4E5N Science Physics (5076) Formula Test

Name: ____________________ Class: ________ Date: ____________

Topics		Variables	Formula
Kinematics	1	v – speed (ms^{-1}) d – distance travelled (m) t – time taken (s)	$d = vt$
	2	*Avg speed* TD – total distance (m) TT – total time (s)	Average speed $= \frac{TD}{TT}$
	3	a – acceleration (ms^{-2}) v – final speed (ms^{-1}) u – initial speed (ms^{-1}) t – time (s)	$a = \frac{v-u}{t}$
	4	*Gradient of speed-time graph* = acceleration *Gradient of distance-time graph* = speed *Area under speed-time graph* = Distance	
Dynamics	5	F_R – resultant/net force (N) m – mass (kg) a – acceleration (ms^{-2})	$F_R = ma$
Mass Weight Density	6	W – weight (N) m – mass (kg) g – gravitational field strength (10 Nkg^{-1})	$W = mg$
	7	D – density (kgm^{-3}) m – mass (kg) v – volume (m^3)	$D = \frac{m}{v}$
Turning effect of forces	8	M – moment (Nm) F – force (N) $\perp d$ – perpendicular distance from pivot (m)	$M = F \times \perp d$
Pressure	9	P – pressure (Pa) F – force (N) A – perpendicular area (m^2)	$P = \frac{F}{A}$
	10	F_1 – force acting on piston 1 A_1 – cross sectional area of piston 1 F_2 – force acting on piston 2 A_2 – cross sectional area of piston 2	$\frac{F_1}{A_1} = \frac{F_2}{A_2}$
Energy Work Power	11	W – work done (J) F – force (N) d – distance moved in the direction of the force (m)	$W = F \times d$
	12	E_k – kinetic energy (J) m – mass (kg) v – speed (ms^{-1})	$E_k = \frac{1}{2}mv^2$
	13	E_p – gravitational potential energy (J) m – mass (kg) g – acceleration due to gravity (10 ms^{-2}) h – height (m)	$E_p = mgh$
	14	P – power (W) E – energy used (J) t – time (s)	$E = Pt$
Wave Properties	15	T – period (s) f – frequency (Hz)	$f = \frac{1}{t}$
	16	v – speed of wave (ms^{-1}) f – frequency (Hz) λ – wavelength (m)	$v = f\lambda$
Light	17	n – refractive index i – angle in optically less dense medium (°) r – angle in optically denser medium (°)	$n = \frac{\sin i}{\sin r}$

SUMMARY – PHYSICS FORMULAE

Chapter 2 – Kinematics

1.	$v = \frac{d}{t}$	v – speed (ms^{-1}) d – distance travelled (m) t – time taken (s)
2.	$Average\ speed = \frac{Total\ distance\ travelled}{Total\ time\ taken}$	
3.	$a = \frac{v-u}{t}$	a – acceleration (ms^{-2}) v – final speed (ms^{-1}) u – initial speed (ms^{-1}) t – time (s)
4.	$Distance\ travelled = Area\ under\ speed - time\ graph$	
5.	$Speed = Gradient\ of\ distance - time\ graph$	

Chapter 3 – Dynamics

6.	$F_R = ma$	F_R – resultant force (N) m – mass (kg) a – acceleration (ms^{-2})

Chapter 4 – Mass, Weight & Density

7.	$W = mg$	W – weight (N) m – mass (kg) g – acceleration due to gravity ($10\ ms^{-2}$)
8.	$D = \frac{m}{v}$	D – density (kgm^{-3}) m – mass (kg) v – volume (m^3)

Chapter 5 – Turning Effect of Forces

9.	$M = F \times \perp d$	M – moment (Nm) F – force (N) $\perp d$ – perpendicular distance from pivot (m)

Chapter 6 – Pressure

10.	$P = \frac{F}{A}$	P – pressure (Pa) F – force (N) A – perpendicular area (m^2)
11.	$\frac{F_1}{A_1} = \frac{F_2}{A_2}$	F_1 – force acting on piston 1 A_1 – cross sectional area of piston 1 F_2 – force acting on piston 2 A_2 – cross sectional area of piston 2
12.	$P = h\rho g$	P – pressure of liquid (Pa) h – depth of liquid (m) g – acceleration due to gravity ($10\ ms^{-2}$)

Chapter 7 – Work, Energy & Power

13.	$W = F \times d$	W – work done (J) F – force (N) d – distance moved in the direction of the force (m)
14.	$E_k = \frac{1}{2}mv^2$	E_k – kinetic energy (J) m – mass (kg) v – speed (ms^{-1})
15.	$E_p = mgh$	E_p – gravitational potential energy (J) m – mass (kg) g – acceleration due to gravity ($10\ ms^{-2}$) h – height (m)
16.	$P = \frac{W}{t}$ or $\frac{\Delta E}{t}$	P – power (W) W – work done (J) E – energy used (J) t – time (s)

Chapter 11 – General Waves Properties

17.	$T = \frac{1}{f}$	T – period (s) f – frequency (Hz)
18.	$v = f\lambda$	v – speed of wave (ms^{-1}) f – frequency (Hz) λ – wavelength (m)

Chapter 12 – Light

19.	$n = \frac{\sin i}{\sin r}$	n – refractive index i – angle in optically less dense medium (°) r – angle in optically denser medium (°)
20.	$n = \frac{c}{v}$	n – refractive index c – speed of light in vacuum (or air) $= 3 \times 10^8 ms^{-1}$ v – speed of light in medium (ms^{-1})
21.	$n = \frac{1}{\sin c}$	n – refractive index c – critical angle (°)

Chapter 16 – Current of Electricity

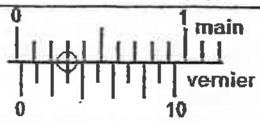
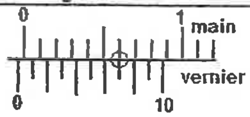
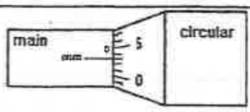
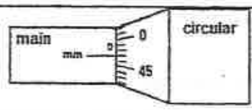
22.	$I = \frac{Q}{t}$	I – current (A) Q – charge (C) t – time (s)
23.	$\varepsilon = \frac{W}{Q}$	ε – electromotive force (V) W – work done (J) Q – charge (C)
24.	$V = \frac{W}{Q}$	V – potential difference (V) W – work done (J) Q – charge (C)

SUMMARY CHAPTER 1 – PHYSICAL QUANTITIES, UNITS AND MEASUREMENT

Physical quantities	Consists of a numerical magnitude and a unit
Base quantities	Mass (kg), length (m), time (s), current (A), amount of substance (mol), temperature (K) and light intensity (cd)
Derived quantities	Quantities derived by multiplication or division of base quantities e.g. area (m^2), density (kg/m^3) and speed (ms^{-1})
Scalar quantities	Have magnitude but no direction (e.g. distance, speed, mass, pressure, energy, density)
Vector quantities	Have both magnitude and direction (e.g. displacement, velocity, weight, force, acceleration)

Common SI Prefixes								
Power	10^9	10^6	10^3	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}
Prefix	giga	mega	kilo	deci	centi	milli	micro	nano
Abbreviation	G	M	k	d	c	m	µ	n

Length measurement

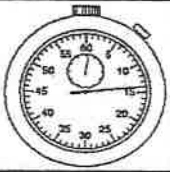
Apparatus	Accuracy	Positive zero error	Negative zero error
Vernier calipers	0.01 cm	 Zero mark on vernier scale slightly to the right Zero error = + 0.03 cm (count from 0 on vernier)	 Zero mark on vernier scale slightly to the left Zero error = - 0.03 cm (count from 10 on vernier)
Micrometer screw gauge	0.01 mm	 Zero mark on circular scale below main scale Zero error = + 0.03 mm (count up from 0)	 Zero mark on circular scale above main scale Zero error = - 0.03 mm (count down from 0)
Measuring tape and metre rule	0.1 cm	----------	----------

Time measurement

Digital stop watch

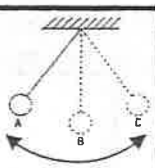
- Accuracy = 0.01 s
- Human reaction time (typically 0.3 s) affects the accuracy of readings.
- Taking multiple readings and using the average value can reduce the error due to human reaction time.
- 1 minute = 60 seconds

Analog stop watch



- Accuracy = 0.1 s
- Long hand measures the seconds.
- Short hand measures the minutes.

Pendulum



- Period is the time taken for the pendulum to complete one oscillation.
- One oscillation is complete as the bob moves from one end to another and back to the original position (A to C and back to A).
- Period is affected by length of pendulum string (longer length, longer period) and acceleration due to gravity (larger g, shorter period).
- Period is **not** affected by the mass of bob or the angle of release of the bob.

Ticker Tape Timer

How to read ticker tape?

Given ticker tape vibration is 40 times per second

Time interval between dots = 1 / 40 = 0.025 s

Total time = No. of interval x Time interval

= 6 x 0.025 = 0.15 s

Drawing vector diagram: Parallelogram method

Steps to draw vector diagram

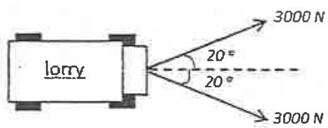
1) Choose and state scale used
2) Draw arrows to scale
3) State magnitude of vector
4) State direction with reference to other vectors

Common Errors

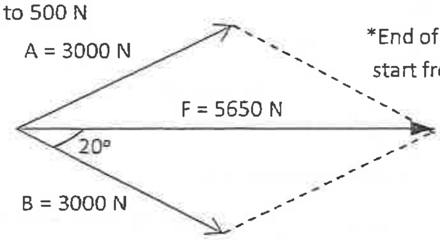
- Inappropriate scale chosen.
- Diagram too small.
- Orientation of diagram different from question.
- Direction specified using incorrect terms.
- Missing/wrong arrowheads.
- Drawing solid lines for construction lines.
- Missing/wrong labels (e.g. labeling arrow length instead of vector magnitude).
- Forgetting to multiply length of arrow by scale to obtain magnitude of vector.

Finding resultant vector

Given A = 3000 N and B = 3000 N, find the resultant force F.



