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O Levels & IGCSE

PHYSICS NOTES

5054 & 0625

BY TEAM MOJZA

CONTENTS

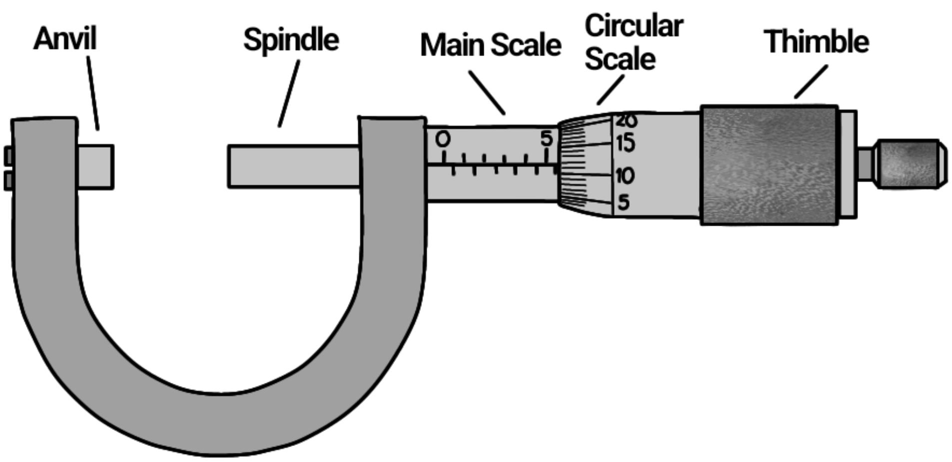
Section 1: General Physics

Chapter 1: Making Measurements

- Instruments for measuring length

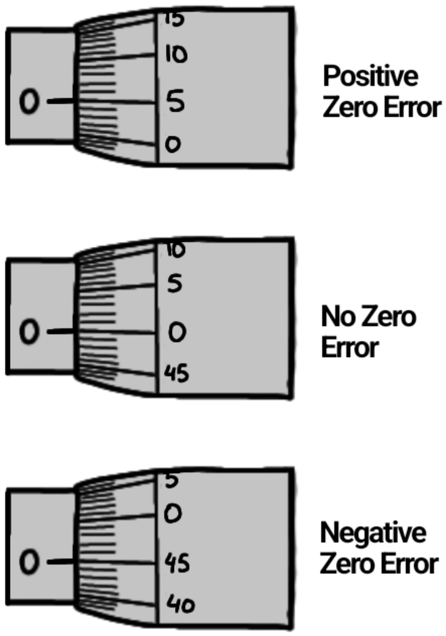
➜ The SI unit of length is metre (m).
➜ A metre rule can be used to measure lengths from 1cm to 1m.
➜ A metre rule can only be used to measure straight lengths.
➜ A measuring tape is used for curved surfaces or surfaces longer than 1m.
➜ A micrometre screw gauge can be used for measuring up to 0.01 mm.

Quantity	SI Base Unit	Symbol
Mass	Kilogram	kg
Length	Metre	m
Time	Second	s
Current	Ampere	A
Temperature	Kelvin	K



- Zero error

➜ In the measurement of length, there may be a zero error.
➜ A general definition of zero error is when an instrument gives a reading when the true reading is zero.
➜ A metre rule or tape may have a zero error if the start of the length is not aligned with the zero mark.
➜ For micrometres, the zero on both the scales should align when they are closed.
➜ The SI unit of time is second(s).



- Instruments for measuring time

➜ Pendulum: measures in oscillations
➜ Clocks
➜ Stopwatches

- Using a pendulum

➜ Each complete to and fro motion is called an oscillation.
➜ The period of a pendulum is the time taken for one complete oscillation.
➜ The period should be measured accurately by recording the total time taken for around 20 oscillations and taking the average, instead of measuring only one oscillation.

- Human reaction error

Stopwatches and clocks require a human to start and stop the time being recorded. Humans may have a slight delay in pressing the button, causing some inaccuracy.

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- Volume

➜ A measuring cylinder is used to measure volume.
➜ Always measure volume from the bottom of the meniscus and keep the cylinder upright.
➜ To measure the volume of irregular objects, we use displacement.

- Measuring volume by displacement

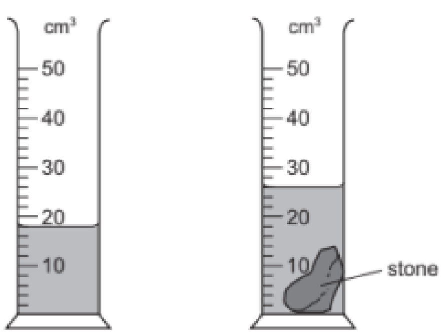
➜ Fill a measuring cylinder with water enough to cover the object
➜ Measure the volume (this is the initial volume)
➜ Drop the object in the water; it must be fully immersed in the water
➜ Measure the new volume (this is the final volume)
➜ Subtract the initial volume from the final volume to obtain the volume of the object
➜ Volume of irregular object = Final volume - Initial volume

- Example question

Take a look at this past paper question. The measurement in the first cylinder, i.e: the initial volume, is 18 cm^3 (we're following the 2, 4, 6, 8 sequence here. That means the measurement after 10 will be 12, then 14, then 16, then 18). The measurement in the second cylinder, i.e: the final volume, is 26 cm^3 (following the 2, 4 6, 8 sequence)
➜ Final volume: 26
➜ Initial volume: 18
➜ 26-18 = 8
➜ The volume of the stone is 8 cm^3, hence the answer is A

- Example question

The diagram shows a measuring cylinder used to measure the volume of a small stone.



What is the volume of the stone?

A 8 cm^3 **B** 9 cm^3 **C** 14 cm^3 **D** 26 cm^3

- Magnitude

➔ The size or an amount of something. For instance, 56 km, where 56 is the magnitude and km is the unit.
➔ Unit: Physical quantity. e.g: seconds, metres, km.

- Scalar quantities

➔ These only have a magnitude (numerical value).
➔ Mass is a scalar quantity. It doesn't have a direction.
➔ Distance, speed, time, mass, energy, and temperature are scalar quantities.

- Vector quantities

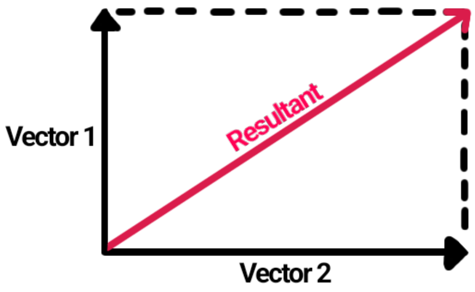
➔ These have a magnitude (numerical value) and a direction.
➔ Displacement is a vector quantity, because it has a size, and a direction as well. 36 km north is a displacement; it tells you the distance and the direction of the distance.
➔ Distance isn't a vector quantity because it only tells you how long you have to go, and not the direction.
➔ Force, weight, velocity, acceleration, momentum, electric field strength, and gravitational field strength are vectors.

- Calculating vectors

➔ Scalars can be added through ordinary arithmetic. Since vectors involve a direction, they should be calculated through the following methods.
➔ The arrowhead represents the direction of the vector.
➔ The arrow's length represents the magnitude (size) of the vector.

- Calculating vectors graphically

➔ Choose an appropriate scale according to the page, e.g. 1 cm = 1N
➔ Draw the first vector in the direction it's given, e.g. 5N north should be a vertical line with its arrowhead upward (the size of the vector depends on the scale you've chosen)
➔ Draw the second one similarly; the two vectors should be at right angles to each other
➔ Complete a rectangle
➔ Then, from the point where the two forces intersect, draw a line diagonally. This is our resultant vector
➔ Measure the resultant's length and convert it according to the scale you've chosen. This gives us the resultant's magnitude
➔ Use a protractor to measure the angle



- Calculating vectors through calculation

1. Draw a vector diagram here as well, but here it's not necessary for it to be exactly to scale. It can be sketched.
2. Label the resultant, component and sides clearly.
3. Use Pythagoras' Theorem to find the magnitude/size of the resultant vector.
4. To find the angle of the resultant vector, use SOH-CAH-TOA. Remember that this tells us the *angle* of the resultant and not its *size*.

- Pythagoras' Theorem

➜ $c^2 = a^2 + b^2$
➜ c = hypotenuse of the triangle
➜ a and b = the other two sides (it can only be applied to right-angled triangles)
➜ The angle θ between sides b and c is given by: $\sin\theta = a/c$ or $\cos\theta = b/c$ or $\tan\theta = a/b$

- SOH CAH TOA

➜ **SOH**: **S**IN = **O**pposite/**H**ypotenuse
➜ **CAH**: **C**OS = **A**djacent/**H**ypotenuse
➜ **TOA**: **T**AN = **O**pposite/**A**djacent

Chapter 2: Kinematics

- Distance vs Displacement

➜ Distance is the total length covered by an object, regardless of the direction.
➜ Displacement is the distance covered in a straight line in a specific direction.
➜ The displacement is 0 if the object returns to the original place.
➜ Distance is a scalar, while displacement is a vector quantity.

- Speed

➜ Speed is the distance travelled per unit time.
➜ It is a scalar quantity.
➜ The SI unit of speed is m/s.
➜ It is always positive.

Speed = Distance travelled/Time taken

Average speed = Total distance/Total time

- Velocity

➜ Velocity is speed in a given direction.
➜ It is a vector quantity.
➜ e.g 5 m/s **east.** We not only know how fast something is going, but which direction it's going in as well.
➜ The SI unit of velocity is m/s.
➜ It can be negative or positive.

Velocity = Displacement/Time

Average velocity= Total displacement/Time

- Constant Speed/Velocity

➜ It is when the speed is not increasing/decreasing and the object is travelling at a fixed speed.

- Acceleration

➜ Acceleration is the change in velocity per unit time, i.e: how quickly something speeds up or slows down.
➜ When the velocity of an object changes, we say an object **accelerates.**
➜ It is a vector quantity.
➜ The SI unit of acceleration is m/s^2.
➜ Acceleration can be negative due to decrease in velocity.
➜ Negative acceleration is known as deceleration or retardation.
➜ **Acceleration = $\Delta v/t$**
➜ Δ indicates change, and in this case, change in velocity divided by time.
➜ The change in velocity is found through $a = v-u/t$ (the difference between the final and initial velocity), where:
v = final velocity
u = initial velocity
t = time

- Uniform and non-uniform acceleration

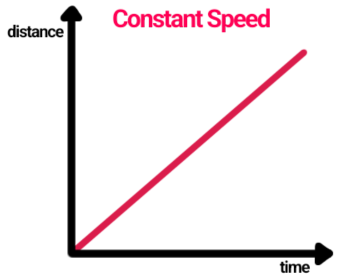
Uniform/constant acceleration is when the velocity of an object increases/decreases by the same magnitude per unit time throughout the given period (it remains constant).
Non-uniform/changing acceleration is when the acceleration is not uniform; it keeps changing.

