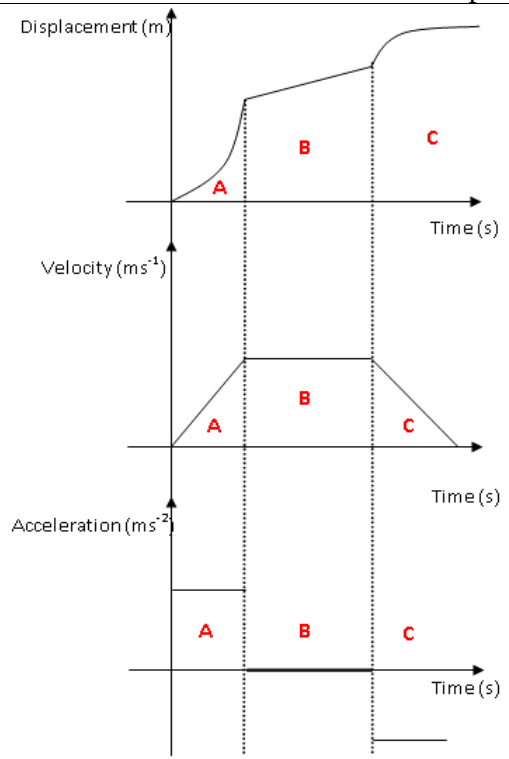
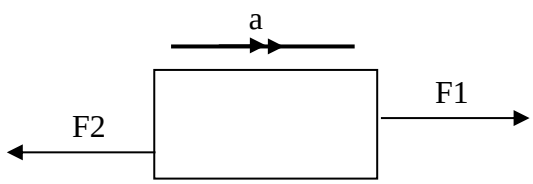
Physics Formulae List

Topics	Formulaes	Important Definitions and Pointers
Kinematics	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ $s = \frac{1}{2}(u + v)t$ $v = u + at$ s = displacement (m) u = initial velocity (ms^{-1}) v = final velocity (ms^{-1}) a = acceleration (ms^{-2}) t = time (s) Gradient of v – t graph ⇨Acceleration Area under v – t graph ⇨ Distance travelled	 **Important Note!** ✓ When v = 0 ms^{-1}, it can only mean two things, ➢ The object is at rest. ➢ It is undergoing a turning point. **Formulas!** ✓ S = D ÷ T can be only be used when there's no acceleration or average speed value is used. ✓ v = u + at Displacement – time graph ***Gradient*** *represent* ***velocity****, hence just replace the word gradient with velocity* In A, the gradient is increasing at a constant rate, thus the velocity is increasing at a constant rate. In B, the gradient is constant, thus the velocity is a constant. In C, the gradient is decreasing at a constant rate, thus the velocity decreases at constant rate. Velocity – time graph ***Gradient*** *represent* ***acceleration****, hence just replace the word gradient with acceleration* ***Area*** *represent* ***displacement*** In A, the velocity is increasing at a constant rate, thus the acceleration is a positive constant. In B, the velocity is a constant, thus the acceleration is zero. In C, the velocity decreases at a constant rate, thus the acceleration is a negative constant. The graph has shown positive areas; hence it shows that the displacement moved by the object is in the POSITIVE direction. However, if the area is negative, it symbolises that the object is moving in opposite direction. *If the question request for displacement, it could be calculated by* *Displacement = |Positive area| – |Negative area|*

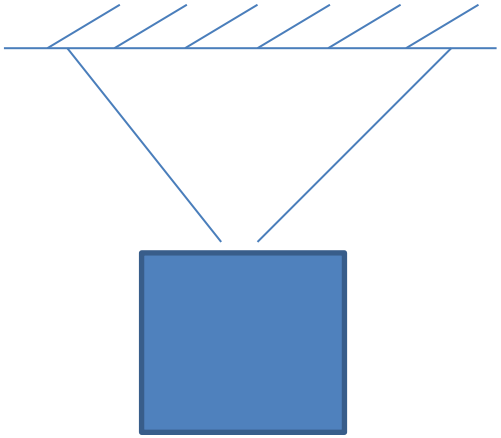
		However, if distance is required, *Distance = |Positive area| + |Negative area|* *If the question request for the meeting point between two objects and IF they start at the same point, construct the following equation* *Distance moved by A (Area covered by A in v-t graph) = Distance moved by B(Area covered by B in v-t graph)* **<u>Definitions</u>** 1. Velocity is defined as the rate of change of displacement per unit time. 2. Acceleration is defined as the rate of change of velocity per unit time. 3. Speed is a scalar quantity, i.e., only has magnitude 4. Velocity is a vector quantity, i.e., has magnitude and direction. **<u>Answering Templates</u>** 1. Describe the motion of the object. The _____(y axis. It can be velocity/acceleration/displacement) is increasing/decreasing at increasing/decreasing rate (rate means gradient) and the object is moving in _____ direction. 2. Explain why the average speed of object A is higher than that of B. For the same time interval, the distance travelled/area under the graph for object A is higher than that of B, hence object A will have a higher average speed. 3. From the velocity-time graph, by using the idea of kinematics, explain why object A experiences terminal velocity? Initially, A experiences gravitational acceleration. As the velocity of A increases, the opposing air resistance acting on A increases, causing the resultant acceleration of A decreases. Hence, velocity of A will increase at a decreasing rate, until it reaches constant velocity, which is termed as terminal velocity.

Dynamics	$F_{net} = ma$ F = **RESULTANT** force m = mass a = acceleration	**<u>Definitions</u>** ➢ Newton first law states that an object will continue its motion or at rest unless an external force acts on it. ➢ Newton second law states that the resultant force acting on the object is equal to the product of mass and acceleration, the direction of the force is the same as the direction of the motion. ➢ Newton third law states that when body A acts on body B, body B will have an equal and opposite force, i.e., action reaction force, on body A **<u>Answering Templates</u>** 1. Explain why the object will experience terminal velocity. Initially, the object will experience <u>gravitation acceleration</u>. As the <u>velocity of the object increases</u>, the <u>air resistance (or any other drag force) will increase</u>. Since the <u>weight (or any applied force) of the object is constant</u>, the <u>resultant force acting on the object will decrease</u>, causing the acceleration to decrease. The <u>air resistance will increase until it is equal and opposite of the weight</u>, which causes the resultant force to be zero. Hence, the object will experience <u>zero acceleration, which causes the velocity to be constant.</u> 2. Explain why the velocity of the object increases at an increasing rate. The applied force acting on the object increases at an increasing rate. Hence, the resultant force acting on the object increases, resulting in an increasing acceleration. **<u>Pointers</u>** ➢ Friction acts in the **<u>OPPOSITE DIRECTION OF FORCE APPLIED</u>**, not the direction of motion. ➢ There are 2 ways to calculate resultant force, which would be illustrated below.  Method 1: $F = ma$ Method 2: $F_{net} = ma$ *By combining the two methods* $Since\ F_{net} = F1 - F2$ $\therefore F1 - F2 = ma$

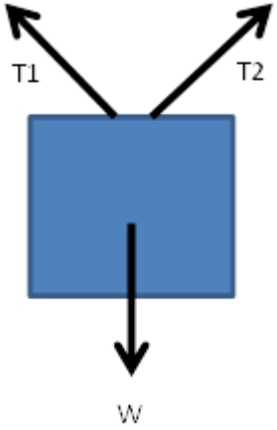
- Basic knowledge of Free Body Diagram

  - It is used to show all the forces ACTING ON an object

Example

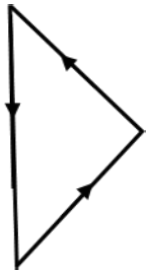


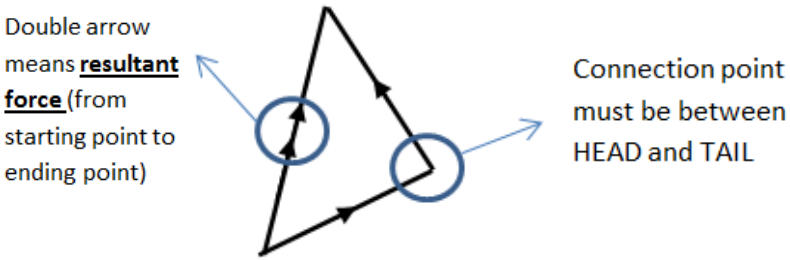
Free Body Diagram



In this case, there are only 3 forces acting on the box, namely the weight and the two tensions acting ON the box by the string.

- Drawing of vector triangle
  - No resultant force
  - With resultant force





- Picking up of key words from the questions/graph techniques
  - "Constant speed/velocity"
    The above keywords show that the acceleration is zero; hence the resultant force would be zero. This would mean that forward force = backward force.
  - F-t graph
    Normally, value(s) of force need to be read from the graph and calculate the resultant force. As such, the acceleration of the object could be found. Area under the F-t graph represents the change in momentum. By dividing change in momentum by mass, it will give you change in velocity. *Momentum is not in your syllabus, so just remember that area under F-t graph is directly proportional to change in velocity.

