
There are 3 particular rays which can be drawn accurately in ray diagrams. They are:

- A ray parallel to the principal axis is refracted by the lens to pass through F.
- A ray through C is not deviated.
- A ray through F is refracted parallel to the principal axis.



Images produced by Thin Converging Lens

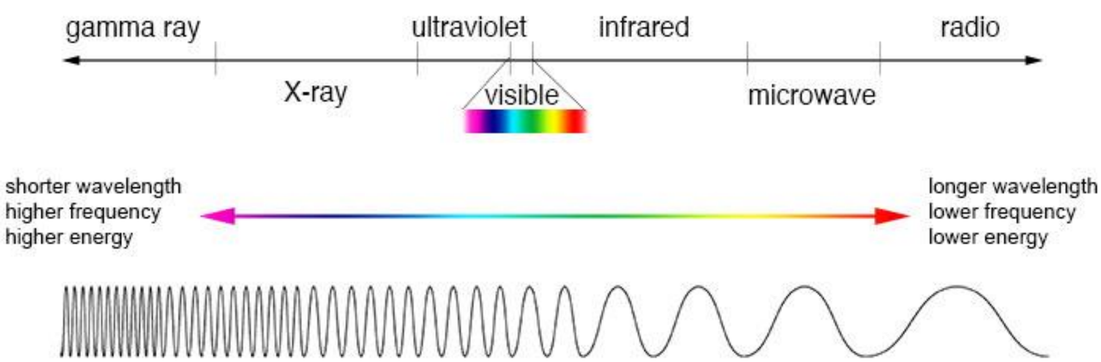
A virtual image cannot be casted on a screen. Let the green line be the object. The following quadrants indicate the characteristics of the image formed.



Chapter 14 – Electromagnetic Spectrum

Components of the Electromagnetic Spectrum

The components of the electromagnetic spectrum are as depicted.



Properties of Electromagnetic Waves

Electromagnetic waves have the following properties in common:

- They transfer energy from one place to another.
- They are transverse waves.
- They can travel through vacuum with the speed of light.
- They show wave properties and obey the wave equation.

Uses of Electromagnetic Waves

Radiation	Uses
Radio waves	• Radio and television communication
Microwaves	• Satellite communication for mobile phone networks • Microwave cooking
Infra-red rays	• Remote control • Intruder alarms
Visible light	• Optical fibres • Lasers
Ultra-violet rays	• Sterilisation • Forgery detection
X-rays	• Airport security • Cancer treatment
Gamma rays	• Cancer treatment • Sterilisation

Ionisation

The process in which an electron is given enough energy to break away from an atom is ionisation. This process results in the formation of 2 charged particles or ions: a molecule with a net positive charge and a free electron with a negative charge.

Ionisation is harmful to living cells as it results in the destruction or the modification of living tissues. In the electromagnetic spectrum, as the frequency of the ray increases, it possesses more energy. These include X-rays and gamma rays. They have enough energy to possess ionisation.

Prolonged exposure to ultra-violet light may result in harmful effects such as the pain of sunburn or skin cancer.

Chapter 15 – Sound

Sound waves are longitudinal. They cannot travel through vacuum since vacuum comprises an empty space where there are no atoms or molecules to vibrate. Sound cannot be heard in space because there is no air.

How do we hear Thunder?

The thunder causes the neighbouring air molecules to vibrate back and forth, resulting in a series of compressions and rarefractions through the air to reach us.

Displacement-Position Graph

Given a displacement-position graph where the displacement to the right is taken as positive, we can determine the regions of compressions and rarefractions. We define a compression as a region of high pressure and a rarefraction as a region of low pressure.

Transmission of Sound through a Medium

The speed of sound differs in solids, liquids and gases. This is due to the difference in the strength of the interatomic forces and the closeness of the atoms in the 3 states. As sound is transmitted through the vibrations of particles, solids will transmit sound the fastest as the particles are closest together. As such, sound will travel the slowest in gases.

Echo

The reflection of sound waves from a surface heard as a separate sound or a series of sounds is known as an echo. When a man shouts at a wall, the sound wave he hears is an echo which is a result of the reflection of the sound waves from the wall. However, the amplitude of the echo is smaller than the sound wave which he shouted because some sound energy is absorbed by the wall.