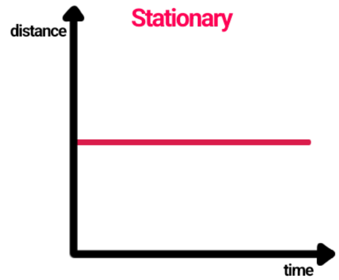
Q It takes 10 s for an object to accelerate from 10 m/s to 25 m/s. What is the object's average acceleration?

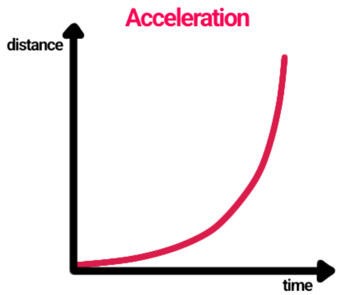
➜ final velocity: 25 m/s
➜ initial velocity: 10 m/s
➜ time: 10s
➜ therefore: 25-10 = 15 (applied v-u) 15/10 = 1.5 (divided by time, which was 10s)
Answer: 1.5 m/s^2

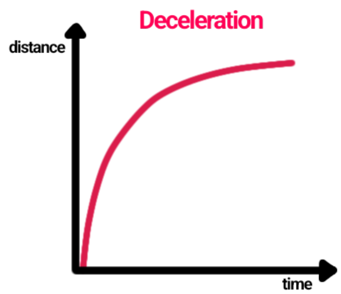
- Distance-time graphs

➜ The gradient of a distance-time graph tells us the speed, and how large or small the speed is.
➜ It shows how the **distance** of an object from a point varies over **time.**
➜ Gradient = Distance/Time
➜ The gradient of a tangent at a given time on a distance-time graph gives us the speed at that specific time.
➜ A horizontal line in distance-time graph shows that the object is at rest.
➜ A straight line with a constant, unchanged gradient represents speed.
➜ Increasing acceleration is represented on a distance-time graph by a curve of increasing gradient - rising curve.
➜ Decreasing acceleration is represented on a distance-time graph by a curve of decreasing gradient - falling curve.



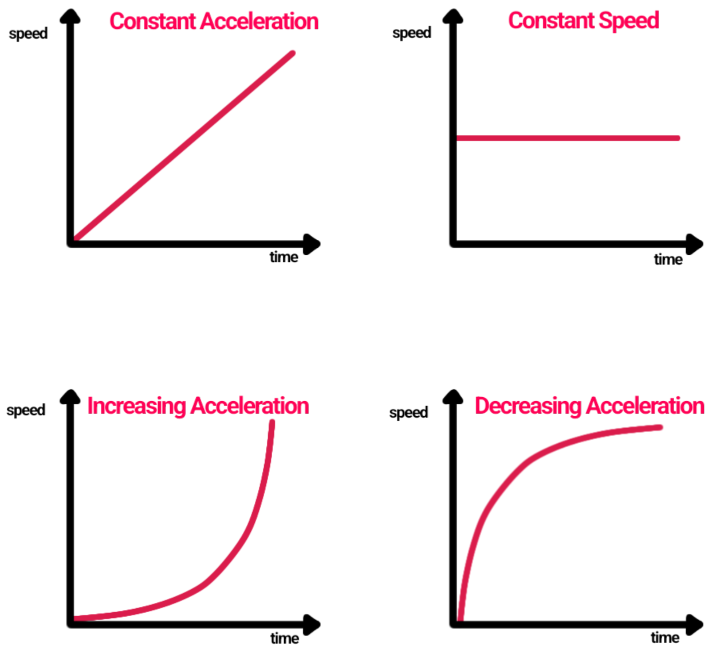






- Speed-time graphs

➜ The gradient of a speed-time graph gives us the acceleration.
➜ Because it tells us the acceleration, we apply: change in velocity/change in time to find the acceleration $\Delta v/t$
➜ The gradient of a tangent on a speed-time graph gives the acceleration at that given time.
➜ The area under the graph of a speed-time graph represents the distance travelled.
➜ A straight line represents constant acceleration.
➜ A rising curve shows increasing acceleration.
➜ A falling curve shows decreasing acceleration.
➜ A horizontal line shows constant speed.
➜ A flat line at 0 speed shows an object at rest.



- Finding the distance
➜ Find the shapes under the curve
➜ Apply the formula for their area
➜ Find the base and height through the graph provided
➜ Add up all the areas

- Freefall
➜ All objects will fall with constant acceleration during free fall unless there is air resistance, which gets larger the longer it falls for.
➜ This acceleration is not dependent upon the mass or size of an object.
➜ This is when they're under the influence of only the force of gravity, i.e. free fall.
➜ The symbol for free fall is *g.*
➜ Acceleration due to gravity, near to the surface of the Earth, is constant at 9.8 m/s^2.
➜ Meaning that for every second an object falls, its velocity will increase by 9.8

Chapter 3: Mass and Weight

- Mass

➜ Mass is the amount of matter in an object.
➜ SI unit: kilograms (kg)
➜ It is sometimes given in grams (g), so you might need to convert to kg: 1 kg = 1000 g.
➜ The mass of an object resists change from its state of rest or motion (inertia).
➜ This mean that the greater the mass of the object, the harder it is to speed it up/slow it down/change its direction.
➜ It opposes any attempt to change the object's motion.
➜ Weights and masses are compared using a beam/equal-arm balance.

- Gravitational field

➜ A region in which a mass experiences experiences a force due to gravitational attraction.
➜ The Earth has a gravitational field. If there's any mass within that region, the Earth will pull that mass towards itself due to the presence of a gravitational field.
➜ We feel this pull due to gravity as **weight.**
➜ The gravitational field strength is the force per unit mass at a point in a gravitational field.
➜ **Gravitational field strength = Weight/Mass**

- Weight

➜ Weight is the force of gravity acting on a mass.
➜ Measured in Newtons (N).
➜ Its size depends on the gravitational field strength and the mass of the object.
➜ It acts vertically downwards.
➜ Weight = Mass x Gravity **(W = mg)**
➜ The value of gravity on earth is 9.8 N/kg, commonly taken as 10 N/kg.
➜ Weight can be measured using a force metre.
➜ A spring balance can be used as well; an object is hung on it and the spring stretches depending on how great the weight is.

Chapter 4: Density

- Density

➜ Density is the mass per unit volume.
➜ **$\rho = m/V$**
➜ It is measured in g/cm^3 or kg/m^3.
➜ To convert a density from g/cm^3, we multiply it by 10^3.
➜ The mass of any substance can be measured by a balance.
➜ For regularly shaped objects, the volume can be calculated by mathematical formulas after taking measurements of lengths.
➜ For irregularly shaped objects, the volume can be measured by putting the object in a measuring cylinder containing a liquid. The difference in the final and initial volumes is the volume of the object.
➜ The density can then be calculated by the formula.

- Floating and Sinking

➜ Density of water = 1000 kg/m^3 OR 1g/cm^3.
➜ An object with greater density than water willl sink in it, and vice versa.
➜ An object will float in a liquid if the average density of the object is less than density of the liquid it's being placed in.
➜ Floating has a relationship with volume and mass.
➜ If two different liquids don't mix, the less dense liquid will float on top of denser liquid.

Chapter 5: Forces

➜ A force is either a push or a pull that one object exerts on another object.
➜ It can produce, slow down, speed up or stop motion or change its direction.
➜ The SI unit of force is Newtons (N).

- Vectors

In vector diagrams, vector quantities such as forces are represented by an arrow.
➜ The length of the arrow is proportional to the size of the force.
➜ The direction of the arrow shows the direction of the force.

- Drawing vectors

Step 1: Choose an appropriate scale

Step 2: Measure the required angle using a protractor from the baseline/second force.

Step 3: Draw an arrow of length proportional to the force using the scale taken.

Adding vectors

- Parallel vectors

➜ If they are in the same direction, they will be added.
➜ If they are in opposite directions, the resultant will be in the direction of the greater force and its size will be the difference of the two vectors.
➜ If they are equal and opposite, there will be no resultant.

- Non-Parallel vectors

tip to tail method
➜ Redraw one of the vectors, placing the tail of the vector at the tip of the second vector. Join the two corners to get the resultant vector. The direction of the resultant will be from the tail of the first vector to the tip of the second vector.

parallelogram method
➜ Complete the parallelogram; the diagonal of the parallelogram will be the resultant. The direction of the resultant will be from the intersection point of the actual vectors to the intersection point of the vectors u drew to complete the parallelogram. Or in other words, from both tails to both heads.

- Friction

➜ Friction is the force that opposes motion between two surfaces in contact and results in the production of heat if the object moves/slides.
➜ Air resistance (drag) is a form of friction, caused by a body moving through the air.
↳ it slows down anything travelling through air, and may also cause the object to heat up
➜ Friction results in energy loss because of the conversion of energy from kinetic to thermal.

- Terminal Velocity

➜ When a parachutist jumps from an aeroplane, two forces act on them:
↳ Weight
↳ Air resistance (drag)
➜ At first, the air resistance is small
➜ The downwards force (weight) causes the parachutist to accelerate
➜ As he speeds up, the air resistance increases
↳ air resistance acts **opposite** to the weight
➜ Eventually, the air resistance balances with the weight
➜ The parachutist then travels at a constant speed due to the balance — *terminal velocity*
➜ When the parachute opens, it creates an upward unbalanced force, slowing him down.
➜ During a fall in the presence of air resistance, the acceleration will slowly decrease untill it is 0. When there is no acceleration, the object will fall at constant speed and this is known as terminal velocity.
➜ The reason for the decrease in acceleration is that, with the increase in speed, the air resistance also increases, and there comes a point when the downwards force and the

upwards force by the air resistance cancel each other out. Thus, there is no resultant force which results in no acceleration.

- Braking force

➜ The force that slows the car when the driver applies the brakes..
⤷ how far the object travels after brake applied.

- Thinking distance

➜ Distance covered by the driver when he sees the obstacle and reacts by applying the brakes.
⤷ doesn't depend on the road's conditions.
⤷ depends on driver's response time.

- Newton's first law

Every object will continue in its state of rest or uniform motion in a straight line unless a resultant force acts on it.

- Newton's second law

When a resultant force acts on an object of a constant mass, the object will accelerate in the direction of the resultant force. The product of the mass and acceleration of the object gives the resultant force.

Force = Mass x Acceleration

- Newton's third law

Every action has an equal and opposite reaction.
$F_1 = F_2$
$mass_1 \times acceleration_1 = mass_2 \times acceleration_2$

- Air resistance

A frictional force that opposes motion in the air. It slows down anything travelling through the air and also causes the object to heat up.

- Circular motion

When an object is travelling in a circle at a constant speed, the velocity is always changing as the direction is constantly changing. The resultant force of an object in circular motion is towards the centre of the circle.