Scale: 1 cm to 500 N

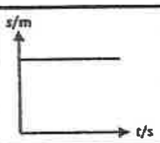
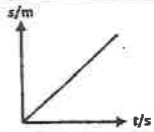
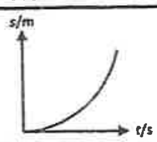
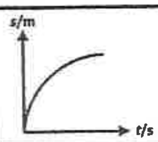


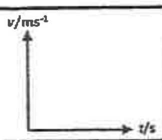
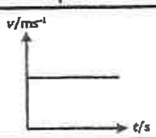
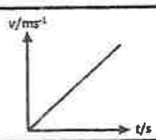
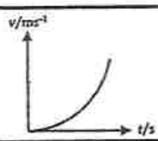
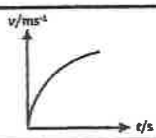
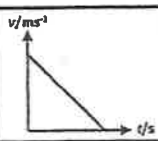
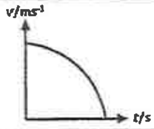
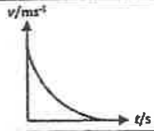
*End of arrows A and B start from same point

The resultant force F is 5650 N, 20° clockwise from the 3000 N force.

SUMMARY CHAPTER 2 – KINEMATICS

Quantity	S.I Unit	Definition	Formula	Scalar/Vector
Distance, s	m	Total length travelled **irrespective** of the direction of motion.	————	Scalar
Displacement, s	m	**Distance** travelled in a **stated direction**.	————	Vector
Speed, v	m/s	**Distance** travelled per unit time. (Rate of change of **distance**) s = distance travelled (m) t = time taken (s)	$v = \frac{s}{t}$	Scalar
Average Speed, v_{ave}	m/s	**Total distance** travelled divided by **total time** taken. TD = total distance travelled (m) TT = total time inclusive of rest time (s)	$v_{ave} = \frac{TD}{TT}$	Scalar
Velocity, v	m/s	**Distance** travelled in a **stated direction** per unit time. (Rate of change of **displacement**) s = displacement travelled (m) t = time taken (s)	$v = \frac{s}{t}$	Vector
Acceleration, a	m/s^2	Rate of change of **velocity**. v = final velocity (m/s) u = initial velocity (m/s) t = time taken (s)	$a = \frac{v-u}{t}$	Vector

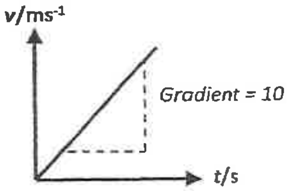
Distance-time graph							
At rest	**Constant Speed**	**Constant Acceleration**	**Increasing Acceleration**	**Decreasing Acceleration**	**Constant Deceleration**	**Increasing Deceleration**	**Decreasing Deceleration**
			*(Not in syllabus)*	*(Not in syllabus)*		*(Not in syllabus)*	*(Not in syllabus)*
**Calculating the gradient of distance-time graph gives the speed of the object.							

Speed-time graph							
At rest	**Constant Speed**	**Constant Acceleration**	**Increasing Acceleration**	**Decreasing Acceleration**	**Constant Deceleration**	**Increasing Deceleration**	**Decreasing Deceleration**
							
**Calculating the gradient of speed-time graph gives the acceleration of the object. **Calculating the area under the speed-time graph gives the distance travelled by the object.							

Acceleration due to Gravity, g

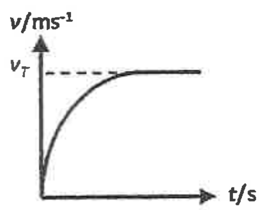
Without air resistance (Free fall)

- All objects fall with the same <u>constant acceleration</u> due to gravity, <u>regardless of the mass and size</u>.
- On Earth, $g \approx$ <u>10 m/s^2</u>.



With air resistance

- Objects fall with *<u>decreasing acceleration</u>* and may reach *<u>terminal velocity</u>* (i.e. no acceleration).
- Terminal velocity of an object is achieved when the <u>air resistance equals the weight</u> of the object.



SUMMARY CHAPTER 3 – DYNAMICS

Forces

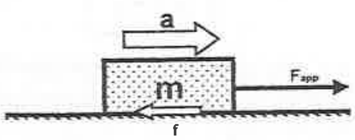
A force is a **vector** quantity (i.e. has both **direction** and **magnitude**) with SI unit of **Newton (N)**.
Effects of forces: A force can change the **motion**, **speed**, **direction** and **shape** of an object.

Newton's Laws (No need memorise)

- **Newton's First law** states that an object **at rest** will remain **at rest** and an object **in motion** will **continue in motion** at a **constant speed** in a straight line unless a **net external force** acts on it.
- **Newton's Second Law** states that the **resultant force** acting upon an object is equal to the **product** of the **mass** and the **acceleration** of the object. The direction of the force is the same as that of the object's acceleration.
- **Newton's Third law** states that for every action there is an **equal** and **opposite** reaction. Forces always occur in **pairs** and act on **different** objects.

Balanced Forces ($F_{net} = 0$) (1st Law)

E.g.



F_{net} is resultant force in (N)
F_{app} is the force applied (N)
f is the friction (N)

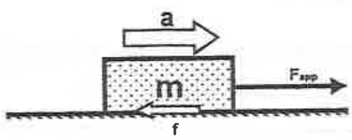
When $F_{app} = f$
$F_{net} = F_{app} - f = 0$

From $F_{net} = ma$ → $m \neq 0$, a must be 0.

Object can be…
1. At rest
2. Moving at **constant** speed

Unbalanced forces ($F_{net} \neq 0$) (2nd Law)

E.g.



F_{net} is resultant force in (N)
F_{app} is the force applied (N)
f is the friction (N)

When $F_{app} \neq f$
$F_{net} = F_{app} - f \neq 0$

From $F_{net} = ma$ → $m \neq 0$, a cannot be 0.

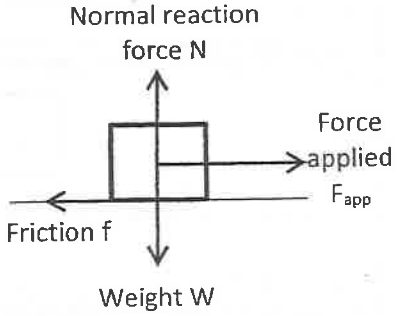
Object can be…
1. Accelerating
2. Decelerating

To find acceleration, use $F_{net} = ma$
where m is the mass of object (kg)
a is acceleration of object (ms^{-2})

Drawing free-body diagram

Steps to draw free-body diagram
1. Identify **all forces** acting on object (look out for key words such as rough surface)
2. Use arrows to represent the direction of forces (no need to draw to scale)
3. Label forces **clearly** on diagram

E.g.
Block pushed across **rough** table



Friction

Definition	Friction is a force that **opposes motion** between **two surfaces** that are **in contact**.
Factors affecting friction	1. Roughness of surfaces in contact 2. Type of material in contact 3. Force pressing the surfaces together ***Not affected by the surface area of contact***
Ways to reduce friction	1. Use smooth surfaces 2. Apply lubricant between surfaces 3. Separate surfaces using air cushion 4. Place ball and roller bearings between moving parts
Effects of friction	**Positive effects** • Slowing down motion of object • Hold objects with slipping • Walk without slipping **Negative effects** • Causes wear and tear • Reduce efficiency in machinery due to heat generated

SUMMARY CHAPTER 4 – MASS WEIGHT DENSITY

Mass	Weight
Mass is the measure of the amount of substance in an object.	Weight is the gravitational force acting on an object.
SI unit: kilogram (kg)	SI unit: Newton (N)
Mass is always constant.	Weight changes with gravitational field strength.
Mass is a scalar quantity.	Weight is a vector quantity.
Mass is measured using a beam balance or electronic balance. 	Weight is measured using a spring balance. 

Gravitational field and Gravitational field strength

- Gravitational field is a region in which a mass experiences a force due to gravitational attraction.
- Gravitational field strength, g, defined as the gravitational force acting per unit mass.

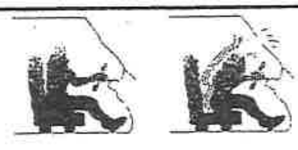
Formula relating mass and weight

$$W = mg$$

g = gravitational field strength (N/kg)
W = weight (N) m = mass (kg)

Inertia

- Inertia is defined as the reluctance of a body to change its state of rest or uniform motion in a straight line due to its mass.
- Inertia is dependent on the mass of an object and not the weight.
- An object with a larger mass would have a larger inertia.
- Real life example of inertia: Sudden braking of car causing objects to move forward.



Density

Density is defined as the mass per unit volume.

$$\rho = \frac{m}{v}$$

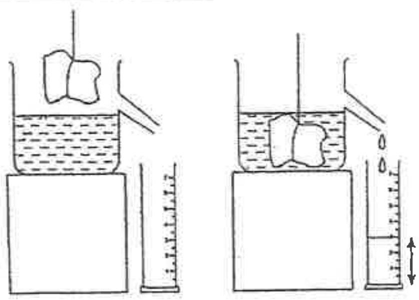
ρ = density (kg/m³) m = mass (kg) v = volume (m³)

SI unit: kg/m³
Conversion: 1 g/cm³ = 1000 kg/m³

An object will float on a liquid if it is less dense than the liquid whereas an object will sink in a liquid if it is denser than the liquid.

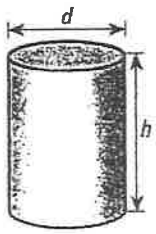
An object with a large mass need not have a high density. (e.g. ships has hulls filled with air which decreases the total density of the ship)

Determining density of irregular shaped solids

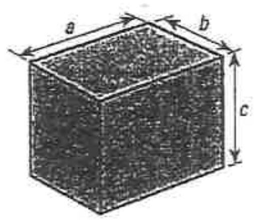


Density of irregular shaped solids can be obtained by measuring its volume by the liquid displaced by the fully submerged solid and by measuring the mass of the solid using an electronic balance.

Determining density of regular shaped solids



Volume of cylinder = $\frac{\pi d^2}{4} \times h$



Volume of cuboid = $a \times b \times c$

Density of regular shaped solids can be obtained by measuring its dimensions and calculating using known formulas.