Pitch, Frequency, Loudness and Amplitude

The higher the pitch, the higher the frequency. The higher the amplitude, the higher the loudness.

Ultrasound

Ultrasound is a type of sound wave with frequencies greater than 20kHz. It has a frequency which exceeds the upper limit of normal human hearing. It is used in ultrasonic scanning (pre-natal scanning). This involves sending ultrasound waves into a patient's body and detecting the reflected ultrasound.

Chapter 16 – Static Electricity

Knowledge of the triboelectric series is not required. You just have to understand that in the charging of objects by rubbing, it involves the transfer of electrons. For protons, use the terminology 'positive charges' and for electrons, just use its original terminology, 'electrons'.

Charging Objects by Rubbing

When a rod is rubbed with fur, it results in the transfer of a certain number of electrons from the fur to the rod. The rod becomes negatively charged. Since the fur has lost the same number of electrons, it becomes positively charged. As part of energy conservation, no charge is created or destroyed.

Charging by Induction

To induce a negative charge on a conductor	To induce a positive charge on a conductor
Two neutral, insulated metal spheres, A and B, are placed touching each other.	
When a negatively charged rod is brought near P, the electrons on P are repelled away from the rod. They move onto Q. P is left with a positive charge.	When a positively charged rod is brought near P, the electrons from Q are attracted to the rod. They move onto P. Q is left with a negative charge.
Q is separated from P while the negatively charged rod is kept in position.	Q is separated from P while the positively charged rod is kept in position.
The rod is removed. P and Q now possess equal amounts of opposite charge.	

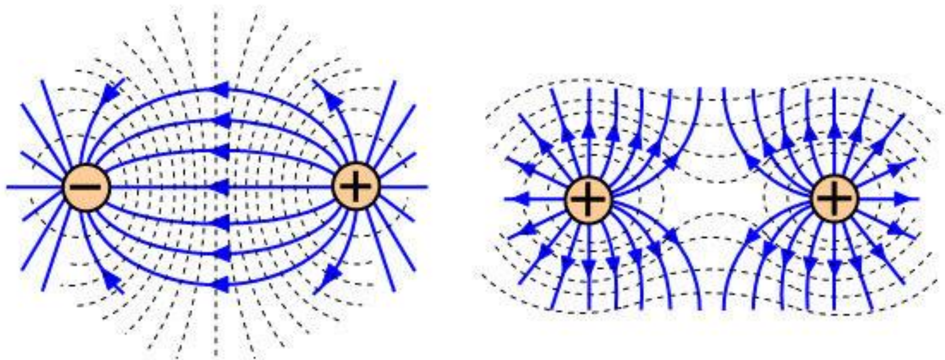
Charging Objects by Earthing

You're charging a single sphere. Recall that positive charges never move. It's only the free electrons that possess this property.

How to determine the Direction of Electron Flow?

If a positively charged rod is used, the electrons travel from earth to the sphere to neutralise the excess positive charges. Similarly, if a negatively charged rod is used, the electrons travel from the sphere to earth.

Electric Field



An electric field is a region of space where an electric charge experiences an electric force. The rules for drawing electric field lines are:

- The direction of field lines must begin from a positive charge and end on a negative charge.
- The number of lines drawing leaving a positive charge or ending on a negative charge is directly proportional to the magnitude of the charge.
- No two electric field lines can cross each other.

Electrons gyrate (orbit in a spiral/circle) and they do not move in a straight line.

Hazards of Electrostatics

For example, the rotating tyres of a moving truck acquire negative charge as they rub against the surface of the road. Parts of the metal body of the truck near the tyres then become positively charged by induction. Sparks may be produced. This in turn might ignite any highly flammable load and cause a fire.

Trucks which transport petrol or highly flammable liquids usually have a metal chain or conductive strip at the rear end, dangling to the ground. This chain conducts electrons from the ground to neutralise the positive charge on the metal body of the truck before it can build up and cause sparks.

In summary, static electricity can pose potential hazards which include sparks and fires. The example above is the electrostatic discharge of a flammable substance during transportation.

