‘O’ Level *Physics*

Power Bank!

Version 2.0

Definitions in Physics 6091 O-Level Syllabus

Topics	Definition
Measurements	A **physical quantity** is one that can be measured and consists of a numerical magnitude and a unit. Each complete to-and-fro motion of an object is one **oscillation**. The **Period T** of a pendulum is the time taken for a complete oscillation.
Kinematics	**Scalar** quantities are physical quantities that have *magnitude* only**.** **Vector** quantities are physical quantities that possess both *magnitude* and *direction.* **Speed** is the distance moved per unit time. **Displacement** is distance travelled in a specified direction. **Average speed** is total distance travelled over total time. **Velocity** is the *rate of change of displacement.* **Acceleration** is the *rate of change of velocity.* **Uniform Acceleration** *is the constant rate of change of velocity.* **Free fall** is when an object falls and experiences only the gravitational force.
Dynamics	A **force** is a push or a pull that one object exerts on another. **Newton's 1st Law of motion** states that every object will continue in its state of rest or uniform motion in a straight line unless a resultant force acts on it. {note : This is also known as **Law of Inertia**} **Newton's 2nd Law of motion** states that when a resultant force acts on an object of constant mass, the object will accelerate and move in the direction of the resultant force. The product of the mass and acceleration of the object is equal to the resultant force. **One Newton (1 N)** is defined as the force that will produce an acceleration of 1 m s^{-2} on a mass of 1 kg. **Newton's 3rd Law of Motion** states that for every action, there is an equal and opposite reaction. **Friction** is a force that opposes sliding motion between two surfaces in contact.
Mass, Weight, Density	**Mass** is a measure of the amount of matter or substance in an object. **Density** is the mass per unit volume of a substance. **Weight** is the gravitational force acting on a mass. **Gravitational field** is a *region* in which a mass experiences a force due to gravitational attraction. **Gravitational field strength** is defined as the gravitational force acting per unit mass on an object. {eg. g =10N/kg}

Topics	Definition
	Inertia of an object refers to the reluctance of the object to change its state of rest or motion due to its mass.
Turning effect of Force	**Moment of a force** is the product of force and the perpendicular distance from the pivot to the line of action of the force. **Principle of moments** states that when a body is in equilibrium, the sum of clockwise moments about a pivot is equal to the sum of anticlockwise moments about the same pivot. The **centre of gravity** of an object is defined as the point through which its whole weight appears to act. **Stability** refers to the ability of an object to return to its original position after it is slightly displaced.
Energy, Work and Power	**Energy** is the capacity to do work. **Principle of conservation of energy** states that energy can neither be created nor destroyed. It can be converted from one form to another or transferred from one body to another. Total energy in an isolated system remains constant. **Work done** by a constant force on an object is given by the product of the force and the distance moved by the object in the direction of the force. **One Joule** is the amount of work done by a force of 1 N which moves an object through a distance of 1 m in the direction of the force. **Gravitational potential energy** is the energy which a body possesses because of its position relative to the ground. **Kinetic energy** is the energy a body possessed due to its motion. **Power** is the rate of work done or rate of energy converted. **Efficiency** is the ratio of useful energy (or power) output over the total energy (or power) input and is usually expressed as a percentage. **One watt** is defined as the rate of work done or energy conversion of one joule per second. **Renewable Energy** is defined as energy from sources that can be replenished naturally.
Pressure	**Pressure** is defined as force per unit area. **Atmospheric pressure** is the weight of a layer of air that acts on the Earth per unit area.
Temperature	When two bodies are in thermal contact and there is **no net flow** of heat between them, they are said to be in **thermal equilibrium**. **Temperature** is a measure of the degree of hotness or coldness of a body. **Heat** refers to the amount of thermal energy that is being transferred from a hotter to a colder region.

Topics	Definition
	Thermometric property is a measurable physical property that varies continuously and linearly with temperature. **Ice point** is the temperature of pure melting ice at one atmospheric pressure and is assigned a value of 0^0C. **Steam point** is the temperature of steam from water boiling at one atmospheric pressure assigned a value of 100^0C.
Kinetic Model of Matter	Tiny particles in continuous motion is known as the **kinetic model of matter**. **Brownian motion** is the random motion of particles suspended in a fluid.
Heat Transfer	**Heat** refers to the amount of thermal energy that is transferred from a hotter to a colder region. **Conduction** is the process of thermal energy being transferred through a medium from one particle to another without any flow of the medium. **Convection** is the transfer of thermal energy by means of convection currents in a fluid (liquid or gas), due to a difference in density. **Radiation** is the transfer of thermal energy in the form of electromagnetic waves such as infrared radiation without the aid of a medium.
Thermal Properties of Matter	**Internal Energy** consists of kinetic energy (due to the motion of particles) and potential energy (due to the intermolecular forces) present in the molecules of a substance. **Heat capacity C**, is the amount of thermal energy required to raise the temperature of a body by 1 K or 1°C. (unit : J/K) **Specific heat capacity**, c, is the amount of thermal energy required to raise the temperature of unit mass of a material by 1 K or 1°C (J/kg ° C) **Latent heat** is the energy released or absorbed during a change of state, without a change in temperature. (unit : J) **Latent heat of fusion**, $\mathbf{L_f}$ of a solid is the amount of thermal energy required to change it from solid to liquid state, or vice versa, without any change in temperature. (unit : J) **Specific latent heat of fusion** l_f of a solid is the amount of thermal energy required to change a unit mass of the solid to liquid, or vice versa, without a change in temperature. (unit : J/kg) **Latent heat of vaporization**, **Lv**, of a substance is the thermal energy required to change it from liquid to vapour state, or vice versa, without any change in temperature. (unit : J) **Specific latent heat of vaporization**, **lv** of a substance is the thermal energy required to change unit mass of a substance from liquid to vapour state, or vice versa, without any change in temperature (unit : J/kg)

Topics	Definition
	Condensation is a change of state of a substance from gas to liquid and energy is released. **Boiling** is a process whereby a liquid changes to gas at constant temperature (its boiling point) **Evaporation** is a change of state of a substance from liquid to gas below boiling point. **Freezing** is a change of state when a substance changes from liquid to soild without any change in temperature. **Melting** is a change of state when a solid changes to a liquid upon heating at a constant temperature.
Light	**First law of reflection** states that the incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane. **Second law of reflection** states that the *angle of incidence* is equal to the *angle of reflection*. **Angle of incidence** is the angle between an incident ray and the normal at the point of incidence. **Angle of reflection** is the angle between a reflected ray and the normal at the point of incidence. **Angle of refraction** is the angle between a refracted ray and the normal at the point of incidence. **Refractive Index** is the *ratio of speed of light* in vacuum or air to the speed of light in the denser medium. An **optically denser** medium slows down the speed of light when it enters from a less optically dense medium. **The first Law of refraction** states that the incident ray, the refracted ray and the normal all lie in the same plane at the point of incidence. **The second law of refraction** states that, for two given media, the ratio of the sine of the *angle of incidence i* to the *sine of the angle of refraction r* is a constant. **Critical Angle, c** is defined as the angle of incidence in the optically denser medium for which the angle of refraction in the less dense medium is 90°. **Total Internal Reflection** takes place only when a ray of light travels from an optically denser to optically less dense medium with an angle of incidence greater than the critical angle. The light is totally and internally reflected. **Focal length** is the distance between the optical centre and the principal focus of a lens. **Focal plane** is a flat surface perpendicular to the principal axis which passes through the principal focus. **Optical centre** is the point midway between the lens' surfaces on its principal axis. (light rays passing through the optical centre are not

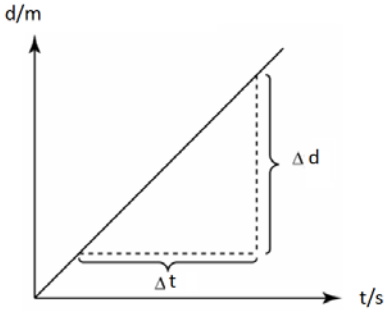
Topics	Definition
	refracted) **Principal axis** is the horizontal line passing symmetrically through the optical centre of the lens. **Principal focus** is the point at which all rays parallel to the principal axis converge to (or diverge) after refraction by the lens. **Real image** is an image formed by a lens that can be captured on a screen. It is formed by the actual intersection of light rays. **Virtual image** is an image formed by a lens/mirror that cannot be captured on a screen. It is NOT formed by the actual intersection of light rays. **Normal** is a line that is perpendicular to the reflecting or refracting surface at the point of incidence.
General Wave Properties	The **source** of a wave is a vibration or oscillation. **A wave** is a disturbance in a medium that carries energy without a net movement of particles. **Transverse waves** are waves that travel in a direction <u>perpendicular</u> to the direction of vibration. **Longitudinal** waves are waves that travel in a direction <u>parallel</u> to the direction of vibration. **Crests** and **troughs** are the highest and lowest points of a transverse wave. Any two points in a wave are said to be in **phase** if they move in the <u>same direction</u> and have the <u>same speed</u> and the <u>same displacement</u> from the rest position. **Wavelength** is the shortest distance between any two points in a wave that are in phase, e.g. two successive crests or troughs or compression or rarefaction. **Amplitude** is the *maximum displacement* of a point of a wave from rest position. **Frequency** of a wave is the number of complete waves produced per second. **Period** is the time taken for one point on the wave to complete one oscillation. This is also the time taken to produce one complete wave. **Wavefront** is an imaginary line on a wave that joins all points that are in the *same phase*.
Sound	**Sound** is produced by vibrating sources placed in a medium which produce regions of compression and rarefaction. Longitudinal waves show areas of **compression** and **rarefaction** : **Compressions** are regions of high pressure due to particles being close together.

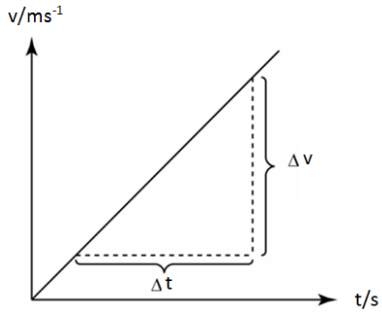
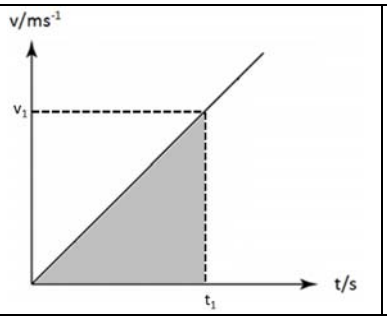
Topics	Definition
	Rarefactions are regions of low pressure due to particles being spread further apart. **Echo** is the reflected sound from a surface heard after an interval of silence. The **maximum pressure change** gives the **amplitude** of the sound wave. Sound with frequencies above the upper limit of the human range of audibility (20 000 Hz) is known as **ultrasound**. Sound with **higher frequency** will have a **higher pitch**. **Louder** sounds have higher amplitude.
Static Electricity	**Electrostatics** is the study of static electric charges. **Laws of charges** states that like charges repel and unlike charges attract. **Electrostatic induction** is the process of charging a conductor without any contact with the charging body. An **electric field** is a region where an electric charge experiences an electric force. The **direction of the field** is defined as the direction of the force on a *small positive charge*. The **strength of an electric field** is indicated by how close the field lines are to each other.
Current of Electricity	An **electric current** is a measure of the rate of flow of electric charge. **1 Amphere** is the flow of 1 coulomb of charge per second. **Electromotive force (EMF)** of an electrical source is defined as the work done by the source in driving a unit charge around a complete circuit. The **potential difference (p.d.)** across a component in an electric circuit is defined as the work done by the source to drive a unit charge through the component. **Resistance** of a metallic component is defined as the ratio of the potential difference V across it to the current I flowing through it. **Ohm's Law** states that current passing through a metallic conductor is directly proportional to the potential difference across its ends, provided the physical conditions (e.g. temperature) are constant.
D.C. Circuits	A **series circuit** is a connection where the components are connected one after another in a single loop and there is **only one path** through which electric current can flow. A **parallel circuit** is a connection where there is **more than one** path through which current can flow.

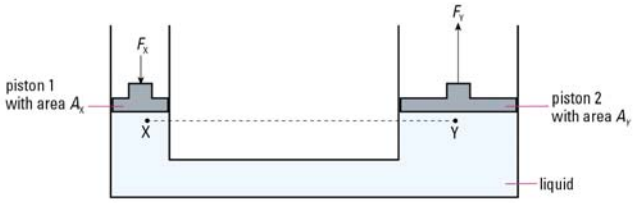
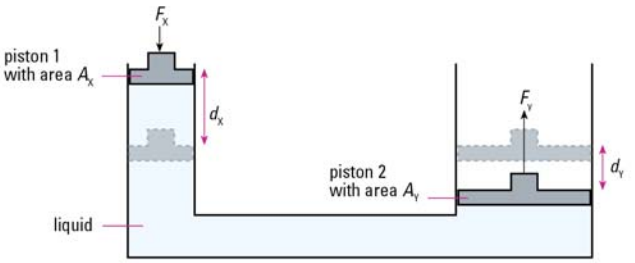
Topics	Definition
	A **potential divider** is a line of resistors connected in series. It is used to provide a fraction of the voltage of a source to another part of the circuit. **Transducers** are electrical or electronic devices that convert energy from one form to another. **Input transducers** convert non-electrical energy to electrical energy. Eg. microphone, Thermocouple, *Thermistor and LDRs* **Output transducers** convert electrical energy to other forms of energy. Eg. microphone, loudspeaker, LED, voltmeter and ammeter. **Thermistor** is a device whose resistance varies with temperature. **Light-dependent resistor** is a device whose resistance varies with amount of light shining on it.
Practical Electricity	**Alternating current** is an electric current that periodically reverses its direction and changes its magnitude in a circuit. **Live** wire (brown) is usually at a *high voltage* like 240 V in Singapore. **Neutral** wire (blue) is usually at *zero voltage*. The **earth** wire (green and yellow) is a low-resistance wire which is connected to the metal casing of the appliance. The other end of the earth wire is connected to the earth so that any leakage of large current will be directed to the ground. **Circuit breakers** are safety devices that can switch off the electrical supply in a circuit when there is an overflow of current. A **fuse** is a safety device included in an electrical circuit to prevent excessive current flow by breaking the circuit. **Double insulation** is a safety feature in electrical appliances. They normally use two-pin plug (only live and neutral wire). The electric cable is insulated from the internal components of the appliance and the internal components are also insulated from the external casing (normally plastic).
Magnetism	**Law of magnetism** states that: **Like poles** repel, **unlike poles** attract. **Magnetic Induction** is the process whereby an object made of a magnetic material becomes a magnet when it is near or in contact with a magnet. A group of atomic magnets pointing in the same direction is called a **magnetic domain**. A **magnetic field** is a **region** in which a magnetic object, placed within the influence of the field, experiences a magnetic force. Magnetic materials (e.g. iron) which are easily magnetized but do not retain their magnetism are called **soft magnetic materials**.

Topics	Definition
	Magnetic materials (e.g. steel) which are harder to magnetize but retain their magnetism are called **hard magnetic materials**.
Electromagnetism	**Motor Effect** is produced when a current carrying conductor is placed in a magnetic field**.** A **D.C. Motor** is a device that converts electrical energy to mechanical energy.