- Deformation

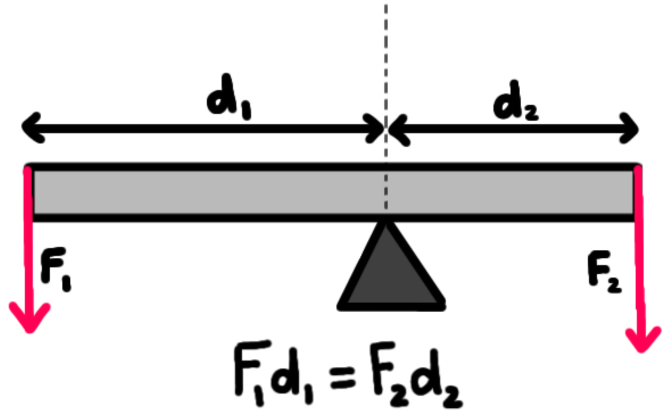
➜ Attaching a load to spring can extend it.
➜ The extension doubles if two springs are connected to each other directly.
➜ The extension halves if load is attached to two springs in parallel as the load is shared.
➜ Hooke's law states that the extension of a spring is directly proportional to the force applied.
Force = Spring constant x Extension
➜ Hooke's law is only applicable until the limit of proportionality, after which the object does not obey the law and the extension is imbalanced.
➜ A straight line on a load-extension graph shows the object is obeying Hooke's law.
➜ A curved line shows that the limit of proportionality has been crossed.
➜ The point on the graph at which it starts curving is the limit of proportionality.

- Moments

➜ A moment is the turning effect of a force.
➜ They occur when a force causes an object to rotate about a pivot.
➜ The size of the moment is determined by the size of the force and the perpendicular distance from the pivot.
➜ **Moment = Force x Perpendicular distance**
➜ The unit of moment is Newton Meter (Nm)
➜ Opening or closing a door is an example of a moment

- Principle of Moments

➜ The Principle of Moments states that for an object to be in equilibrium, the sum of clockwise moments must be equal to the sum of anticlockwise moments.
➜ $\mathbf{F_1 d_1 = F_2 d_2}$



- Centre of Mass and Stability

➜ The centre of mass of an object is the point at which the weight of the object appears to act.
➜ For symmetrical objects, the centre of mass is at the point of intersection of its symmetries.
➜ When an object is suspended, its centre of mass will come below it.
➜ To find the centre of mass of a lamina, it is suspended from a point and a plumb line is hung from it.
➜ A line is drawn using a pencil along the plumb line.
➜ This is repeated from multiple points; the point of intersection of the lines is the centre of mass.
➜ An object is stable if the line of action of its centre of gravity passes through its base.
➜ If the line of action of its centre of mass does not pass directly through its base, the object will topple over.
➜ The lower the centre of mass of an object, the greater the stability.
➜ The greater the base area of an object, the greater the stability.

Chapter 6: Momentum

➜ Momentum is defined by the equation:
momentum = mass x velocity
↳ **p = m x v**
↳ p stands for momentum
➜ It is the amount of motion in a body.
➜ units: kg m/s
➜ Momentum is a vector quantity. It can be negative and positive.
➜ For example, a 2 kg mass moving at 10m/s has momentum 20 kgm/s

- Conservation of Momentum

➜ **The principle of the conservation of momentum:** When there's no external force (e.g. friction) the total momentum of a body remains the same
➜ In a collision, the total momentum before the collision and the total momentum after it must be equal
↳ If an object is travelling to the right, it has positive momentum
↳ If an object is travelling to the left. It has negative momentum

- Impulse

➜ When a resultant force acts on a mass, its momentum will change.
➜ Impulse of a force = force x time for which it acts
↳ **impulse = F x t**
➜ Impulse = change in momentum
↳ **F x t = mv - mu**
↳ u is the initial velocity of the mass
↳ v is the final velocity of the mass

Chapter 7: Work, Power, and Energy

- Energy

➜ The SI unit of energy is Joules (J). It's a scalar quantity.
➜ Energy is defined as the capacity to do work
➜ The law of conservation of energy states that energy can neither be created nor destroyed; it can only be converted from one form to another.
⤷ no matter how much it changes its form, the total amount of energy remains constant,
➜ Energy can change into different types, such as kinetic, gravitational potential, chemical, elastic (strain), nuclear, electrostatic and internal (thermal), but the total energy always remains constant.

- Types of Energy

➜ Kinetic energy is the energy an object has when it's moving.
➜ Gravitational potential energy is the energy possessed by an object due to its position in a gravitational field.
➜ Chemical energy is the energy contained in a chemical substance, like a battery.
➜ Elastic Energy is the energy possessed by an already stretched object e.g. a spring.
⤷ compressing or stretching a spring causes the energy to transfer to elastic strain energy.
➜ Nuclear energy is the energy of the nucleus of an atom.
➜ Thermal energy is the energy of an object due to its temperature.
➜ Electrostatic energy is stored in charged objects. It's transferred by electric currents.
➜ Total internal energy is the sum of all energies possessed by an object, mostly kinetic and heat.

- Energy transfers

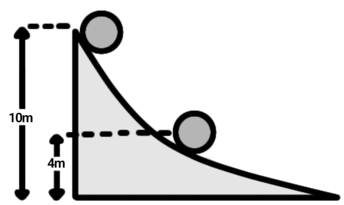
➜ Energy can be converted to other formby a force (mechanical work done), heating (by conduction, convection or radiation), electrical current (electrical working), or by waves (electromagnetic, sound and others).
➜ In a battery, the chemical energy stored in it converts to kinetic energy by **electric current.**
➜ In a boiler, **heating** water converts chemical energy, which is stored in a fuel, to the water's thermal energy store.
➜ Sound waves transfer energy from a source to our eardrums.
➜ In a roller coaster, potential energy is converted to kinetic energy by force (mechanical working) due to the gravitational force.

➜ In a heater, the electric fire element has thermal energy stored. It's converted to electromagnetic **waves** and heat.
➜ If a person is cycling, chemical energy is stored in their body's muscles. This is t to elastic energy through **mechanical working.**
➜ When a match is lighted, the chemical energy stored converts to heat and light

- Gravitational potential energy

➜ The gravitational potential energy is dependent on the height of the object and the gravitational field.
➜ It is the energy an object gains when it's lifted up, and loses when it falls.
➜ When the object rises, the GPE will increase.
➜ When the object is lowered, the GPE will decrease.
➜ **GPE = Mass x Gravitational field strength x Height**

Q: A ball is rolling down a ramp with a mass of 0.5 kg, and a gravitational field strength of 9.8 N/kg. Calculate the loss in the gravitational potential energy of the ball.



In this question, we've been asked to calculate the **loss** of the GPE of the ball. This means that we need to find out the **change** in its GPE. To calculate the change in GPE we use the equation:

$\Delta E_{\square} = mg\Delta h$, where:
Δ indicates change
⤷ change in height = final height - initial height

$E_{\square}$ is the potential energy
m = mass
g = gravitational field strength
h = height

If we apply the equation to solve this question:
Mass = 0.5
Gravitational field strength = 9.8
Final height = 4
Initial height = 10

0.5 x 9.8 (4 - 10) = -29.4 J

Therefore, ΔE□ = -29.4 J

- Kinetic energy

➜ Kinetic energy is the result of the speed of the object.
➜ If an object is resting on the ground, it doesn't have any kinetic energy. Once you apply force and it starts moving, it gains kinetic energy.
➜ The faster it moves, the more kinetic energy it has.
➜ **Kinetic Energy = ½ x mass x speed^2**
➜ Any sort of movement involves kinetic energy.

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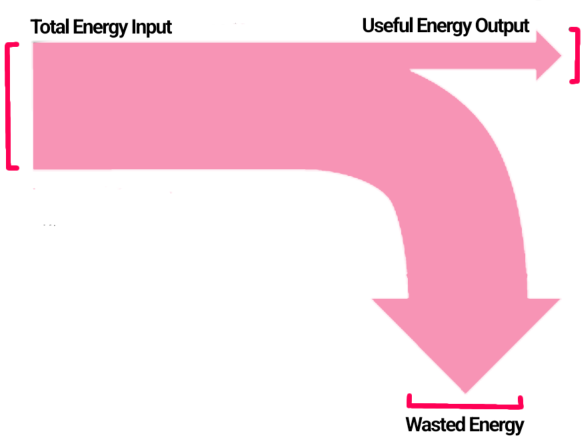
- Sankey Diagrams

➜ Some energy transfers are useful while some are wasted.
➜ We use Sankey Diagrams to show this.
➜ The thickness of the arrow going in shows how much energy, in total, went into the device.
➜ The thickness of the arrow going forwards tells us how much energy was usefully transferred.
➜ The arrow going downwards tells us how much energy was wasted.



➜ The arrow leaving and the one going on must be equal to show conservation of energy.
➜ **Total energy in = Useful energy out + Wasted energy**

We can rearrange this according to what we need to find, including wasted energy, which would be:

Wasted energy = Total energy in - Useful energy out

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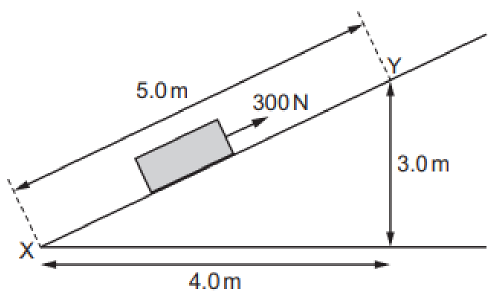
- Work

➜ Work is done when an object moves in the direction of the force applied.
➜ The greater the force or the distance travelled, the greater the work done.
➜ Energy is transferred whenever work is done.
➜ **Work done = Energy transferred**
➜ **Work = Force x Distance travelled**
➜ The unit of work is Joules, or Newton Metres.

- Example question

(Source: O Level (5054) May/June 2016 p1 variant 1)

14 A 300 N force is applied to a box to move it up a ramp, as shown.



How much work is done by the force when moving the box from X to Y?

A 900 J **B** 1200 J **C** 1500 J **D** 3000 J

Here, we want to find out the work done from point X to point Y. The formula for work done is:
Work done = Force x Distance travelled.
The distance between the two is 5.0 m, and the force is 300N. Applying the formula for work done, we'll multiply the two:
Work done = 300N (force) x 5.0 m (distance travelled)
Work done = 1500 J

Therefore, the work done by the force is 1500 J.

Energy Resources

- Renewable and Non-renewable energy

➜ Renewable energy resources are those which cannot run out and are generally non-polluting.
➜ Non-renewable energy resources are those which can run out and cause damage to the environment, and once used up, they cannot be replaced.
➜ Hydroelectric, geothermal, solar, tidal, biogas and wind energies are **renewable.**
➜ Coal, oil, natural gas (fossil fuels) and nuclear energies are **non-renewable.**
➜ Geothermal, nuclear and tidal are energies which don't come from the Sun.