Application of Electrostatics

The concepts of electrostatics can be applied to photocopiers, laser printers, electrostatic spray painting and electrostatic precipitator.

Chapter 17 – Current of Electricity

Voltmeter and Ammeter

Recall that ammeters are connected in series an voltmeters are connected in parallel.

Ohm's Law

Ohm's Law states that the current flowing through a metallic conductor is directly proportional to the potential difference across the ends of the conductor provided that the temperature and other physical conditions remain constant.

Metallic conductors obey Ohm's law whereas filament lamps and semiconductor diodes do not.

Current-Voltage (I/V) Characteristics Graph

Conductors which do not obey Ohm's law are known as non-ohmic conductors.

Component	Description
Metallic conductor at constant temperature	The current is proportional to the potential difference. The conductor obeys Ohm's law as it has constant resistance.
Filament lamp	The graph resembles a $f(x) = \tan(x)$ curve. The current does not obey Ohm's law as its resistance increases as its current increases. This is because the temperature of the lamp increases (heat emission) as the current flowing through it increases.
Semiconductor diode	A semiconductor diode allows electric current to flow in only one direction. The diode does not obey Ohm's law. In the forward bias direction, the current increases very rapidly when the voltage rises above 0.6V, showing that the forward bias has very low resistance. In the reverse bias, the current is negligible, showing that the reverse bias diode has very high resistance.

Resistivity

Using the resistivity formula, as the cross-sectional area of the wire increases, the wire becomes thicker so it will have less resistance. Similarly, a thinner wire has more resistance.

Chapter 18 – D.C. Circuits

Potentiometer

A potentiometer is also known as a variable potential divider.

Transducer

This refers to a device that transforms energy from one form to another. You must know the difference between an input and output transducer.

Transducer	Description	Example
Input transducer	Converts non-electrical energy to electrical energy.	Solar cell, microphone, LDR, thermistor
Output transducer	Converts electrical energy to non-electrical energy.	Loudspeaker, LED

Light-Dependent Resistor (LDR)

An LDR is a resistor whose electrical resistance varies inversely as the amount of light falling on it changes.

	Brightness Level	
	Bright	**Dim**
Resistance	Low	High

Thermistor

A thermistor is a thermal resistor whose resistance varies inversely with temperature.

	Temperature conditions	
	Hot	**Cold**
Resistance	Low	High

Chapter 19 – Practical Electricity

Dangers of Electricity

There are two major dangers when using electricity, namely, the risk of an electric shock and fire. These dangers can be caused by:

- The use of wires with damaged insulation
- The overheating of cables
- Touching wet electrical appliances

Damaged Insulation

The insulation of a wire protects us from touching it. A live wire exposed because of damaged insulation is dangerous. This will cause an electric shock if someone touches it. Any damaged insulation between the live and neutral wires may result in a short circuit. The current flowing through will then suddenly become very large.

Safe Use of Electricity

There are three wires in a power circuit – the live wire, the neutral wire and the earth wire. A p.d. of 240V drives the current through the wires when the circuit is closed.

Live Wire

The live wire is at a potential of 240V. Since our bodies are usually at earth potential (0V), if someone touches a live wire, the large p.d. will cause a large current to flow through his body. The effect is likely to be fatal. The live wire is connected to the switch. This is because even when the switch is off, the appliance will not be live. If a neutral wire is connected, when the switch is off, the appliance will still be live. The fuse is connected to the live wire so that when the fuse blows, the electricity supply is cut off and no current will flow from the live wire to the appliance. When the user touches the appliance, he will not experience an electric shock.

Neutral Wire

The neutral wire stays at earth potential (0V). If a person touches the neutral wire, the person should not get an electric shock as the neutral wire is at the same potential as the body. There is no current flowing through the body. Ensure that the neutral wire and live wire are not in contact.

Earth Wire

The earth wire is connected to the ground and serves as a safety device. It is connected to the metal casing of an appliance. If the earth wire is absent, in the event of a current leakage, when the user touches the appliance, he/she will experience an electric shock.