PHYSICS FORMULA

Topics	Formula	Symbols / Units / Remarks
Measurements	• Period of pendulum $T = 2\pi\sqrt{\frac{l}{g}}$ T: Period of pendulum (s) l: length of pendulum (m) g: gravitational field strength (N/kg)	
Kinematics	• Average Speed $average\ speed = \frac{total\ distance}{total\ time}$	Unit: m/s
	• Average Velocity, $v = \frac{\Delta x}{\Delta t}$ Δx: total **displacement,** Δt: total time	
	• Acceleration , $a = \frac{v-u}{\Delta t}$ v: final velocity u: initial velocity Δt: total time	Unit: m/s^2
	• Gradient of distance-time graph = speed • Gradient of displacement-time graph = velocity  $Gradient = \frac{\Delta d}{\Delta t}$ $= speed/velocity\ of\ object$ $\Delta d = change\ in\ distance$ $\Delta t = change\ in\ time$	

Topics	Formula	Symbols / Units / Remarks
	• Gradient of speed/velocity - time graph = acceleration	Unit: m/s^2
	 $Gradient = \frac{\Delta v}{\Delta t}$ $= acceleration$ $\Delta v = change\ in\ speed/velocity$ $\Delta t = change\ in\ time$	
	• Area under the speed-time graph = total distance travelled • Area under the velocity-time graph = total displacement travelled	
	 $Area\ under\ graph = distance\ \ travelled$ $= area\ of\ triangle$ $= \frac{1}{2} \times t_1 \times v_1$	
Dynamics	Newton's Second Law, $F_{net} = ma$	Unit: N
Mass, Weight, Density	• Weight, $W = mg$ • Density, $\rho = \frac{m}{V}$	N kg/m^3
Turning effect of Force	• Moment of force $moment = F \times d$ d = ⊥ distance from line of action of force to pivot • Principle of Moment $sum\ of\ anticlockwise\ moments\ = sum\ of\ clockwise\ moments$	Nm
Energy, Work and Power	• Work Done $WD = F \times d$ *d:* distance travelled in the direction of force • Power $\boldsymbol{P = \frac{E}{t} = \frac{WD}{t}}$ • Gravitational Potential Energy $\boldsymbol{E_P = mgh}$	J W J

Topics	Formula	Symbols / Units / Remarks
	• Kinetic energy $$E_K = \frac{1}{2}mv^2$$ • Efficiency, $E = \frac{useful\ output\ power}{input\ power} \times 100\%$	J % (no unit)
Pressure	Pressure, $P = \frac{F}{A}$ • Pressure of liquid column $$P = h\rho g$$	Pa, N/m^2
	• For Hydraulic jack $$\frac{F_x}{A_x} = \frac{F_y}{A_y}$$  	
	Or work done at piston A = work done at piston B $\mathbf{F_x X d_x = F_y x d_y}$ Or Vol change at piston A = Vol change at piston B. $\mathbf{A_x x d_x = A_y x d_y}$  	
Temperature	• Calculating temperature for thermometer based on length expansion $$\theta°C = \frac{X_\theta - X_0}{X_{100} - X_\theta} \times 100$$ • For thermocouple, $$\varepsilon = k\Delta\theta$$	Valid for 100 parts. Need to modify if interval is not 100 parts ε – emf

Topics	Formula	Symbols / Units / Remarks
Thermal Properties of Matter	• Heat Capacity : Q = **C** x Δθ • Heat Capacity and specific Heat Capacity C = m x c • Specific Heat Capacity : Q = m x **c** x Δθ • Specific Latent heat of fusion $E = m\boldsymbol{l_f}$ • Specific Latent heat of vaporization $E = m\boldsymbol{l_v}$	J/°C, J/K J/kg°C, J/kgK J/kg J/kg
General Wave Properties	• Wave velocity, $\boldsymbol{v = f\lambda}$ • Wave frequency, $\boldsymbol{f = \frac{1}{T}}$	v – m/s f – Hz λ - m T - s
Light	• Refractive index $\boldsymbol{\eta = \frac{c}{v}}$ • Snell's Law (refraction) $\boldsymbol{\eta = \frac{\sin i}{\sin r}}$ • Critical Angle, $\boldsymbol{\eta = \frac{1}{\sin C}}$	c – speed of light 3.0 x 10^8 m/s v – speed of light from <u>air to medium</u> <u>ONLY</u>
Current of Electricity	• Current $I = \frac{Q}{t}$ • Voltage $V = \frac{E}{Q}$ • Ohm's Law $R = \frac{V}{I}$ • Resistance of a wire $R = \rho\frac{l}{A}$	A V Ω ρ – Ωm l – m A – m^2
D.C. Circuits	<u>Resistance in series</u> $R = R_1 + R_2 + R_3$ • Voltage is shared among all the components • Same current flows through all the components	

Topics	Formula	Symbols / Units / Remarks
	Resistance in parallel $$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$ • Voltage is the same for parallel resistors • Sum of current flowing through each component equals to the current flowing through the source.	
Practical Electricity	$$\boldsymbol{P = VI}, \quad \boldsymbol{P = I^2R}, \quad \boldsymbol{P = \frac{V^2}{R}}$$ Electrical Energy $$\boldsymbol{E = Pt}$$ $$\boldsymbol{E = VIt}$$	

MUST KNOW KEY CONCEPTS/IDEAS/FACTS IN PHYSICS 6091

Topics	Key Concepts/ Ideas
Measurements	

SI Base Units

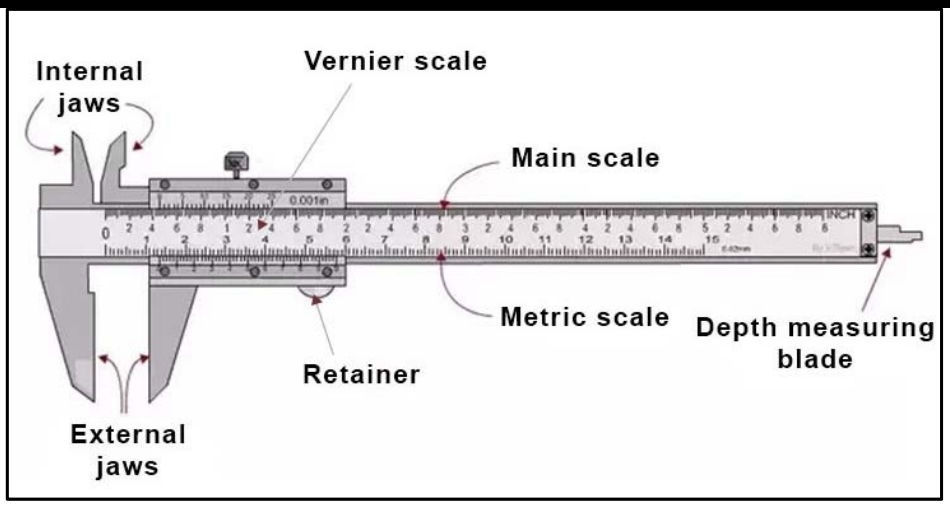
Quantity	Symbol	Unit	Abbreviation
Length	l	Meter	m
Mass	m	Kilogram	kg
Time	t	Second	s
Temperature	T	Kelvin	K
Amt. of Substance	n	Mole	mol
Electric Current	I	Ampere	A
Luminous Intensity	I_v	Candela	cd

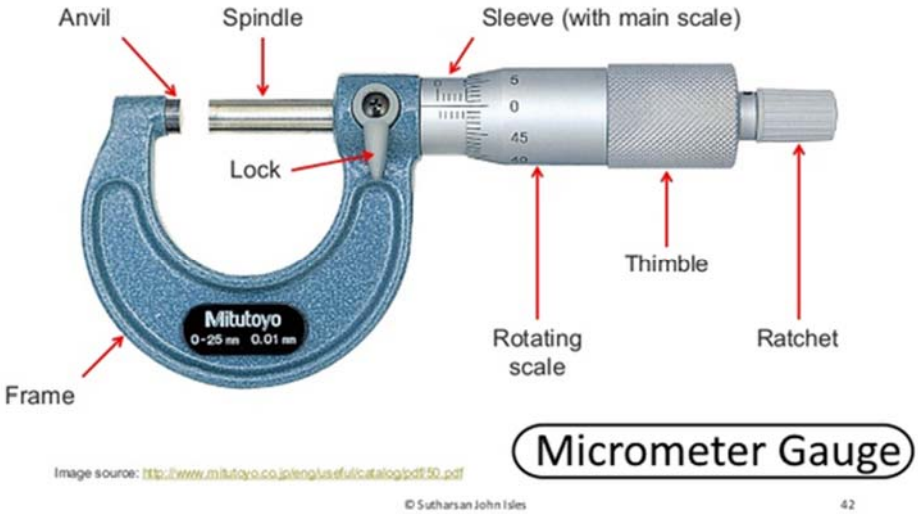
Table 2. Commonly used SI prefixes

Prefix	Symbol	Factor	Numerically	Name
giga	G	10^9	1 000 000 000	billion
mega	M	10^6	1 000 000	million
kilo	k	10^3	1 000	thousand
centi	c	10^{-2}	0.01	hundredth
milli	m	10^{-3}	0.001	thousandth
micro	μ	10^{-6}	0.000 001	millionth
nano	n	10^{-9}	0.000 000 001	billionth

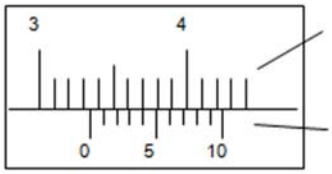
Diameter of atom : 10^{-10} m
Average width of human hair : 1.0×10^{-4} m
Average radius of earth : 6.3×10^6 m

Topics	Key Concepts/ Ideas



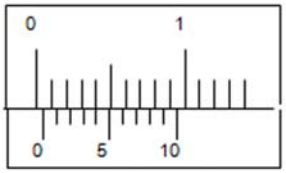


Topics	Key Concepts/ Ideas
	Zero error and vernier calipers



measured reading = 3.3 + 0.04 = 3.34

fig. (a)

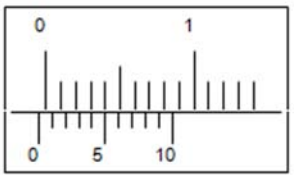


Vernier scale zero is right of main scale zero

Correct measurement with positive error = 3.34 - 0.04 = 3.30

positive zero error = 0.04

fig. (b)



Vernier scale zero is left of main scale zero

Correct measurement with negative error = 3.34 - (-0.04) = 3.38

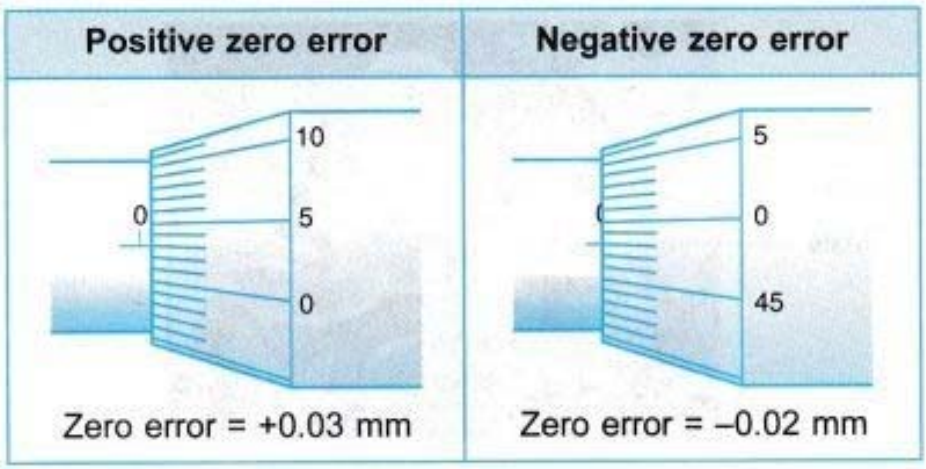
negative error = - 0.04

fig. (c)

Zero error and micrometer

Positive zero error: zero marking on thimble scale is below the datum line (zero mark on main scale can be seen)

Negative zero error: zero marking on thimble scale is above the datum line (zero mark on main scale cannot be seen)



Topics	Key Concepts/ Ideas
Kinematics	**Graphs of motion**

Motion graphs

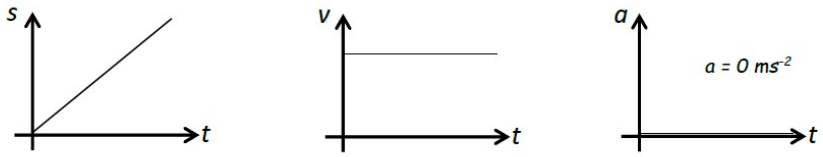
s-t : displacement-time graph

v-t : velocity-time graph

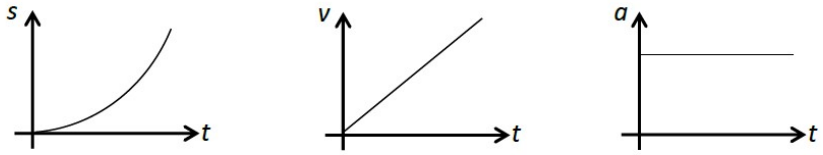
a-t : acceleration-time graph

Typical Example

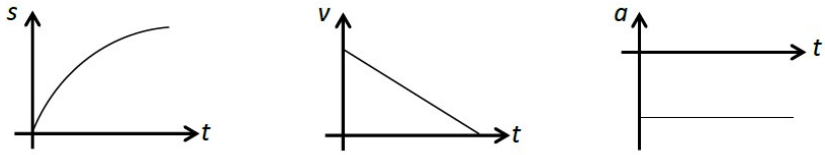
- Constant velocity

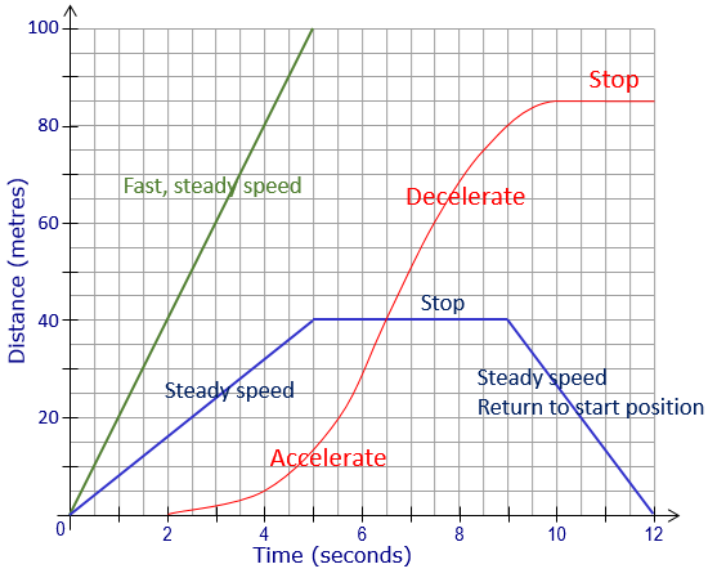


- Accelerating uniformly



- Decelerating uniformly





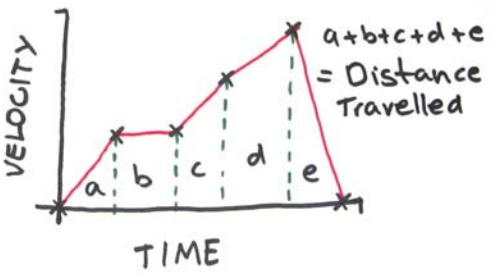
The **green line** shows a fast, steady speed, moving from 0 to 100 m in 5 seconds.

The **blue line** shows a journey with a stop and a return to the starting position.

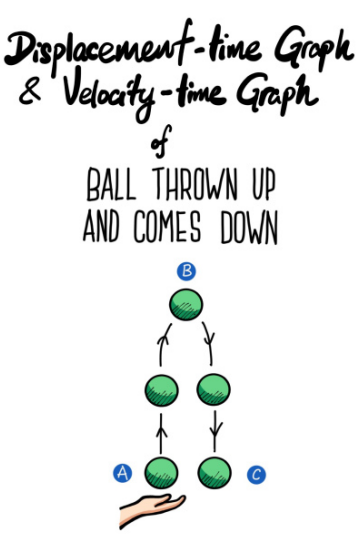
The **red line** shows a journey starting 2 seconds later than the other two, with an initial acceleration, then a deceleration and then a stop.