Turning effect of Forces

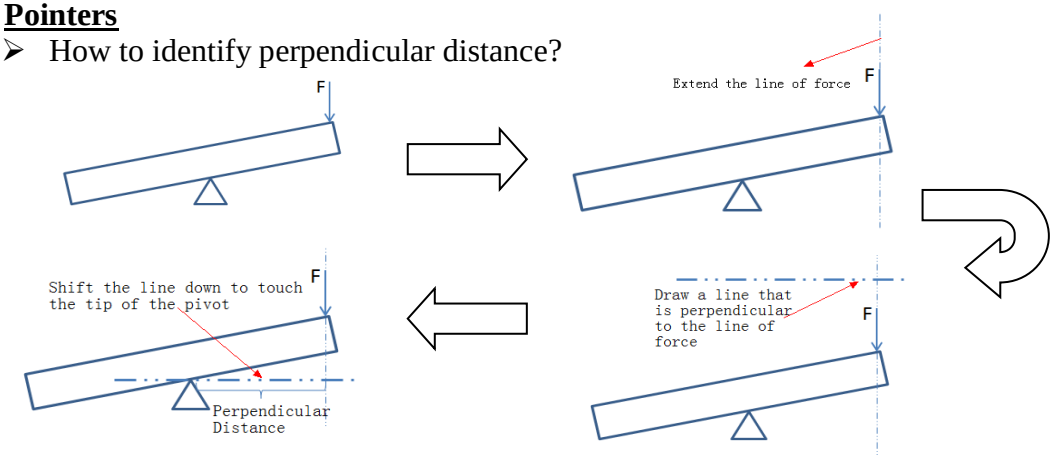
Moment = Force × **Perpendicular** distance away from the pivot **between the line of action of force and pivot**

Definitions

- Principle of moment states that in equilibrium, the sum of all clockwise moment about any pivot, is equal to the sum of all anti-clockwise moments about the same pivot.

Pointers

- How to identify perpendicular distance?



- Answering template

1. In every stable system, there is a need to state the following in your working.
   By Principle of Moment, Sum of clockwise moment = Sum of anti-clockwise moment

2. Explain why the object is in stable equilibrium.
   As the line of action of weight acting from the centre of gravity lies within the base area of the object, it is able to create clockwise/anti-clockwise moment (choose one depending on the question) to rotate the object back to its original position.

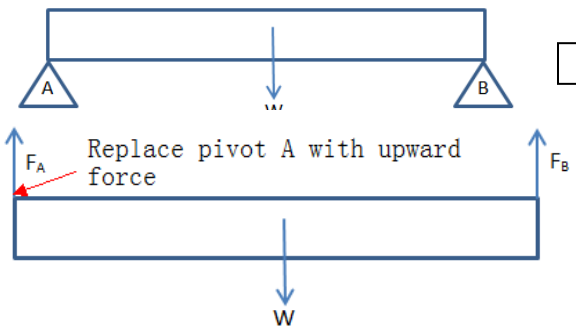
3. Explain why the object is in neutral equilibrium when the position of the c.g. is directly above the pivot.
   The perpendicular distance between the line of action of weight and the pivot is zero, hence there is no moment created by the weight, which results in zero net moment acting on the object. As such, when the object experience any moment created by any force exerted on it, it will move away from its original position.

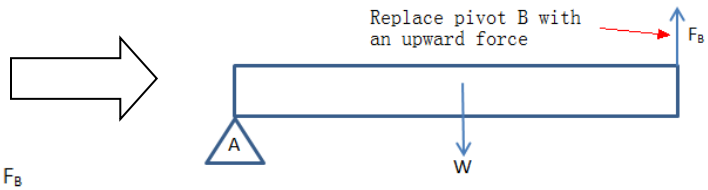
4. State and explain what happen to force A if it is placed closer to the pivot.
   As the perpendicular distance between the force A and the pivot decreases, force A has to be increased to generate the same amount of anti-clockwise/clockwise (countering) moment to counter the anti-clockwise/clockwise moment generated by force B.

5. Explain why, after a metal sheet swings freely, it comes to rest and remains at rest in that position.
   The metal sheet is in stable equilibrium, hence when it experiences a swing, the weight provides a counter moment to bring the metal sheet back to its original position. In this position, the perpendicular distance between the line of action of weight and the pivot is zero, hence there is no moment created by the weight, which results in zero net moment acting on the object.

- Solving techniques for two pivots questions

Assuming that the question request to take moment at about pivot A,





With the diagram above (right), F_B can be calculated by using the answering template.

If the calculation of F_A is required, draw the free body diagram of the plank.

Total upwards force = Total downwards force

Calculate the unknown from the equation above

Energy, Work, Power	W = F × //d W = Work done by the force applied F = Force applied //d = Distance that is parallel to the line of force $P = \frac{W}{t}$ P = Power of the system W = Work done on the system t = time taken **P = F × v** P = Power of the system F = Force applied v = velocity of the object	**<u>Definitions</u>** ➢ Work done is defined as the product of force and distance moved by the object in the direction of the force ➢ Power is defined as the rate of work done (i.e. energy) ➢ Law of conservation of energy states that no energy can be created nor destroyed; it can only be converted from one form to the other, keeping the total amount of energy constant in a closed system. **<u>Pointers</u>** ➢ Answering template - No loss of energy to the surroundings By conservation of energy, Total energy at point A = Total energy at point B $P.E_A + K.E_A = P.E_B + K.E_B$ (Sub in the formulas)

Potential Energy (P.E)
=
mgh

Kinetic Energy (K.E)
=
$\frac{1}{2}mv^2$

m = mass of the object

g = gravitational acceleration (10 ms^{-2})

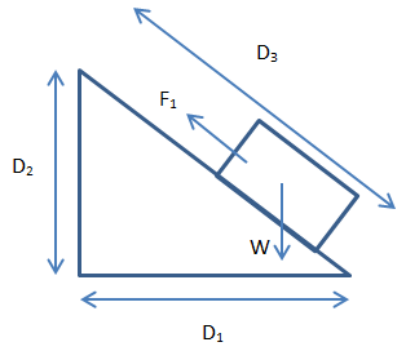
h = height of object AWAY from the reference point, i.e. commonly treated as the ground.

v = velocity/speed of the object

- Loss of energy is accounted for.

By conservation of energy,
Total energy at point A = Total energy at point B
$W.D_{object} - W.D_{friction} + P.E_A + K.E_A = P.E_B + K.E_B$.
(Sub in the formulas)

- Identification of parallel distance



Work done can be calculated in two ways

Method 1: W = F × //d
= W × D_2 (∵ D_2 is parallel to W)

From method 1, it can be realised that the work done = potential energy, i.e. mgh.

Method 2: W = F × //d
= F_1 × D_3 (∵ D_3 is parallel to F_1)

- Energy = Work done. You can use GPE/KE and treat it as work done to calculate power

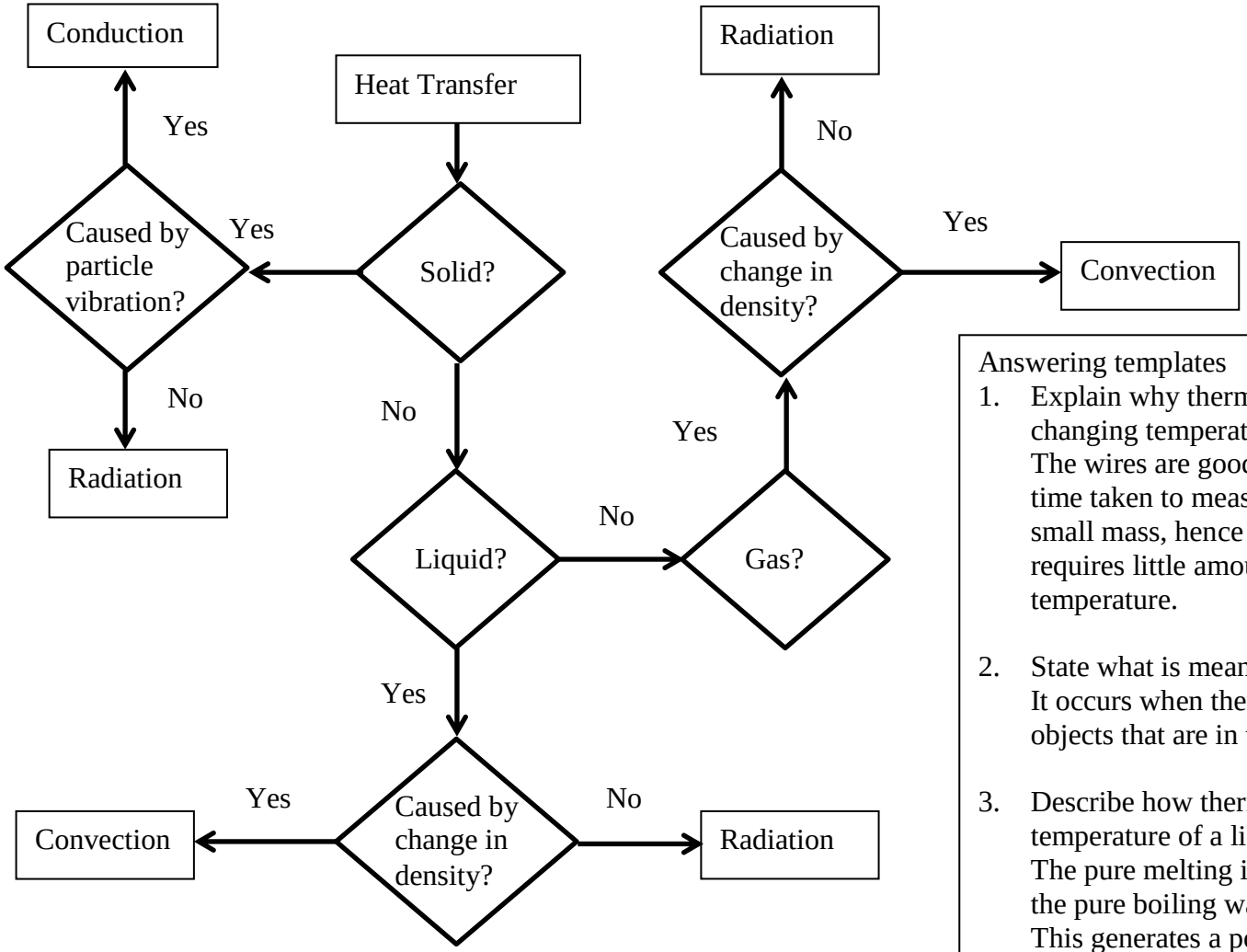
- Common questions
  1. In the practical scenario, the actual speed of the object is lesser than the calculated value. Suggest one reason why.
     Energy has been used to overcome work done due to friction/air resistance/heat.