SUMMARY CHAPTER 5 – TURNING EFFECT OF FORCES

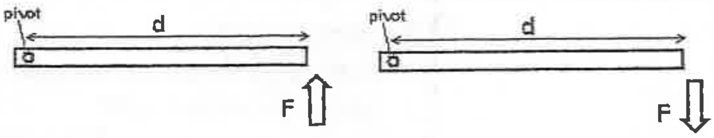
Moments of a force

The moment of a force about a pivot is defined as the **product** of a force and the **perpendicular** distance from the **line of action** of the force to the pivot.

$$M = F \times \perp d$$

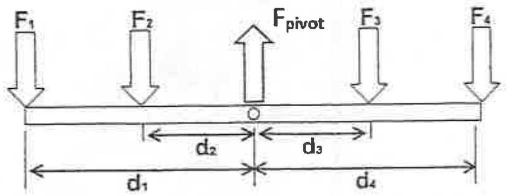
M = Moment of a force (SI unit in **N m**)
F = Force (SI unit in **N**)
d = Perpendicular distance from pivot to line of action of force (SI unit in **m**)
Direction of moment: **anti-clockwise** or **clockwise**

Note:
Do not confuse with formula for work done (W = F x d)



Principle of Moments

The Principle of Moments states that when an object is in **equilibrium**, the **sum of clockwise moments** about any point is **equal** to the **sum of anticlockwise moments** about the **same** point.



At equilibrium:
1) Sum of clockwise moments = Sum of anticlockwise moments

$$F_3d_3 + F_4d_4 = F_1d_1 + F_2d_2$$

2) Sum of downward force = Sum of upward force

$$F_1 + F_2 + F_3 + F_4 = F_{pivot}$$

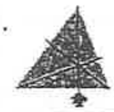
Note:
- For a **uniform** object, the CG lies at centre of object.
- For a **light** object, the weight of object is negligible.

Centre of gravity

Centre of gravity (CG) is the point where the **whole weight** of the object **appears** to act.

Note
- For a regular object such as a box, uniform ruler and sphere, the CG is at the **centre**. When pivoted there, the object will be balanced.
- The CG of an object can be outside the object and need not be within the object.
- **Higher** the CG, the **less stable** the object is.

Experimental procedure to find CG of irregular object

1. 	2. 	3. 

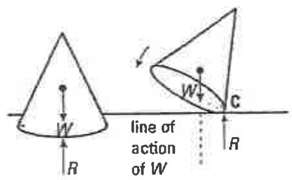
1. Drill three small holes at the corners of the object.
2. Hang a plumb line with a pin and trace a line through the object.
   (Weight always acts **downward** and so CG lies along the plumb line.)
3. Hang the plumb line at another point and trace a line through the object.
   (Point of intersection gives the CG of the object.)
4. Hang the plumb line at a third point.
   (Confirmation of CG of object if this third line intersects the same point.)

Stability

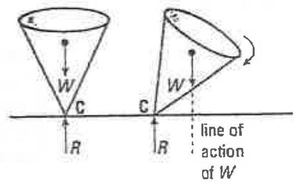
Stability refers to a body's **ability to return to its original position** after it is slightly displaced.

Note:
Stability is increased by:
1) **lowering** the C.G 2) **increasing** the area of base

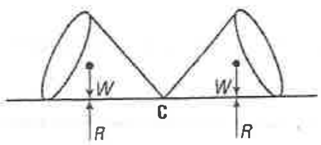
Stable Equilibrium
When tilted, the CG rises. The line of action of weight **falls within** its base. The moment due to the weight of object about the pivot causes it to turn back to its original position.



Unstable Equilibrium
When tilted, the CG is lowered. The line of action of weight **falls outside** its base. The moment acts about the point of contact and turns it away from its stable position.



Neutral Equilibrium
The CG remains at the same height when displaced. The body will stay at any position that it has been displaced.



SUMMARY CHAPTER 6 – PRESSURE

Definition
Pressure is the amount of force acting perpendicularly per unit area.

SI unit : Pascal (Pa)

Note
Smallest contact area would give the largest/maximum pressure and vice versa.

Application of concept of pressure
- Snowboard increases the area of contact with the snow which reduces pressure exerted on snow.
- Sharp knife blade with a small area of contact enables easily cutting by increasing the pressure exerted on the object.

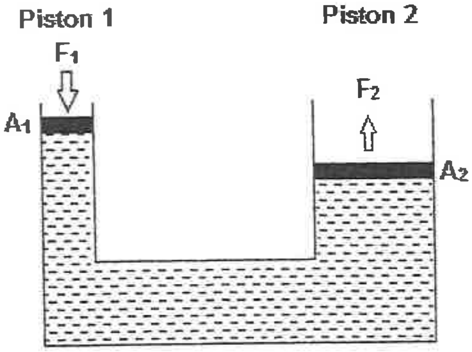
$$P = \frac{F}{A}$$

P = pressure (Pa or N/m^2)
F = force (N)   A = area (m^2)

Note
Conversion of units of area maybe required (e.g. mm^2 to m^2, cm^2 to m^2) when solving questions.

Conversion: 1 cm^2 = 0.0001 m^2

Hydraulic system



Hydraulic system makes use of 2 properties of liquids:
1. Liquids are incompressible.
2. Pressure applied to one end of the piston would be transmitted equally to all parts of the liquid.

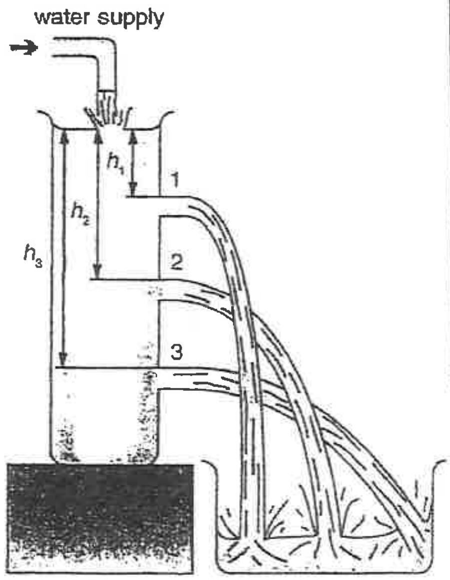
Note
- A smaller force F_1 applied at Piston 1 leads to a larger force F_2 at Piston 2.
- As the volume of liquid moved down from Piston 2 is equal to the volume of liquid moved up Piston 1, Piston 1 would move a larger distance as compared to Piston 2.

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

F_1 = Force on Piston 1 A_1 = Area of Piston 1
F_2 = Force on Piston 2 A_2 = Area of Piston 2

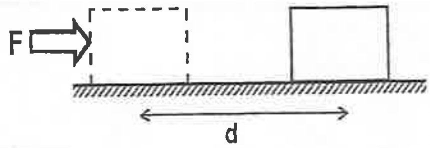
Note
Conversion of units of area maybe required (e.g. mm^2 to m^2, cm^2 to m^2) when solving questions.

Pressure of liquid
- Caused by the weight of liquid above the surface area.
- Pressure increases with the depth of liquid.
- Pressure is not affected by the shape of container.



SUMMARY CHAPTER 7 – WORK ENERGY POWER

Work



Note: No work done when no resultant force acts on the object or when object does not move in the direction of the force.

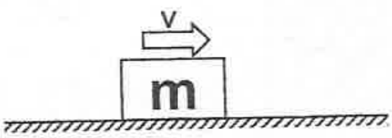
Work done on an object is defined as the **product** of the force applied and the distance **moved in the direction of the force**.
SI unit: joule (J)

$$W = F \times d$$

W = work done (J) F = force (N)
d = distance moved in the direction of the force (m)

Energy

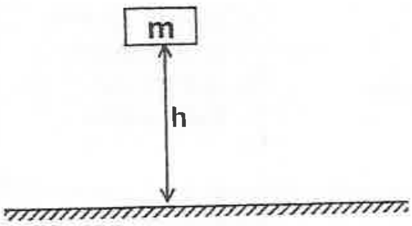
Energy is defined as the **ability to do work**.
S.I unit: joule (J)
Forms of energy: Kinetic energy (due to the motion of a body), elastic potential energy (e.g. stretched spring), gravitational potential energy (due to the position of the body), chemical potential energy (e.g. food, fuel cells)



Kinetic energy is the energy possessed by a body due to its **motion**.

$$E_k = \frac{1}{2} mv^2$$

E_k = kinetic energy (J) m = mass (kg) v = speed (m/s)



Gravitational potential energy is the energy possessed by a body due to its **relative position** to the Earth.

$$E_p = mgh$$

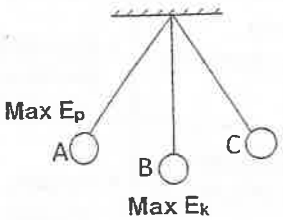
E_p = potential energy (J) h = gain/ loss in height (m)
g = acceleration due to gravity (m/s^2) m = mass (kg)

Principle of Conservation of Energy

Principle of Conservation of Energy states that energy **cannot be created or destroyed**, but only **converted** from one form to another. The **total energy** in an isolated system remains **constant**.

Swinging pendulum

A to B
Gain in E_k = Loss in E_p

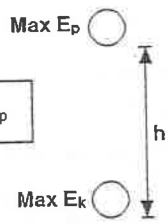


B to C
Loss in E_k = Gain in E_p

E_p is converted into E_k and back to E_p as pendulum oscillates.

Object dropped from height

Gain in E_k = Loss in E_p



E_p possessed by object is converted to E_k as the object falls. (Max E_k just before object hits the ground)

Power

$$P = \frac{W}{t} = \frac{\Delta E}{t}$$

Power is defined as the **rate of doing work**.
SI Unit: watts (W)
P = power (W) W = work done (J) Δ E = energy converted (J) t = time (s)

SUMMARY CHAPTER 8 – KINETIC MODEL OF MATTER

Kinetic Model of Matter

- Kinetic model of matter states that all matter is made up of a large number of tiny atoms or molecules which are in continuous motion.

Evidence of Molecular Motion : Brownian Motion

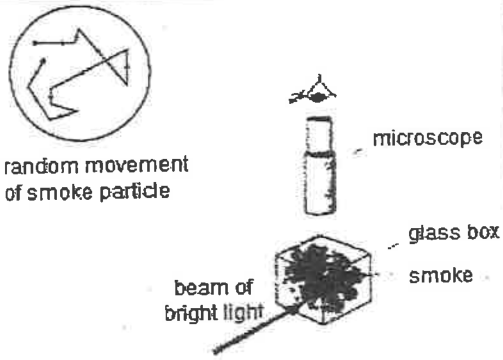
- Brownian motion refers to the random motion of particles that are suspended in fluids (gases or liquids).

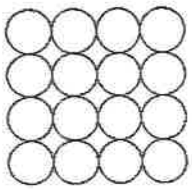
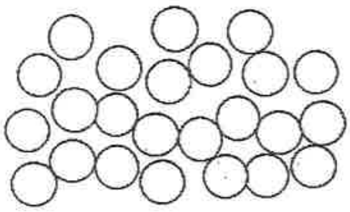
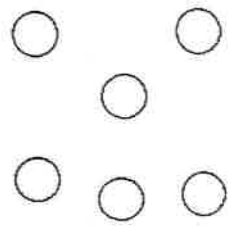
Observations

- Smoke particles are seen as bright specks under light through a microscope.
- Smoke particles in air moved in a random and irregular motion.
- Larger particles observed to have less irregular and random motion.