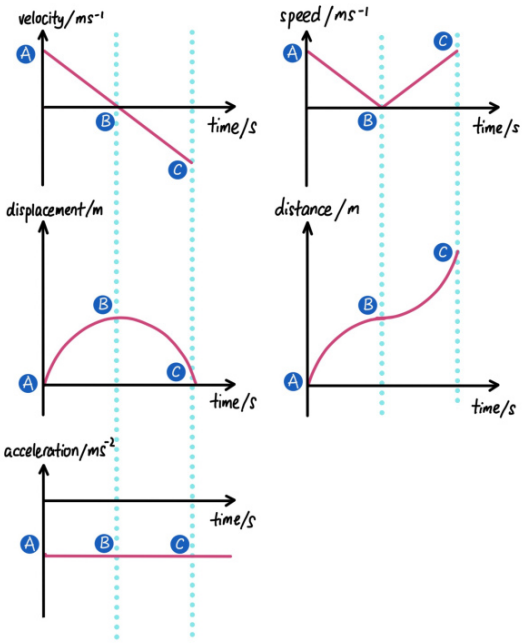
Topics	Key Concepts/ Ideas

Area under velocity-time graph

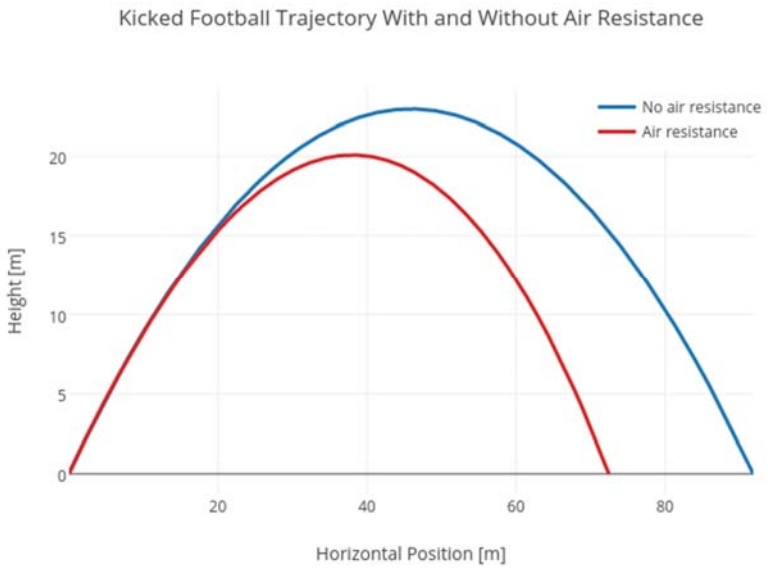


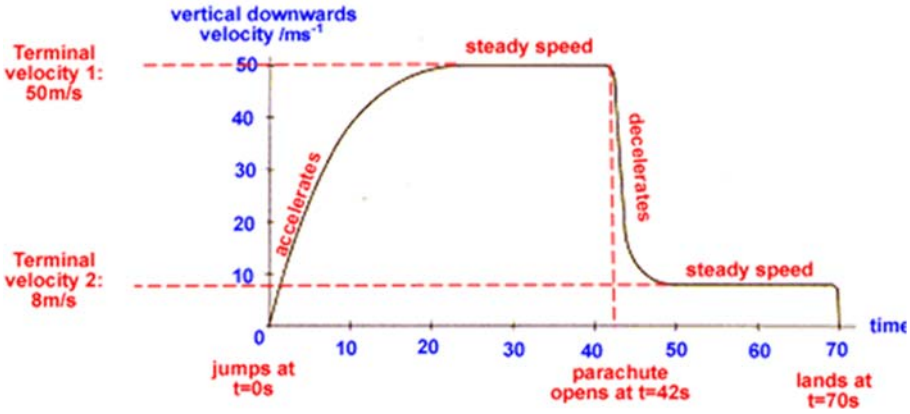
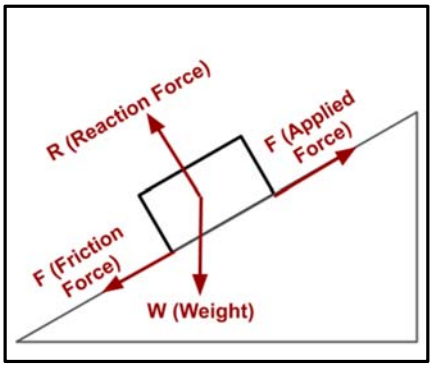
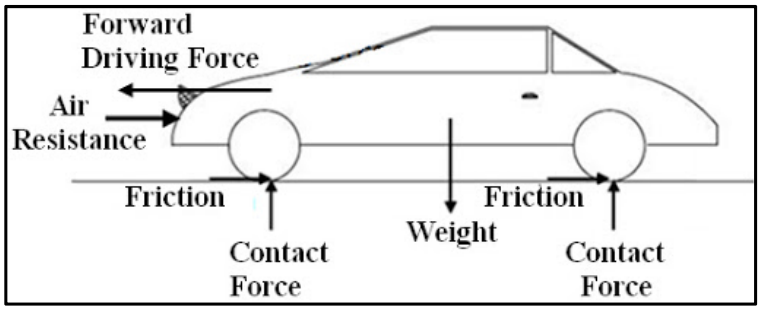
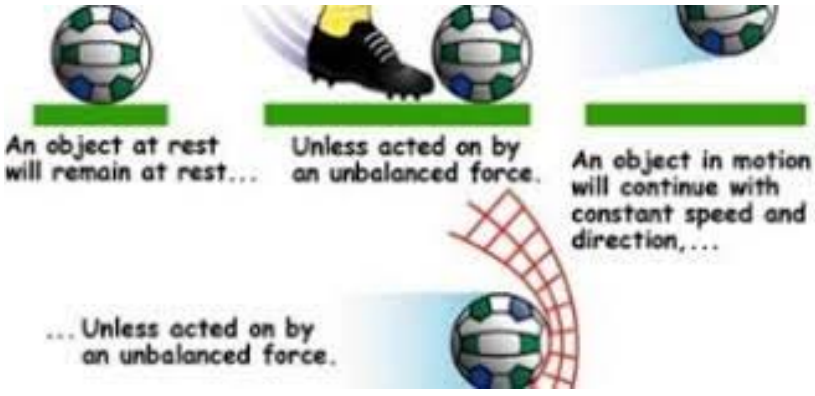
Object thrown up





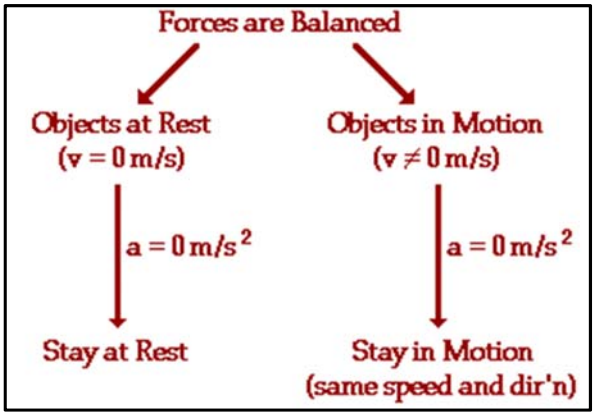
An example of motion with and without air resistance

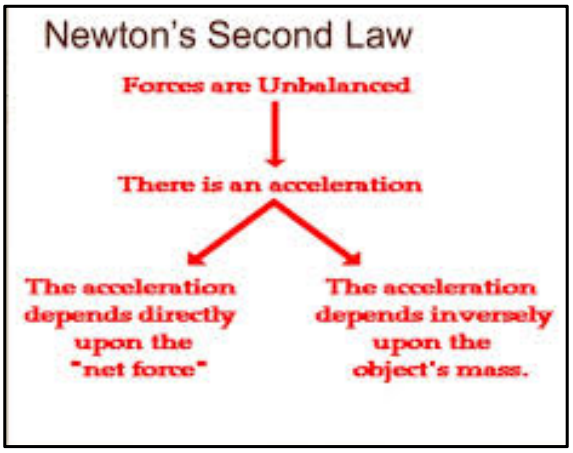


Topics	Key Concepts/ Ideas
	Parachutist vel-time graph  **Terminal velocity** occurs when the weight is equal to the air resistance, resulting in zero net force.
Dynamics	**Free body force diagram**   **Newton's first Law** 

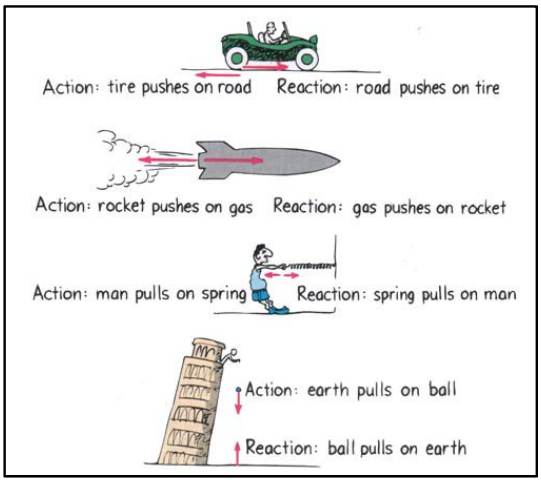
Topics	Key Concepts/ Ideas

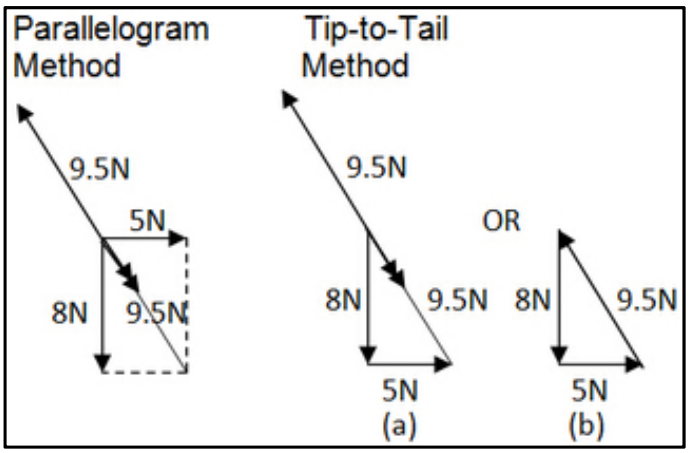
Effect of Balanced and Unbalanced Forces on Motion





Newton's Third Law

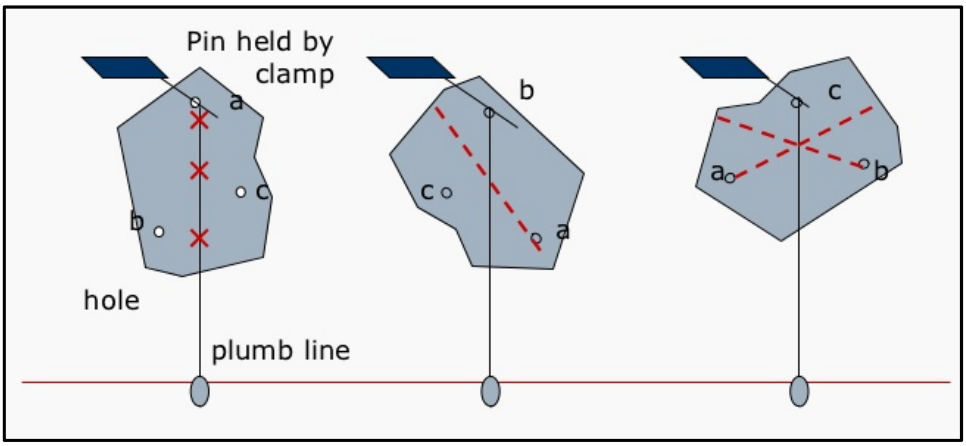


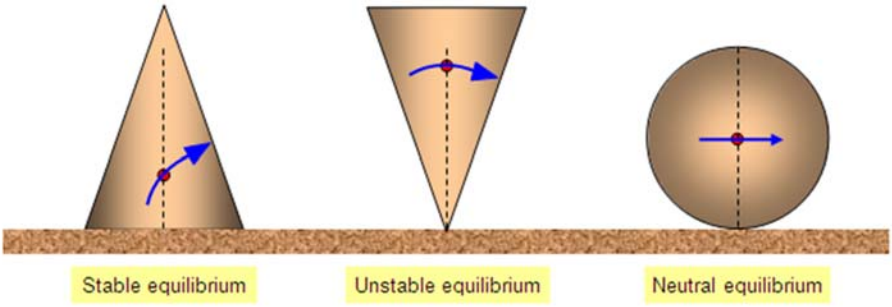
<table>
<tr><th>Topics</th><th>Key Concepts/ Ideas</th></tr>
<tr><td></td><td><u>Vector Diagrams</u>
 
</td></tr>
<tr><td>Mass, Weight, Density</td><td><u>Difference between Mass and Weight</u>

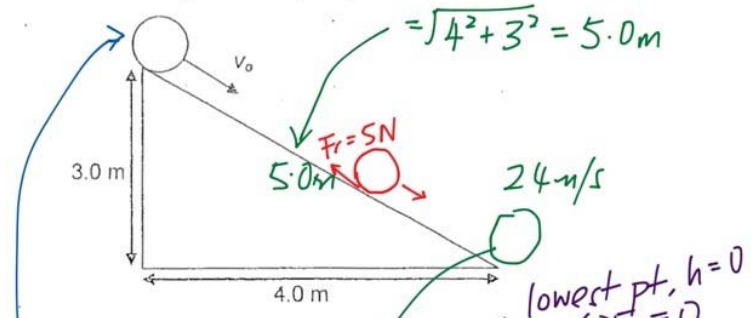
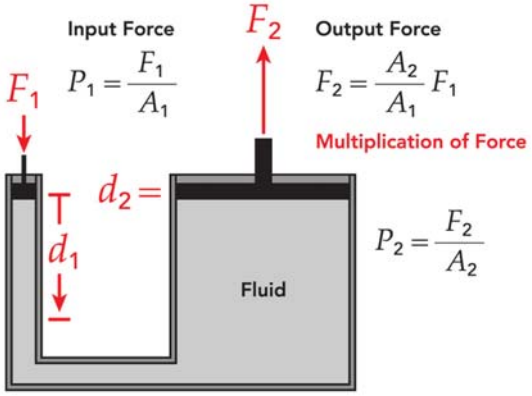
<table>
<tr><th>Mass</th><th>Weight</th></tr>
<tr><td>• The amount of matter in a body</td><td>• Due to the pull of gravity on a body</td></tr>
<tr><td>• Has only magnitude, i.e. a scalar</td><td>• Has both magnitude and direction, i.e. a vector</td></tr>
<tr><td>• Measured in kilograms (kg)</td><td>• Measured in newtons (N)</td></tr>
<tr><td>• Constant regardless of the gravitational field strength</td><td>• Varies according to the gravitational field strength</td></tr>
<tr><td>• Usually measured by a beam balance or calibrated electronic balance</td><td>• Usually measured by a spring or compression balance</td></tr>
</table>

Conversion of density from kg / m^3 to g / cm^3 and vice versa:
1000 kg / m^3 = 1.0 g / cm^3</td></tr>
</table>

Topics	Key Concepts/ Ideas
Turning effect of Force	**C.G. of an irregular figure**

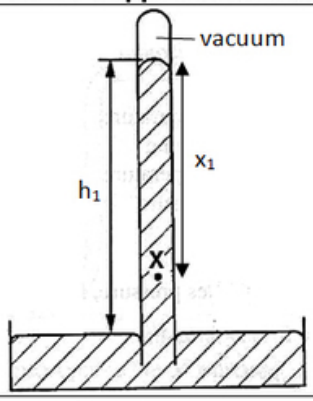
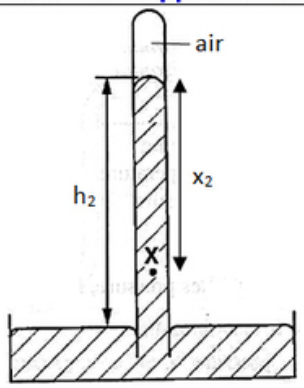


Stable Equilibrium	Unstable Equilibrium	Neutral Equilibrium
		
If cone is slightly tilted: • centre of gravity rises before returning to its original height; • the moment of its weight causes the cone to return to its original position	If cone is slightly tilted: • centre of gravity drops and unable to return to its original height; • moment of its weight causes the cone to topple	If cone is slightly tilted: • centre of gravity remains at the same height; • moment of its weight is zero and cone stays in the position to which it is displaced.