  2. Explain how the swimmer exerts work done on the water.
     As the swimmer exerts a force on the water, the water moves in the direction of the force. Hence, it shows that there is work done on the water by the swimmer.

  3. Suggest why the loss in GPE is lesser than the increase in KE and explain how COE applies to this situation.
     Some of the loss in GPE is used to overcome work done due to friction/air resistance. This amount of work done has been converted into heat and sound energy.

Transfer of Thermal Energy	Conduction ➢ Process description When one end of the object is being heated, the particles will gain kinetic energy and hence vibrate faster. The particles will then collide with its neighbouring particles. This allows the transfer of energy from one particle to the other. This process will repeat itself to heat up the whole object. ➢ Common question Why metals are able to conduct heat faster than wood? Answer: Metals possesses both particles and sea of delocalised electrons while wood only consists of particles. The particles in metals and wood gain kinetic energy to vibrate more vigorously and collide with its neighbouring particles to transmit thermal energy. As metal possesses additional electrons, the electrons gain kinetic energy to move from hotter to colder region, this allow the electrons to collide with the particles, which increase the rate of transfer of thermal energy. Hence, thermal energy can be conducted through particle vibration and electron diffusion, which results in energy being conducted at a faster rate. Convection ➢ Process description When the particles are being heated, the volume will increase, causing the <u>density to decrease</u>. As such, the liquid particles will float up to the top, displacing the cold liquid downwards due to <u>its high density</u>. This process will repeat itself to cause convection current. Take note that in convection, it is always important to inject the idea that the movement of molecules is caused by the **<u>change in density.</u>** Radiation ➢ Characteristics Black/Dull/Rough surfaces are good absorber and emitter of heat Light/Shiny/Smooth surfaces are good reflector of heat, or poor absorber of heat. ➢ Common Question Suggest a suitable material for cooling fins Black, dull and rough copper will be suitable for cooling fins as it is a good conductor of heat which is able to conduct heat away from the component. Having a black, dull and rough surface enable the cooling fins to be able to <u>absorb heat energy well from the component and release heat efficiently</u> to the surrounding, hence being able to cool the component down. Key point to take note of: While describing the use of radiation, make sure that you use the <u>correct characteristics</u> for each purpose.

➢ **Flowchart**

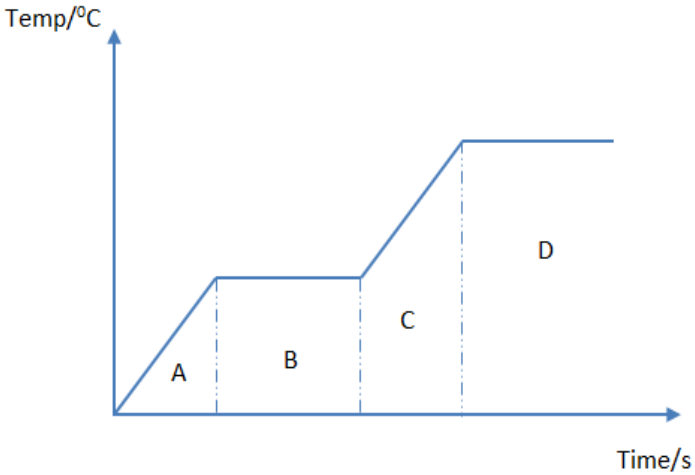


Answering templates

1. Explain why thermocouple is able to measure a rapidly changing temperature.
   The wires are good conductor of heat which reduces the time taken to measure the change in temperature. It has small mass, hence it will have low heat capacity which requires little amount of heat to detect a small change in temperature.

2. State what is meant by thermal equilibrium.
   It occurs when there is no net heat transfer between two objects that are in thermal contact.

3. Describe how thermocouple is used to measure the temperature of a liquid X.
   The pure melting ice will be placed in cold junction and the pure boiling water will be placed in hot junction. This generates a potential difference between the two junctions. By placing liquid X in hot junction, it will result in a new potential difference across the two junctions, which can be used to calculate the temperature of liquid X as the potential difference is directly proportional to the temperature differences between the two junctions.

Thermal Properties of Matters	$Q = mc\Delta\Theta$ $C = mc$ $Q = mL_f$ $Q = mL_v$ Q = Heat energy m = mass c = specific heat capacity C = heat capacity $\Delta\Theta$ = **CHANGE** in temperature L_f = specific latent heat of fusion L_v = specific latent heat of vapourisation	**Definitions** ➢ Specific heat capacity is defined as the heat energy required **per unit mass** to raise the temperature of the body by one kelvin. ➢ Heat capacity is defined as the heat energy required to raise the temperature of the body by one kelvin. ➢ Specific latent heat of fusion is defined as the heat energy required **per unit mass** to change the state of substance from solid to liquid, or vice versa, without a change in temperature. ➢ Specific latent heat of vaporisation is defined as the heat energy required **per unit mass** to change the state of substance from liquid to gas, or vice versa, without a change in temperature. **Pointers** ➢ Applying the correct formula  **Area A and C** - There is a change in temperature, hence heat energy can be only calculated by using the formula, $Q = mc\Delta\Theta$ **Area B and D** - There is **NO** change in temperature because the heat energy absorbed is being used to <u>overcome the force of attraction between the particles</u>, hence the formula, $Q = mc\Delta\Theta$, **CAN'T** be used. - For area B, the formula, $Q = mL_f$, should be used as it is the melting process. - For area D, the formula, $Q = mL_v$, should be used as it is the boiling process. ➢ Understand the flow of heat energy Example 2kg of water needs to be boiled by an electric kettle which has a power rating of 5kW. The initial temperature of the water is 20 ^{0}C. Assuming specific heat capacity of water is 4200Jkg^{-1}K^{-1}, calculate the time required.

The first thing to realise that the following condition,

By the law of conservation of energy,

Energy absorbed by the water = Energy given out by the heater
(Power rating of the heater × time)

- Common assumptions in such question
  1. Kettle/Container has negligible heat capacity.
  2. Heat energy given out by the kettle is fully absorbed by the water.
  3. No heat loss to the surroundings.
- Ways to improve on the experimental results
  1. Introduce lagging to reduce the heat loss to the surroundings
  2. Paint the container black so as to increase the heat absorption rate
  3. Obtain the heat capacity value of the container by heating the container first.

Kinetic Particle Theory

General Thinking Process → Particles gain K.E → Average speed of the particles increases → Particles vibrate more vigorously → Frequency of collision between ___ and ____ → Average force per unit area → Pressure

***Only for change in temperature

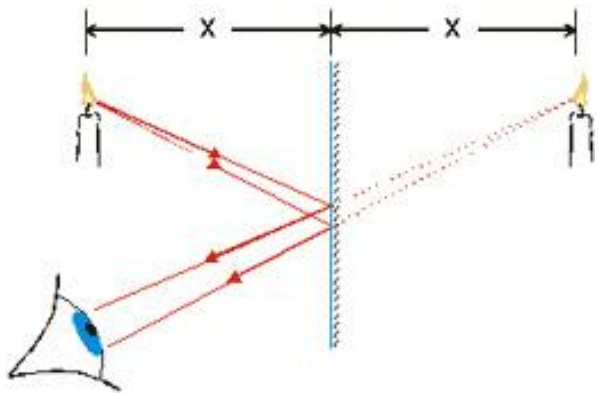
Answering Templates

1. The gas in the cylinder exerts the same pressure on the piston as it does on the sealed end, which has a smaller cross sectional area. Explain why the pressures are the same.
   - With a larger cross sectional area, the <u>number of particles colliding</u> with the wall of container is larger, hence the <u>frequency of collision</u> between the gas molecules and the wall of container increases.
   - This will result in a <u>larger amount of average force</u> acting on the wall of the container. Hence, the <u>force acting on the wall per unit area remains constant</u>, hence the pressure exerting on a larger cross sectional area is the same as that of a smaller cross sectional area.

2. After 10 strokes, more air is pumped into the inner tube. The volume of the inner tube remains constant. Explain, in terms of the air molecules, why the pressure increases with each stroke.
   - With each stroke, the <u>number of air particles per unit volume</u> in the tube increases, hence the <u>frequency of collision</u> between the gas molecules and the wall of container increases.
   - This will result in a <u>larger amount of average force per unit area</u> acting on the wall of the container.

3. Explain why a jet of steam is more dangerous than the same mass of boiling water.
   - As steam particles had overcome the forces of attraction between the particles, it moves faster and possesses a larger amount of kinetic energy as compared to boiling water.
   - Hence, the frequency of collision between the steam particles and the (object in contact) increases, causing the average force exerted on the (object in contact) by the air particles to increase, resulting in a larger amount of pressure exerted that can cause damages/injuries.

4. Explain why the temperature of the substance remains constant during freezing/melting process.
   - During freezing/melting, thermal energy is released/gain to form/overcome the forces of attraction between the particles to changes its state from liquid/solid to solid/liquid.
   - Hence, the rate of thermal energy gained by the substance and the rate of thermal energy lost by the substance is the same, causing it to reach thermal equilibrium with the surroundings.

Light	**Definitions** ➢ Laws of Reflection a. The angle of incidence is the same as the angle of reflection. b. Incident, reflected ray and normal line will lie on the same point on the same plane. ➢ Snell's Law a. The ratio of sine of angle of incidence to the sine of the angle of refraction is a constant b. Incident, reflected ray and normal line will lie on the same point on the same plane. ➢ Refractive index is defined as the ratio of the speed of light in VACUUM and the speed of light in the medium. ➢ Critical angle is defined as the angle of incidence in the optically denser medium when the angle of refraction in the optically less dense medium is 90^0. **Pointers** ➢ Drawing of Light ray diagrams Reflection  Important things to take note 1. The distance between the mirror and the object is equal to the distance between the mirror and the image. 2. Image is formed only if there are two light rays intersect at a point, regardless if it is a real or virtual light ray.