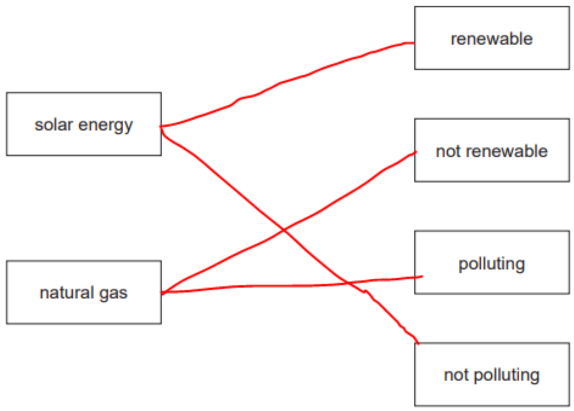
Renewable Energy Sources	Non-Renewable Energy Sources
Hydroelectric Energy	Coal
Geothermal Energy	Oil
Solar Energy	Natural Gas
Wind Energy	Nuclear Energy
Biogas	

- Example question

(Source: IGCSE (0625) May/June 2015 p3 variant 3)

(a) The boxes on the left contain the names of some sources of energy. The boxes on the right contain properties of some sources of energy.

Draw **two** straight lines **from each box** on the left to the two boxes on the right which describe that source of energy.



[2]

Non-renewable energy resources

- Fossil fuels

➜ Fossil fuels include coal, oil (used in boilers and domestic cookers) and natural gas.
➜ They're formed by the remains of plants and animals which lived millions of years ago
➜ Their energy is stored as chemical energy.
➜ They are used in transportation (primarily relying on petrol and diesel), generating electricity, and heating

- Advantages

➜ Readily available when energy demand suddenly increases.
➜ Reliable for energy production on a large scale.

- Disadvantages

➜ Burning fossil fuels pollutes the atmosphere with harmful gases e.g. carbon dioxide and sulphur dioxide.
➜ Increases global warming; sulphur dioxide causes acid rain.
➜ Predictions say fossil fuels will run low in the next 200 years.
➜ They takes millions of years to form.
➜ The demand for fossil fuels is increasing with a decreasing supply.
➜ Extracting sulphur dioxide from the waste gases or removing sulphur from fuel are costly processes, increasing the price of electricity.

Important: Electricity by itself isn't renewable or non-renewable, it all depends on how it's generated.

- Generating electricity

➜ Coal is burned in a boiler, producing heat.
➜ We then use this heat to boil water which produces steam.
➜ The kinetic energy of this steam turns the turbine when it's forced around the system through a rotor.
➜ The turbine then turns the coil in the generator, converting kinetic energy to electricity.
➜ The steam in the turbine will be cooled and condensed, then be pumped back to repeat the process.

- Example question

(Source: IGCSE (0625) May/June 2015 p3 variant 3)

Q Coal-fired power stations are polluting. State an advantage of using coal as a source of energy. [1]

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Any one from:
- Relatively cheaper
- Widely available
- Can be used on a large scale
- Always available

- Nuclear fuel

➜ The fission of uranium isotopes can be used to produce electricity.
➜ The process of generating electricity is pretty much similar to that of fossil fuels, except that the boiler is replaced by a nuclear reactor.
➜ Nuclear reactors heat water to turn the turbine, consequently generating electricity.
➜ Research is being carried out to investigate how energy released by nuclear fusion can be used to produce electrical energy on a large scale.

- Advantages

➜ Does not emit carbon dioxide or sulphur dioxide
➜ No air pollution
➜ Reliable energy is produced on a large scale
➜ As long as a reactor is operating normally, it's safe

- Disadvantages

➜ Generates radioactive waste which is difficult to dispose
➜ Uranium will run out one day due to its finite supply
➜ If there's an accident with the reactor, radioactive material can leak from it and spread over large areas

Renewable energy resources

- Biofuel

➜ Energy derived from **recently** living organisms.
➜ Fossil fuel is also made from living organisms, but those ones existed millions of years ago, so they aren't recent.
➜ Biofuel is generally made from plants and algae.
➜ This is because plants can photosynthesise and absorb the **Sun's energy**, which can later be released when they're burned for fuel.
➜ Chemical energy is stored in biofuels e.g. ethanol and methane.

- Advantages

➜ Renewable: we can grow plants again and again
➜ Easy to transport
➜ Relatively cheaper to make
➜ They're thought of as carbon neutral; there's no overall release of CO_2

- ➜ Doesn't emit sulphur dioxide
- ➜ Reduces landfills

- Disadvantages

- ➜ We need somewhere to grow the plants, which means clearing land; this can involve cutting down forests and the release of tons of CO_2
- ➜ Damaging to the environment
- ➜ Carbon dioxide is released back into the atmosphere when biofuels are burned
- ➜ Cheap to make at a small scale, but not feasible for large-scale production
- ➜ It's unstable due to its methane content and may explode

- Hydroelectric dams

- ➜ The conversion of flowing water into electricity through a dam.
- ➜ Water that comes from upstream is trapped.
- ➜ Turbines and generators are used.
- ➜ The mechanical energy created by moving water spins rotors on a turbine.
- ➜ This turbine is connected to an electromagnetic generator, which produces energy when the turbine spins.
- ➜ The elevation created by the dam creates gravitational force for turning the turbine when water is released.
- ➜ **Pumped storage:** Some dams have a lower reservoir as their base, where water is stored to be pumped back to the higher reservoir for release when electricity is in demand
- ➜ **Dam:** A large barrier constructed to raise the level of water and control its flow.

- Advantages

- ➜ Cost-effective
- ➜ Reliable and available on demand
- ➜ Generates electricity on a large scale

- Disadvantages

- ➜ Initial setup is expensive
- ➜ Large dams destroy habitats; land previously used for farms or forestry may have to be flooded
- ➜ Pumped storage releases greenhouse gases

- Wave energy

- ➜ Converts energy from the natural rise and fall of sea waves into electricity.
- ➜ It can only be installed along coastlines.
- ➜ The mechanical energy of the tidal currents turns turbines connected to a generator. The generator produces electricity.

- Advantages

➔ No direct greenhouse gas emissions
➔ No pollution
➔ Reliable due to ocean patterns being predictable, hence can produce electricity on demand
➔ Suitable for small islands as well

- Disadvantages

➔ Very specific set-up locations
➔ Expensive to build
➔ Its development is slow, so its technology isn't advanced enough to produce electricity on a large scale

- Geothermal

➔ Thermal energy generated and stored in the Earth's crust.
➔ It is also given off due to radioactive decay.
➔ Water is pumped down a shaft into hot rocks until it heats up so much that it converts into steam, which turns turbines and drives generators, producing electricity.

- Advantages

➔ Reliable and consistent
➔ Smaller power stations
➔ They can provide base-load power

- Disadvantages

➔ It can only be used in volcanic regions where the underlying rocks are hot enough
➔ Power plants are expensive to build

- Solar energy

➔ Solar energy is energy directly from the Sun and obtained through solar cells.
➔ The Sun's energy is transferred by visible light and infrared radiation.
➔ The Sun's electromagnetic waves transfer energy, which is stored as internal energy in solar panels.
➔ Solar cells are mostly made up of silicon (semiconductors) which convert sunlight into electricity.
➔ Cells are connected together to supply electricity to homes.
➔ Energy generated by solar cells can be stored in batteries for later use.
➔ A solar furnace focuses the Sun's rays onto a small area.
➔ The energy can be used to convert water into steam which can be used to drive turbines of a generator.

- Wind energy

➜ Wind turbines are used to obtain energy from the wind.
➜ They're generally placed in exposed areas with lots of strong winds.
➜ Each turbine has a generator inside it.
➜ As the blades spin, they turn the generator which converts kinetic energy from the blades' movement into electrical energy.

- Advantages of Wind and Solar energy

➜ Don't produce any pollutants
➜ Low running costs

- Disadvantages Wind and Solar energy

➜ High upfront costs
➜ Making them does produce pollutants
➜ Dependent on weather; if the Sun doesn't shine or the wind doesn't blow, it won't produce any electricity.
➜ Supply can't be increased in times of peak demand
➜ Takes up a lot of space; a lot of solar panels (and turbines, in case of wind energy) are needed to produce a serious amount of power
➜ Expensive to set up
➜ Wind turbines are considered noisy and unsightly

- Efficiency

➜ During the conversion of energy from one form to another, some energy may be lost such as heat
➜ A device's efficiency is the percentage of the energy usefully transferred after being supplied to it
➜ Efficiency = Useful energy output/Total energy input x 100%
➜ In terms of power, Efficiency = Useful power output/Total power output x 100%

- Power

➜ Power is the rate of transfer of energy.
➜ Power is the rate of doing work.
➜ Power = Energy transferred/Time
➜ The unit of power is Watt (W) or Joules per second.

Chapter 8: Pressure

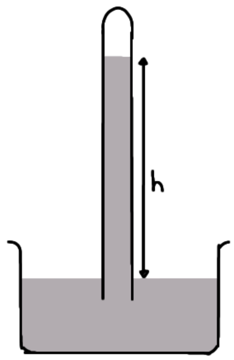
➜ Pressure is the force acting per unit area.
➜ Pressure = Force/Area
➜ The greater the force, the greater the pressure.
➜ The greater the area, the lesser the pressure.
➜ The unit of pressure is Pascals (Pa), or N/m^3.

- Liquid Pressure

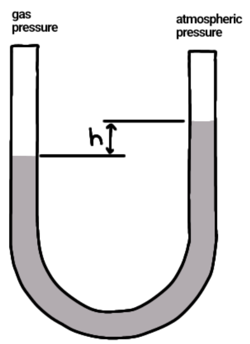
➜ A liquid exerts pressure on an object immersed in it.
➜ The pressure is equal throughout a liquid in all directions.
➜ The pressure depends on the depth and density of the liquid.
➜ Liquid pressure = Liquid's density x Gravity x Depth
➜ The volume of the liquid or the shape of the container does not affect the pressure.

- Barometer

➜ A barometer is used to measure atmospheric pressure.
➜ It has mercury in an inverted tube.
➜ If the atmospheric pressure increases, the mercury will rise up the tube.
➜ If atmospheric pressure decreases, the mercury will fall in the tube and rise in the container.



Barometer



Manometer

Section 2: Thermal Physics

Kinetic Particle Theory

- Solids

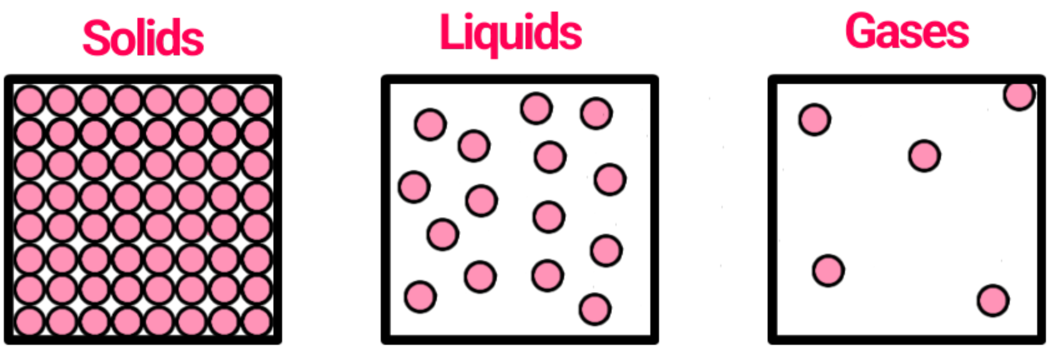
➜ Strong intermolecular forces between the particles, resulting in the properties of solids/the properties are due to the intermolecular forces.
➜ Particles are close together with a fixed pattern and regular arrangement (lattice-like).
➜ Particles vibrate about their fixed positions.
➜ Fixed volume and shape with high density.
➜ Not easily compressed.
➜ Relatively possess the least potential energy.