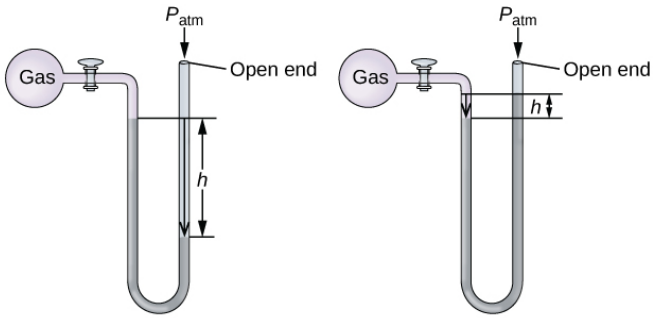
Topics	Key Concepts/ Ideas
Energy, Work and Power	**<u>An example on Conservation of Energy Calculation</u>** A 0.5 kg ball rolls down a ramp with an initial speed v_o as shown in the figure.  Given that the friction on the slope is 5.0 N and that the speed of the ball at the bottom of the slope is 24.0 ms^{-1}, what is the value of v_o? $KE + GPE = KE + GPE + WD_{Friction}$ $\frac{1}{2}mv^2 + mgh = \frac{1}{2}mv^2 + F_r \times d$ (parallel distance ↑ to Friction) $\frac{1}{2}\times 0.5 \times V_o^2 + 0.5\times 10\times 3 = \frac{1}{2}\times 0.5\times 24^2 + 5\times 5$ $0.25V_o^2 + 15 = 169$ $V_o^2 = 616$ $V_o = 24.8\ m/s$
Pressure	**<u>Hydraulic Press</u>**  $F_1 d_1 = F_2 d_2$ $d_1 = \frac{F_2}{F_1}d_2 = \frac{A_2}{A_1}d_2$

Topics	Key Concepts/ Ideas

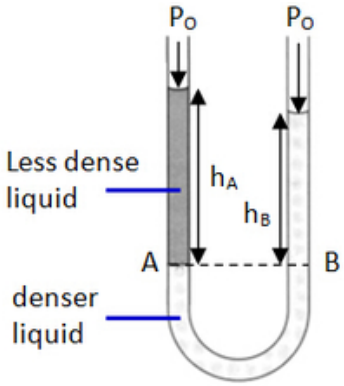
Reading a Barometer

No air trapped in the tube	Some air trapped in the tube
	
$p_{atm} = h_1 \rho g$ $p_x = x_1 \rho g$	$p_{atm} = h_2 \rho g + p_{air}$ $p_x = x_2 \rho g + p_{air}$
$x_1 > x_2$ $h_1 > h_2$	

Manometer



Manometer and two liquids



$$P_A = P_B$$

$$P_O + h_A \times \rho_A \times g = P_O + h_B \times \rho_B \times g$$

Topics	Key Concepts/ Ideas
Temperature	**<u>Themometric properties</u>** **Calibrating thermometer** 1. Mark ice point and steam point 2. Divide space in between into 100 equal parts
Kinetic Model of Matter	**<u>Brownian motion set-up</u>**

THERMOMETRIC PROPERTY	THERMOMETER
Volume expansion of a gas	Gas thermometer
Volume expansion of a liquid	Laboratory or clinical thermometer
Volume expansion of a solid	Bi-metallic strip thermometer
Pressure change of a fixed mass of gas	Constant – volume gas thermometer
Changes in e.m.f.	Thermocouple
Changes in electrical resistance	Resistance thermometer or thermistor

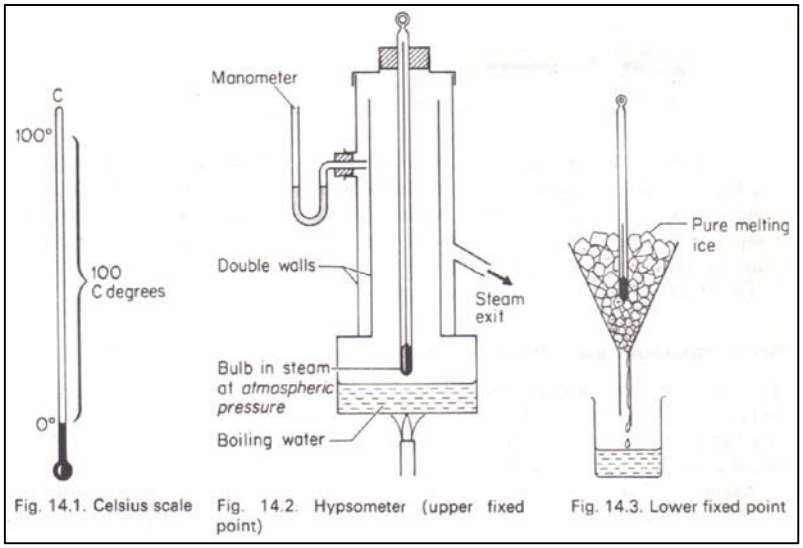
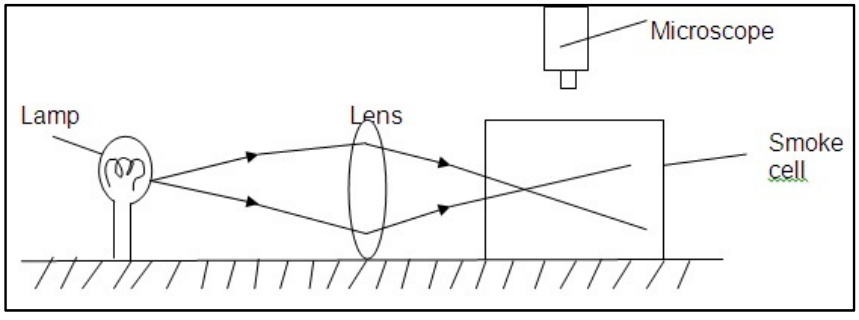
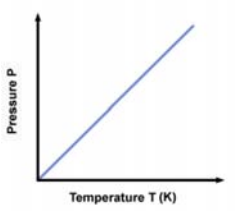
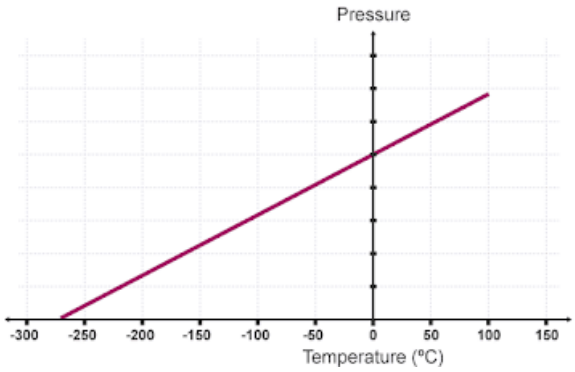
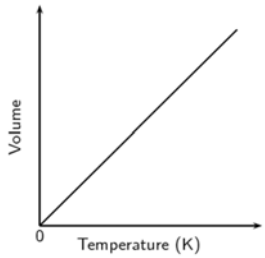
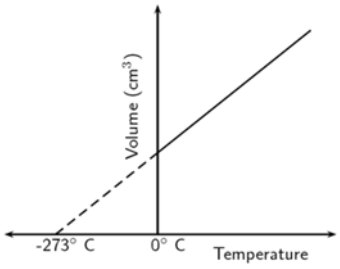
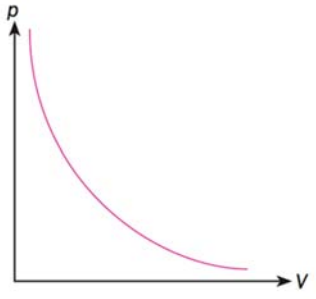
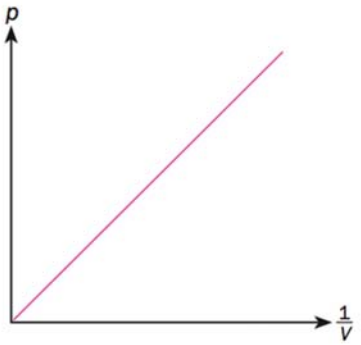


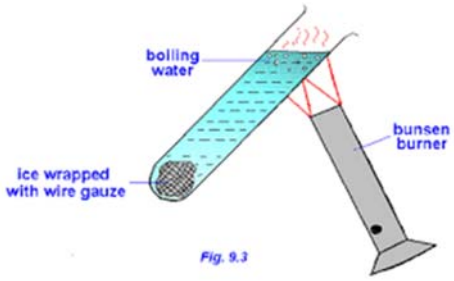
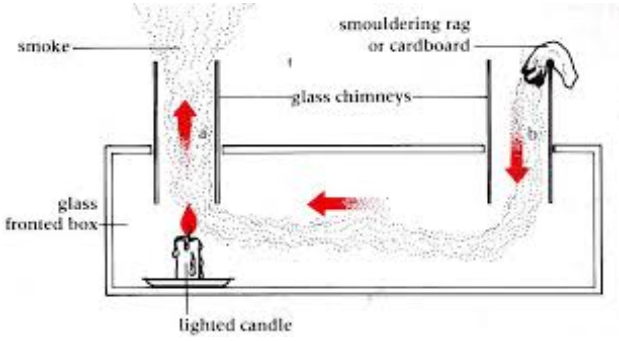
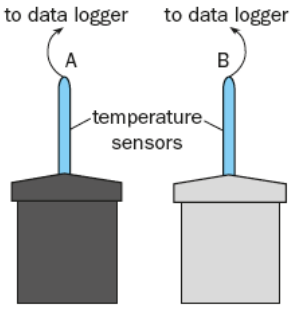
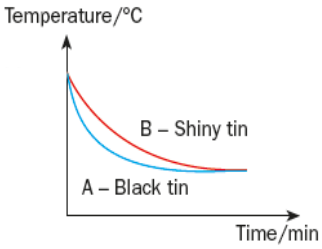
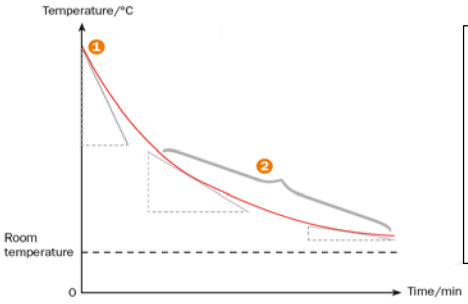
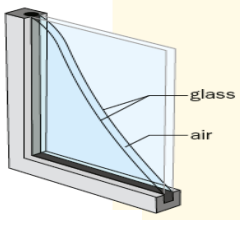
Fig. 14.1. Celsius scale

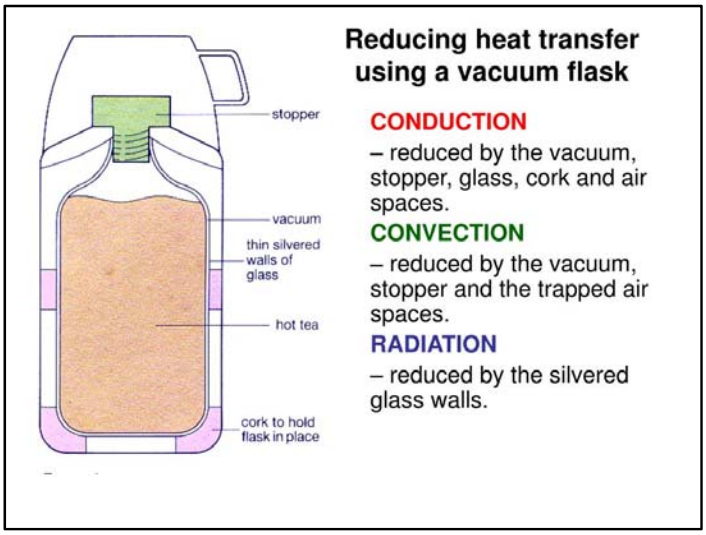
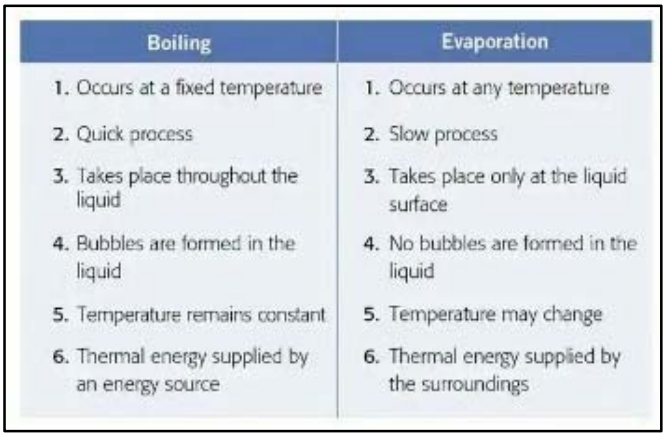
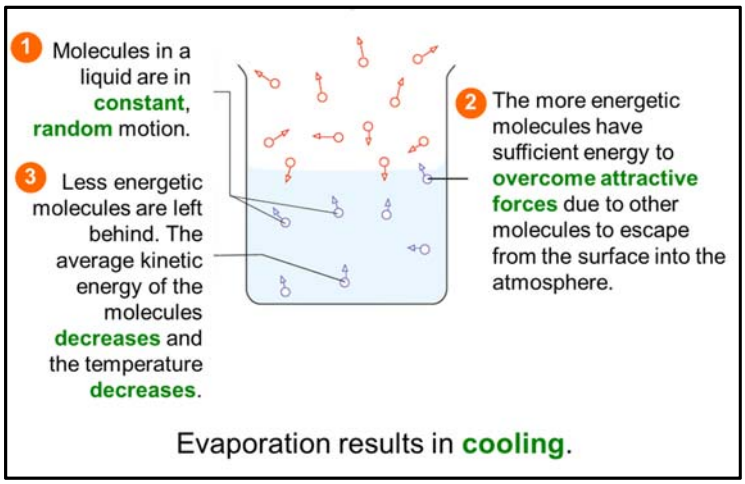
Fig. 14.2. Hypsometer (upper fixed point)

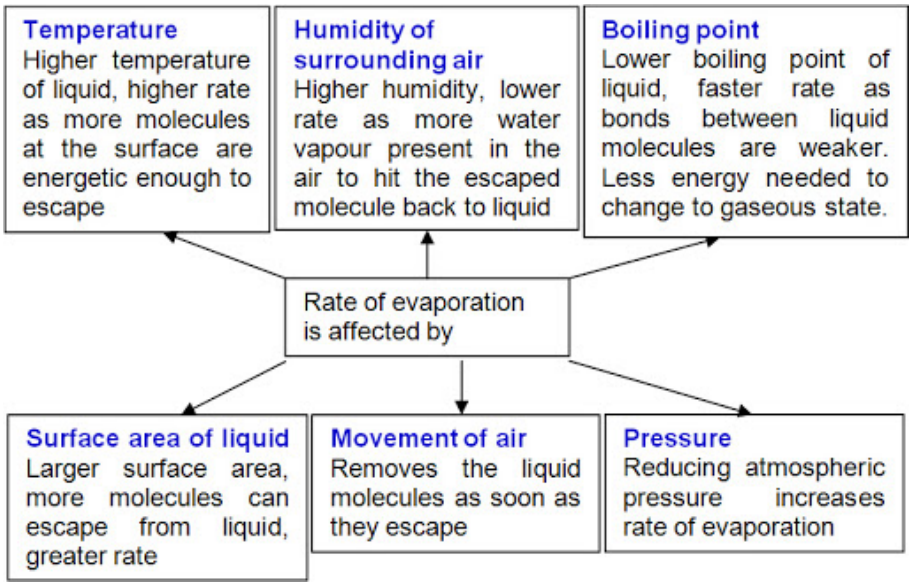
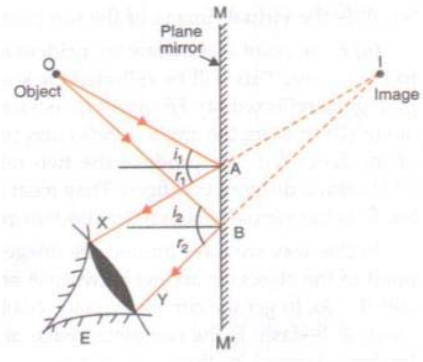
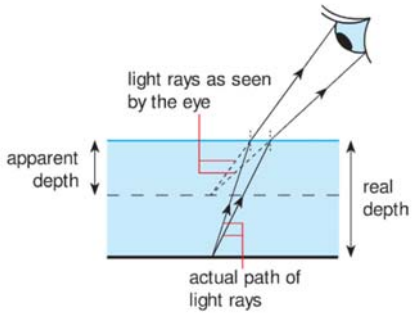
Fig. 14.3. Lower fixed point



Topics	Key Concepts/ Ideas
	P-T relationship : (V constant) The pressure p of a fixed mass of gas is **directly proportional** to its temperature T(K) at constant volume. (P α T)   **V-T relationship : (P constant)** The volume V of a fixed mass of gas is **directly proportional** to its temperature T(K) at <u>constant pressure</u>. (V α T)   <u>Theory</u> : temp increase…pressure increase…volume increase.. rate of collision decrease… pressure decrease back to remain constant. **P-V relationship : (T constant)** The **pressure *p*** of a **fixed mass** of gas is **inversely proportional** to its **volume *V*** at **constant temperature**. (P α 1/V)  

Topics	Key Concepts/ Ideas
Heat Transfer	**<u>Experiment to prove water is a poor conductor</u>**  Fig. 9.3 **<u>Experiment to demonstrate convection in gas.</u>**  **<u>Experiment to prove black is a better emitter</u>**    The higher the temperature of an object relative to its surrounding temperature, the higher the **rate of emission of infrared** radiation.  Trapped air between two panes of glass help to reduce heat loss (rate of emission of infrared radiation)

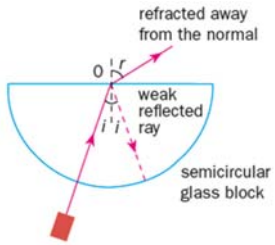
Topics	Key Concepts/ Ideas
	
Thermal Properties of Matter	 **<u>Evaporation causes cooling</u>** 

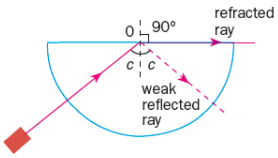
Topics	Key Concepts/ Ideas
	Factors affecting rate of evaporation 
Light	**Reflection**  Characteristics of a plane mirror image: • It is **laterally** inverted. • It is the same **size** as the object. • It is **upright**. • It is **virtual** (it cannot be captured on a screen). • Its distance from the mirror is **equal** to the distance of the object from the mirror. **Refraction**  Ray diagram for why objects appear bent in water. $n = \frac{real\ depth}{apparent\ depth}$

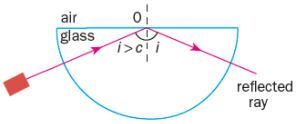
Topics	Key Concepts/ Ideas

Critical Angle and Total Internal Reflection (TIR)

O is the centre of the semicircular glass block.