Formulas

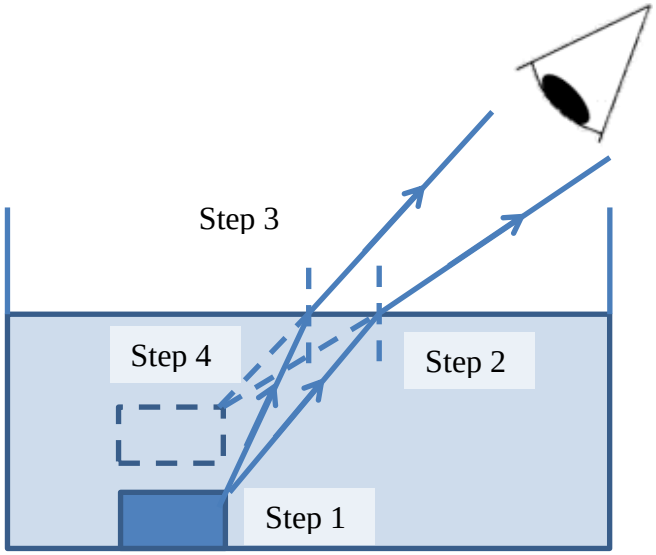
$$n = \frac{\sin i}{\sin r}$$

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

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

$$n = \frac{Real\ Depth}{Apparent\ Depth}$$

Refraction



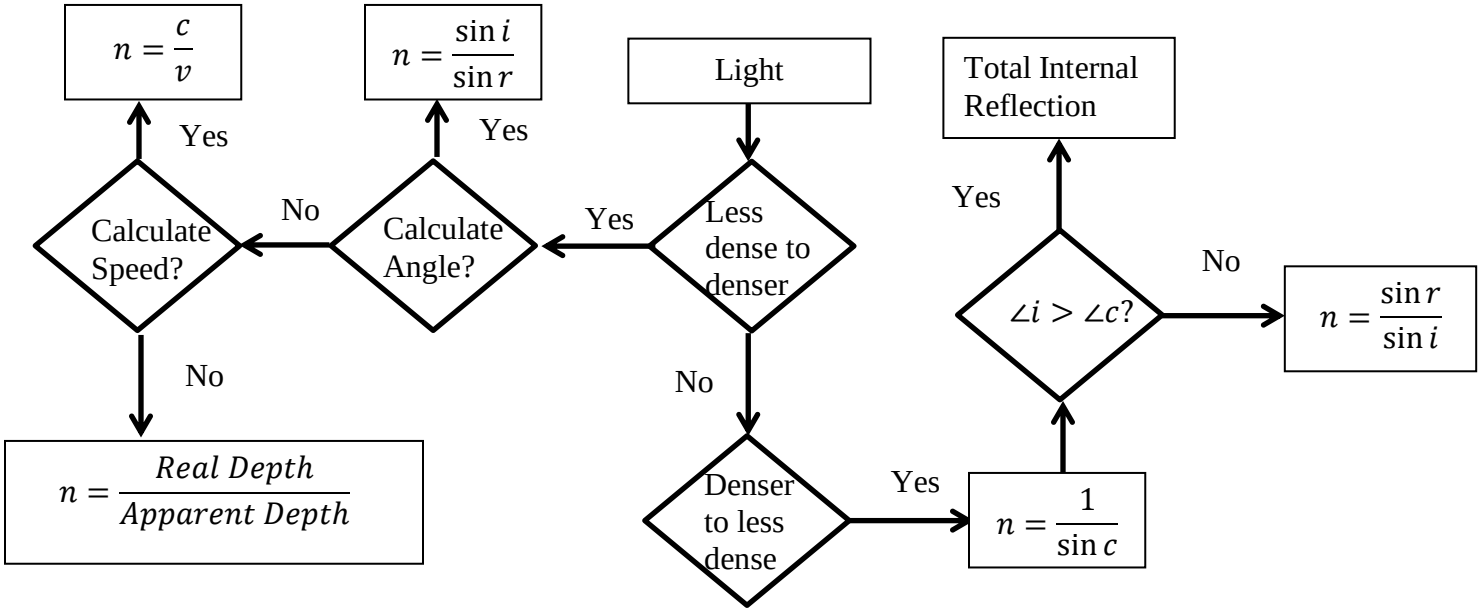
Step 1
Draw two non-parallel lines at a particular of the object.

Step 2
Draw normal line when the light ray touches the boundary line between two mediums.

Step 3
Since the light ray is travelling from denser to less dense medium, the light ray will refract, i.e bend, away from the normal.

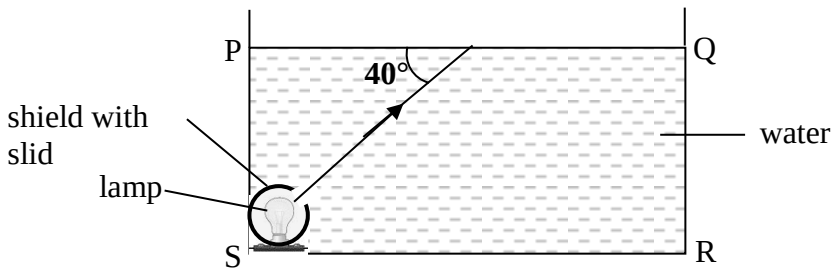
Step 4
Since the light rays are unable to intersect to form a real image, it means that virtual image will be formed through the formation of the virtual light rays. Virtual light rays will be formed by drawing dotted lines that follows the gradient of the refracted ray.

➢ Calculation



➢ **Example**

In the figure below, a lamp with slid has been switched on. The refractive index of the water is 1.33.



Take note!

Make use full of the flowchart above to determine the usage of formulas! ☺

Complete the light ray diagram above and justify your answer through calculations.

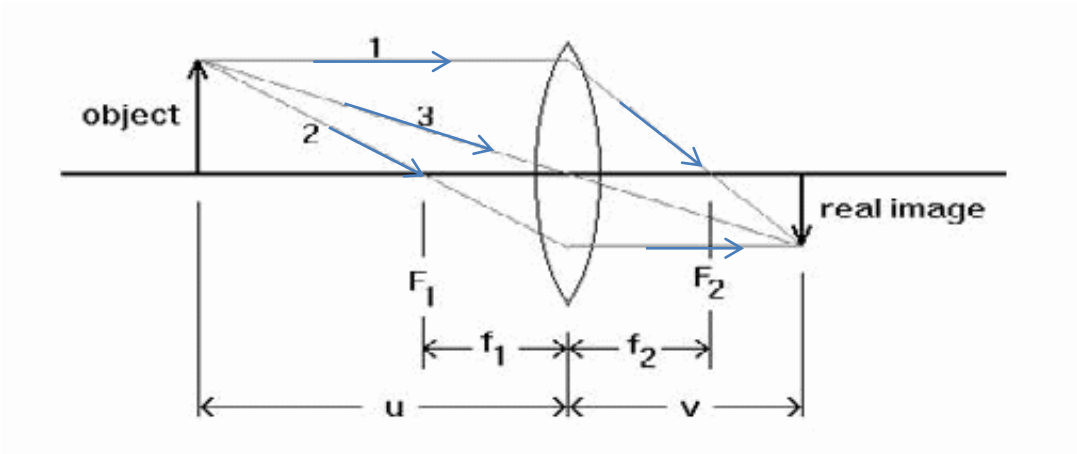
Step1
From the flowchart, you should be able to see that when light ray travels from optically denser medium to less dense medium, **<u>the first thing is to check for critical angle</u>**.

$$n = \frac{1}{\sin c}$$
$$1.33 = \frac{1}{\sin c}$$
$$c = 48.8°$$

Step 2
Check if $\angle i > \angle c$
In this case, the $\angle i = 50°$(do take note that **<u>this angle is between the normal and the ray</u>**) , which is > $\angle c$ (48.8°). Hence, there will be total internal reflection.

➢ **Techniques to conquer lens questions**

Know the fundamental two lines to draw

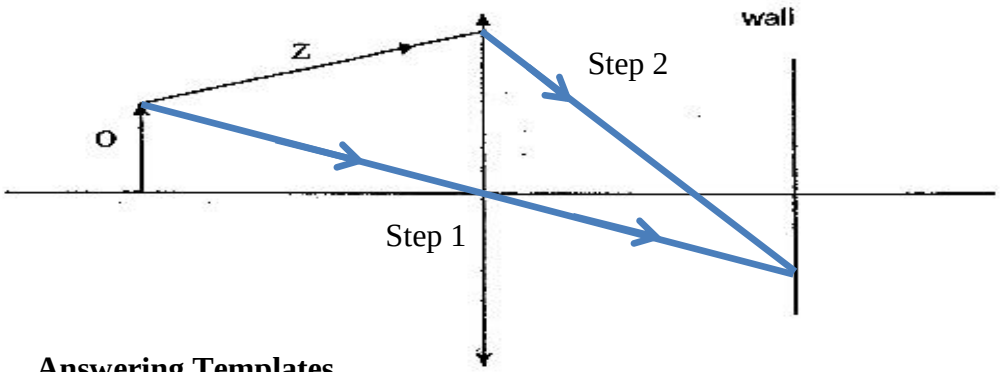


Important pointers to understand in the light ray diagram

a. Line 1 and 3 are the most fundamental light rays to draw as it helps you to locate the position of the image.
b. Sharp image can only be formed when ALL the light rays intersect at the same point, else the image will be blurred.
c. Line 3 is the most important line as you will need this line to locate the position of the image for most of the questions.

Hwa Chong Paper (Question 3)

An object, O, is placed in front of a lens of diameter 10cm such that a sharp image is formed on the wall.



Step 1
As the question has stated that a SHARP image will be formed on the wall, make full use of ray 3 (as stated in the diagram above) and locate the position of the image.