Scenarios

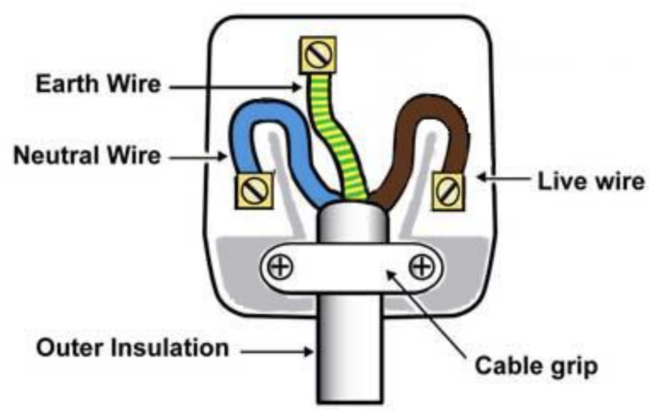
Scenario	Observation
Live and earth	Appliance becomes live as the earth wire is now connected to the circuit instead of earth.
Live and neutral	Appliance will not work as there is a short circuit.
Neutral and earth	Nothing occurs.

Assume that a live wire carries x A of current in the live wire. When the appliance is functioning normally, the neutral wire will also carry x A of current.

Three-Pin Plug

The three-pin plug consists of the live wire, the neutral wire and the earth wire. The colour codes of the three wires are as follows:

Live wire: **brown**
Neutral wire: **blue**
Earth wire: **yellow** and **green** stripes



Always remember that the live wire is connected to the fuse and the earth wire is connected to the metal casing of the appliance. If the metal casing is connected to the neutral wire, current from the metal casing will be carried away by the neutral wire. The circuit breaker will not trip and users will not realise when there is an electrical fault in the appliance.

Switch

If the switch is connected to the neutral wire of a fan, the fan will still be connected to the high voltage source when the switch is open, meaning that the fan is still live. The fan will still operate when the switch is open.

Double Insulation

Some appliances need not have an earth wire as they are double insulated. They have only a 2-pin plug, using only the live and neutral wires. Even if the wires inside become loose, one cannot experience an electric shock. The casing is made of plastic and the live wire cannot touch the casing. The accessible metal parts cannot become live unless the two independent levels of insulation fail.

Fuse

A fuse is a safety device which protects the electrical appliance or wire from overheating in the event of an electrical fault, and it can also protect us. The fuse melts and breaks the circuit when the current exceeds its specified value.

If an electrical appliance operates normally at 3.5A, we generally use a 5A fuse. Using a 3A fuse is unsuitable as excess current will flow through the circuit, causing overheating and damaging the appliance. It is advised not to use a 10A or 13A fuse as it might allow excess current to flow through the circuit. If excess current flows through the circuit, it can lead to irreparable damage to the appliances.

Circuit Breaker

Some circuit breakers can only be used once as they are made of steel. Steel is a hard magnetic material so it is difficult to be demagnetised. It maintains magnetism even after the circuit breaker is disconnected. The circuit breaker cannot be reset.

Chapter 20 – Magnetism

Uses of Magnets

There are both hard and soft magnetic materials. Hard magnetic materials are used as permanent magnets whereas soft magnetic materials are used as temporary magnets.

Hard magnetic materials (steel)	Soft magnetic materials (iron)
Used as a permanent magnet	Used as a temporary magnet
Difficult to magnetise	Easy to magnetise
Difficult to lose its magnetism once magnetised	Easy to lose its magnetism

The magnetic field lines for a magnet and a solenoid are the same.

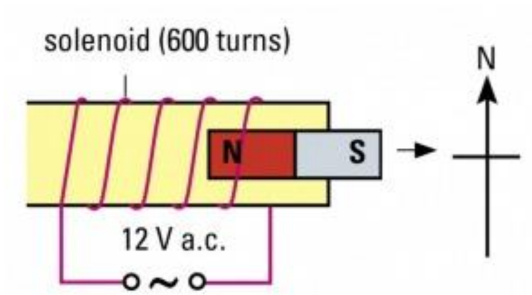
Magnetisation using Direct Current

A steel bar is placed in a solenoid (a cylindrical coil of wire) and a direct current is passed through the solenoid. The solenoid produces a strong magnetic field which magnetises the steel bar. When the current through the solenoid is switched off, the steel bar stays magnetised.