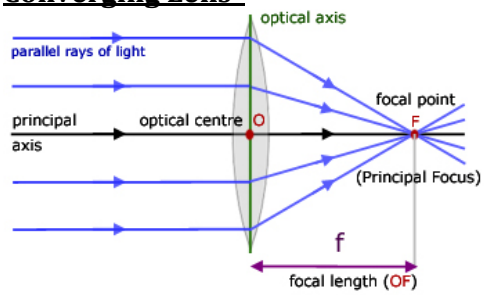
Conditions for TIR

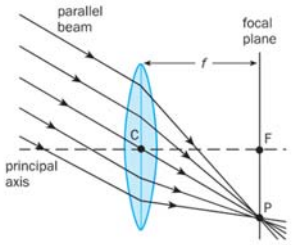
- Light travel from optically denser to optically less dense medium
- Angle of incidence is greater than critical angle.

Advantages of optical fibre

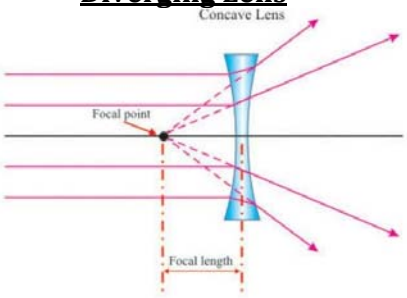
1. Greater bandwidth – can carry much more information over longer distances than copper wires.
2. Less signal degradation – less signal loss than copper wires
3. Light weight – light weight, thin and more durable than copper wires
4. Data security – signals are difficult to tap.
5. Lower cost – cheaper to manufacture as compare to copper wires

Converging Lens

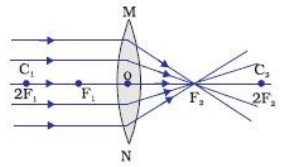
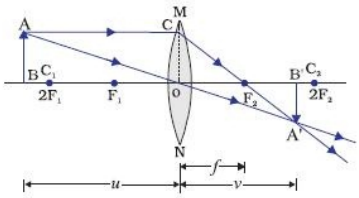
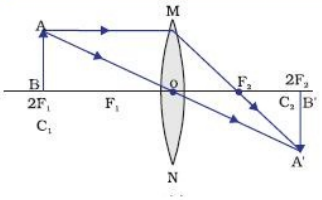
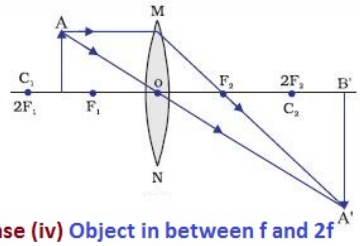
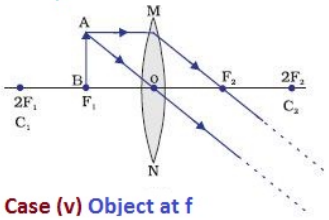
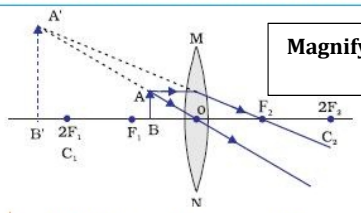
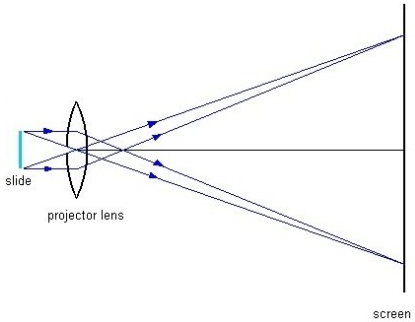


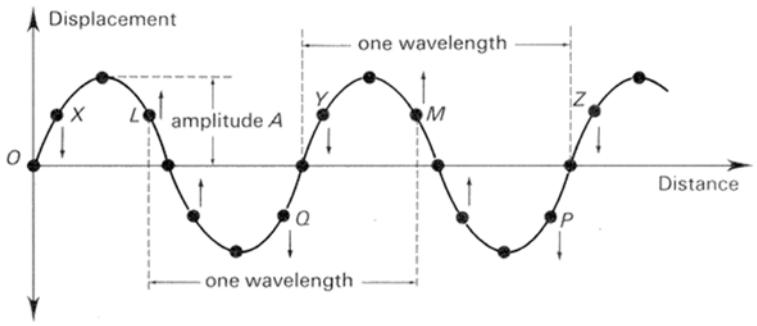
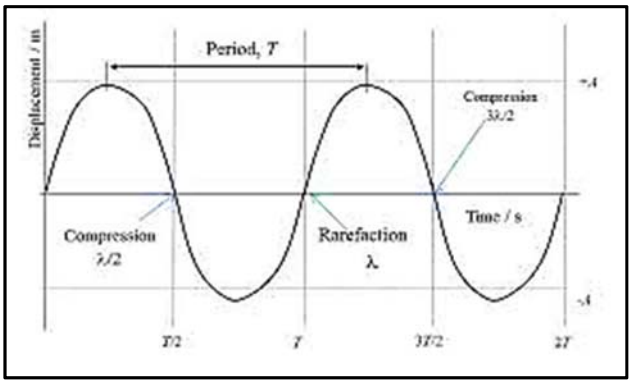
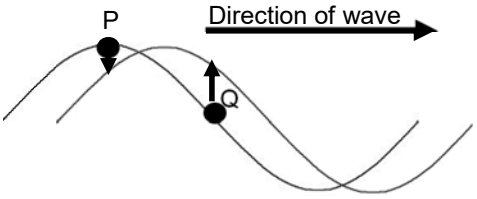


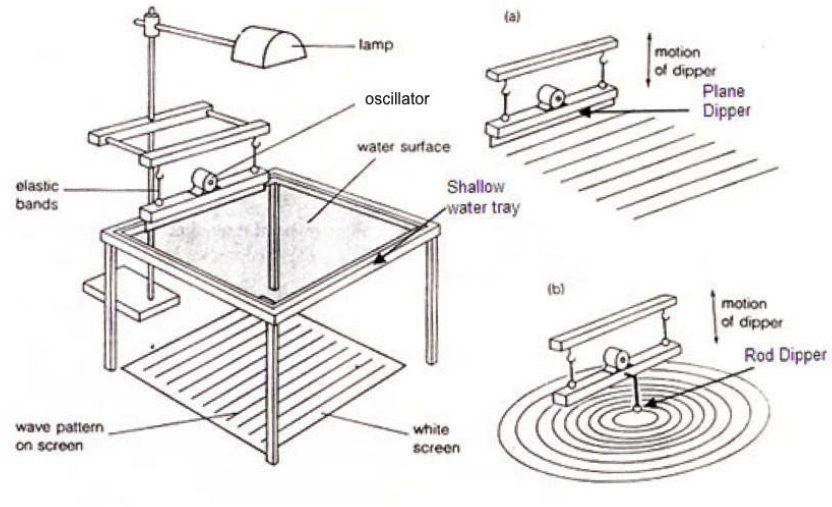
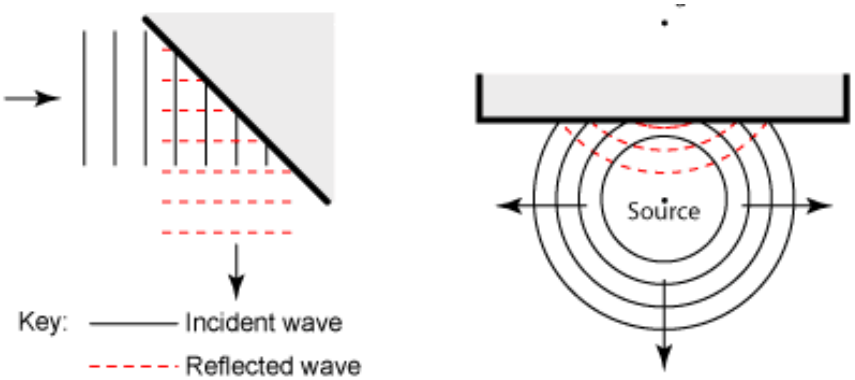
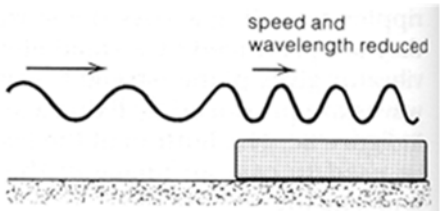
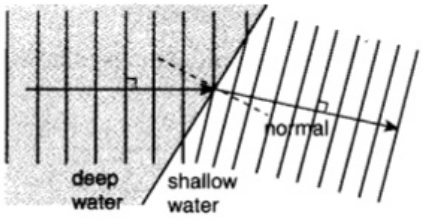
Diverging Lens

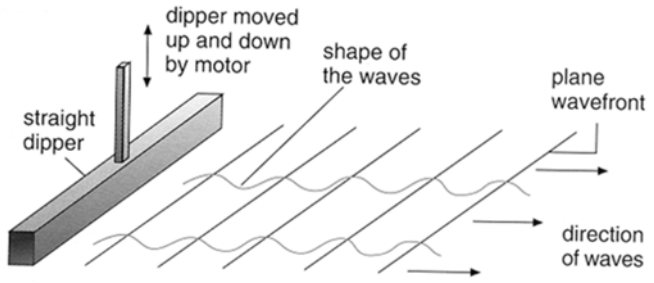
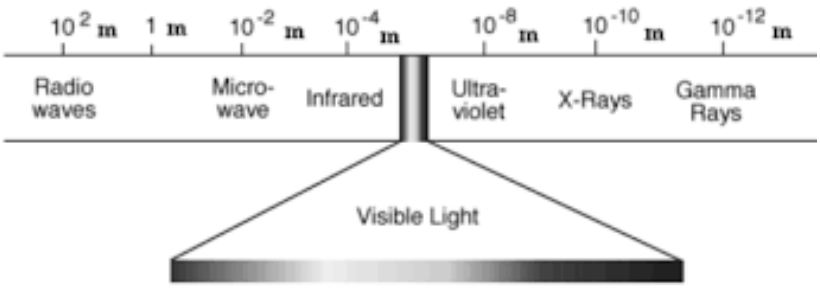


Parallel rays (not parallel to the principal axis) enter the lens and focus at focal plane.

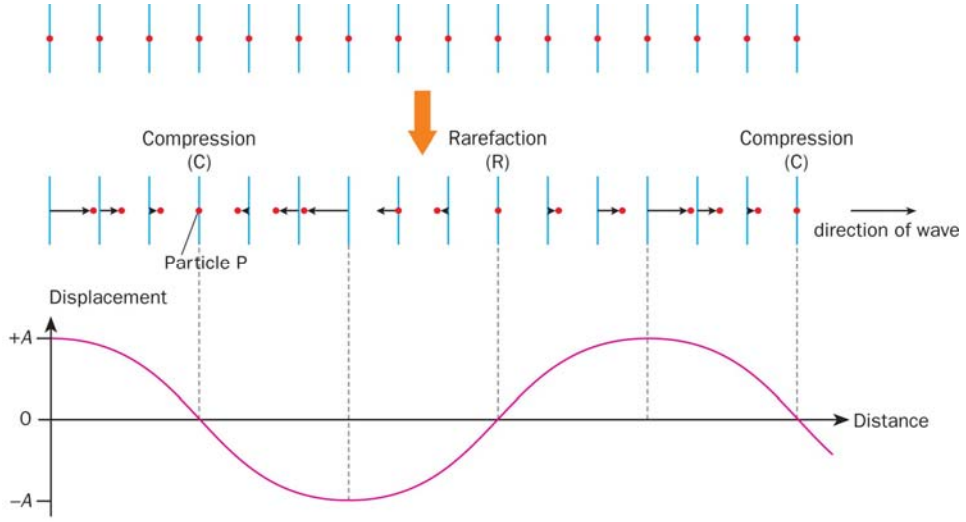
Topics	Key Concepts/ Ideas
	Possible scenarios when object placed at different positions.  Case (i) Object at infinity  Case (ii) Object at beyond 2f  Case (iii) Object at 2f  Case (iv) Object in between f and 2f  Case (v) Object at f  Case (vi) Object distance < f **Magnifying glass** Type of image produced: 1. Object is placed ≤ F, then image will be **virtual** and **upright**. 2. Object is placed >F, then image will be **real** and **inverted**. 3. Object is placed <2F, then image will be **magnified**. 4. Object is placed =F, then image will be **same size** and **same distance**. 5. Object is placed >2F, then image will be **diminsed**. If **half** of the lens is **blocked**, the image will **still be sharp and whole** but it will **become dimmer** as lesser rays will converge on the image. **Projector ray diagram** 

Topics	Key Concepts/ Ideas
General Wave Properties	**<u>Displacement-Distance graph</u>**  The displacement of **<u>all particles</u>** from their rest positions at different distances from the source of disturbance at <u>a given instance</u> is captured in a displacement-distance graph. **<u>Displacement-Time graph</u>**  The displacement of a **<u>single particle</u>** over a <u>period of time</u> is shown above as the displacement-time graph. To determine the next position or direction of particle, draw the next wave in the direction of the wave propagation. 

Topics	Key Concepts/ Ideas
	Ripple tank  **Reflection of water waves**  • **No change in frequency, wavelength and speed of reflected wave.** **Refraction of water waves**  **Figure 8a** Water waves travel more slowly in shallow water. This can be used to demonstrate refraction  • When water waves travel from **deep to shallow** (i) It bends towards the normal (ii) Wavelength decrease and speed decrease (iii) Frequency remains the same • Speed of wave depends on the medium and depth

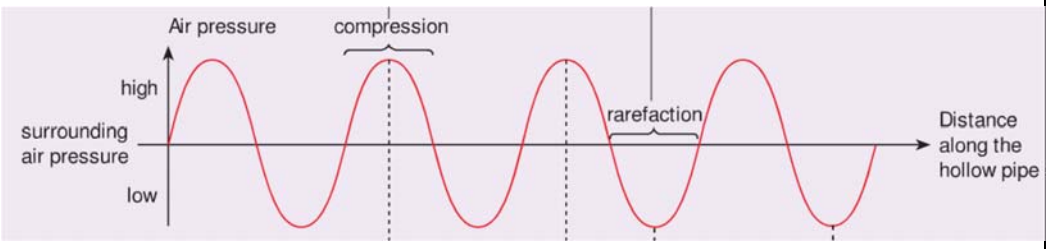
Topics	Key Concepts/ Ideas
	wavefront  Figure 13.11 Plane water waves
EM waves	**EM spectrum**  red : 700 nm UV : 400 nm **Properties of EM waves** • They are transverse in nature. • They can travel through a vacuum. • They travel at the speed of light in vacuum, $c = 3.0\times10^{8}$ m/s • The obey the wave equation $v = f \times \lambda$ • When an EMW travels from one medium to another (e.g. from air to glass), its speed and wavelength change but frequency does not change. *Frequency depends only on the source of the wave.* • They can be reflected and retracted. **Uses of EM waves** (i) radio waves (e.g. radio and television communication) (ii) microwaves (e.g. microwave oven and satellite television). (iii) infra-red (e.g. infra-red remote controllers and intruder alarms) (iv) light (e.g. in optical-fibres for medical uses and telecommunications) (v) ultra-violet (eg. sunbeds and sterilisation) (vi) X-rays (eg. radiological and screening baggage at airport) (vii) gamma rays (eg. medical treatment) **Effects of electromagnetic waves** • Exposure to ionising radiation (e.g. UV radiation, X-rays, γrays) can damage biological molecules (e.g. proteins and DNA) and lead to abnormal patterns of cell division. This may cause cancers or developing foetus to become deformed.

Topics	Key Concepts/ Ideas
Sound	Sound travels via compression and rarefaction of air particles. The displacement-distance graph is for all particles along the vibrating medium.