- Liquids

➜ Weaker forces of attraction than solids.
➜ Particles are close together with an irregular pattern.
➜ Particles are free to move about other particles and adapt to the shape of the container.
➜ Particles slide past each other in layers.
➜ Move in clusters/layers.
➜ Fixed volume but no fixed shape.
➜ Less dense than solids.
➜ More easily compressed than solids.
➜ More potential energy than solids.

- Gases

➜ Barely any forces of attraction.
➜ Particles are far apart/irregular pattern.
➜ Particles move randomly according to Brownian motion.
Brownian motion is the random constant motion of all particles of matter.
➜ No fixed shape or volume.
➜ Easily compressed with pressure.
➜ Relatively possess the most potential energy.
➜ Least dense.



- Boiling

➜ Change of state from liquid to gas.
➜ Occurs at a fixed temperature known as the boiling point.
➜ Bubbles are formed at the bottom of the liquid and escape through the surface.
➜ Occurs throughout the liquid.

- Evaporation

➜ Change of state from liquid to gas.
➜ Only occurs at the surface of a liquid.
➜ Particles with high energy escape from the surface.
➜ Evaporation causes cooling as it results in the decrease of the average kinetic energy of the Liquid. Since temperature depends on the kinetic energy, it decreases. As its temperature drops, it takes energy from the surroundings, causing the surroundings to cool.
➜ Can occur at a range of temperatures below the boiling point.
➜ Rate of evaporation increases with the surface area, wind and temperature.

- Pressure Changes

➜ The high-speed movement of molecules and their collisions exert force on the walls of the container; force exerted per unit area results in pressure exerted on the container walls.
➜ Increase in temperature results in an increase in kinetic energy.
➜ The temperature at which matter possesses no kinetic energy is known as **absolute zero which is -273 degree Celsius.**
➜ Increasing the temperature of a gas will give it kinetic energy, speeding up the molecules which increases the pressure.
➜ Pressure is inversely proportional to volume, if the temperature is kept constant.
➜ Atmospheric air also exerts pressure, as it forms a large column above us, exerting a pressure of 10^5 Pa.
➜ Boyle's law states that for a fixed mass at a constant temperature, the product of the original pressure and volume is equal to the product of the final pressure and volume.
➜ $p_1V_1=p_2V_2$

Thermal Properties

- Thermal Expansion

➜ Most materials expand when heated.
➜ Due to higher energy, the particles move or vibrate faster, pushing further apart from each other.
➜ The molecular spacing increases but the molecular size is constant.
➜ Solids expand slightly due to strong forces of attraction.
➜ Liquids expand more due to weaker forces of attraction.
➜ Gases expand a lot due to no forces of attraction.
➜ This property is used in a thermometer where the liquid expands on heating.
➜ A liquid in glass thermometer has a liquid inside a glass tube; the liquid expands when the bulb of the thermometer is heated and the scale is used for the reading.
➜ Solid materials may buckle on expansion.
➜ Metal railway tracks, bridges and roads may buckle due to expansion.
➜ Gaps are built where the metal may expand so they can have more room.
➜ Most materials contract when temperature is decreased, however, water expands. Its maximum density is at 4°C, after which it expands.

- Applications

➜ Liquid-in-glass thermometer
➜ Shrink-fitting of axles in motor vehicles
➜ Opening of tight-fit metal lids
➜ Bimetallic strips
➜ Fire Alarms
➜ Thermostats

- Measuring Temperature

➜ Heating a substance can change physical properties such as volume and resistance.
➜ These changes can be used to measure temperature.
Conversion of °Celsius to Kelvin:
0°C = 273 K
$T = 273 + \theta$ (where T represents temperature in Kelvin and θ in °Celsius)

- Specific heat capacity

➜ Specific heat capacity is the energy required per unit mass per unit temperature change.
➜ The unit of specific heat capacity is J/kg°C.
➜ Energy = Mass x Specific heat capacity x Change in temperature
➜ $Q = mc\Delta T$

- Change of state

➜ Solids, liquids, and gases change states between each other.
➜ The processes include melting, boiling, freezing, condensation.
➜ When the state of an object is changing by one of the processes, the temperature remains constant.
➜ The energy may be increasing or decreasing but the temperature remains constant in the transitional state.
➜ This energy is being used to break or form the intermolecular forces in the substance.
➜ The temperature doesn't change because the kinetic energy remains constant.
➜ In melting and boiling, the thermal energy input is used to increase the potential energy but not the kinetic energy.
➜ In condensation and solidification, the kinetic energy of the material is converted into thermal energy and transferred to the surroundings.

Thermal Processes

➜ Thermal energy is transferred from a body at a higher temperature to one at a lower temperature.

- Conduction

➜ Transfer of thermal energy through matter without transfer of matter
➜ Conduction is the main method of energy transfer in solids.
➜ It can not occur in a vacuum and is negligible in fluids.
➜ Metals are good conductors of heat.
➜ Non-metals are poor conductors of heat.
➜ Poor conductors are known as insulators.
➜ Air is an insulator of heater.
➜ When a substance is heated, the particles vibrate faster.
➜ They collide into each other while vibrating, transferring the energy.
➜ The energy is transferred from atom to atom.
➜ Delocalized electrons in metals can speed up conduction as they are free to move and they travel at high speeds, transferring heat throughout the solid, making metals better conductors.
➜ To test conduction, ball bearings can be attached to strips of a material with wax.
➜ Heating the strip at one end will cause conduction, when energy reaches the other end the wax will melt and the ball bearing will fall.
➜ The faster the ball bearing falls, the better the conductivity of the material.

- Convection

➜ Convection is the transfer of thermal energy through a fluid by the transfer of the fluid itself.
➜ Convection is the main way of energy transfer in liquids and gases.
➜ Convection can not occur in solids and in a vacuum.
➜ When a fluid is heated, the molecules gain energy and push each other apart.
➜ The fluid expands and the density decreases at the point of high temperature.
➜ The hot fluids being less dense rise and cold fluids being denser take their place.
➜ The hot fluids cool down eventually and come back down; the cold fluids that had heated up take their place.
➜ This produces convection currents and spreads energy throughout the fluid.
➜ Heating by convection can only occur above the heat source because the hot fluids rise.
➜ Cooling units are placed at the top.
➜ Heating units are placed at the bottom.

- Radiation

➜ All objects radiate energy.
➜ Hotter objects radiate more.
➜ Thermal radiation is a part of the infrared region of the electromagnetic spectrum.
➜ When infrared radiation is absorbed, the temperature increases.
➜ It is the only method of energy transfer in a vacuum.
➜ Heat from the Sun reaches the Earth by radiation.
➜ Black and dull surfaces are better absorbers and emitters of radiation.
➜ White and shiny surfaces are poor absorbers and emitters of radiation.
➜ Objects are painted black and dull for maximum temperature change.
➜ Objects are painted white and shiny for minimum radiation emission and temperature change.
➜ Rate of emission is increased by surface temperature and surface area.
➜ An object emits heat if its surroundings are colder.
➜ An object absorbs heat if its surroundings are hotter.
➜ Rate of absorption and rate of emission of energy must be equal in order to maintain a constant temperature.
➜ Global warming is being caused because the rate of absorption is more than the rate of emission due to greenhouse gases that absorb radiation.

Uses of transfer of heat

- Conduction

➜ Good conductors such as metals to make pots, boilers and radiators.
➜ Bad conductors such as wood, plastic, rubber, etc. to make handles of pots and boilers.
➜ Air to insulate houses and prevent energy loss e.g. in double-glazed windows, in lagging and fleece jackets.

- Convection

➜ Convection currents set up by heaters, boilers and even radiators to heat our houses and water.

- Radiation

➜ Infrared detection thermometers; used to check the body temperature of people in airports, hospitals etc.

- Cases Involving multiple methods of heat transfer

➜ Car radiators: conduction and radiation, as the liquid inside the radiator is heated by conduction and then transferred to the radiator, where the heat dissipates by radiation.
➜ Fire: convection and radiation, as the air absorbs radiation and heats up, and then via convection currents, the area nearby is heated up.
➜ Vacuum flasks: Heat loss through conduction and convection is reduced by making the flask double-walled with a vacuum in between, and radiation reduced by making the surfaces shiny.

Section 3: Waves

General Properties of Waves

- Basics

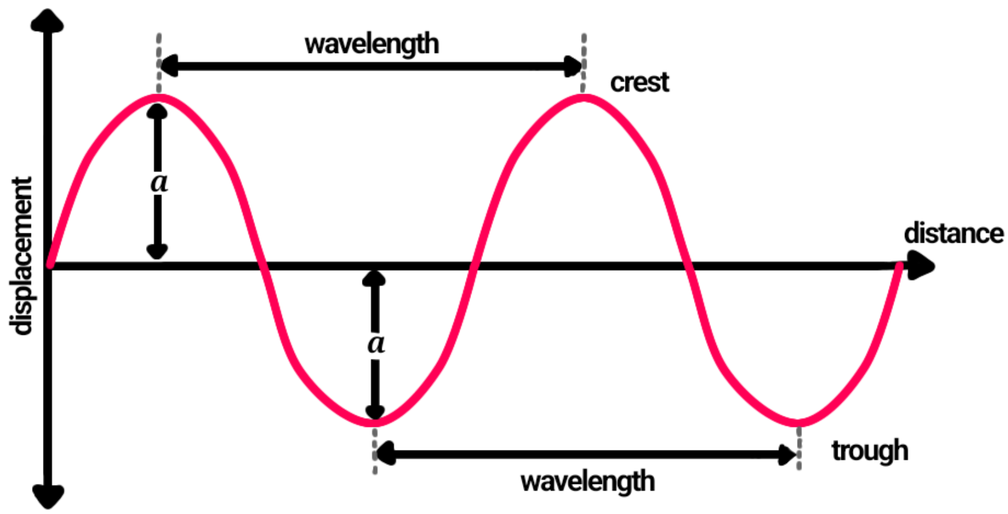
➜ A wave is a disturbance that transfers energy without transferring matter.
➜ There are two types of waves - transverse and longitudinal waves.
➜ Transverse wave: the direction of vibration of particles of the medium is perpendicular to the direction of travel of the wave. Examples: electromagnetic waves.
➜ Longitudinal wave: the direction of vibration of particles of the medium is parallel to the direction of travel of the wave. Examples: sound waves, seismic P waves.