Conclusion

- The random motion is due to the air particles moving about randomly and bombarding the suspended smoke particles unevenly.



States of matter	Solid	Liquid	Gas
Diagram			
Properties of states of matter	• Fixed shape • Fixed volume • Usually hard and rigid (Large force needed to change shape) • Relatively high density • Incompressible	• Fixed volume • No fixed shape • Relatively high density • Incompressible	• No fixed volume • No fixed shape • Low density • Compressible
Arrangement of particles	• Particles are arranged in a regular pattern / orderly manner.	• Particles are not arranged in a regular pattern / are randomly arranged.	• Particles are not arranged in a regular pattern / randomly arranged and will occupy any available space.
Distance between particles	• Particles are closely packed together with little space between them.	• Particles closely packed together but slightly further apart as compared to solids.	• Particles are very far apart with a lot of empty spaces between them.
Forces between particles	• Strong attractive and repulsive forces act between particles.	• Strong attractive and repulsive forces act between particles.	• Negligible forces act between particles.
Motion of particles	• Particles vibrate about fixed positions.	• Particles vibrate and slide over each other within the liquid.	• Particles are moving randomly at a high speed.
Effect of temperature on particle motion	• The particles gain energy and vibrate faster as the temperature increases.	• The particles gain energy and slide faster over each other through the liquid as the temperature increases.	• The particles gain energy and move faster in random direction as temperature increases.

SUMMARY CHAPTER 9 – TRANSFER OF THERMAL ENERGY

Thermal energy transfer

- Thermal (or heat) energy always travels from a region of higher temperature to a region of lower temperature.
- Thermal equilibrium is reached when two objects are at the same temperature and there will be no net transfer of thermal energy between the objects.

Conduction

Definition: Process by which thermal energy is transmitted by vibrations through a medium from one particle to another without any flow of the medium.

How it works?

- Particles absorb heat and gain kinetic energy.
- Particles start to vibrate faster and collide with less energetic neighbouring particles.
- Energy is transferred between particles until the same temperature is reached.
- For metals, free electrons are able to move through particles and collide with other electrons and particles, transferring energy along the way.

Note:

- Main mode of heat transfer for solids
- Occurs more readily in solids than liquid and gases due to smaller distance between particles.

Applications using concept of conduction

Double glazed windows, cavity walls, felt insulation, computer heat sinks

Convection

Definition: Process by which thermal energy is transmitted from one place to another by the movement of heated particles in a gas or liquid due to density differences.

How it works?

- When liquid is heated, it expands, becomes less dense and rises.
- Surrounding colder and denser liquid sinks and replaces the hot liquid.
- The process repeats itself and a convection current is setup.

Note:

- Main mode of heat transfer for gases and liquids.
- Cannot occur in solids as particles in solids are held in fixed positions.
- Occurs more readily in gases and liquids as gases expand much more than liquids.

Applications using concept of convection

Air conditioners, refrigerators, land and sea breeze and car engine cooling system

Radiation

Definition: Process by which thermal energy is transmitted by electromagnetic infrared waves without the aid of a medium.

Affected by

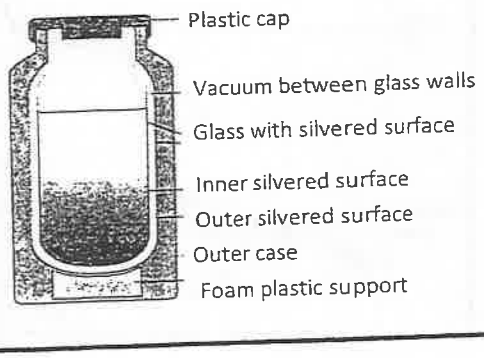
1. Surface area
   - Heat is radiated faster from a larger area.
2. Surface temperature
   - Heat is radiated faster from a hotter object.
3. Surface colour and texture
   - Black and rough surfaces are good absorber and emitter of radiant heat.
   - White and smooth surfaces are poor absorbers and emitters of radiant heat.

Note:

- Radiation can occur through a vacuum as it does not need a medium, unlike convection and conduction.
- Radiation occurs very quickly as infrared waves travel at 3×10^8 m/s
- Radiation travels towards all directions.

Applications using concept of radiation

Light coloured buildings in hot countries, white coloured space suits, solar panels painted black



Vacuum Flask

- Plastic cap reduces heat transfer by conduction as it is a poor heat conductor. It prevents heat transfer by convection as heated particles cannot escape the flask.
- Vacuum prevents heat transfer by conduction and convection as there is no medium for heat transfer.
- Silvered surfaces reduce heat transfer by radiation as it is both a poor emitter and absorber of radiant heat.
- Foam plastic support reduces heat transfer by conduction as it is a poor heat conductor.

SUMMARY CHAPTER 10 – THERMAL PROPERTIES OF MATTER

Internal Energy

- Consists of potential energy (due to intermolecular forces of attraction) and kinetic energy (due to motion of particles).
- Average kinetic energy of particles changes with temperature.
- Average potential energy changes with distance between particles (during change in states).

Melting and Freezing

- Melting is the process where energy supplied changes the state of a substance from solid to liquid state without a change in temperature.
- Melting point is the fixed temperature at which a substance changes from solid to liquid state at standard atmospheric pressure.

- Freezing is the process where energy removed changes the state of a substance from liquid to solid state without a change in temperature.
- Freezing point is the fixed temperature at which a substance changes from liquid to solid state at standard atmospheric pressure.

Boiling and Condensation

- Boiling is the process where energy supplied changes the state of a substance from liquid to gas state without a change in temperature.
- Boiling point is the fixed temperature at which a substance changes from liquid to gas state at standard atmospheric pressure.

- Condensation is the process where energy removed changes the state of a substance from gas to liquid state without a change in temperature.
- Condensation point is the fixed temperature at which a substance changes from gas to liquid state at standard atmospheric pressure.

Evaporation

Evaporation is the process where a substance changes from liquid to gas state without boiling.

Affected by:

1. Exposed surface area (larger area, faster rate)
2. Temperature of liquid (higher temperature, faster rate)
3. Wind (stronger wind, faster rate)
4. Humidity (lower humidity, faster rate)
5. Pressure (low pressure, faster rate)
6. Nature of liquid (low boiling point, faster rate)

How does evaporation occur?

- The molecules in a liquid are always moving randomly at different speeds.
- At the surface, liquid molecules with sufficient energy to overcome attraction forces of the liquid and atmospheric pressure are able to escape into the atmosphere.
- Less energetic molecules are left behind and the average kinetic energy of the molecules in the liquid decrease.
- The average temperature of the liquid decreases.

Boiling vs Evaporation

Similarities

- Both involves a change in state from liquid to gas
- Both involves absorbing of energy

Differences

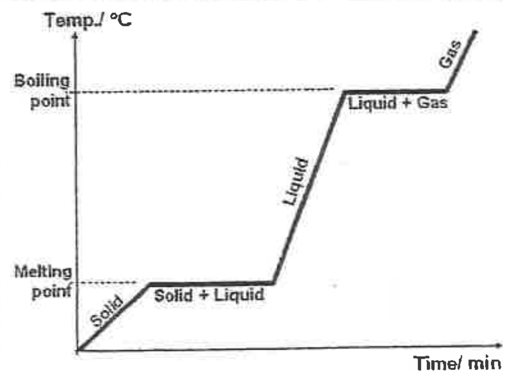
Boiling	Evaporation
Occurs at a fixed temperature	Occurs at any temperature
Occurs throughout the liquid	Occurs at the liquid surface
Bubbles observed	No bubbles observed
Temperature of liquid remains constant	Temperature of liquid decreases
Quick process	Slow process

Reading a heating curve

(cooling curve would have temperature decreasing as time increases)

How does energy of particles change in a heating curve?

- When the temperature is increasing, heat supplied is used to increase the average kinetic energy of the molecules (i.e. particles move faster). Average potential energy of the molecules increases slightly when temperature increases due to the slight increase in distance between molecules.
- When there is a change of state, heat supplied is used to increase the average potential energy (i.e. intermolecular distance increases) and to overcome atmospheric pressure (for boiling only) while the average kinetic energy of the molecules remains unchanged.



SUMMARY CHAPTER 11 – GENERAL WAVE PROPERTIES

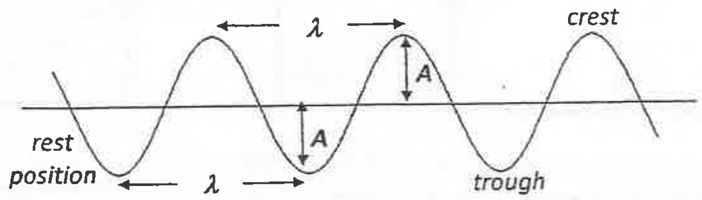
What are waves?

- Waves are disturbances caused by a <u>source of vibration</u> that <u>carries energy</u> from one point to another <u>without transfer of medium</u>.