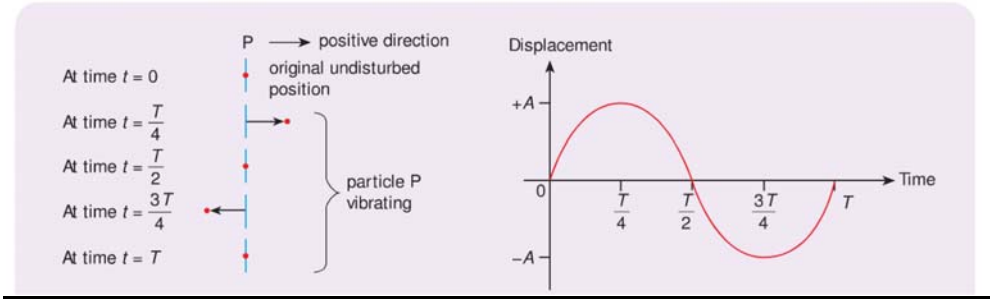


Speed of particle at the end of amplitude (max displacement) is **zero**.

Speed of particle at the original position (zero displacement) is **maximum**.



The displace-time graph of one particle in a sound wave.



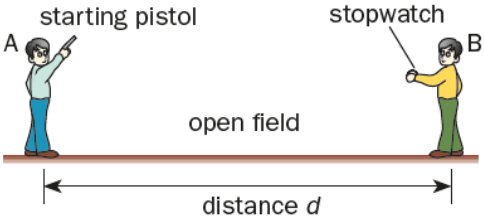
Topics	Key Concepts/ Ideas

Speed of sound

Table 1 Speed of Sound in Various Media

Medium	Speed of sound (m/s)
air (20 °C)	344
air (0 °C)	331
air (−20 °C)	319
glass (Pyrex)	5170
steel	5000
water	1496
wood (maple)	4110

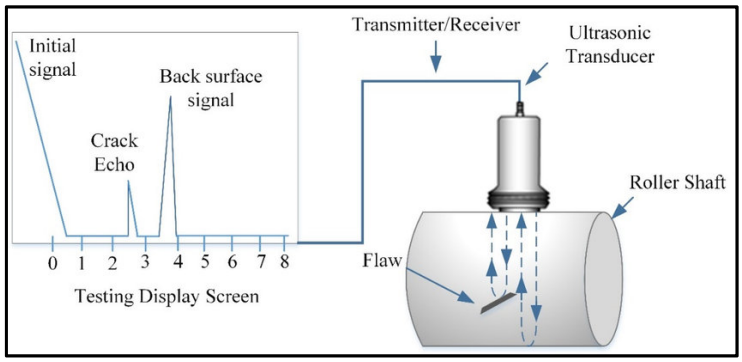
Measuring speed of sound using direct method



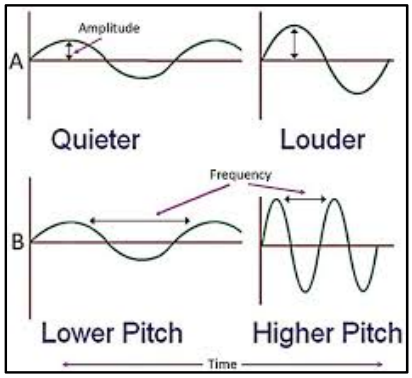
Use of ultrasonic sound:

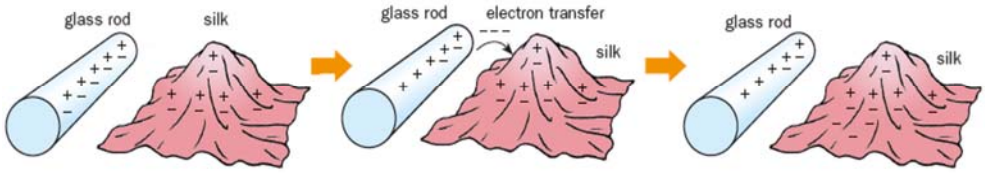
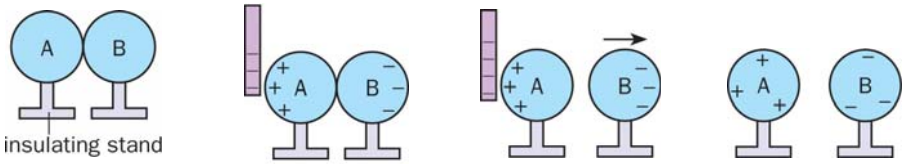
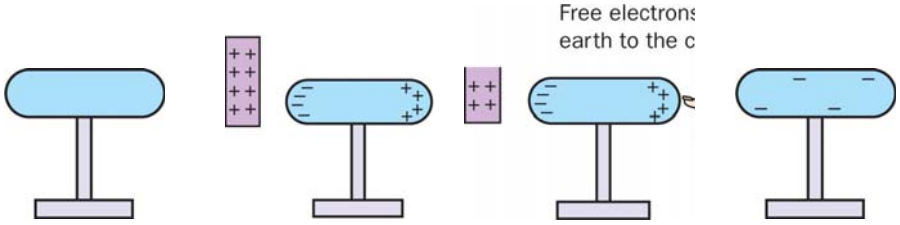
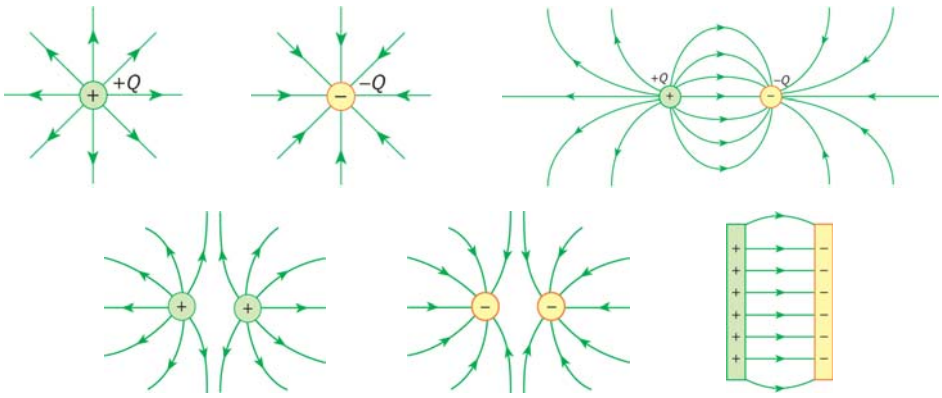
1. To clean objects like electronic components. The components to be cleaned are kept in a cleaning solution and ultrasonic waves are sent into the solution. Due to the high frequency, the dirt particles get detached from the components.
2. To detect cracks in metal blocks. Ultrasonic waves are sent through the metal blocks and if there are cracks, the waves are reflected back and the cracks can be detected.
3. Used in ultra sound scanners for getting images of internal organs of the human body.
4. To break small stones formed in the kidneys into fine grains so that they are removed through the urine.

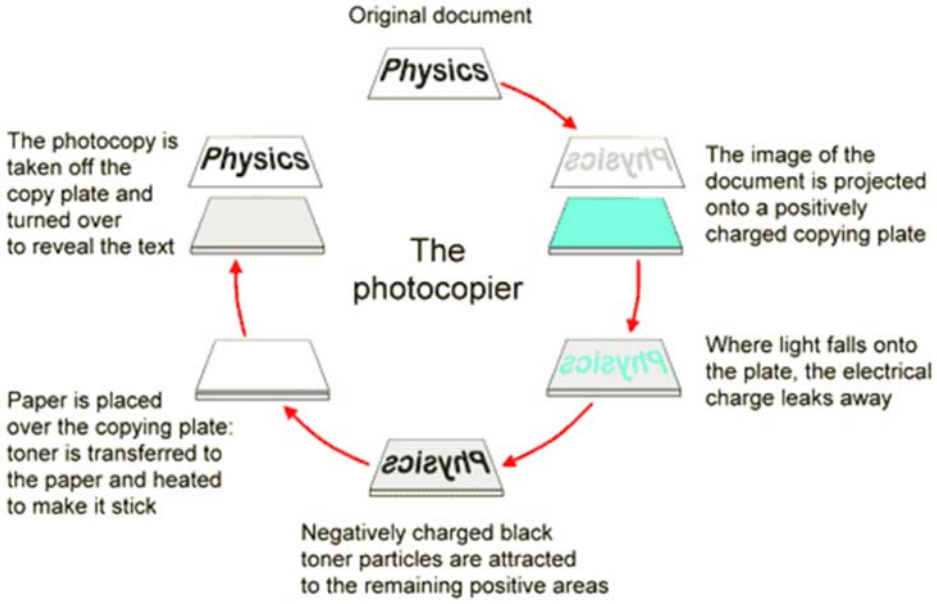
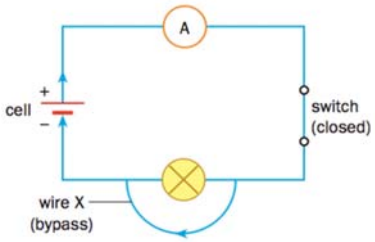
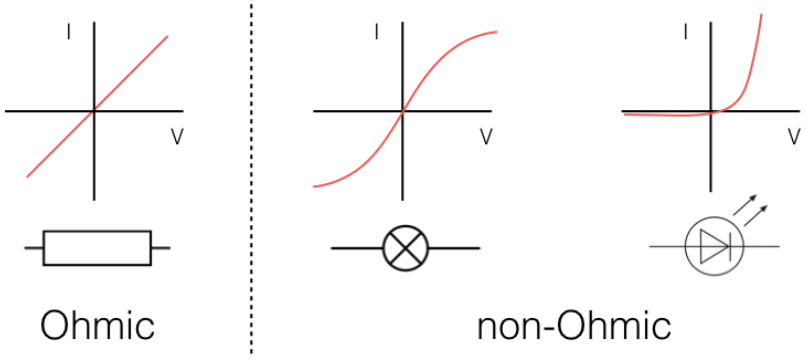
Use of Ultrasound to check crack



Amplitude and Pitch



Topics	Key Concepts/ Ideas
Static Electricity	**Electrostatic Charging by Friction** An electric phenomenon in which friction transfers electrons from one body to another.  **Charging two spheres by induction** A method of charging in which a conductor is charged without contact with the charging body. step 1 step 2 step 3 step 4  **Electrons** in A are repelled to the far end of B. A has excess **positive** charges, while B has excess **negative** **Charging single sphere by induction** step 1 step 2 step 3 step 4  **Electric Field** 

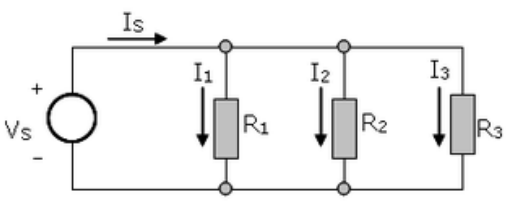
Topics	Key Concepts/ Ideas
	Photocopying using electrostatic charging 
Current Electricity	**Short Circuit**  current flows through alternative path of **least resistance** and by-pass the bulb. **I-V graphs**  • **Resistance** of filament bulb **increases** as current (temp) increase (gradient of **V-I graph** should increase) • For diode, the current is taken to be **zero** or **very close** to zero when connected with negative polarity.

Topics	Key Concepts/ Ideas
	Factors affecting Resistance
D.C. Circuits	**Current and voltage relationship in series and parallel circuits**

Table 2 Factors That Affect Resistance

Factor	Less resistance	Greater resistance
Length	L_1	L_2
Cross-sectional area	A_1	A_2
Material (Resistivity)	Copper	Iron
Temperature	T_1	T_2

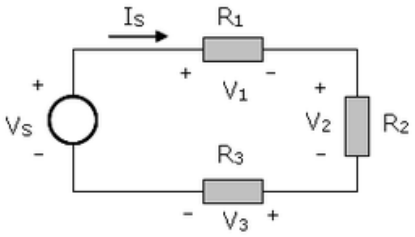
I



Parallel Circuit

$I_S = I_1 + I_2 + I_3$

$= V_S/R_1 + V_S/R_2 + V_S/R_3$

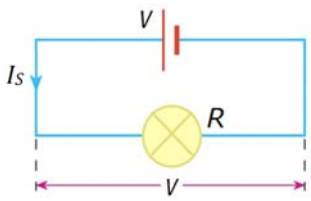


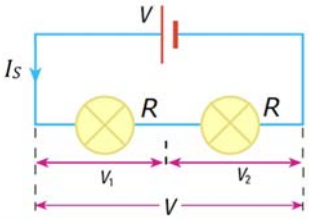
Series Circuit

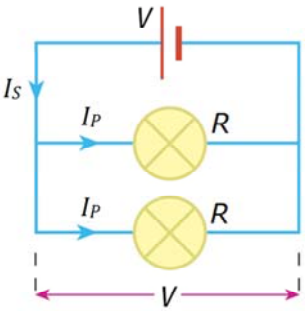
$V_S = V_1 + V_2 + V_3$

$= I_S R_1 + I_S R_2 + I_S R_3$

Connecting light bulbs in series or parallel







normal brightness

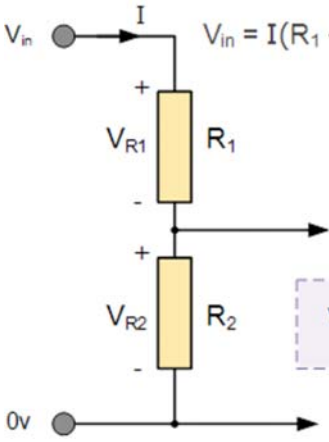
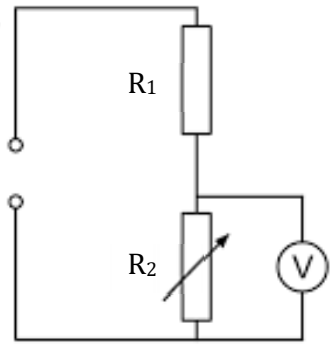
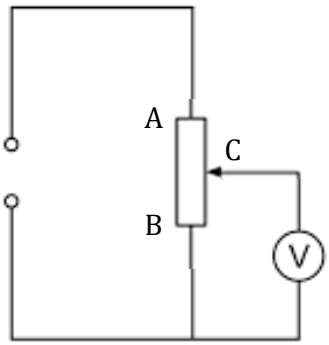
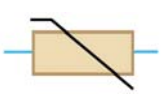
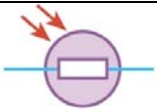
- $I = \frac{V}{R}$

less bright

- $I_S = \frac{V}{2R}$
- $V_1 = V_2 = \frac{V}{2}$

normal brightness

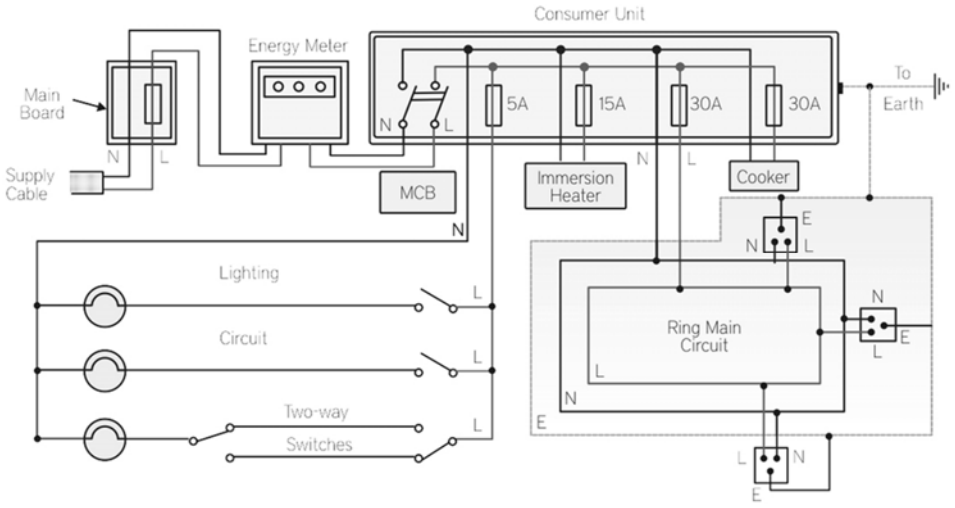
- $I_S = \frac{2V}{R}$
- $I_P = \frac{I_S}{2} = \frac{V}{R}$

Topics	Key Concepts/ Ideas
	Potential divider using fixed resistors  $V_{out} = V_{in}\left(\frac{R_2}{R_1 + R_2}\right)$ V_{out} is a fixed voltage **Potential divider using variable resistor** a.  b.  • V can be increased by increasing resistance of variable resistor R_2 to increase the ratio of R_2 to $(R_1 + R_2)$ or vice versa • R2 can be replaced with thermistor or LDR (resistance of thermistor decreases when temperature increases and resistance of LDR decreases when light intensity increases) V can be varied by changing position of sliding contact C of the **potentiometer** to change the ratio of R_{CB} to R_{AB}.  thermistor  LDR