In electromagnetism, we will study that the polarity of this electromagnet is dependent on the Right Hand Grip rule, ideally, the flow of current. When a steel bar is magnetized using a d.c. supply in a solenoid, the solenoid is made of an insulated wire. This is to allow current to flow around the steel bar instead of through it to ensure that magnetisation is effective.

Demagnetisation using Alternating Current

A low voltage alternating current flows through the solenoid. While the current is still flowing, withdraw the magnet slowly in an east-west direction far away from the solenoid.



As the magnet is withdrawn from the solenoid, the magnetism becomes weaker until it is completely demagnetised.

Magnetic Shielding

Some equipment needs to be protected from the influence of external magnetic fields. Soft magnetic materials can be placed to divert magnetic field lines through themselves and away from the equipment.

Chapter 21 – Electromagnetism

Fleming's Left Hand Rule

For a particle to experience a force in a magnetic field, the particle must:

- Be electrically charged.
- Be moving in a direction perpendicular to the magnetic field.

The direction of electron flow is opposite to the direction of conventional current flow. Conductors with currents flowing in the same direction attract, whereas conductors with currents flowing in the opposite direction repel.

Effect of Magnetic Field on Particles

Electrons will gyrate in a magnetic field as a force acts on them. However, when a neutron travels in a magnetic field, it will remain stationary as it has a neutral charge so there will be no induced force. This is the same for all waves which are part of the electromagnetic spectrum.

Applications of the Magnetic Effect of Current

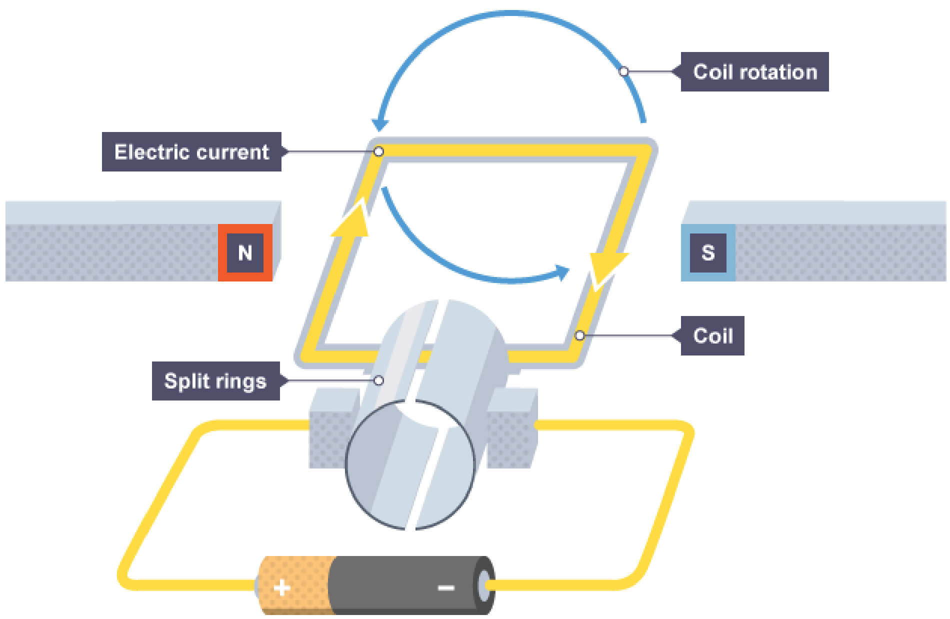
Magnetic Relay

The magnetic relay is a device using an electromagnet in one circuit to switch on another circuit. The metal core should be made of soft iron since iron is a temporary magnet. The magnetic relay can be used for a longer duration. Compared to using a steel core, the magnet will be permanently magnetised so the magnetic relay is only a one-time usage.

Other usages of the magnetic effect are in electric bells and circuit breakers.

The D.C. Motor

The difference between a motor and a generator is that a motor relies on direct current (D.C.) but a generator relies on alternating current (A.C.). Moreover, a motor converts electrical energy to kinetic energy but a generator converts kinetic energy to electrical energy.