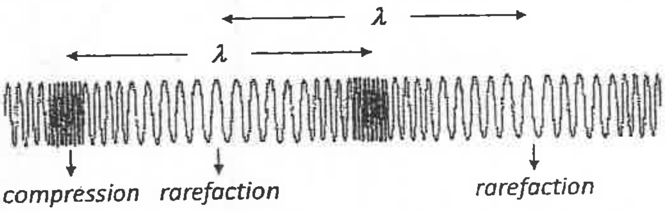
2 types of waves

Transverse Wave	Longitudinal Wave
- Particles vibrate <u>perpendicularly</u> to direction of wave motion - E.g. water waves, light, electromagnetic waves	- Particles vibrate <u>parallel</u> to direction of wave motion - E.g. sound waves

Parts of a transverse wave

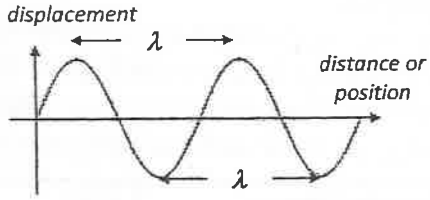


Parts of a longitudinal wave



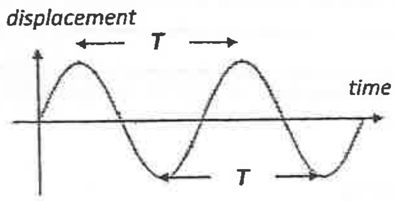
2 types of graph

1. Displacement-distance graph



- shows displacement of **all** particles in the wave at a particular point in time
- amplitude and wavelength λ can be read directly from graph

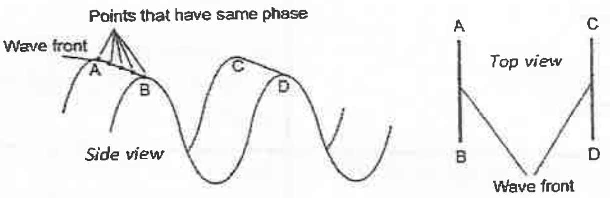
2. Displacement-time graph



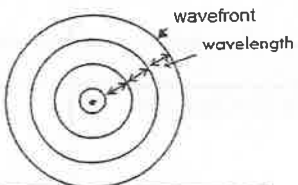
- shows displacement of **one** particle with respect to time
- amplitude and period T can be read directly from graph

Wave Terms

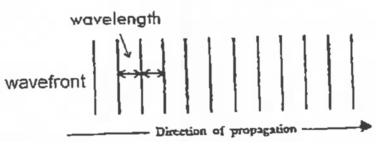
Wavefront – an imaginary line that joins all adjacent points that are in phase.



Note: Distance between two wavefronts gives the wavelength.



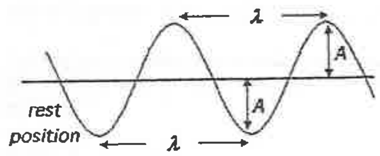
Circular wavefronts viewed from top



Plane wavefronts viewed from top

Amplitude A – the maximum displacement from the rest (or undisturbed) position (SI unit: *m*)

Wavelength λ – the distance between two successive crests or troughs (SI unit: *m*)



Period T – the time taken to generate one complete wave (SI unit: *s*)

Frequency f – the number of complete waves generated per second (SI unit: *Hz*)

$$f = \frac{1}{T}$$

Wave speed v – the distance moved by a wave per second (SI unit: ms^{-1})

$$v = f\lambda$$

SUMMARY CHAPTER 12 – LIGHT

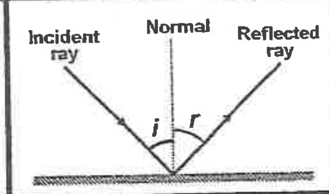
Reflection

Laws of Reflection

1) The incident ray, the reflected ray and the normal all lies on the same plane.
2) Angle of incidence is equal to the angle of reflection.

Angle of incidence: The angle between the incident ray and the normal.

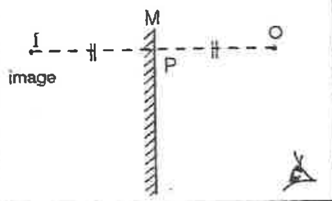
Angle of reflection: The angle between the reflected ray and the normal.



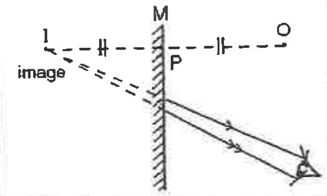
Steps to draw ray diagram

1) Locate the image
2) Draw reflected rays from a point on the image to eye.
3) Draw incident rays from mirror to the same point on the object.

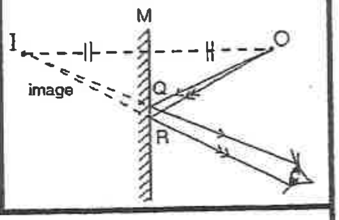
Step 1



Step 2



Step 3



Characteristics of image of plane mirror

1) Upright 2) Virtual 3) Same size as object 4) Same distance away from mirror as the object 5) Laterally inverted

Refraction

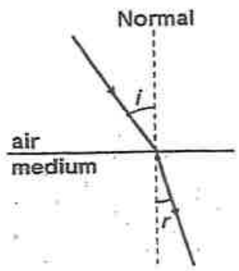
Refraction is the bending of light as it travels from one medium to another due to change in the speed of light.

Laws of Refraction

1) The incident ray, the refracted ray and the normal at the point of incidence all lies on the same plane.
2) For two given media, the ratio of $\frac{\sin i}{\sin r}$ is a constant.

Angle of incidence: the angle between the incident ray and the normal.

Angle of refraction: the angle between the refracted ray and the normal.



Finding the angle of refraction, angle of incidence or refractive index

$$n = \frac{\sin i(\textit{less dense medium})}{\sin r(\textit{denser medium})} \text{ or } n = \frac{\sin a}{\sin m}$$

'n' is the refractive index of the medium.
'i' is the angle between the ray and normal in the optically less dense medium.
'r' is the angle between the ray and normal in the optically denser medium.

Note
'i' and 'r' are not the angle of incidence and angle of refraction

'a' denotes angle in air while 'm' denotes angle in medium

Refractive index of a medium is the ratio of the speed of light in vacuum over the speed of light in that medium.

$$n = \frac{c}{v}$$

'c' is the speed of light in vacuum where c = 3 x 10^8 m/s.
'v' is the speed of light in the medium.

Note
Refractive index is always greater than 1

Refractive index is a ratio and has no units

Total internal reflection

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°.

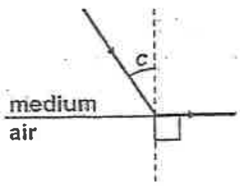
Finding the critical angle of the medium

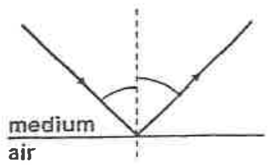
$$n = \frac{1}{\sin c}$$

'n' is the refractive index of medium.
'c' is the critical angle of the medium.

2 conditions for total internal reflection to occur

1) The light ray must be traveling from the optically denser medium to the optically less dense medium.
2) The angle of incidence must be greater than the critical angle.





SUMMARY CHAPTER 13 – ELECTROMAGNETIC SPECTRUM

Characteristics of electromagnetic waves

- all are transverse waves
- all transfer energy from one point to another
- all travels at 3 x 10^8 m/s <u>in vacuum</u>
- can travel through vacuum
- obey the law of refraction and reflection
- obey the wave equation $v = f\lambda$
- do not carry electric charge

Name of wave	Wavelength Range (m)	Trends of frequency and wavelength		Uses
Radio waves	$10^{-1} – 10^{5}$	↑ Increasing wavelength	↓ Increasing frequency	Radio and television communication
Microwaves	$10^{-3} – 10^{-1}$			Microwave oven, satellite television and mobile phone networks
Infra-red rays	$10^{-7} – 10^{-3}$			Infra-red remote controllers, night – vision equipment and intruder alarms
Visible light	10^{-7}			Lasers and optical fibres in medical uses and telecommunications
Ultra-violet rays	$10^{-8} – 10^{-7}$			Sunbeds, sterilisation of equipment, forgery detection and fluorescence effect
X-rays	$10^{-13} – 10^{-8}$			Cancer treatment, radiography, checking welds, luggage checks, medical and dental inspections
Gamma rays	$10^{-14} – 10^{-10}$			Cancer treatment, checking welds

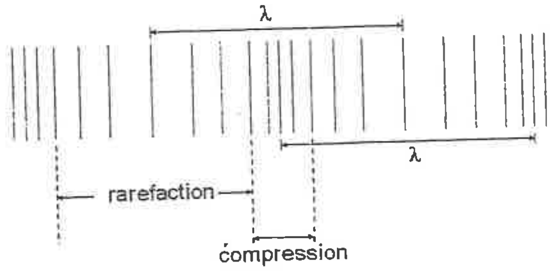
Things to know

- recall how the wavelength and frequency varies across the electromagnetic spectrum (no need to memorise the exact range of wavelength and frequency)
- state/know the characteristics of electromagnetic waves
- state the uses of the various electromagnetic waves
- perform calculations using $v = f\lambda$ and $T = 1/f$

SUMMARY CHAPTER 14 – SOUND

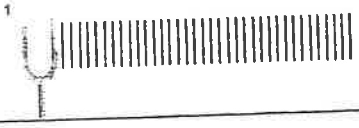
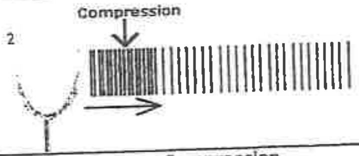
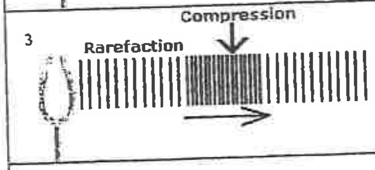
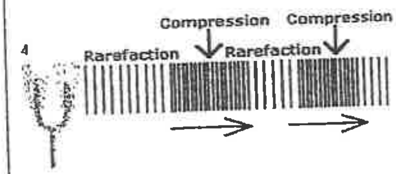
Properties of sound

- Produced by a vibrating source in a medium.
- A form of **longitudinal wave** where particles oscillate parallel to direction of wave motion, **carrying energy** from one point to another.

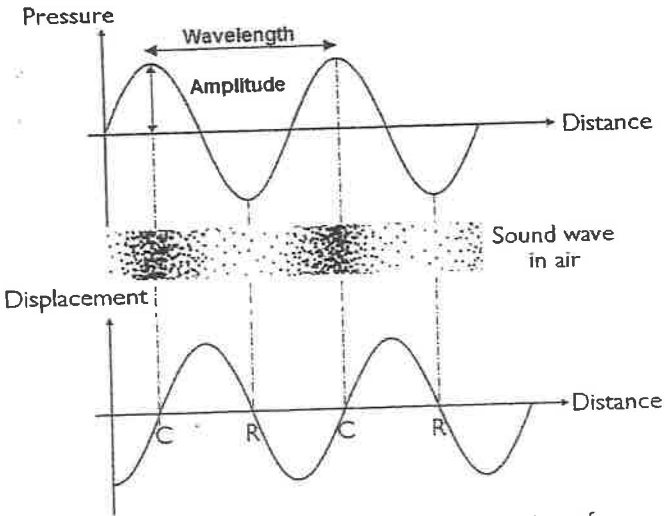


- Compressions are regions where pressure is **slightly higher** than the surrounding pressure.
- Rarefactions are regions where pressure is **slightly lower** than the surrounding pressure.
- Obeys the wave equation (**v = fλ**).
- Requires a medium to travel (**cannot** travel through vacuum).
- Travel **fastest** in solids, followed by liquid and gases.
- Hearing frequency of humans (**20 Hz to 20 kHz**).