Step 2
In order for a sharp image to be formed, all light rays need to intersect at that point. Hence, it is an indication that light ray Z will converge to that intersection point.

➢ **Answering Templates**

1. Explain why light refracts when it travels from optically less dense to optically denser medium?
   The speed of light decreases when it travel from optically less dense to optically denser medium, hence it refracts towards the normal.

2. Explain why light doesn't refract?
   The direction of the light ray is perpendicular to the surface, hence the light ray will pass through the medium without refraction.

3. Instead of using red light, explain how the image distance would change if blue light is used.
   As the speed of blue light in lens is lesser than that of red light, blue light refracts more than red light, hence the light rays will intersect at a shorter distance away from the lens to form a sharp image.

4. Explain how the light ray diagram shows that the image formed is a virtual image.
   Due to the refraction of the light rays travelling through the lens, they diverge from each other. Hence, the virtual light rays will converge backwards to form a virtual image.

Waves & Sound

One echolocation

$$v = \frac{2d}{t}$$

Two Echolocation

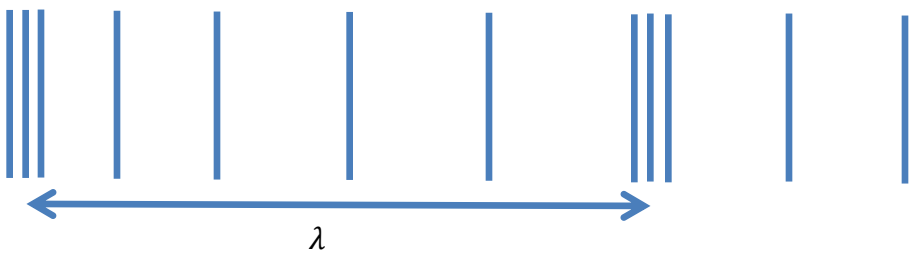
$$v = \frac{d_{difference}}{t_{difference}}$$

Definitions

- Longitudinal waves are defined as waves which its direction of vibration of the particles is parallel to the direction of its wave motion.
- Transverse waves are defined as waves which its direction of vibration of the particles is perpendicular to the direction of its wave motion.
- Wave motion is defined as the vibration of particles which transfer of energy from one place to another, without the transferring of medium.
- Wavefront is defined as an imaginary line that connect all the particles that are of the same phase.
- Period is the time taken for one complete cycle
- Frequency is the number of complete cycle that a wave can complete per unit time.

Pointers

- Identification of wavelength from particle vibration

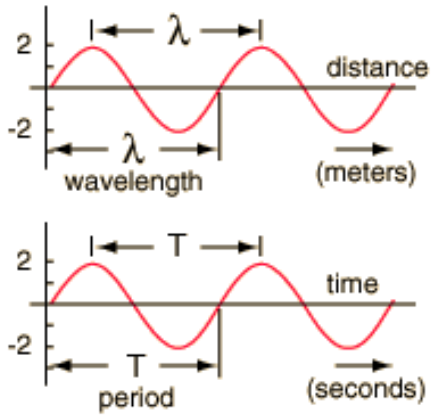


The easiest way out to determine the wavelength.

Step 1
Identify the centre of compression which is always the middle of the "compressed" lines.

Step 2
Identify the adjacent centre of the compression and the distance between them will be the wavelength.

- Graphs



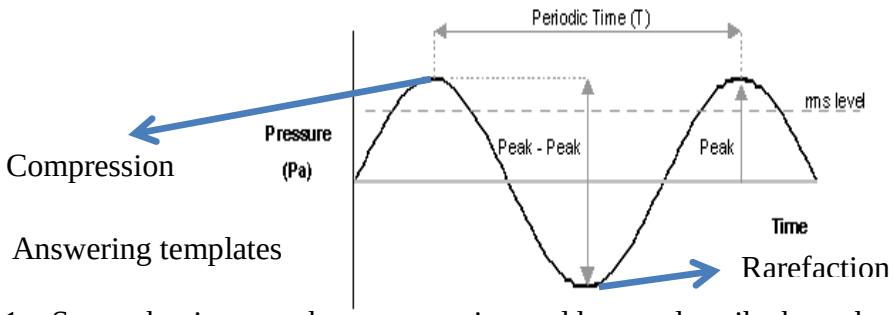
Very important note!

Take note of the **HORIZONTAL** axis.

Should the horizontal axis be **time** axis, the length between each crests will represent **period**.

Should the horizontal axis be **distance** axis, the length between each crests will represent **wavelength**.

➢ Pressure time graph



Compression experience a higher pressure than the surrounding atmospheric pressure, hence it will reach the positive peak value.

Rarefaction experience a lower pressure than the surrounding pressure as the particles experience "pulling away" effect which cause the net pressure to decrease. Hence, it will have the lowest value.

Answering templates

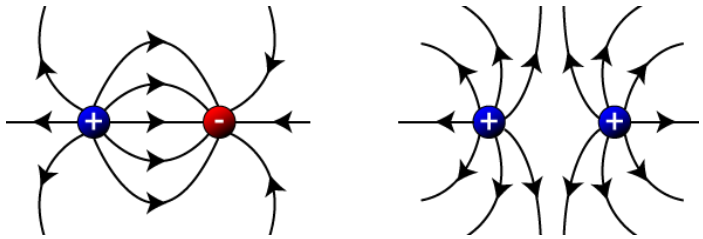
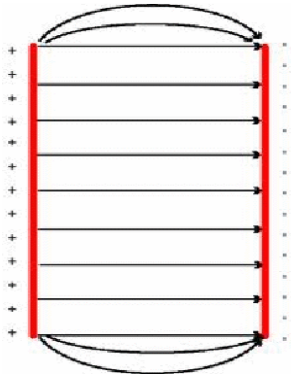
1. State what is meant by wave motion and hence, describe how the water waves generated in the ripple tank can be used to illustrate transverse wave.
   Wave motion is defined as the vibration of particles which transfer energy from one place to another, without the transferring of medium. As the water particles vibrate vertically, due to the force of attraction between the particles, the neighbouring particles vibrate at a constant time delay from each other, hence causing the transfer of energy from one particle to another. Since the direction of vibration of the water particles is perpendicular to the direction of wave motion, it is a transverse wave.

2. Describe how sound is formed.
   When a sound wave passes through the air particles (it can be any other particles), the particles will vibrate more vigorously and collide with its neighbouring particles to form alternate regions of compressions and rarefactions. When the particles are moving towards each other, it forms a region of compression. When the particles are moving away from each other, it forms a region of rarefaction. This allows sound energy to be transferred from one particle to another.

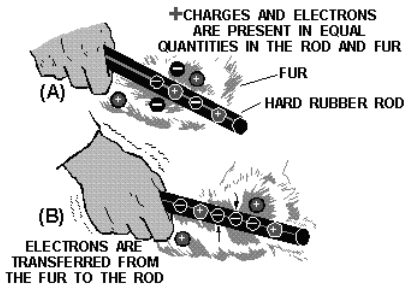
3. State what is meant by ultrasound and explain the type of wave that ultrasound belongs to.
   Ultrasound is a sound wave which has a high frequency that exceeds the higher limit of audible frequency of 20 kHz. As the direction of vibration of air particles is parallel to the direction of wave motion, ultrasound belongs to longitudinal wave.

4. State what is meant by infrasound
   Infrasound is a low frequency sound wave which has a low frequency that is lower than the lower limit of audible frequency of 20 Hz.

5. State what is meant by wavefront and how can wavefront be used to identify the wavelength of a wave.
   Wavefront is an imaginary line that connects all the particles that are of the same phase together. The distance between two adjacent wavefronts can be used to identify the wavelength of a wave.

Static Electricity	**Definitions** ➢ Electric field is defined as the region whereby a test charge would experience an electric force. **Pointers** ➢ Drawing of electric fields  - Number of field lines ∝ amount of charge - Electric field lines will NEVER cross each other because they will undergo vector addition process. - Field lines must be CURVED, unless it is in the exact middle between two charges.  - It can be noticed that most of the field lines are straight lines, which is mainly due to the close distance between the two plates. - The curved field lines are being used to illustrate the behaviour of field lines when the distance between the charges becomes significantly large.

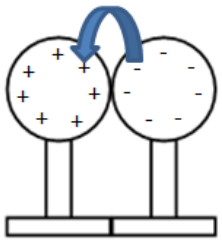
- Understand the difference between insulators and conductors
  - Insulator



By nature, insulators don't allow the transfer of electrons between them.

However, through rubbing process, it could excite the electrons in the insulators by injecting additional kinetic energy into them. As such, the electrons are able to gain sufficient energy to flow from the fur to the rod.

  - Conductor



By nature, conductors allow the transfer of electrons between them. Hence, when two oppositely charged spheres come into contact, the electrons will flow from the negatively charged sphere to the positively charged sphere as opposite charges attracts.

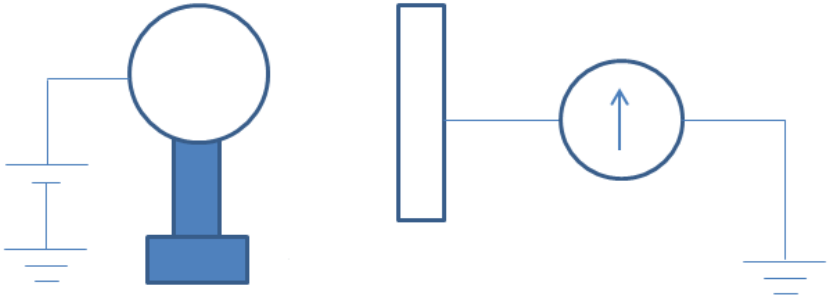
The transfer of electrons will only stop when both spheres have the same number of protons and electrons

  - Conductors and insulators

When conductors and insulators come into contact, there will not be any transfer of electrons as insulators do not allow that to occur.