The figure above illustrates how a D.C. motor works. The direction of the magnetic field is towards the right. Conventional current flows from the positive terminal to the negative terminal of the cell.

Split-ring commutator	Carbon brushes
Reverses the direction of current in the coil every half a revolution (i.e. passes the vertical position).	To complete the external circuit where an electrical load is connected.

On the left arm of the coil, the direction of current flow is towards the north. On the right arm of the coil, the direction of current flow is towards the south. This catapult field gives rise to a pair of equal and opposite forces acting on the left and right arms of the coil.

Using Fleming's Left Hand Rule, the direction of the force on the left arm is downwards but on the right arm, it is upwards. The coil rotates in an anti-clockwise manner until it reaches a vertical position. At this point, the current is cut off because the split-ring commutator is no longer in contact with the carbon brushes. Recall that the commutator is in contact with the brushes when the coil is horizontal. However, the momentum of the coil will carry it slightly beyond this vertical position due to inertia.

The turning effect can be increased by:

- Increasing the number of turns in the coil
- Increasing the magnitude of the current
- Inserting a soft iron core within the coil to concentrate the magnetic field

Chapter 22 – Electromagnetic Induction

Laws of Electromagnetic Induction

Faraday's Law states that the magnitude of the induced e.m.f. in a conductor is directly proportional to the rate at which the magnetic field lines are cut by the conductor.

In his experiments, he observed that the magnitude of the induced current increases when:

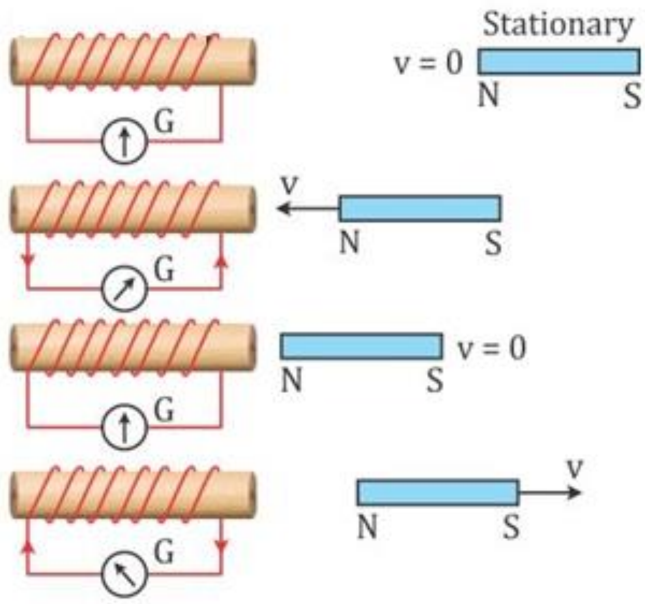
- The magnet is moved in and out of the coil at a faster velocity
- A stronger magnet is used
- The number of turns in the coil is increased
- A soft iron core is winded onto the coil (strengthens the magnetic field lines)

Lenz's Law states that the induced current is always in a direction to oppose the change (motion) producing it.

Faraday's Law	Lenz's Law
When a current-carrying conductor experiences a change in magnetic flux, an e.m.f. is induced.	The induced current flows in a direction opposite to the change producing it.

The Galvanometer Experiment

The galvanometer is an instrument used for detecting and measuring small values of electric current. 4 different cases are depicted and their explanations are stated below.



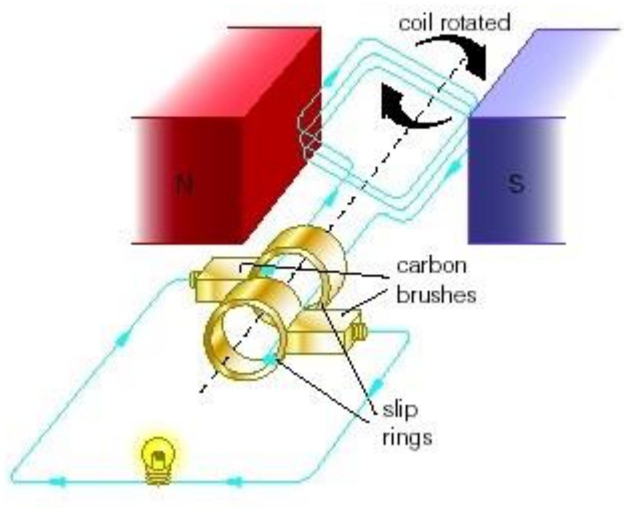
Case 1: The magnet does not induce a magnetic field and e.m.f. in the solenoid.