- Terminology

➜ Wavelength λ, is the distance between two consecutive, identical points, such as two consecutive crests.
➜ Frequency f, is the number of wavelengths that pass a point per unit time.

$f = 1/T$. T is the time period for one complete wave/wavelength.
Unit: Hertz (Hz)
The frequency of the wave stays the same as the wave travels.

➜ Amplitude a, is the maximum distance from the mean position.
➜ Wave speed v, is the distance travelled by a point on the wave per unit time.
➜ Phase: points having the same velocity (i.e. same speed and same direction) are considered to be in phase .e.g. in the diagram, A and C, and B and D are in phase.



➜ **Wave equation**: Wave speed = Frequency x Wavelength

$$v = f\lambda$$
$$v \propto f$$
$$v \propto \lambda$$

➜ **Wavefront** is an imaginary line joining all the points of a wave that are in phase e.g. all the crests or all the troughs, etc.

➜ **Ray** is a line perpendicular to the wavefronts, indicating the direction of travel of wave.

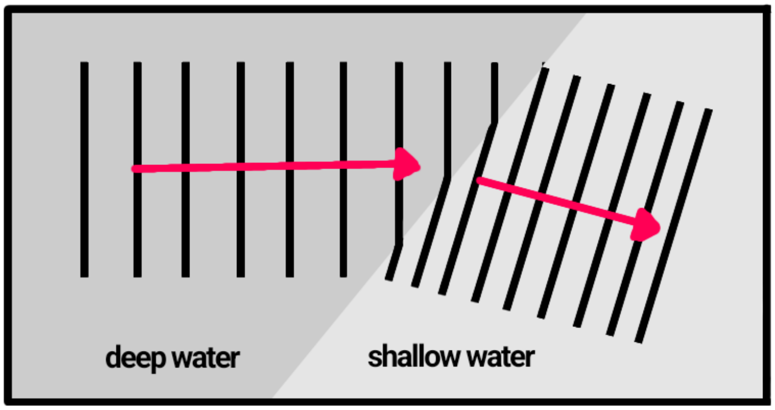
- Properties of waves

➜ Reflection, refraction and diffraction are properties of waves.

➜ **Reflection** is the bouncing back of light from a smooth surface, with the angle of incidence equal to the angle of reflection.

➜ **Refraction** is the bending of light when it passes from one medium to another, due to change in speed, and hence, wavelength.

➜ In shallow water, the wavelength decreases, so the speed also decreases. Frequency is fixed as it depends on the source of the wave.



➜ The ray bends towards the normal, because the speed decreases in shallow water and so does the wavelength.

➜ **Diffraction** is the spreading of waves around the edges of an obstacle/a gap (depends on the size of the gap and the size of the wavefront).

➜ If the gap is small compared to the wavelength, then the wavefronts curve and spread more.

➜ If the gap is big compared to the wavelength, then the wavefront remains almost straight except at the edges of the gap where some curvature occurs around the edge.

➜ If there is only one edge of the gap, then the wave would curve around that edge.

Light

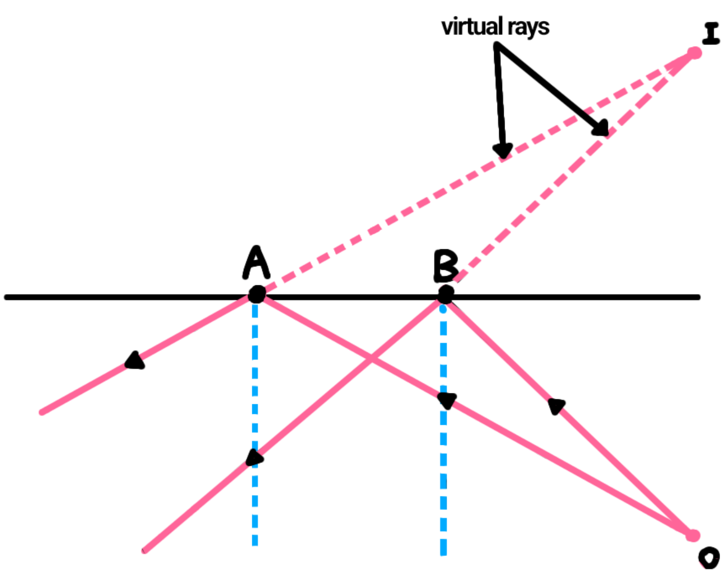
- Reflection

➜ **Normal** is an imaginary line drawn perpendicular to the surface at the point of incidence.
➜ **Angle of incidence** is the angle between the incident ray and the normal.
➜ **Angle of reflection** is the angle between the reflected ray and the normal.
➜ Law of reflection states that the angle of incidence is equal to the angle of reflection.
➜ Incident ray, reflected ray and the normal all lie in the same plane.
➜ Real images are images that can be produced on a screen and are formed by rays that actually pass through the screen.
➜ Virtual images are images that cannot be produced on a screen and are formed by virtual rays that are traced back from real rays.

Properties of an image in a mirror

1. Distance between the mirror and the image is equal to the distance between the mirror and the object.
2. Image is the same size as the object.
3. Image is virtual.
4. Image is laterally inverted.

How to construct an image seen in a mirror



- Refraction

➜ The bending of light when it passes from one medium to the other.
➜ Light is refracted because its speed changes in different media.
➜ Light's speed and wavelength change, but the frequency remains the same.
➜ Angle of refraction is the angle between the refracted ray and the normal to the surface.

- Properties of refraction

➜ Light is bent towards the normal when it enters an optically denser medium.
➜ Light is bent away from the normal when It enters an optically rare (less dense) medium.
➜ An incident ray perpendicular to the boundary is not refracted.
➜ Refractive index n, tells how bent light would be after entering the material.
➜ Snell's Law:
$n_1 \text{Sin}\theta_1 = n_2 \text{Sin}\theta_2$ (In air, the refractive index is 1)
Refractive index of medium 1 x Angle of incidence = Refractive index of medium 2 x Angle of refraction
➜ Critical Angle c is the angle of incidence which produces an angle of refraction of 90°.
➜ There is always a faint reflected ray alongside a strong refracted ray, when light passes from a dense medium to a less dense medium. However, when the angle of incidence is greater than the critical angle, total internal reflection occurs and there is no refraction.
➜ Total internal reflection occurs when a light ray does not cross the boundary between two media; it is totally reflected at the boundary.
➜ Uses of total internal reflection by fibre optics cables:
1. Endoscopy
2. Providing light to a hard to reach area
3. Telephone
4. TV signals
5. Internet signals

➜ Advantages of fibre optics cables over copper ones:
1. Faster data transfer
2. More secure data transfer
3. Feasible to use over long distances
4. Cheaper
5. Thinner and lighter so easier to handle and install

However, optic fibre cables are weaker than copper and can break when bent too much.

- Lenses

➜ A converging/convex lens bends light inwards.
➜ A diverging/concave lens spreads light out, always produces a diminished image, and has a virtual (produced by tracing back real light rays) focal point behind the lens
➜ Optical centre is the centre of the lens.
➜ Principal axis is the line through the optical centre of a lens at right angles to the lens.

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➜ **Principal focus (focal point) is the point on the principal axis of a lens to which light rays parallel to the principal axis converge, or appear to diverge from.**
➜ **Focal length is the distance between the optical centre and the principal focus of a lens.**
➜ An image is blurry if all the light rays from the object do not converge at, or very near to the screen.

- Ray Diagrams

You have to draw:
➜ A ray parallel to the principal axis which is refracted through the principal focus, F.
➜ A ray through the optical centre, which does not refract.
➜ A ray through the principal focus, which is refracted parallel to the principal axis.
➜ **Magnification is the ratio of image length to object length**

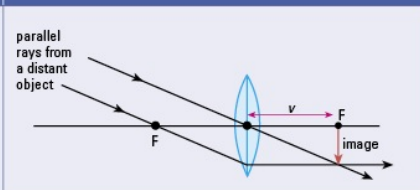
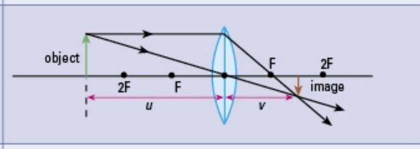
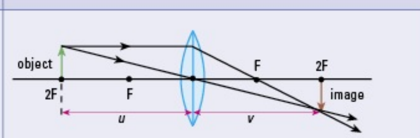
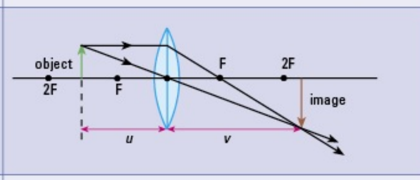
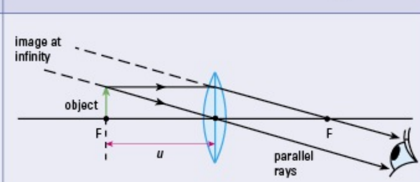
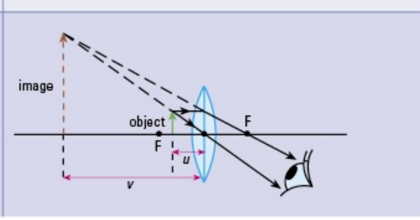
Object distance (u)	Ray diagram	Type of image	Image distance (v)	Uses
$u = \infty$		- inverted - real - diminished	$v = f$ - opposite side of the lens	- object lens of a telescope
$u > 2f$		- inverted - real - diminished	$f < v < 2f$ - opposite side of the lens	- camera - eye
$u = 2f$		- inverted - real - same size	$v = 2f$ - opposite side of the lens	- photocopier making same-sized copy
$f < u < 2f$		- inverted - real - magnified	$v > 2f$ - opposite side of the lens	- projector - photograph enlarger
$u = f$		- upright - virtual - magnified	- image at infinity - same side of the lens	- to produce a parallel beam of light, e.g. a spotlight
$u < f$		- upright - virtual - magnified	- image is behind the object - same side of the lens	- magnifying glass

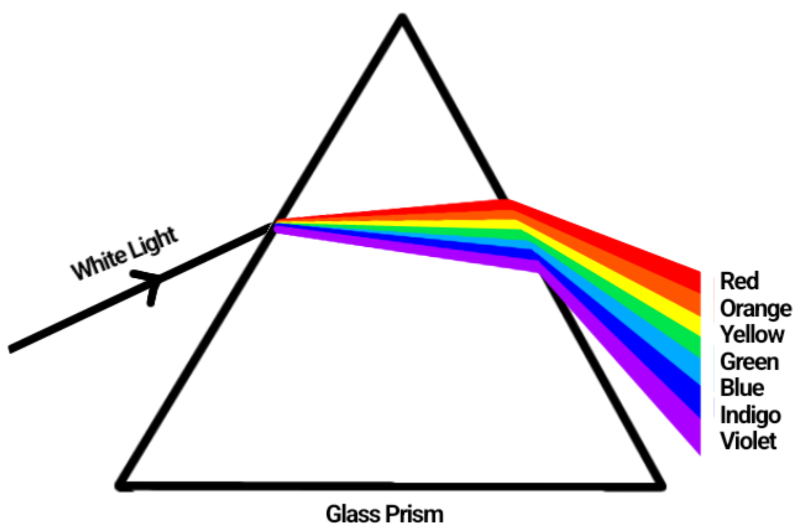
Diagram from: [MiniPhysics]

- Eye sight correction

➜ For normal vision, the rays of light should meet and form an image on the retina at the back of the eye.
➜ In long-sightedness, the image is formed behind the eye, causing nearby images to appear blurred or out of focus.
➜ A converging lens can be used to correct long-sightedness.
➜ In short-sightedness, the image is formed in front of the eye, and distant objects appear to be blurred or are difficult to see.
➜ A diverging lens is used to correct short-sightedness.