Propagation of sound

1 	Layers of air in undisturbed position.
2 	Prong moves outward and air layers move together to form a compression.
3 	Prong moves inward and air layers spread out to form a rarefaction.
4 	Prongs vibrate and a series of compressions and rarefactions is generated to form a sound wave and energy is transferred from one particle to another.

Pressure-distance graph and displacement-distance graph



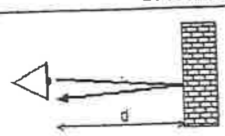
- Wavelength: Distance between **two consecutive** centres of **compressions** or **rarefactions** in the sound wave.
- Amplitude: **Maximum** pressure change in the sound wave.

Note: The centre of compression has the **highest** pressure while the centre of rarefaction has the **lowest** pressure.

Echoes

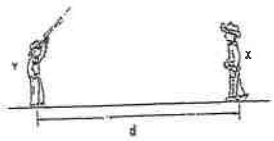
- Reflection of sound off a hard flat surface

Calculating distances using echoes

	$v = \frac{2d}{t}$	d = distance from wall t = time taken v = speed of sound

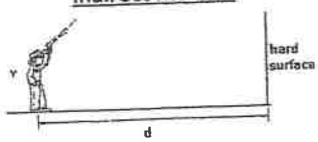
Finding the speed of sound in air

Direct method



1. Measure distance between firer and observer (distance > 300 m).
2. Firer fires pistol and observer starts timing when pistol flash is seen.
3. Observer stops timing when sound is heard. Time interval is recorded.
4. Calculate speed using v = d/t.
5. Firer and observer swap places and repeat experiment (to remove effect of wind).
6. Repeat experiment a few times and find average value.

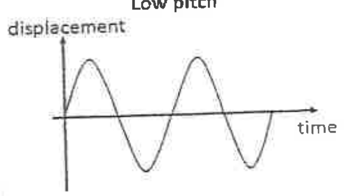
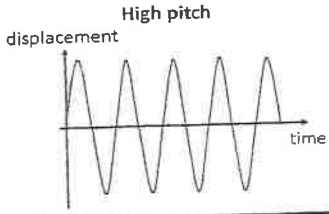
Indirect method



1. Measure distance between firer and hard surface (distance > 300 m).
2. Firer fires pistol and starts timing simultaneously.
3. Firer stops timing when sound echo is heard. Time interval is recorded.
4. Calculate speed using v = 2d/t (2d as the sound moves to the wall and back).
5. Repeat experiment a few times and find average value.

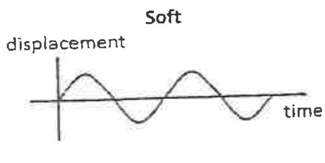
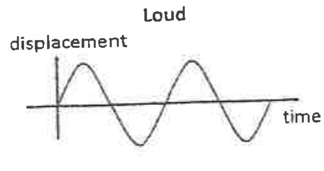
Pitch of sound

- The **higher** frequency of sound, the **higher** the pitch of sound.

Low pitch	High pitch
	

Loudness of sound

- The **larger** the amplitude, the **louder** the sound.

Soft	Loud
	

SUMMARY CHAPTER 15 – STATIC ELECTRICITY

Electric charges

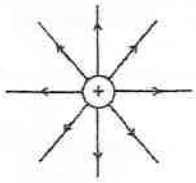
- Two types of charge: positive and negative
- Charges are measured in **coulombs** (C).
- One electron has the charge of 1.6×10^{-19} C.
- **Law of Electrostatic: Unlike** charges **attract**, **like** charges **repel**.
- **Further** the distance between charges, the **weaker** the forces.

Electric field

- Electric field is a region in which an **electric charge** experiences a force.
- The direction of the field is given by the direction of the force of the field on a **positive** test charge.
- **Stronger** electric field is represented by **closer** electric field lines.

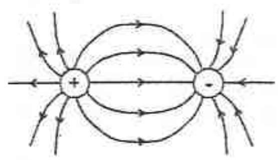
Electric field patterns

Isolated positive charge



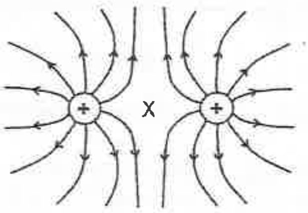
- Field lines are spread evenly.
- Field lines points outward radially.

One positive (+q) and one negative charge (-q)



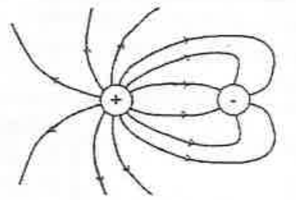
- Field lines connect in a loop.
- Field lines point from positive to negative charge.

Two identical positive charges



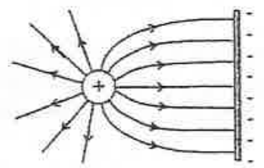
- Field lines curls away from each other.
- No overlap of field lines.
- No electric force acts at point X.

One positive (+2q) and one negative charge (-q)



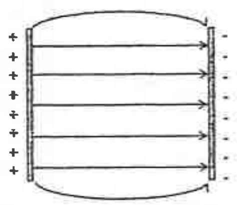
- Field lines from stronger charge envelop weaker charge.
- Twice the number of field lines for positive charge to negative charge.

One positive charge and one negative plate



- Field lines spread radially for side of charge facing away the plate.
- Field lines are joined to plate for side of charge facing towards the plate

One positive plate and one negative plate



- Field lines between the plates are evenly spaced to show uniform electric field.
- Field lines at the edge of plates are curved.

Discharging a charged conductor

Charged insulator

- Heating (intense heat ionises air to form ions which neutralises excess charges)
- Humid conditions (water molecules in air are electrical conductors which allows excess charges to be transferred to water molecules)

Charged conductor

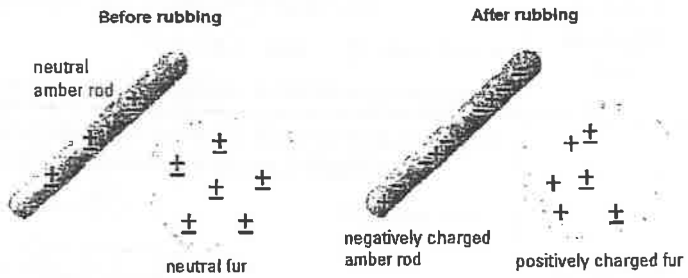
- Earthing (a path for electrons to move from earth is provided which neutralises excess charges)

Drawing electric field patterns

- Field lines begin from **positive** charges and end on **negative** charges.
- The number of field lines drawn leaving a positive charge or ending on a negative charge is **proportional** to the magnitude of the charge.
- Field lines **cannot** cross each other.
- Field lines start and end **perpendicular** to the surface of the charge.

Charging by friction

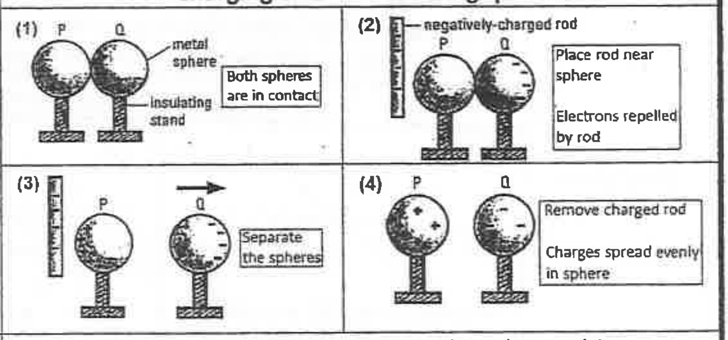
- Used for charging electrical insulators (electrons are unable to move freely within the material).
- Charges are gained when two objects are rubbed against one another whereby negative charges (**electrons)** are transferred between them.
- Object that gains electrons will be negatively charged while the object that loses electrons will be positively charged.



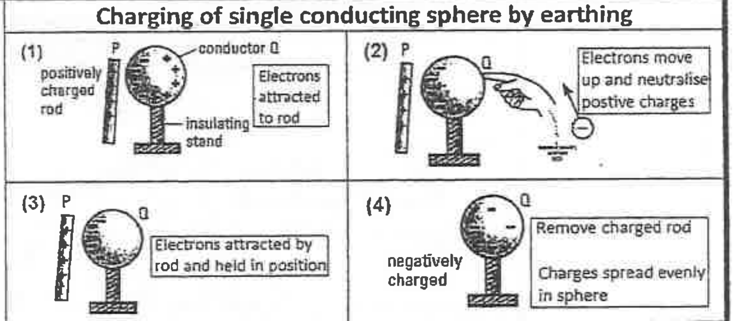
Charging by induction

- Used for charging electrical conductors (electrons are able to move freely within the material).

Charging of two conducting spheres



Charging of single conducting sphere by earthing



Examples of hazards of static electricity

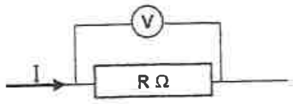
Lightning

- Thunderclouds are charged by friction between the water molecules in the thunderclouds and air molecules.
- The charged clouds ionises the air and the ionised air provides a conducting path for electric charge to be discharged to the nearest or sharpest object on the ground.