Case 2: By Faraday's Law, there is an induced current and e.m.f. in the solenoid. According to Lenz's Law, the right end of the solenoid will be an induced north pole.

Case 3: Case 3 is similar to Case 1 since the magnet has a velocity of 0m/s.

Case 4: By Faraday's Law, there is an induced current and e.m.f. in the solenoid. According to Lenz's Law, the induced current will flow in such a direction which opposes the change producing it. The right end of the solenoid will be an induced south pole.

The A.C. Generator



A simple A.C. generator consists of a rectangular coil mounted on an axle which is fixed between the poles of a permanent magnet. When the coil rotates, the magnetic field through it changes. This induces a current in the coil.

Use Fleming's Right Hand Rule to deduce the direction of induced current and the direction of the coil's rotation. The current flows through the two slip-rings to an electrical load, which in this case is a lamp. The two slip-rings each make sliding contact with a fixed carbon brush.

When the coil has rotated through 180°, the sides of the coil will have changed places. Every time the coil turns through 180°, the direction of current reverses through the electrical load. The following are the functions of the slip rings and carbon brushes:

Slip rings	Carbon brushes
Rotate together with the coil.	To complete the external circuit where an electrical load is connected.

Voltage Output of an A.C. Generator

As the coil rotates, the magnetic flux linkage constantly changes. This induces an e.m.f.

When the coil is horizontal, the rate at which the coil cuts the magnetic field lines is the greatest. The magnitude of the induced e.m.f. is at a maximum. When the coil is vertical, the rate at which the coil cuts the magnetic field lines is the least. The magnitude of the induced e.m.f. is at a minimum.

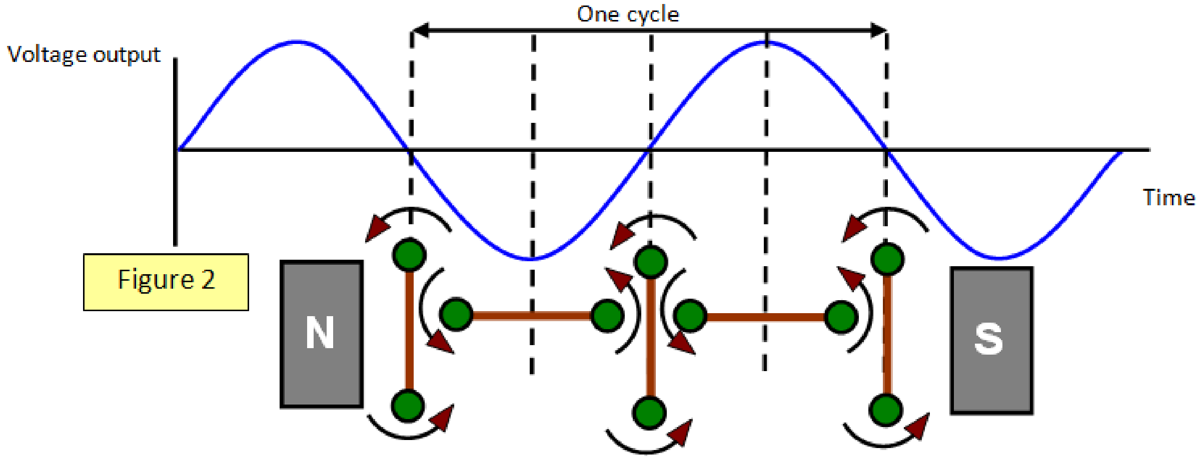


Figure 2

When the speed of the rotation of the coil increases, the frequency of the alternating current and the rate at which magnetic field lines are cut will be doubled. The output voltage doubles and the frequency halves.