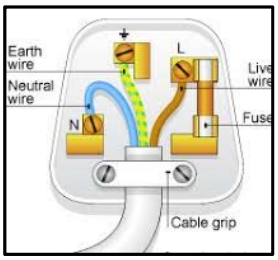
Practical Electricity	**Dangers of Electricity**
	• Two major dangers when using electricity are
	  • risk of **fire**
	  • overheating of cable due to excess heat (note: thin cables have higher resistance and will produce more heat)
	  • damage insulation
	  • risk of an **electric shock** caused by
	  • touching a faulty appliances or exposed live wire due to damage insulation
	  • touching wet electrical appliances

Topics	Key Concepts/ Ideas

Simple household wiring



Plug wiring



Longer earth pin:

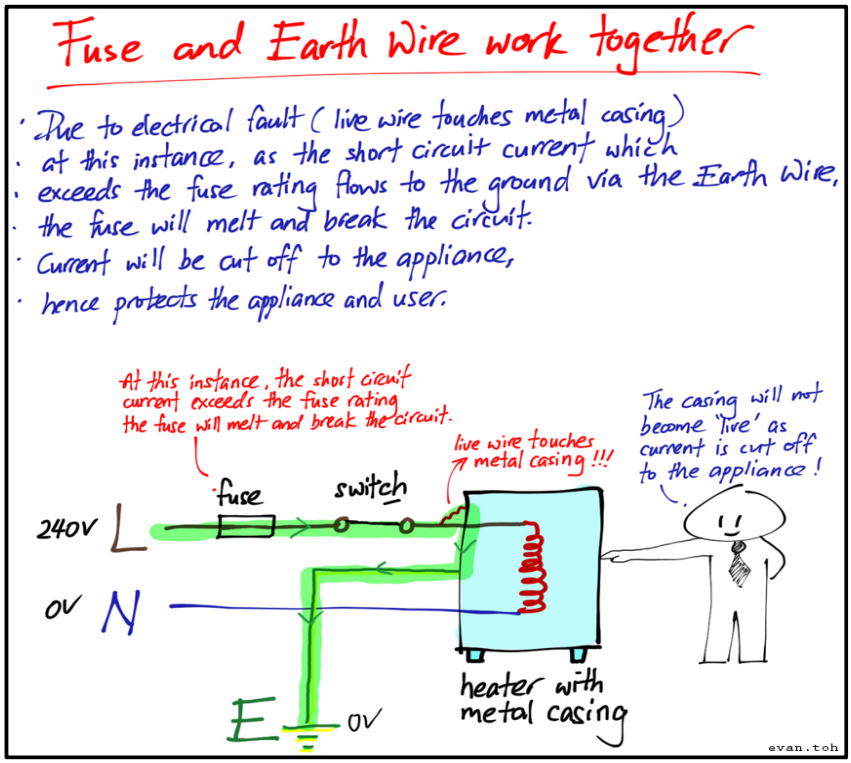
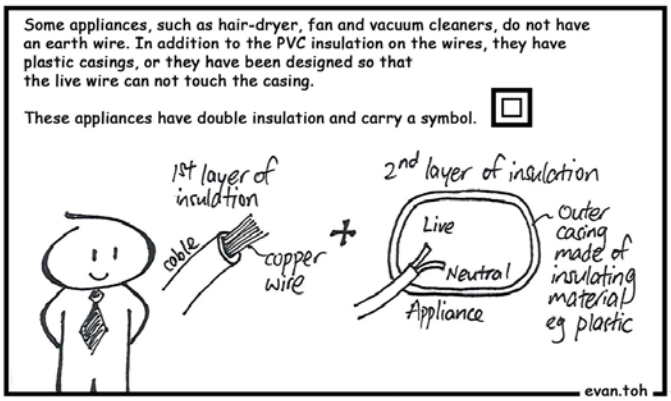
- Provides a return path for current before the live pin engages.
- Helps in opening the safety shutters in wall socket, making possible the insertion of other two pins.

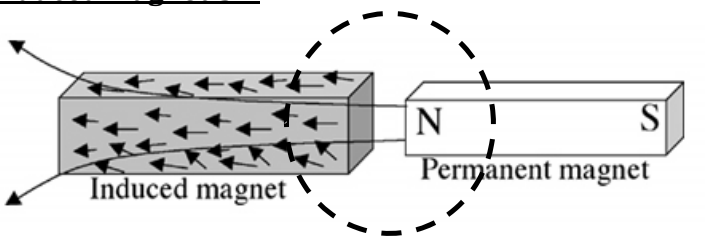
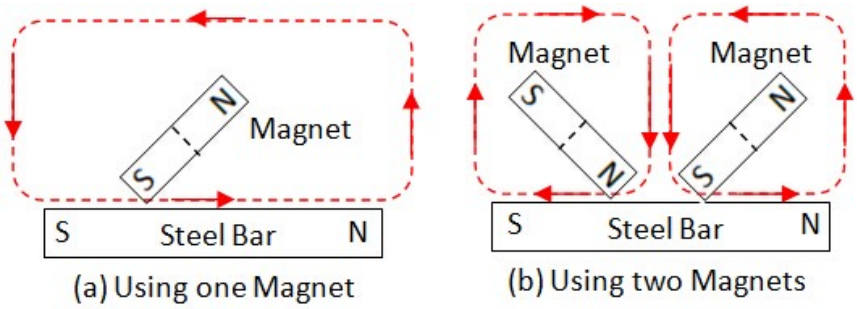
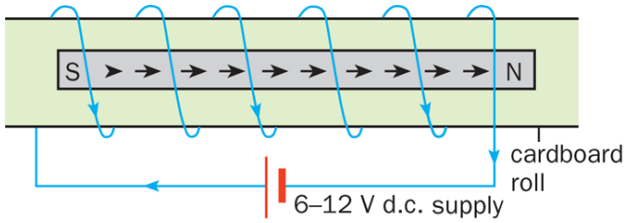
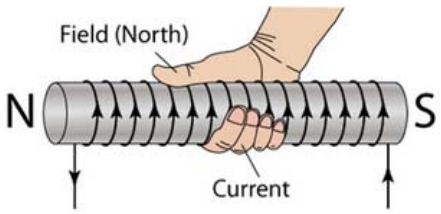
Thicker earth pin:

- Thicker earth pin has a lower resistance. If there is any leakage current, it provide a lower resistant path for the current to ground rather than through the person, preventing an electric shock.

Earth Leakage Circuit Breakers

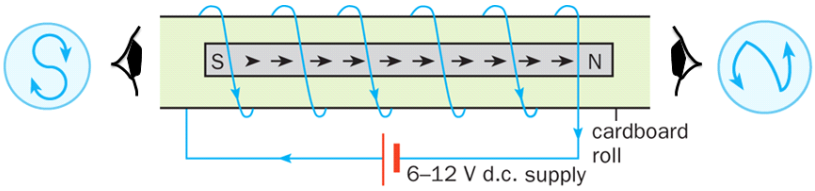
The ELCB detects small current leakages from the live wire to the earth wire. When this happens, the current in the live wire will be greater than the neutral wire, causing the ELCB to 'trip'.

Topics	Key Concepts/ Ideas
	Fuse and Earth wire  Remember to mention appliance will **remain live** if fuse or earth wire is connected incorrectly and a fault occurs. **Double insulation** 

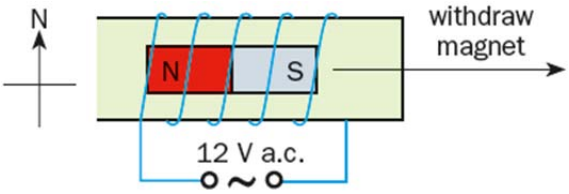
Topics	Key Concepts/ Ideas
Magnetism	**<u>Magnetic materials</u>** : Steel, Iron, Cobalt and Nickle **<u>Induced Magnetism</u>**  In magnetic induction, an opposite pole is always induced (ie. 2 unlike poles facing each other is observed during magnetic. **<u>Magnetising (Single stroke and Double stroke)</u>**  The pole induced at the end of the magnetized steel bar after stroking is of opposite polarity to that of the stroking pole **<u>Magnetising (Electrical method using direct current)</u>**  1. Place a steel bar inside <u>a coil of wire</u> (a solenoid). 2. Pass a direct current through the solenoid for a few seconds. A strong magnetic field is produced on the solenoid and magnetises the steel rod. **<u>Determining the Poles of a Magnet</u>** **1. Right hand Grip Rule** 

Topics	Key Concepts/ Ideas

2. Direction of the current at the ends of the solenoid

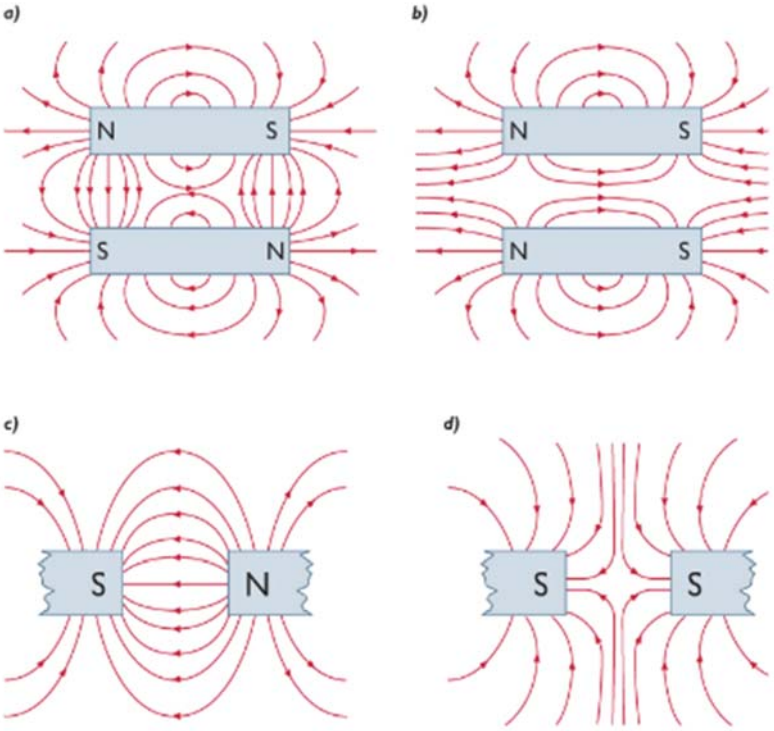


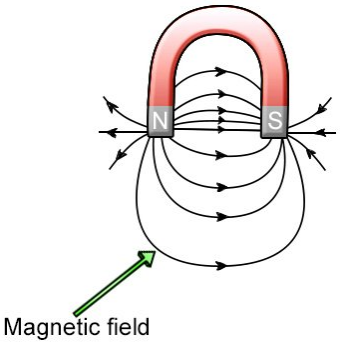
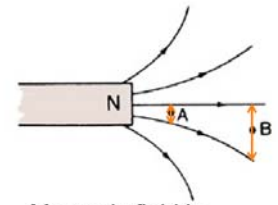
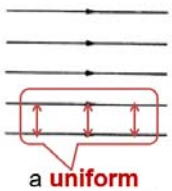
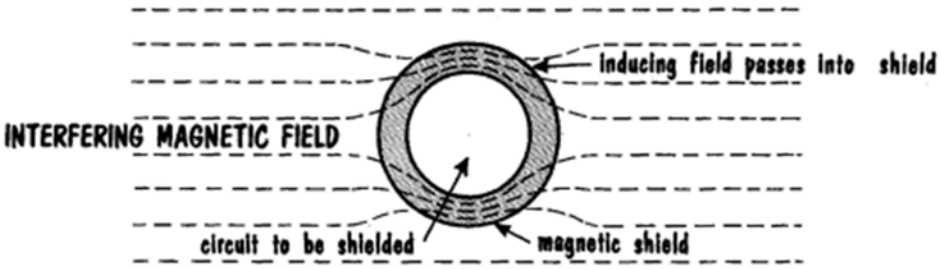
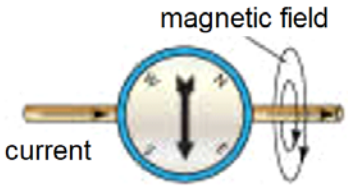
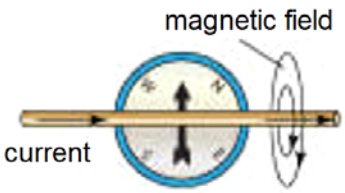
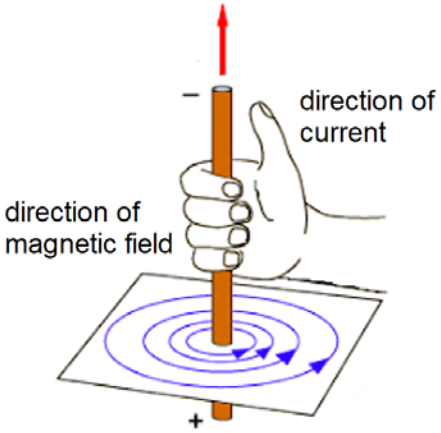
<u>Demagnetising (Electrical method using an alternating current)</u>

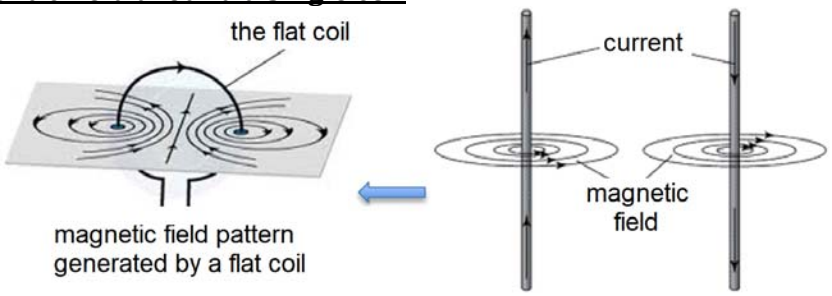
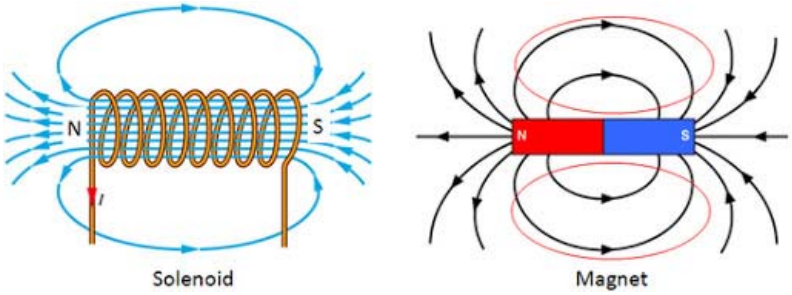
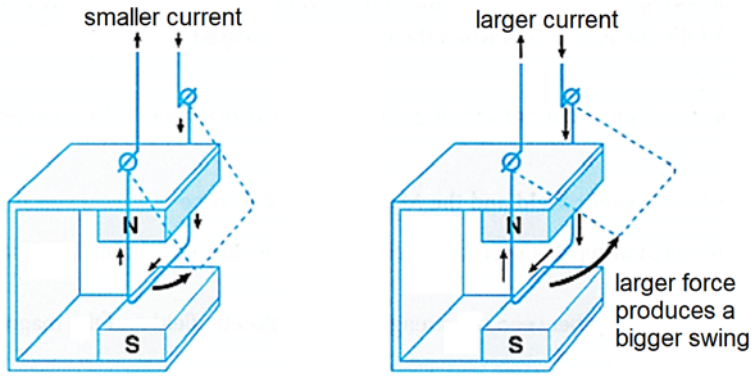
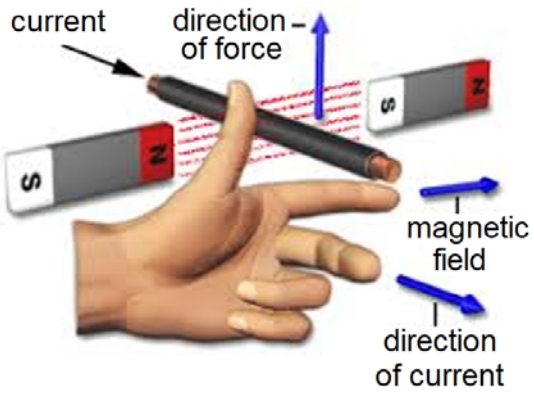


1. Place magnet in a solenoid and pass an alternating current through the solenoid.
2. Withdraw the magnet slowly in an east-west direction further and further away until it becomes demagnetised.