Electrostatic discharge

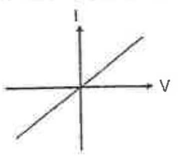
- Accumulation of excessive charges due to friction can lead to sparks that can ignite flammable liquids or cause electric shock.
- Earthing to the ground using conductors prevents accumulation of charges. (e.g. metal chains connecting the body of trucks to the ground allows movement of electrons to neutralise the charges)

SUMMARY CHAPTER 16 – CURRENT OF ELECTRICITY

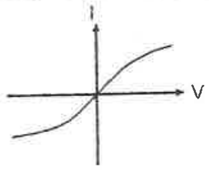
Electric Charge	Two type of charges: protons (positive) and electrons (negative) SI unit: coulomb (C) (1 C = 1.6 x 10^{-19} charges)		
Current	Definition: Current is the **rate of flow** of charge. SI unit: amperes (A) Measured by: **ammeter** connected in **series** to component **Note:** Conventional current direction is opposite to electron flow.	$I = \frac{Q}{t}$	Q = charge (C) I = current (A) t = time (s)
Electromotive Force (e.m.f)	Definition: Electromotive force is defined as the **work done** by a **source** in driving a unit charge around a complete circuit. SI unit: volts (V) Note: 1 V = 1 J/C Measured by: **voltmeter** connected in **parallel** across cell	$\epsilon = \frac{W}{Q}$	ε = e.m.f (V) W = work done (J) Q = charge (C)
Potential Difference (p.d)	Definition: Potential difference is defined as the **work done** in driving a unit charge through two points in a closed circuit. SI unit: volts (V) Note: 1 V = 1 J/C Measured by: **voltmeter** connected in parallel across component	$V = \frac{W}{Q}$	V = p.d (V) W = work done (J) Q = charge (C)
Resistance	Definition: Resistance of a component is the **ratio** of the potential difference across a component to the current flowing through it. SI unit: ohm (Ω) 	$R = \frac{V}{I}$	R = resistance (Ω) V = p.d (V) I = current (A)
	Resistance is **proportional** to the **length** of the wire (**increases** with **increase** in length) and inversely proportional to the **cross-sectional area** of the wire (**decreases** with **increase** in cross-sectional area)	$R = \rho\frac{l}{A}$	ρ = resistivity (Ωm) *l* = length (m) A = cross-sectional area (m^2)
Ohm's Law	Ohm's Law states that the current, I, passing through a conductor is **directly proportional** to the potential difference, V, between its ends, provided that the physical conditions and temperature remain constant.	$\frac{V}{I} = Constant$	

Ohm's Law

IV characteristic graphs



Metallic conductor at constant temperature

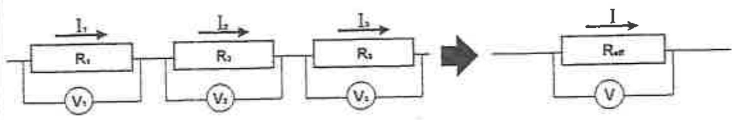


Filament lamp

Note:
For ohmic conductors, their V-I graph are straight lines and passes through the origin.
For non-ohmic conductors, their V-I graphs are not straight lines.

Resistors

Series arrangement

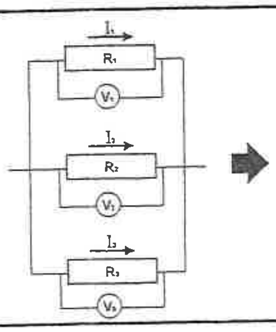


I = $I_1 = I_2 = I_3$ = ... V = $V_1 + V_2 + V_3$ + ... $R_{eff} = R_1 + R_2 + R_3$....

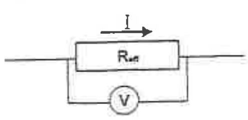
Note for series arrangement:

- Current is the **same** at every point on circuit
- **Sum** of potential difference across individual components is **equal** to the potential difference across the whole circuit
- Component with the **largest** resistance has the **largest** potential difference across it

Parallel arrangement



$$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$



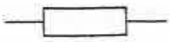
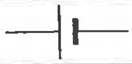
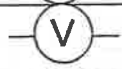
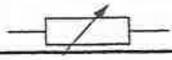
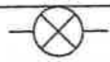
I = $I_1 + I_2 + I_3$ + ...

V = $V_1 = V_2 = V_3$ = ...

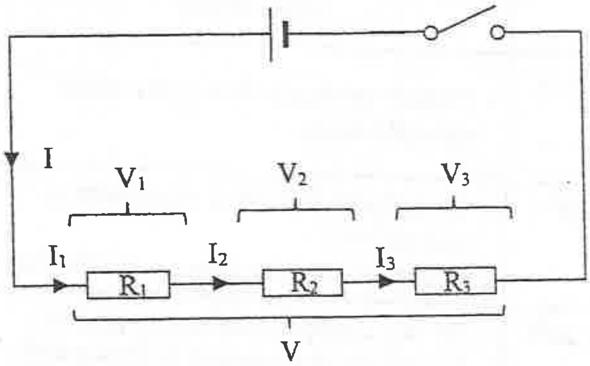
Note for parallel arrangement:

- Potential difference across each resistor is the same
- Current from the source is the **sum** of current in each branch of a parallel circuit
- Component with the **smallest** resistance allows the **largest** amount of current to pass through it

SUMMARY CHAPTER 17 – D.C CIRCUITS

Symbols of components in circuit diagram					
Switch		A.C power supply		Ammeter	
Resistor		Cell		Voltmeter	
Rheostat		Fuse		Lamp	

Series Circuit

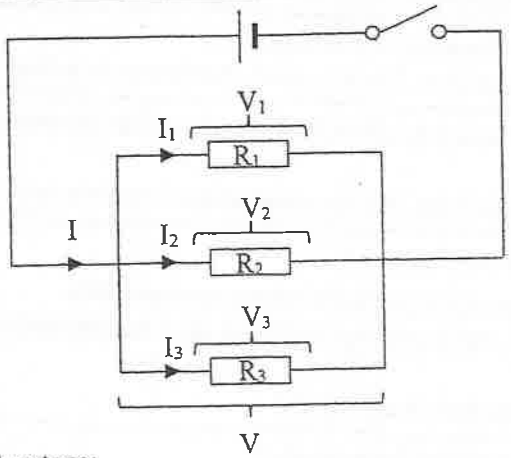


<u>Disadvantage:</u>
Any break along the circuit will cause current to stop flowing in the circuit.
Light bulbs are less bright when connected in series than in parallel.

<u>Advantage:</u>
Light bulbs arranged in series draw less current as compared to parallel arrangement.

Current	Current at any point (I_1, I_2, I_3) in series circuit is the **<u>same</u>**. $I = I_1 = I_2 = I_3 = \ldots = I_N$
Potential Difference	**<u>Sum</u>** of potential difference (V_1, V_2, V_3) in the series circuit **<u>equal</u>** potential difference across whole circuit (V). $V = V_1 + V_2 + V_3 + \ldots + V_N$
Resistance	Effective resistance is the **<u>sum</u>** of the resistance in series. $R_{eff} = R_1 + R_2 + R_3 + \ldots + R_N$ Effective resistance is **<u>always larger</u>** than individual resistance.

Parallel Circuit



<u>Advantage:</u>
Any break along the parallel branch does not affect current flow in the whole circuit.
Light bulbs are brighter when connected in parallel than in series.

<u>Disadvantage:</u>
Light bulbs arranged in parallel draw more current as compared to series arrangement.

Current	**<u>Sum</u>** of current (I_1, I_2, I_3) in each parallel branch is **<u>equal</u>** to the source current (I). $I = I_1 + I_2 + I_3 + \ldots + I_N$
Potential Difference	Potential difference (V_1, V_2, V_3) across each resistor connected in parallel is **<u>equal</u>**. $V = V_1 = V_2 = V_3 = \ldots = V_N$
Resistance	Inverse of effective resistance is the **<u>sum</u>** of the inverse of the individual resistance. $\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_N}$ Effective resistance is **<u>always smaller</u>** than the smallest individual resistance.

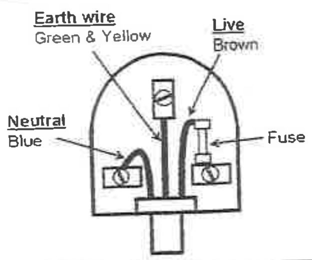
SUMMARY CHAPTER 18 – PRACTICAL ELECTRICITY

Quantity	Formula				Symbols and Units
Electrical Power	P = E/t	P= VI	$P = I^2R$	$P = V^2/R$	E = energy (J) P = power (W) I = current (A) R = resistance (Ω) V = potential difference (V) t = time (s)
Electrical Energy	E = Pt	E = VI t	$E = I^2R\ t$	$E = (V^2/R)t$	
Cost of Energy	E = Pt *1 kW h = 3.6 MJ Cost ($) = Energy used (kW h) x Rate ($/kW h)				E = energy (kW h) P = power (kW) t = time (h)

Hazards of electricity	Causes and Dangers	Precautions
Damaged insulation	• Wear and tear of insulation leads to exposed live wires. • Exposed wire leads to short circuit. • Contact with exposed wire leads to electric shock.	• Inspect wires regularly and replace exposed wires.
Overheating of cables	• Too many plugs in one socket causing cable overload when large current is drawn. • Overheating of cable leads to fire.	• Do not plug too many appliances in one socket. • Use thick wires for high power devices.
Damp conditions	• Wet skin reduces resistance of skin and provides a path of low resistance for current to flow. • Electric shock leading to injuries and death.	• Do not use appliance in wet places. • Do not touch plugs and switches with wet hands.

Safety features	Working principle of safety features
Fuse	• A short length of thin wire that **melts** and disconnects the appliance from the live terminal when the current flowing in the circuit **exceeds** the fuse rating. • Common fuse ratings : 1 A, 2 A, 5 A, 10 A, 13 A, 30 A • Fuse rating used must be **slightly higher** than the **normal operating** current. • Connected to the **live** wire to disconnect the appliance from live terminal when there is a fault.
Switch	• Used to turn on or off an appliance by completing or breaking the circuit. • Connected to the **live** wire to disconnect the appliance from live terminal when there is a fault.
Circuit breaker	• Stops current flow by breaking the circuit quickly (in less than 25 ms) when there is an **excessive** current flow. • Connected to the **live** wire to disconnect the appliance from live terminal when there is a fault.
Earth wire	• Connects the **metal** casing of an appliance to the **earth**. • Provides a **low resistance** path when current leakage occurs and the casing becomes live. • **Large** current flow melts the fuse which disconnects the appliance from live terminal and prevents the user from getting an electric shock. • Earth wire is unnecessary if casing is made of an **insulator** of electricity.
Double Insulation	• Both **wire** and **appliance casing** are covered with insulator of electricity. • Isolates and shields **live** electrical components from the user and prevents the user from getting an electric shock. • **Two** layers of insulation need to fail in order for direct contact with live components. • **Earth** wire is not needed when appliance is double insulated.

Three-Pin Plugs



Live	• **Live** wire is at high voltage of 240 V. (**Brown**) • **Fuses, switches** and **circuit breakers** are connected to the live wire.
Neutral	• **Neutral** wire is at 0 V. (**Blue**) • **Live** and **neutral** wire will carry the **same** amount of current.
Earth	• Earth wires are **low resistance** wires that are usually connected to the **metal** casing of the appliances. (**Green & yellow**) • **No current** flows in earth wire during **normal** operating condition.

SUMMARY CHAPTER 19 – ELECTROMAGNETISM

Properties of magnets

- Magnetic effect is <u>strongest</u> at the poles.
- There are <u>two</u> poles, North and South pole, in a magnet.
- Like poles <u>repel</u>, unlike pole <u>attract</u>.