When the number of turns in the coil increases, the output voltage doubles but the period remains the same.

The magnitude of the induced e.m.f. can be increased by:

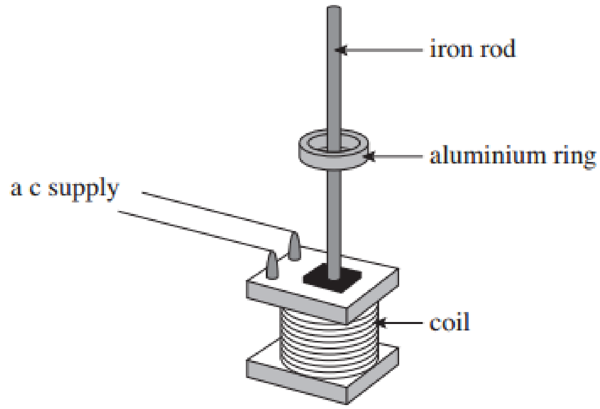
- Increasing the speed of rotation of the coil
- Increasing the number of turns in the coil
- Winding the coil on a soft iron core to concentrate the magnetic field lines through the coil
- Using stronger magnets

Difference between Output Current from an A.C. Generator and Battery Current

The current produced by a battery travels in a single direction – from the positive terminal to the negative terminal, while the current produced from an A.C. generator travels in both directions.

Aluminium Ring Experiment

An experiment is set up as such. The aluminium ring levitates above the base of the stand. This is due to the effect of an induced current in the ring. As the A.C. supply is turned on, there is a change of magnetic field lines cutting the ring. According to Faraday's Law, this induces an e.m.f. in the ring.

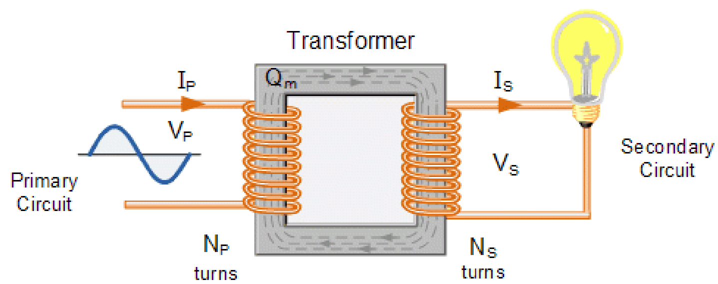


The levitation of the magnet is due to the effect of Lenz's Law which states that the magnetic field of an induced current will oppose the change in the magnetic field that causes the induced current.

If a D.C. supply is used instead, the ring will only levitate momentarily and fall.

Transformers

A transformer has 2 coils of insulated wire, both wound round the same iron core. It only works with an a.c. supply. The 2 coils are known as the primary and secondary coils.



Alternating Voltage

An alternating voltage is a voltage that changes its polarity/reverses its direction periodically.

Turns Ratio

The ratio of the number of turns in the secondary coil to the number of turns in the primary coil is the turns ratio. Given a step-down transformer, thin wires are used in the secondary coil as they have higher resistance and heat up quicker due to Joule heating. The secondary current will increase for a step-down transformer.

The magnetic field in the iron core induces a voltage in the secondary coil. A laminated soft iron core is added to the transformer to reduce the heating effect of the eddy current produced (reduce heat loss) during operation.

Non-magnetic materials like copper cannot be used since they do not have the ability to induce a secondary voltage for the transformer to function well.

Power Transmission

When transmitting electrical power from the power station to the consumer, power is lost due to joule heating of the current in the cables.

To reduce power loss, thick cables can be used. However, these cables are heavy and uneconomical. Another method would be to use a step-up transformer to step up the voltage. This reduces the magnitude of the transmission current.

Cathode-Ray Oscilloscope (CRO)

A cathode-ray oscilloscope is used to:

- Measure D.C. and A.C. voltages
- Display waveforms
- Measure time and frequency

Important concepts are regarding y-gain control and time-base control. Y-gain control amplifies the Y-deflection. The CRO comprises an electron gun, a deflection system consisting x-plates (vertical) and y-plates (horizontal) as well as a fluorescent screen.