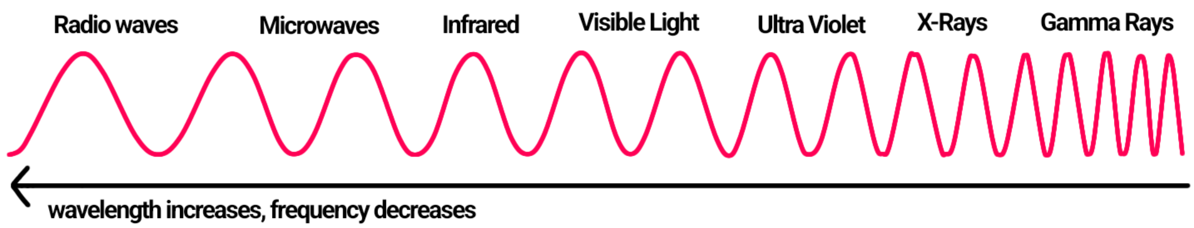
- Dispersion of Light

➜ When white light passes through a prism, a spectrum of colours is obtained - Dispersion.
➜ The refractive index of the prism is different for each colour of light.
➜ Each colour refracts differently, at a different angle of refraction.
➜ ROYGBIV - increasing frequency
➜ VIBGYOR - increasing wavelength
➜ Waves of one frequency are called monochromatic waves. These colours are monochromatic as they have a single, distinct frequency.



Electromagnetic Spectrum

Rugby	Match	Is	Very	Unlike	Xylophone	Game
Radio	Micro	Infra-red	Visible Light	UV Rays	X-Rays	Gamma Rays



➜ Frequency increases from Radio waves to Gamma radiation.
➜ Wavelength decreases from Radio waves to Gamma radiation.

- Basics

➜ Can travel through vacuum; do not require a medium.
➜ The speed of electromagnetic waves in a vacuum and air is 3×10^8 m/s.
➜ Transverse waves.
➜ Can reflect, refract and diffract.
➜ Obey the wave equation.
➜ They carry energy from one place to another and can be absorbed by matter to cause heating and other effects.

- Radio Waves

➜ Radio and TV communications - by transmitting information over long distances.
➜ Radio telescopes - to receive radio signals from stars and galaxies to learn about the universe.

- Microwaves

➜ International communication
➜ Satellite television
➜ Mobile phone networks
➜ The microwaves are transmitted by dish aerials, amplified by satellites and sent back to a dish aerial some other place.
➜ Bluetooth
➜ Cooking in a microwave oven - microwaves make the water molecules vibrate vigorously, causing it to heat nearby particles by bumping into them.

- Infrared radiation

➜ Thermal imaging cameras
➜ Infrared sensors
➜ Intruder alarm - its sensor detects the infrared radiation emitted by a nearby moving body. Or, if anything comes in between the emitter and receiver's path, the alarm is activated.
➜ Remote controllers - to send signals to the appliance which are decoded or encoded.
➜ Optical fibres

- Light Waves

➜ Vision
➜ Photography
➜ Lighting

- Ultraviolet Waves

➜ Sun tan
➜ Produce Vitamin D in the skin
➜ Causes fluorescence
➜ Water treatment plants to kill pathogens as the energy of UV is high enough for it

- X-Rays

➜ To detect broken bones by sending X-rays through the affected area, since bones don't let X-rays pass through, the rest of the X-rays do fall on the film and an image is produced
➜ To kill cancerous cells in radiotherapy
➜ Security scanning machines for scanning luggage
➜ Detect cracks and flaws in metals

- Gamma Rays

➜ Diagnose and treat cancer
➜ Sterilise food and surgical instruments
➜ Detect cracks and flaws in metals

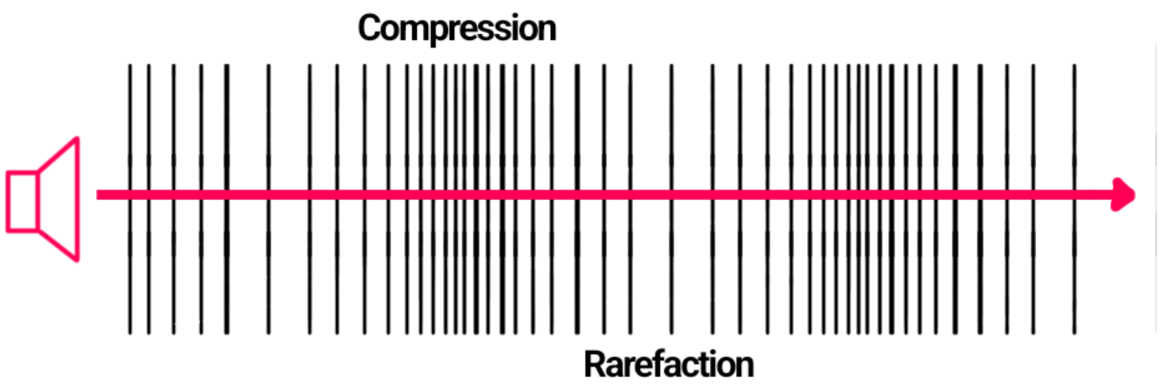
- Dangers

➜ Microwaves: cause heating of soft tissue in the body when they are absorbed by the water in living cells, damaging or killing cells.
➜ Infrared radiation: can cause burns as it transfers heat energy.
➜ Ultraviolet Radiation: causes ionisation and can lead to skin cancer and eye cataracts.
➜ Gamma and X rays: cause ionisation and can lead to cancer.

Sound

- Basics

➜ Sound is produced when something vibrates.
➜ Sound needs a medium to travel; it cannot travel in a vacuum.
➜ This can be demonstrated by placing a ringing bell in a vacuum chamber. As air is pumped out, the sound will become fainter until the point when no sound can be heard although the bell can be seen striking the gong.
➜ Longitudinal wave.
➜ Obeys the wave equation.
➜ The medium particles come close together and then go far apart in the direction of propagation of the wave.
➜ Compression is the region where molecules are close together.
➜ Rarefaction is the region where the molecules are further apart; they're spread apart.
➜ Air pressure is higher in compressions than rarefactions.



➜ The vibration causes air molecules to produce compressions and rarefactions.
➜ The number of compressions or rarefactions produced per second is the frequency of the sound wave.
➜ The distance between consecutive compressions or rarefactions is the wavelength λ.
➜ Limits of audibility: the approximate range of frequencies audible to humans, 20 Hz to 20 000 Hz.
➜ An echo is the reflection of a sound wave.

- Speed of Sound

➜ In air: 330-350 m/s.
➜ Sound is the fastest in solids, then liquids, and then gases. This depends on how close the medium particles are to each other. Being the closest in solids, then in liquids and then in gases.
➜ Speed of sound can increase if the temperature is increased.
➜ Atmospheric pressure does not affect the speed of sound.
➜ The speed of sound in air can be found directly by measuring the time taken for a sound to travel past two microphones with a known distance between them.
➜ Speed of sound in air = distance travelled by the sound wave/time taken

- Musical Notes

➜ Noise is produced by irregular vibrations.
➜ Regular vibrations produce musical notes, having three properties: Pitch, Loudness, Quality/Timbre.
➜ **Pitch:** depends on the frequency of sound.
➜ A high pitched note has a high frequency.
➜ **Loudness:** depends on the sound energy being carried by the sound wave which depends on the amplitude of the wave. The higher the amplitude, the higher the intensity, energy, and loudness of the sound.
➜ **Quality:** when the same note sounds different on different instruments, there is a difference of quality.
➜ No instrument (except for tuning forks and signal generator) emits a monochromatic note, i.e. of one frequency.
➜ Different qualities of the same note on different instruments can be identified by the different shapes formed on the screen of a cathode ray oscilloscope.
➜ Same note may have the same frequency but the quality differs because every note has different additional frequencies.

- Ultrasound

➜ **Sound with a frequency greater than 20,000 Hz.**
➜ Ultrasound waves are partially or totally reflected from surfaces where the density of the medium changes; this property is used for its applications.
➜ Motion sensors, ships and even bats can determine the distance or the presence of an object based on the time the ultrasound wave takes to reflect back.
➜ In medicine, ultrasound is used to determine the gender of a developing foetus. The ultrasound is reflected by the different tissues of the foetus, which the receiver senses and an image is produced of the foetus. Ultrasound has no harmful effects on human tissue.
➜ Ultrasound can also be used to clean jewellery etc. as it has a high frequency. The object is placed in a tank with a solvent and an ultrasound emitter.

Section 4: Electricity & Magnetism

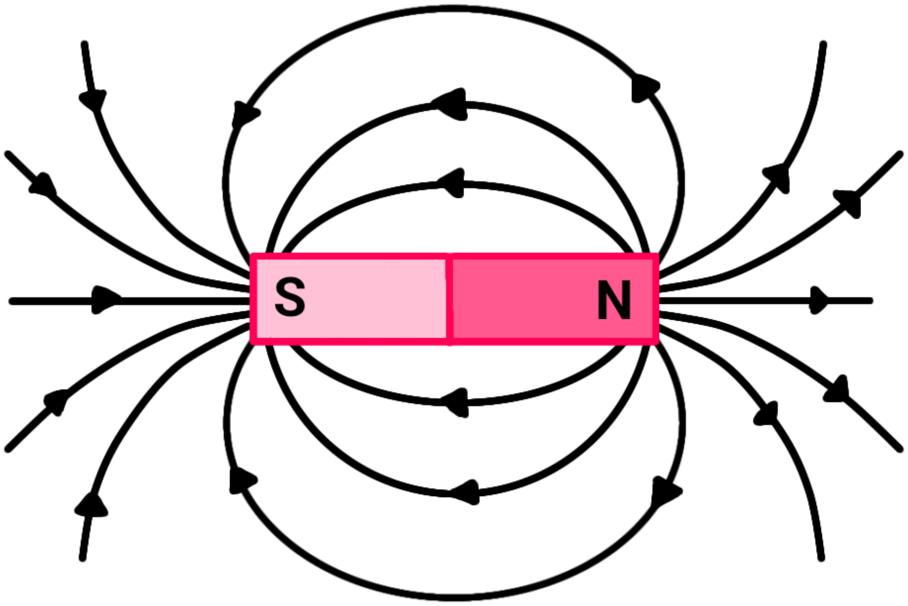
Magnetism

- Magnetic Forces

➜ When two magnets are brought close to each other, they experience a force.
➜ Every magnet has a North and South pole.
➜ If like poles are brought close to each other, they will repel.
➜ If opposite poles are brought close to each other, they will attract.
➜ Magnetic forces are caused by the interaction of magnetic fields.
➜ Magnetic materials attract to both poles.
➜ If a material attracts one pole and repels the other, it is a magnet.
➜ If it is a magnetic material, it will not repel any of the poles.