- Answering technique
  - Focus on the movement/flow of **ELECTRONS**

Example



In this question, the first thing to notice is that the sphere will be positively charged as it is connected to the positive terminal of the power supply.

As unlike charges attract, the electrons of the metal plate will flow to the left hand side of the metal plate as it is attracted by the positively charged sphere. This would cause the right hand side of the metal plate to be positively charged.

As the right hand side of the metal plate is connected to the earth, the earth would transfer electrons to it momentarily, so as to neutralise it. The flow of electrons from the earth to the metal plate causes a momentary deflection in the galvanometer due to its current.

From the explanation at the side, it can be observed that every process is being explained by the flow of **ELECTRONS**. This particular answering technique is extremely important as **protons are unable to flow**. Hence, once you give the impression to the marker that protons move, you will be **heavily penalised**.

Electricity

$$V = IR$$
$$= \frac{W}{Q}$$

$$Q = It$$

$$P = IV$$
$$= I^2R$$
$$= \frac{V^2}{R}$$

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

Series Circuit

$$V_1 + \cdots + V_n = V_T$$

$$R_T = R_1 + \cdots + R_n$$

$$Potential\ divider\ Rule$$
$$V_1 = \frac{R_1}{R_T} \times V_T$$

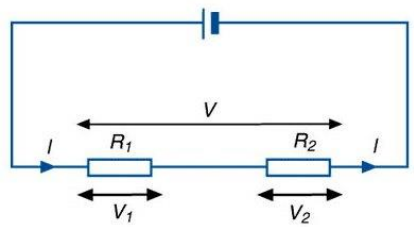
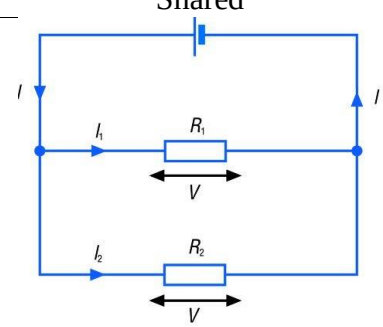
For potential divider rule, it is only applicable for series circuit.

Definitions

- Potential Difference is defined as the amount of electrical energy that has been converted to other forms when one coulomb of charge passes between two points.
- Current is defined as the rate of flow of charges. (i.e. the speed of charge)
- Resistance is defined as the ratio of potential difference across a load and the current flowing through it.
- Power is defined as the rate of work done (same as work, energy, power's definition)
- Ohm's law states that the current flowing through a metallic conductor is directly proportional to the potential difference across it, provided that the physical conditions remain constant.
- Power rating is defined as the maximum power output of the component.

Pointers

- Understand the differences between series and parallel circuit

	Series	Parallel
Potential Difference	Shared	Same
Current	Same	Shared
	 $V_1 + V_2 = V(shared)$	 $I = I_1 + I_2\ (shared)$

Parallel Circuit

$$V_1 = V_2 = V_T$$

$$I_T = I_1 + \cdots + I_n$$

$$R_T = \frac{1}{\frac{1}{R_1} + \cdots + \frac{1}{R_n}}$$

V = potential difference across a load

I = current flowing through a load

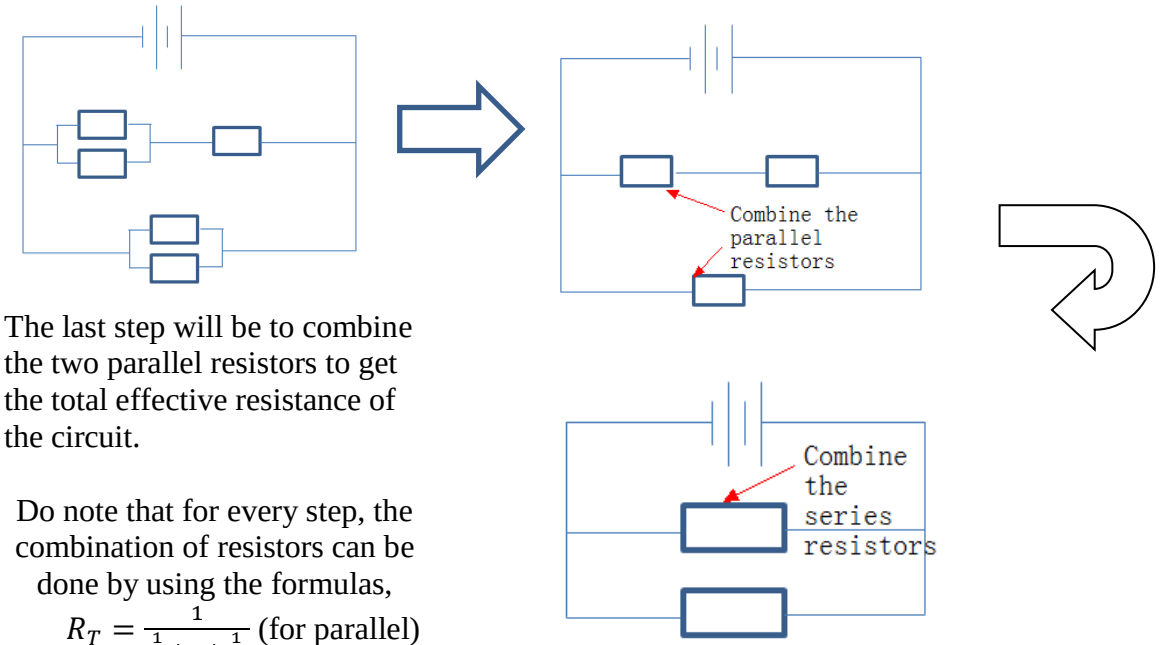
R = resistance of a load

Q = Charge

P = Power

E = Work Done / Energy

- Possess the capability to simplify circuits
  - Combination of series and parallel circuits



The last step will be to combine the two parallel resistors to get the total effective resistance of the circuit.

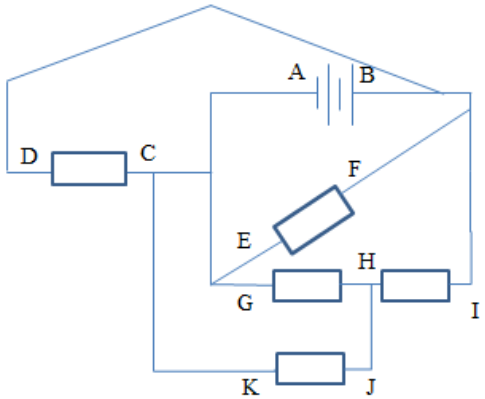
Do note that for every step, the combination of resistors can be done by using the formulas,

$R_T = \frac{1}{\frac{1}{R_1} + \cdots + \frac{1}{R_n}}$ (for parallel)

and

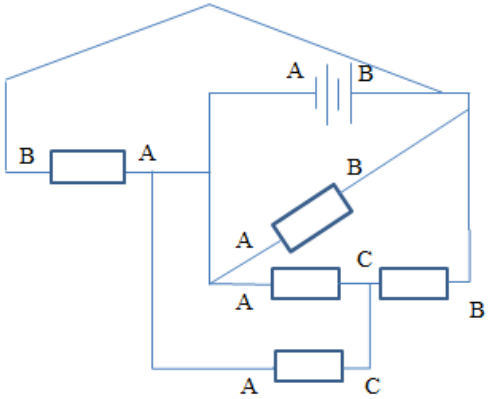
$R_T = R_1 + \cdots + R_n$(for series)

- Common tricks in electricity questions
  - Weird looking circuits

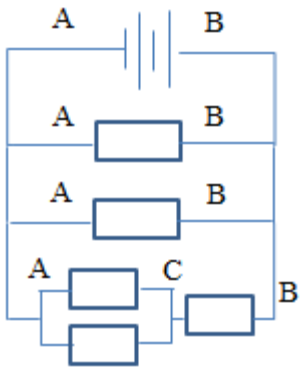


Steps in identifying the potential difference across each load

Step 1: Label all the similar points. For example, on the path from point A to C, there is no resistor; hence, there is no loss in potential. Therefore, point A = point C.

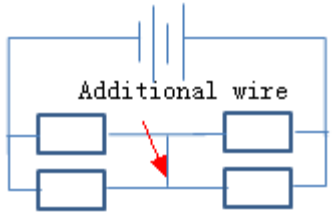


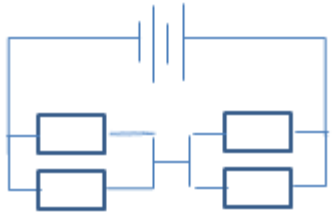
Step 2: Identify the potential difference between each resistor. Should any of the resistors have the same potential difference; it means that they are parallel to each other.



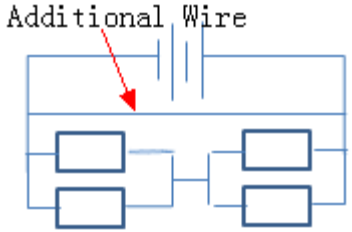
Step 3: Re-draw the circuit. The circuit should look more 'normal' and hence allows you to solve the question more efficiently.

Connecting additional wire





By inputting additional wires, it could be seen that the potential points remain unchanged because there is no resistor in between. Since the potential points remain the same, it shows that both circuits are equivalence to each other.



With the additional wire, which is assumed to have zero resistance, it will cause all the current to flow through it and cause short circuit.