Test for magnetism

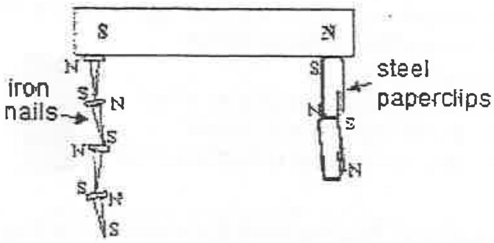
<u>Repulsion</u> is the only way of testing whether an object is a magnet.

Magnetic and Non-magnetic materials

- Magnetic: <u>iron, nickel, cobalt and steel</u> (Note: Even when a material is magnetic, it does not mean it is a magnet. It needs to be magnetised first)
- Non-magnetic: all other materials (Non-magnetic materials cannot be magnetised.)

Soft magnetic materials (e.g. iron)	Hard magnetic materials (e.g. steel)
• Gain and lose its magnetism <u>easily</u> • Used to make <u>temporary</u> magnets in moving coil ammeter, electromagnet	• Gain and lose its magnetism <u>less easily</u> • Used to make <u>permanent</u> magnets in moving coil loudspeaker, compass

Induced magnetism

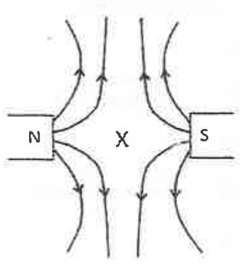


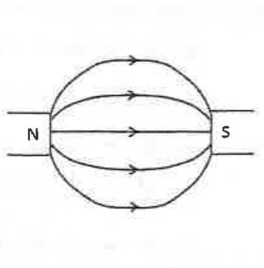
- Induced magnetism is the process whereby a <u>magnetic</u> material (e.g. iron, steel) become magnetised when placed near a magnet.
- End of the induced magnet <u>closer</u> to the magnet will have <u>opposite</u> polarity to that of the magnet.
- Induced magnetism <u>occurs before attraction</u> (i.e. magnetic material will become an induced magnet <u>before</u> getting attracted to the magnet).

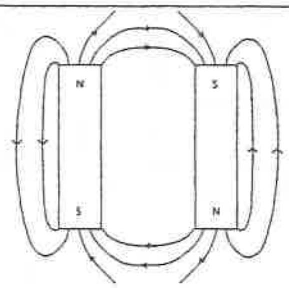
Magnetic field

- Magnetic field is a region surrounding a magnet in which a <u>magnetic material</u> experiences a magnetic force.
- Magnetic field pattern can be plotted using a compass.
- The direction of magnetic field goes from the <u>North pole</u> to the <u>South pole</u>.
- <u>Stronger</u> magnetic field is represented by <u>closer</u> field lines.

Magnetic field patterns

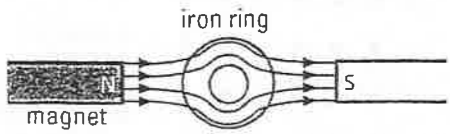


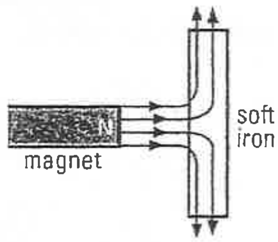




Magnetic shielding

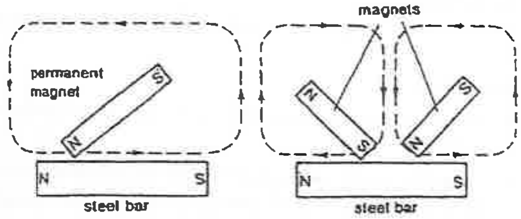
Thin sheets of <u>soft magnetic materials</u> (e.g. iron) can divert magnetic fields that are present as magnetic field lines <u>tend to pass within them</u>. This protects equipment that is sensitive to magnetic fields.





Methods of magnetising

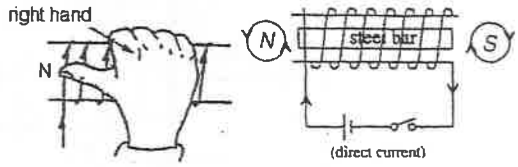
Stroking method



An unmagnetised steel bar is stroked several times with the <u>same</u> pole of a permanent magnet from one end to the other in <u>one direction</u>.

The pole produced at the end of the steel bar where the strokes finish is <u>opposite</u> to the stroking pole used.

Electrical method (using direct current)

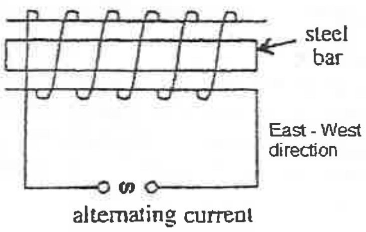


Using a solenoid (a coil of wire) with <u>d.c. supply</u>, insert steel bar inside solenoid in <u>North-South</u> direction.

To determine the North and South pole of the magnet, use <u>right hand grip rule</u>.

Methods of demagnetising

Electrical method (using alternating current)



Using a solenoid with <u>a.c. supply</u>, insert magnet inside solenoid in <u>East-West</u> direction and pull out slowly.

Hammering

Hammering along the East-West direction cause magnetic domains to become unaligned, leads to the loss of magnetism.

Strong heating

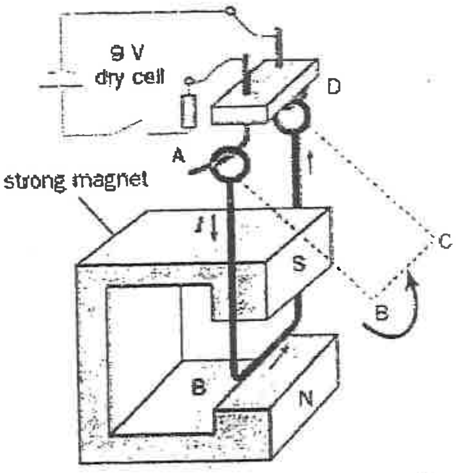
Heat the magnet and allow it to cool along the East-West direction. High temperatures increase the vibrations of the magnetic domains of the magnet, causing them to lose their alignment, which leads to the loss of magnetism.

Experiment to show force acting on current carrying wire in an external magnetic field

The "Kicking" wire experiment

Apparatus
- Horseshoe magnet, dry cells, resistor, switch and wires

Procedure
- Setup the apparatus as shown below without closing the switch.
- Close the switch and observe the movement of the wire.
- Reverse the polarity of the dry cell, close the switch and observe.
- Reset the apparatus to the original setup.
- Reverse the direction of the magnetic field, close the switch and observe the movement of the wire.



Observation
- When switch is closed, the wire is seen to move **outwards**.
- When direction of current is **reversed**, the wire is seen to move **inwards**.
- After resetting to original setup, when the direction of magnetic field is **reversed**, the wire is seen to move **inwards**.

Conclusion
- **Reversing** current (keeping the direction of the magnetic field unchanged) will lead to **reverse** in direction of force.
- **Reversing** direction of magnetic field (keeping the direction of the current unchanged) will lead to **reverse** in direction of force.

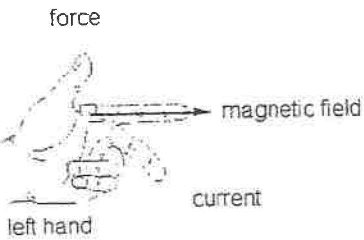
Note: **Increasing** the current or the strength of the magnetic field will **increase** the force acting on the wire.

To find direction of force acting on wire

Fleming's left hand rule
- Forefinger points toward direction of **magnetic field**.
- Second finger points toward direction of **current**.
- Thumb points toward direction of **force** acting on wire.

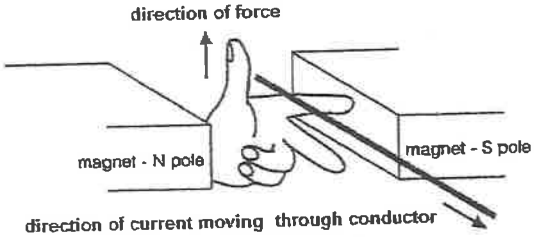
Note: The direction of **conventional current** flow (from **positive** to **negative**) is used.

Fleming's left hand rule



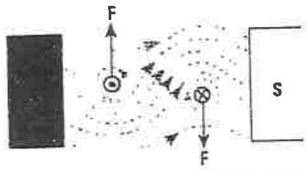
Applying Fleming's left hand rule on current carrying wire

- A current-carrying conductor in a magnetic field experiences a force whenever it is positioned at an angle to the direction of the magnetic field.
- To obtain a larger force acting on the current carrying wire:
  - Increase the **current** flowing through the wire.
  - Increase the strength of **magnetic field**.



Applying Fleming's left hand rule on a current carrying coil

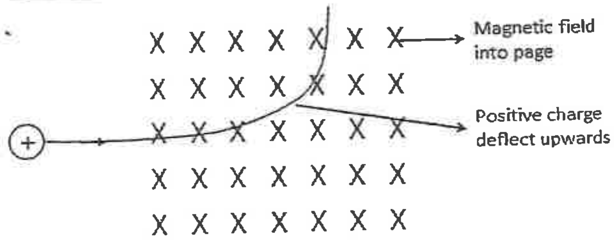
- A current-carrying coil in a magnetic field experiences a **turning effect**.
- Turning effect of the coil can be increased by
  - increasing number of turns of coil
  - increasing current in the coil
  - placing a soft-iron core into the coil



Applying Fleming's left hand rule on moving charged particles

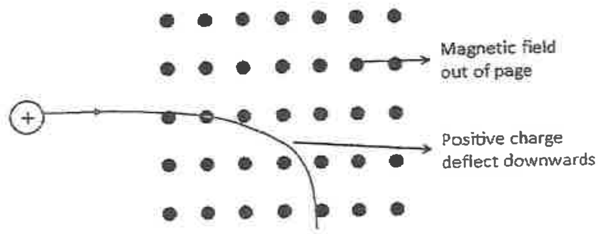
- A beam of protons is deflected to move in a circular path. The direction of force can be determined by Fleming's Left-hand Rule and taking the current to be in the direction of the beam of positive charges.

Beam of proton moving through a magnetic field (Top view)



- The beam of protons deflects downwards when the direction of magnetic field is **reversed**.

Effect of a reverse in direction of magnetic field



- If the beam of **protons** is replaced by a beam of **electrons** and the direction of magnetic field remains unchanged, the direction of deflectio **reverses**.

Effect of a change in the charge of particles