<u>Magnetic Field Pattern</u>

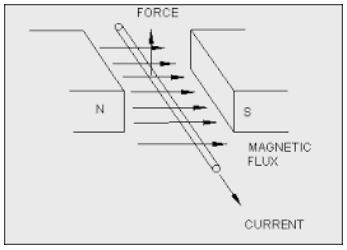


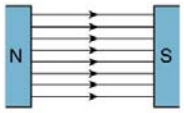
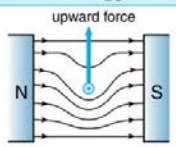
Topics	Key Concepts/ Ideas
	Horseshoe Magnet    Field lines are drawn closer to represent **stronger** fields and vice versa. **Magnetic Shielding**  Field lines **tend to pass through a magnetic substance** rather than through non-magnetic substances like the air.
Electromagnetism	**Magnetic field around a currnet carrying conductor**   

Topics	Key Concepts/ Ideas
	Magentic field around a single coil  **Magnetic Field around a solenoid**  • Magnetic field pattern similar to bar magnet. • Magnetic field can be increased by increasing the current, the number of turns of solenoid and placing a soft iron within the solenoid. **Current carrying wire in a magnetic field produces a Force**  **Flemings Left Hand Rule** 

Topics	Key Concepts/ Ideas

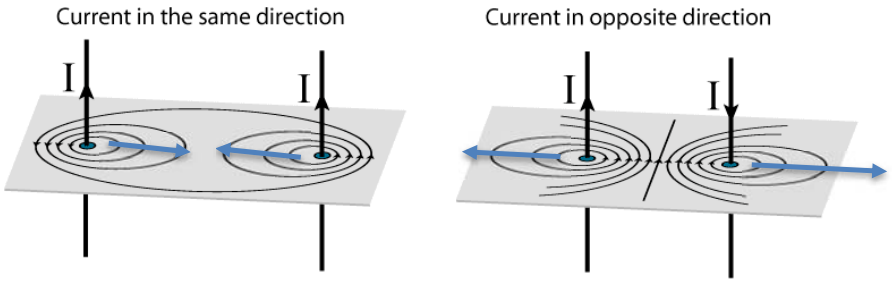
Origin of the Electromagnetic Force



Magnetic field of permanent magnet	*Magnetic field of current-carrying conductor*	*Resultant field of two interacting fields*
(a) 	(b) 	(c) 
Uniform magnetic field lines from the north pole to the south pole.	Magnetic field lines in the form of concentric circles, in an anticlockwise direction based on the right-hand grip rule.	A **catapult field** is produced. The distortion of the magnetic field lines causes the wire to move from the stronger magnetic field to the weaker field.

The **interaction of the magnetic field** due to the <u>permanent magnet</u> and the **magnetic field due to the current carrying wire** gives rise to a **magnetic force** from a region of <u>stronger</u> magnetic field to <u>weaker</u> field.

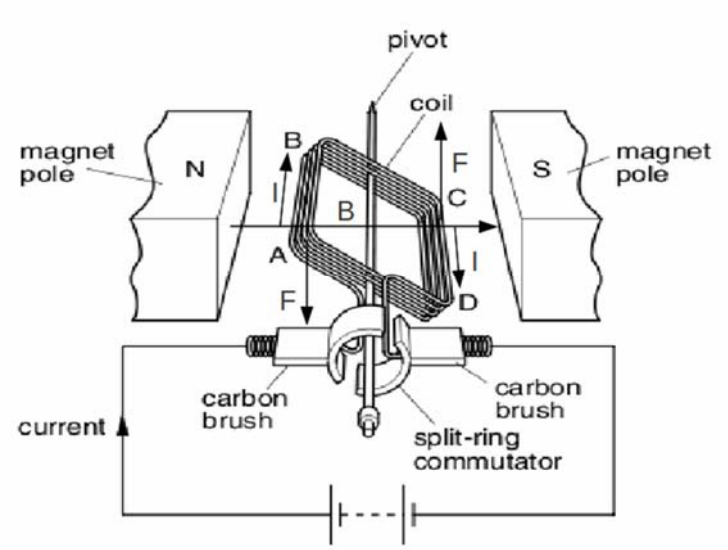
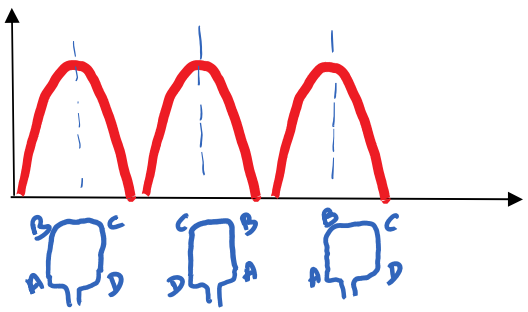
Force of Two current carrying wire

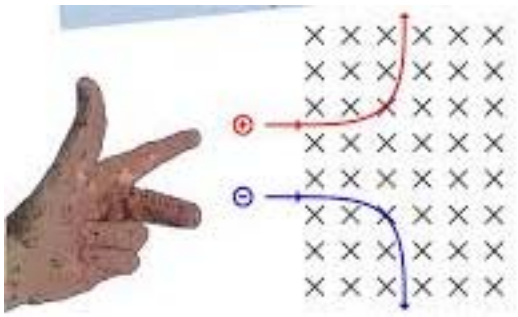
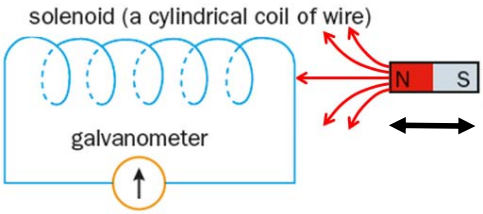


Catapult field produced by 2 straight curretn carrying conductors

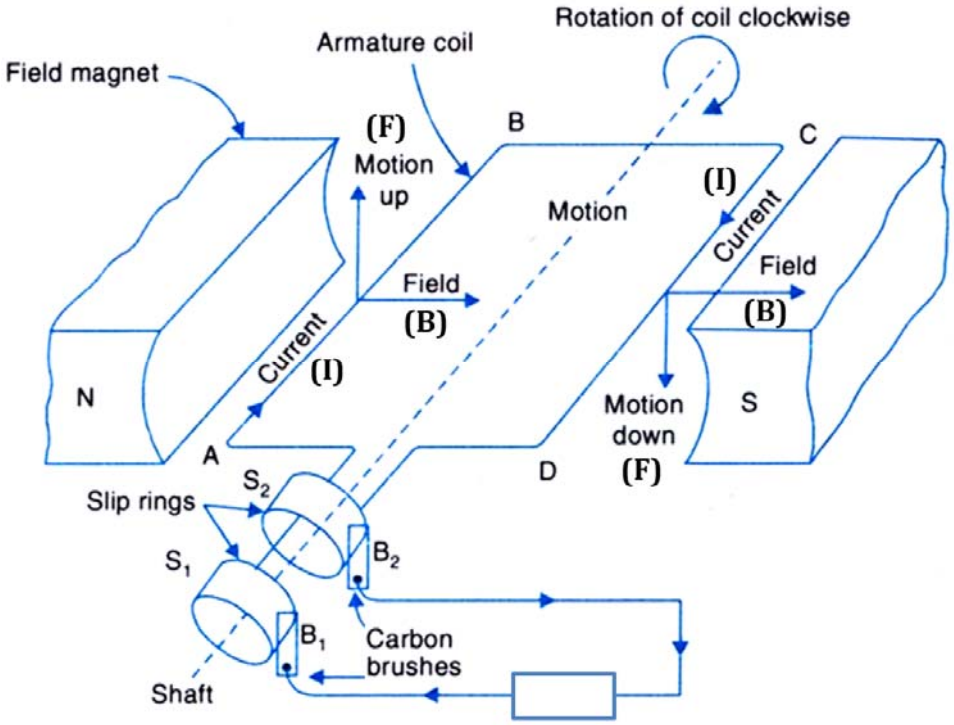
wires attract each other

wires repel each other

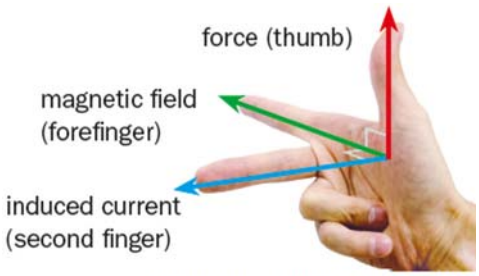
Topics	Key Concepts/ Ideas
	DC Motor  • Carbon brush ensures there is **contact** always between the commutator and the rotating coil. • Split-ring commutator ensures the **current direction reverses every half** a turn and hence the forces also reverse direction to keep the coil(motor) rotating in the same continous direction **Graph of Moment acting on coil against time.** moment  • Moment is a **maximum** everytime coil is **horizontal** (greatest perpendicular distance) • Moment is **zero** everytime coil is **vertical** (zero perndicular distance)

Topics	Key Concepts/ Ideas
	Charged particle is a magnetic field – use FLH Rule  Remember to reserve current direction for **electron** when using **FLR**
Electromagnetic Induction	**NOT INCLUDED FOR 2021 GCE O LEVEL PHYSICS EXAMINATION (CLT)** **Electromagnetic Induction**  • As the magnet moves towards and away from the solenoid, the **magnetic flux** (or magnetic lines of force) **linking** the coils have **changed**. • By Faraday's Law, this will cause an induced emf and hence an induced current to flow. • By Lenz's Law, when the N pole of the magnet moves towards the solenoid, a N pole is form at that end of the solenoid. The current when view from that end will flow in an anti-clockwise direction. • When the N pole of the magnet moves away from the solenoid, a S pole is form at that end of the solenoid. The current when view from that end will flow in a clockwise direction. • Magnitude of induced e.m.f. (i.e current) could be increased by increasing the **number of turns** in the solenoid, **strength** of the magnet or **speed** at which the magnet moved with respect to the solenoid.

Topics	Key Concepts/ Ideas
	AC Generator



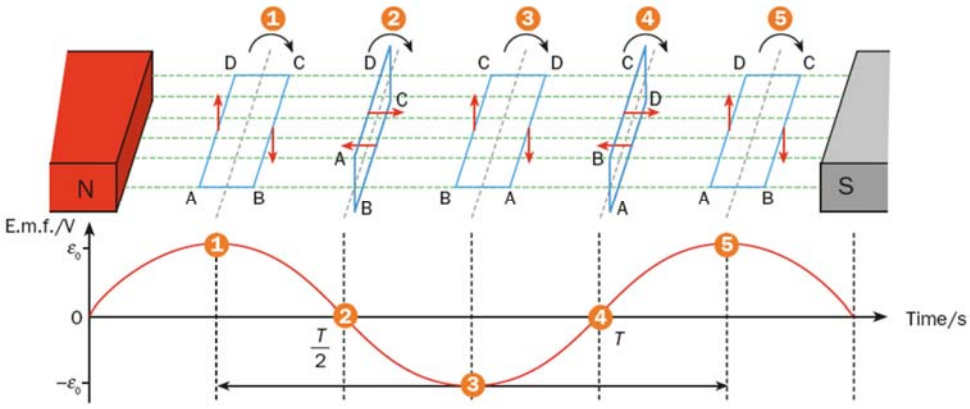
- As the coil rotates in the magnetic field, the change in magnetic flux in the coil induced an alternating e.m.f. between the two ends of the coil.
- The slip rings, in contact with the carbon brushes, ensure that when the coil rotates, the same end of the coil is constantly in contact with the same carbon brushes.
- The **direction of induced current** flowing to the electrical load **changes every half revolution**.

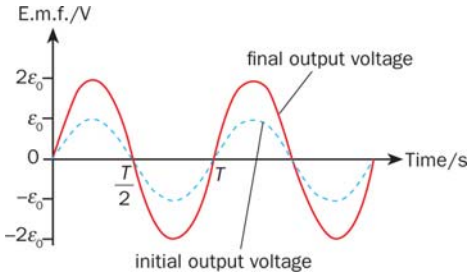


Fleming's Right Hand Rule

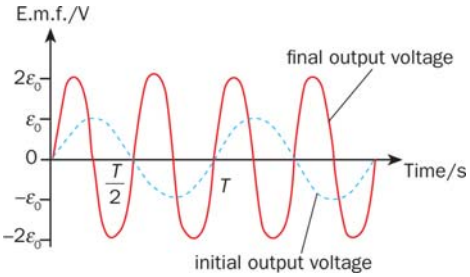
Topics	Key Concepts/ Ideas

Graphical representation of induced emf



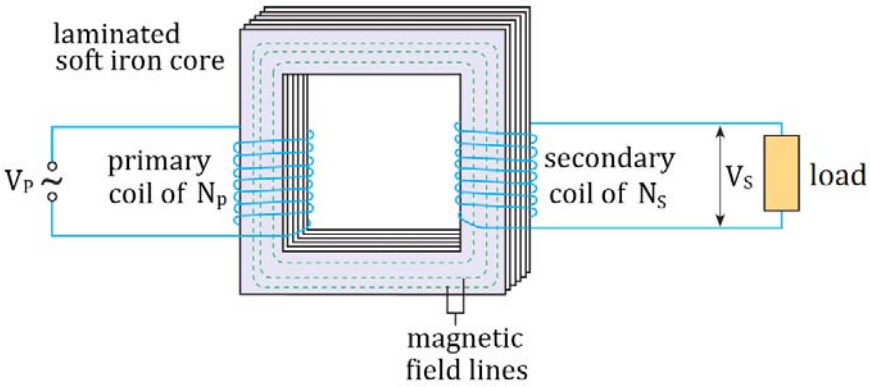


output voltage increased by doubling the number of turns of the coil



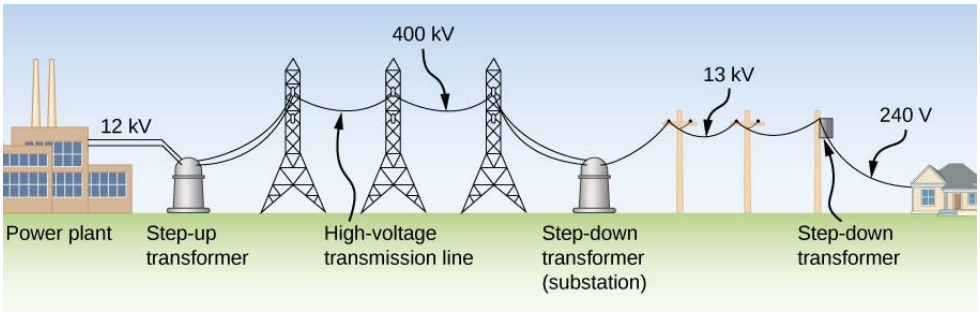
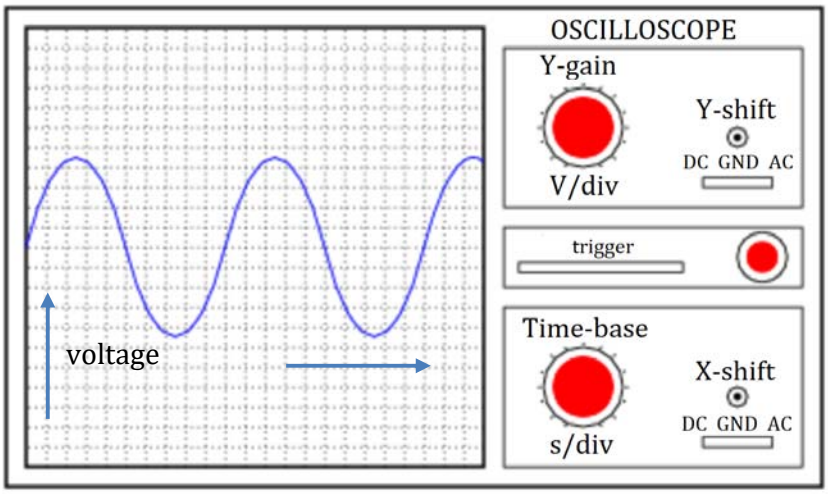
output voltage and frequency doubled by doubling the frequency of rotation

Transformer



The transformer **transfers** electrical **energy** supplied from the primary coil to the secondary coil by **electromagnetic induction** between the two coils.

- The alternating voltage sets up a continually changing magnetic field in the laminated soft iron core.
- The laminated soft iron core that links the magnetic fields produced by the primary coil to the secondary coil.
- The magnetic flux in secondary coil changes, inducing an e.m.f. V_S in the secondary coil and an induced current flows through the load.

Topics	Key Concepts/ Ideas
	Transmission of electrical energy  • High-voltage cables have significant resistance , especially when they are hundred of kilometers long. Due to the resistance in the cables, some of the energy is lost in the form of heat. **$P = I^2R$ (power loss in cable)** • To reduce power loss, power is transmitted at a high voltage and low current by using a step-up transformer. **CRO**  • Y-gain control – amplifies height of electron beam (volts per division) • Time base control – controls speed at which electron beam sweeps across the screen (second per division) • Y-shift or Y-offset – shifts entire trace vertically up or down • X-shift – shifts entire trace horizontally left or right