Dangers of short circuit

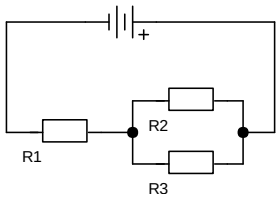
- Can cause fire as large amount of energy will be generated with high amount of current. (according to $P = I^2R$)

➢ **<u>Answering Templates</u>**

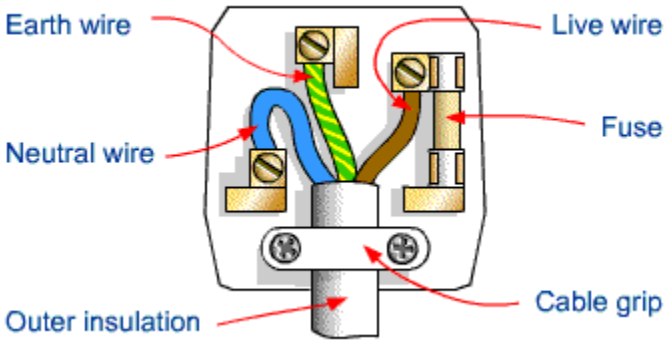
1. Explain why this light bulb has the highest brightness?
   The current flowing through/potential difference across the light bulb is the highest, hence it is able to generate the highest amount of power, which leads to the highest amount of light energy being generated.

2. Explain the change in the resistance. (Assume that it is an I-V graph characteristics for filament lamp)
   The current flowing through the lamp increases at a decreasing rate (gradient decreasing). Hence, the resistance of the lamp increases with the increase of potential difference across the lamp.

3. Explain what happens to the potential difference across R1 when R3 increases.
   As R3 increases, the effective resistance of R2 and R3 increases. Hence by using potential divider rule, the potential difference across R3 will increase, causing the potential difference across R1 to decrease.

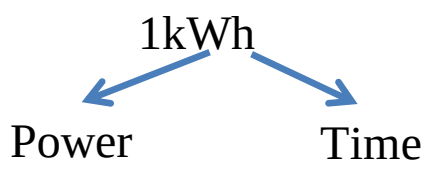


4. State the reason why the resistance of thermistor increases as the potential difference across it increases.
   The increase in temperature causes the resistance to increase ***<u>due to the electron scattering effect(not in your syllabus).</u>***

Practical Electricity	**<u>Pointers</u>** ➢ Purpose of the four wires 1. <u>Live wire</u> It is to connect the circuit to the high potential point of the main supply and supply current to the appliance. 2. <u>Earth wire</u> It is to prevent user from experiencing electrocution in the event when the metal casing gets 'live' by directing the current to the ground through earth wire. 3. <u>Neutral wire</u> It is to complete the circuit. 4. <u>Fuse</u> It is to limit the amount of current flowing through the circuit by breaking the circuit when the current flow exceeds the fuse rating. This can prevent the appliance from getting damaged due to excessive current.  ➢ Answering Templates 1. Explain why fuse need to be placed on the live wire, and not on the neutral wire. Live wire connects the circuit to the high potential point of the main supply. Hence, when the current flow exceeds the fuse rating, fuse will melt and break the circuit before the excessive current damages the appliance. 2. Explain why switch needs to be placed on live wire, and not on the neutral wire. Live wire connects the circuit to the high potential point of the main supply. Hence, switch has to be placed on the live wire to control the operation mode of the appliance through the supply of potential difference to the appliance and the connection of high potential point to the appliance. 3. Explain why the position of live and neutral wire could not be exchanged. The exchange of position will cause the appliance to have a constant connection with the high potential point of the main supply. Hence, it can lead to fire hazard due to the high amount of voltage being supplied to the appliance. 4. Explain why the fuse rating needs to be slightly higher than the current drawn from the main supply. The current drawn from the supply is an alternating current, hence its magnitude of the peak value can exceed the current rating. To prevent such occurrence, the fuse rating needs to be slightly higher than the current rating. 5. Explain why fuse needs to be placed before a switch. In the event of overloading due to the large potential difference across the switch, the fuse can break the circuit before the switch and the electrical appliance gets damaged by the excessive current.

- Calculation of bills
  Electricity bills are calculated by the **ENERGY** usage that a household has used per month. In industrial terms, 1kWh = 1 electrical unit (it can be thought as "1 packet of electrical energy used")

  Common question by student: What does 1kWh represent?



As you can see, the unit is a product of POWER and TIME. Hence, kWh will naturally represent **ENERGY**.

  Usually, the question will give such phrasing, "1kWh cost $0.20" OR "1 electrical unit cost $0.20". Such phrasing actually represents the **cost per 1kWh, i.e. $0.20 for 1kWh of energy**.

  Hence, the cost of the electrical bill = (Energy in kWh) * (Cost per 1kWh)

- Safety measures
  1. Miniature Circuit Breaker (MCB)
     MCB protects the circuit by breaking the circuit when the current flowing exceeds the maximum current rating. The circuit can be reset by switching it on again.

  2. Earth Leak Circuit Breaker (ELCB)
     ELCB will break the circuit when the current in the live wire is greater than that of neutral wire as some of the current has been leaked to the earth wire.

  3. Double insulation
     The first layer of insulation is to insulate the electric cables from internal components. The second layer of insulation is to insulate the internal components from the external casing.

Magnetism

Definitions

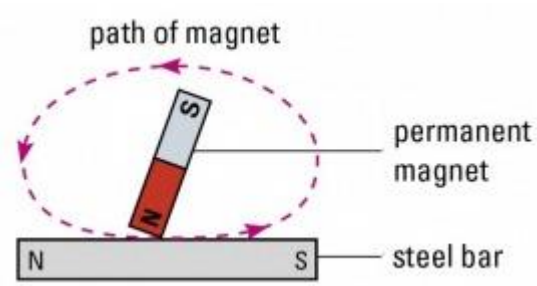
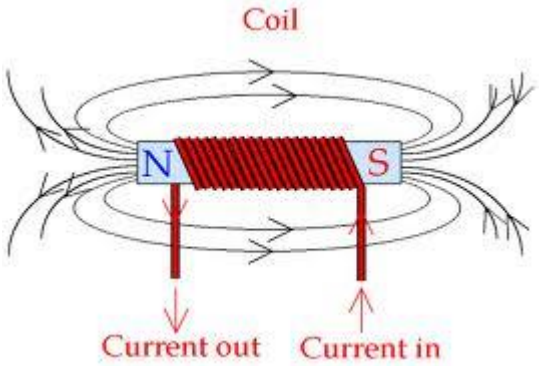
- Magnetic field is defined as a region whereby a magnetic material will experience a magnetic force.

Pointers

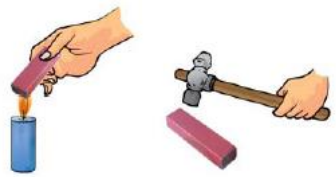
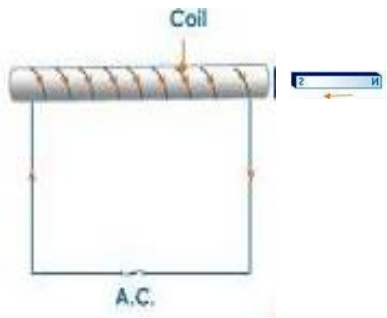
- Usage of Right hand grip rule
  - Current carrying conductor
  - Solenoid

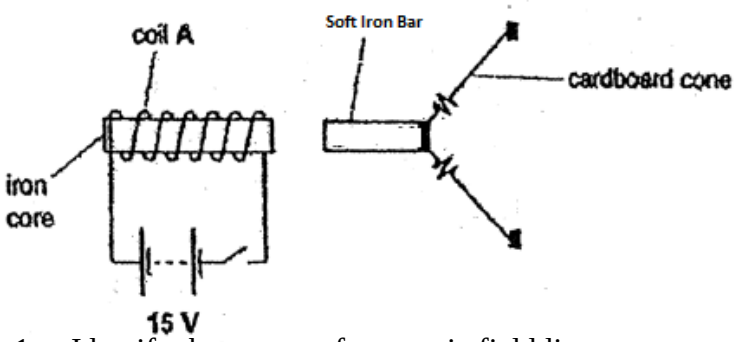
	Thumb	Rest of the fingers
Current-carrying conductor	Direction of current	Direction of magnetic field
Solenoid	North Pole (Direction of magnetic field)	Direction of current

- Magnetising methods

	Diagrams and explanations
Stroking Method	 In the mid of stroking the steel bar, the magnetic field lines from the permanent magnet will **align the domains** in the steel bar. This would cause the steel bar to be magnetised. Repeated process will increase the magnetic field strength of the steel bar, till it reaches its saturated point.
DC Circuit	 When current flows through a solenoid, magnetic field will be generated, this will **align the domains** in the steel bar. Hence, after some time, the steel bar will be magnetised to its saturated point.

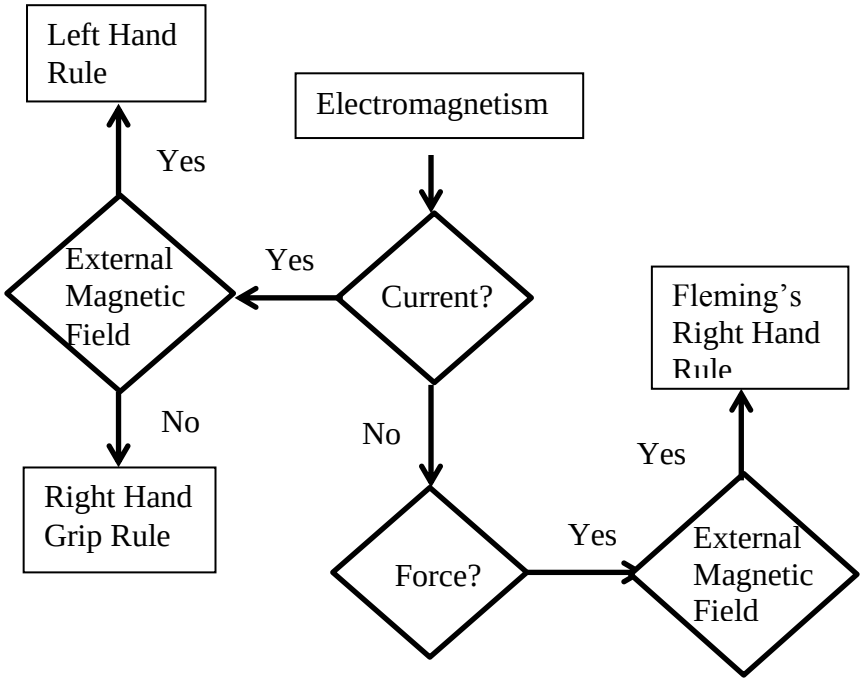
- Demagnetising methods

	Diagrams and Explanations
Heating and Hammering	 Heating and hammering process will cause the domains in the magnetic material to be **misaligned/randomised**. Hence, the magnet will gradually lose its magnetism.
Alternating Current (A.C) supply	 Alternating current will generate an electric current which varies its direction in a short time interval. This causes the direction of the magnetic field generated to vary. Hence, when the magnet is being pulled through the solenoid in the east-west direction, it will cause the order of the domains to be messed up and therefore, the demagnetisation of the magnet.

	➢ Answering technique in magnetism questions  Steps in answering magnetism questions 1. Identify the source of magnetic field lines. 2. Explain how does the field lines affect the magnetic material 3. Conclusion 1. Identify the source of magnetic field lines. When the switch is on, <u>the current flow in the solenoid will magnetise the iron core. By using Right Hand Grip rule, it will induce a North Pole at the left hand side of the iron core</u>. 2. Explain how does the field lines affect the magnetic material With the magnetic field produced by the iron core and the solenoid, it <u>magnetise the iron bar and induce a North pole on the left hand side of the bar</u>. 3. Conclusion As <u>unlike poles attract</u>, it causes a <u>force of attraction between the solenoid and the iron bar</u>, causing it to get nearer to the solenoid.
Electro-magnetism	**<u>Definitions</u>** ➢ Faraday's Law states that the rate of change of magnetic field linking the circuit is directly proportional to the induced e.m.f in the circuit. ➢ Lenz's Law states that the induced current will flow in such a way that it will oppose the change causing it.

Pointers

- Identification of Left hand/Right hand rule



Pointers to take note of when using this flow chart

1. Right Hand Grip Rule has two types, i.e. one is for solenoid, one is for single current carrying conductors.

2. The diamond shape figure is a condition checker.

- Standard answering templates

1. Why does a current carrying conductor experience a force in a region of magnetic field?
   - The magnetic field generated from the current will interact with the external magnetic field to create imbalance magnetic field strength regions.
   - As such, it would cause the magnetic field strength at _____ (whatever region) to be stronger than that of _____ (whatever region). Hence, it would cause an electromagnetic force to be directed from the strong magnetic field region to the weaker magnetic field region

2. Explain why there is a need for laminated soft iron core in the transformer?
   - By laminating the soft iron core, it will reduce the amount of eddy current. This would help to reduce power loss and hence, increase the energy efficiency of the transformer.

3. What is eddy current?
   - It is an induced current caused by changing magnetic field, which can cause spiral flow of current that would cause unnecessary energy loss to the surroundings.

4. Explain why DC supply would not work on transformer?
   - Initially, when the circuit is closed, the current flow at the primary coil will generate a momentary rate of change of magnetic flux linking the secondary coil. Hence, by Faraday's Law, there will only be momentary induced e.m.f in the secondary coil.
   - After which, the current flow in DC supply is constant, hence it is unable to generate a rate of change of magnetic flux linking the secondary coil. Therefore, by Faraday's Law, there will be no induced e.m.f in the secondary coil.

5. Explain the working principle of _____ (Circuit breaker etc) through the principles of magnetism
   - When the circuit is on, the current flowing through the solenoid/wire will cause it to generate magnetic field and magnetise _____ (probably some soft iron armature or something) and induced _____ pole at _____ side of _____. As unlike/like poles attract/repel, this will cause the _____ to be attracted/repel (most likely is attracted, depending on the circuitry and set up). As such, it will cause _____(certain effects)

6. Explain the purpose of split ring commutator
   - The split ring commutator will reverse the direction of current on every half a revolution, so as to ensure that the direction of rotation will remain unchanged.

7. Explain the purpose of slip ring commutator
   - The slip ring commutator will ensure constant electrical conductivity between the coil and the external circuit, so as to transmit the alternating current to the load.

8. Explain the purpose of carbon brush
   - It is to ensure that there is direct contact between the slip/split ring commutator and the circuit, so as to ensure contact electrical conductivity

9. For **DC motor**, the speed of rotation can be increased by increasing the number of coils/current. Explain why.
   - By increasing the number of coils/current, it can help to increase the magnetic field strength of the coil, and hence, it could superimpose with the external magnetic field to create a larger force, which in turn, increase the speed of rotation

10. Explain why the coil will experience max induced e.m.f in the horizontal position.
    - The direction of magnetic flux is perpendicular to the direction of applied force on the coil, hence the coil experiences the max rate of change of magnetic flux linkages.
    - By Faraday's law, the coil will experience a max induced e.m.f.

11. Explain why the direction of current in the wire is from A to B when the wire is moved downwards.
    - The magnetic field is flowing from left to right and the force is acting downwards on the wire, which is located in the magnetic field region.
    - Hence, by using Fleming's right hand rule, the induced current will be flowing from A to B in a closed circuit.

12. For **AC motor**, the amount of induced current could be increased by increasing the number of coils/speed of rotation. Explain why.
- By increasing the number of coils/speed of rotation, it will increase the rate of change of magnetic field linking the coils. Hence, by Faraday's law, it will increase the induced current flowing through the coil.
- However, do take note that **ONLY speed of rotation** will affect the frequency of the induced emf.

13. Explain the working principle of transformer
- As the magnitude and direction of the current flow changes periodically, it will generate a rate of change of magnetic field at the primary coil.
- The soft iron core will concentrate the magnetic field lines.
- As such, the secondary coil will experience a max rate of change of magnetic field. Hence, by Faraday's Law, there will be max induced emf at the secondary coil, which in turn causes the flow of current in the coil.

14. Explain why there is a need of soft iron in transformers
- As soft iron is a soft magnetic material, it can be magnetised and demagnetised easily. Hence, it could concentrate the magnetic field generated by the primary coil and cause the secondary coil to experience the maximum rate of change of magnetic field linkage with minimum response time.

15. Explain why step up transformer is used in transmission of electrical energy.
- By stepping up the voltage, the current flow in the cable will be reduced. Hence, it will be able to reduce power loss to the surroundings.

16. Explain why does the coil still rotate in the same direction after half a revolution
- After half a revolution, the split ring commutator will break the circuit and no current will flow through the coil.
- Due to the inertia/momentum of coil, it will still rotate in the same direction, causing the split ring commutator to establish electrical conductivity between the coil and the external circuit.
- As such, there will be interaction between the current and the external magnetic field and causes force to be induced onto the coil. By Fleming's LHR, the direction of electromagnetic force acting on the coil reverses, hence it causes the coil to rotate in the same direction.

17. Explain why the coil turns. (For DC motor)
- The current flowing through the coil will generate magnetic field to interact with the external magnetic field to create imbalance magnetic field strength regions. This causes the electromagnetic force to act in the direction of strong to weak magnetic field regions.
- Hence, an upward electromagnetic force will be acting on _____ and an equal and opposite downwards electromagnetic force will be acting on ____ to generate a turning effect.

18. Explain the working principle of a dc motor
- The current flowing through the coil will generate magnetic field to interact with the external magnetic field to create imbalance magnetic field strength regions. This causes the electromagnetic force to act in the direction of strong to weak magnetic field regions. Hence, an upward electromagnetic force will be acting on _____ and an equal and opposite downwards force will be acting on ____ to generate a turning effect.
- When the plane of coil is perpendicular to the magnetic field, the split ring commutator will break the circuit and no current will flow through the coil.
- Due to the inertia of coil, it will still rotate in the same direction, causing the split ring commutator to establish electrical conductivity between the coil and the external circuit.
- As such, there will be interaction between the current and the external magnetic field to cause equal and opposite forces to be induced onto the coil. By Fleming's LHR, it causes the coil to rotate in the same direction.

19. Explain why sometimes the coil would not turn even though the d.c motor is switched on.
- The coil is in the vertical upright position, hence there is no current flowing through the coil as the split ring commutator is not in contact with the carbon brush.
- Hence, there is no magnetic flux interaction between the current and the external magnet to induce equal and opposite forces on the coil to generate turning effect.

20. Explain the working principle of an ac generator
- When the coil experience a force that is perpendicular to the external magnetic field, the coil will experience max. rate of change of magnetic field. Hence, by Faraday's Law, there will be max induced emf in the coil.
- As the coil rotates from horizontal to vertical position, the direction of the force with respect to the magnetic field is getting more parallel, causing the rate of change of magnetic flux linking the coil to decrease, hence the amount of emf induced will reduce.
- Similarly, when the coil rotates from vertical to horizontal position, the rate of change of magnetic linking the coil increases, hence the amount of emf induced will increase in the opposite direction.
- The presence of slip ring commutator ensures a constant electrical conductivity between the coil and the external circuit, so as to allow alternating emf to be induced from the rate of change of magnetic field linking the coil.

21. Explain what happens to a d.c motor if a **METAL RING** is used instead of a split ring commutator.
- Due to the low resistance of the metal ring, the current will flow through the metal ring instead of the coil.
- Hence, there is no magnetic field interaction between the current and the external magnet to induce forces on the coil to generate turning effect. Thus, the coil will remain stationary.

22. Explain what happens to a d.c motor if a **SLIP RING COMMUTATOR** is used instead of a split ring commutator.
- The direction of current will remain the same on every half a revolution.
- Hence, by using Fleming's LHR, the direction of electromagnetic force acting on the coil will reverse in every half a revolution. This causes the coil to turn clockwise and anti-clockwise alternatively.
- Due to the air resistance, the turning effect will reduce until the coil stays in a vertical upright position.