- Magnetic Fields

➜ A magnetic field is a region in which a magnetic pole experiences a force.
➜ Magnets have magnetic fields in the area around them.
➜ Field lines can be used to picture the strength and direction of magnetic fields.
➜ Magnetic field lines always go from North to South poles.
➜ Field lines never touch or cross each other.



- Plotting a magnetic field

Method 1:
➜ Place a piece of paper on top of a magnet
➜ Sprinkle iron filings over the paper
➜ Tap the paper gently
➜ The fillings will take the shape of the field lines

Method 2:
➜ Place the magnet on top of a piece of paper
➜ Mark a dot near a corner of the magnet
➜ Put a compass at the dot, one end of its needle should point towards the dot
➜ Mark another dot at the end of the needle
➜ Move the compass to the next dot, repeating the process till you reach the other pole
➜ Join the dots with a smooth curve to get the field line
➜ Repeat multiple times for more field lines

- Magnetic Materials

➜ Magnetic materials are materials that experience a force in a magnetic field.
➜ All magnetic materials are metallic, but not all metals are magnetic.
➜ Iron, Steel, Nickel, and Cobalt are examples of magnetic materials.
➜ Materials which do not experience a force are non-magnetic.
➜ Copper, Aluminium, and Plastic are examples of non-magnetic materials.

- Hard vs Soft materials

➜ Soft magnetic materials are easier to magnetise and easily lose their magnetism.
➜ Iron is an example of a soft magnetic material.
➜ Hard magnetic materials are harder to magnetise and don't lose their magnetism easily.
➜ Permanent magnets are made of hard magnetic materials.
➜ Electromagnets are made from soft magnetic materials.

- Magnetic Induction

➜ Hard magnetic materials can be made by two methods.
➜ Stroking a magnetic material with a magnet will turn it into a magnet by inducing poles at the ends.
➜ Placing a magnetic material inside a coil and passing Direct Current (D.C.) through it makes it a magnet.
➜ Magnets can be demagnetised by hammering them into pieces.
➜ Heating the magnet till it starts to glow and letting it cool slowly demagnetize it.
➜ Passing an Alternating Current (A.C.) current through a magnet and removing it slowly demagnetize it.

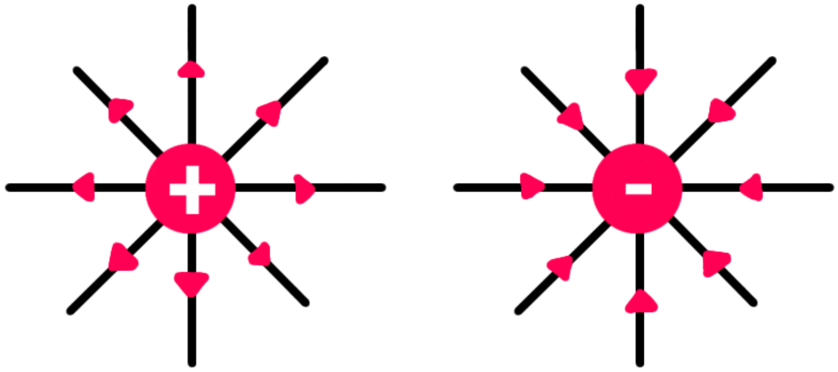
- Electromagnets

➜ Passing Direct Current (D.C) through a solenoid produces a magnetic field similar to that of bar magnets.
➜ Placing a soft magnetic material such as iron will strengthen the fields.
➜ The soft iron core will make it an electromagnet.
➜ They can be turned on or off by switching the current on or off.
➜ It can be strengthened by increasing the current or increasing the number of turns in the coil.

Electricity

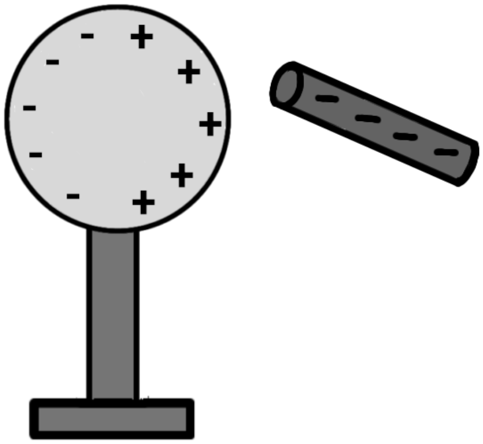
- Electric Charge

➜ Objects can have positive or negative charges.
➜ Like charges repel, opposite charges attract.
➜ Electric charge is measured in Coulombs.
➜ Electric charges create electric fields in the areas surrounding them.
➜ An electric field is a region in which an electric charge experiences a force.
➜ Field lines always go away from positive charges and towards negative charges.
➜ Electrons are negatively-charged particles.
➜ Negative charges are the result of gaining electrons.
➜ Positive charges are the result of losing electrons.
➜ Conductors are materials that allow charge to pass through, such as copper and iron.
➜ Insulators do not allow charge to pass through such as plastic, wood and rubber.



- Induction

➜ When a charged material is brought near an uncharged material, the charged material will induce a charge in the uncharged material.
➜ If a negatively charged rod is brought near an object, it will attract positive charges towards itself and the negative charges will gather on the opposite side.
➜ A positively-charged rod will attract negative charges.

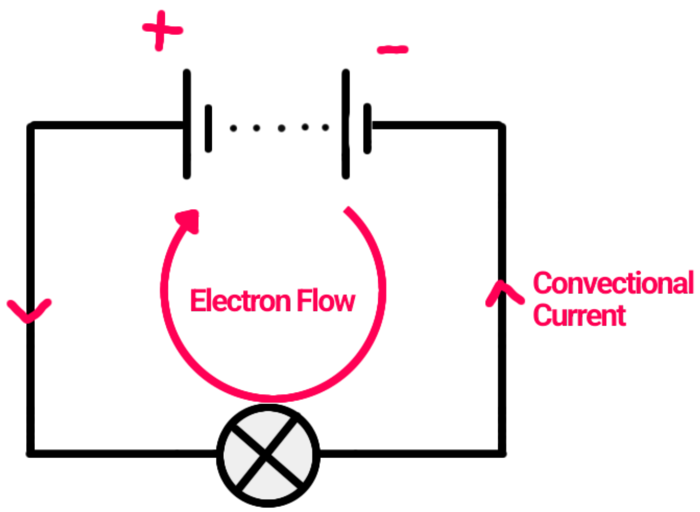


- Charging by Friction

➜ When two different insulating materials are rubbed, electrons get transferred from one body to another.
➜ For example, when a plastic rod is rubbed with a piece of cloth, electrons are transferred from the rod to the cloth.
➜ Charging of solids by friction involves only a transfer of negative charge (electrons), and not protons.

- Current

➜ The rate of flow of charge is known as current.
➜ When two oppositely charged conductors are connected by a conductor, the charges will flow, producing a current.
➜ The greater the flow of charge, the greater the current.
➜ Current is the charge passing a point in a circuit every second
➜ Current = Charge/Time
➜ The unit of current is Amperes (A).
1 Ampere = 1 Coulomb/second
➜ Current can be measured using an ammeter.
➜ Ammeters are always connected in series.kl0
➜ The flow of free electrons in a metal causes current.
➜ Electrons flow from negative to positive terminals.
➜ Conventional current flows from positive to negative terminals.



- Electromotive Force

➜ The electromotive force is the work done in driving a charge around a complete circuit.
➜ It is the potential difference across the battery.
➜ It is measured in Volts (V).
➜1 Volt = 1 Joule/Coulomb

- Potential Difference

➜ Potential difference is the work done in driving a charge through a component.
➜ It is measured in Volts (V).
➜ It is the energy per Coulomb.
➜ 1 Volt = 1 Joule/Coulomb.
➜ Potential difference can be measured using a voltmeter.
➜ The voltmeter should be connected in parallel to the component of which the p.d is to be measured.

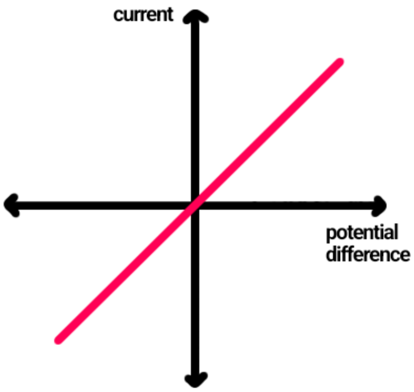
- Resistance

➜ Resistance is the opposition to current.
➜ The higher the resistance, the lesser the current.
➜ Resistance is measured in Ohms.
➜ Resistance = Potential difference/Current
➜ To measure the resistance of a component, the current is measured by attaching an ammeter in series and the potential difference is measured by attaching a voltmeter in parallel.
➜ The readings are used to calculate the resistance by R=V/I
➜ Resistance is caused when the electrons flowing in a metal collide with the metal's ions.
➜ The longer the wire, the greater the resistance.
➜ The greater the cross-sectional area of the wire, the lesser the resistance.
➜ Resistance is directly proportional to the length and inversely proportional to the cross-sectional area.

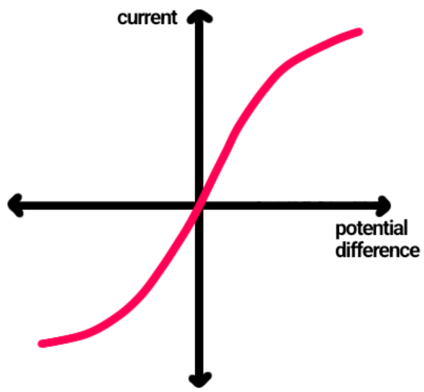
- Ohm's law

V = IR
Potential difference = Current x Resistance

➜ Ohm's law states that resistance is inversely proportional to current when physical conditions such as the temperature are constant.
➜ If the temperature varies, such as in a filament lamp, it will not obey Ohm's law.
➜ Resistors that obey Ohm's law are known as ohmic conductors.
➜ Resistors that do not obey Ohm's law are non-ohmic conductors.
➜ The IV graph of an ohmic resistor is a straight line.
➜ The graph of non-ohmic conductors is curved towards the voltage.
➜ In non-ohmic conductors, such as filament lamps, the temperature increases with time.
➜ The temperature causes the resistance to increase.
➜ Higher resistance means a lower current.



Resistor



Filament Lamp

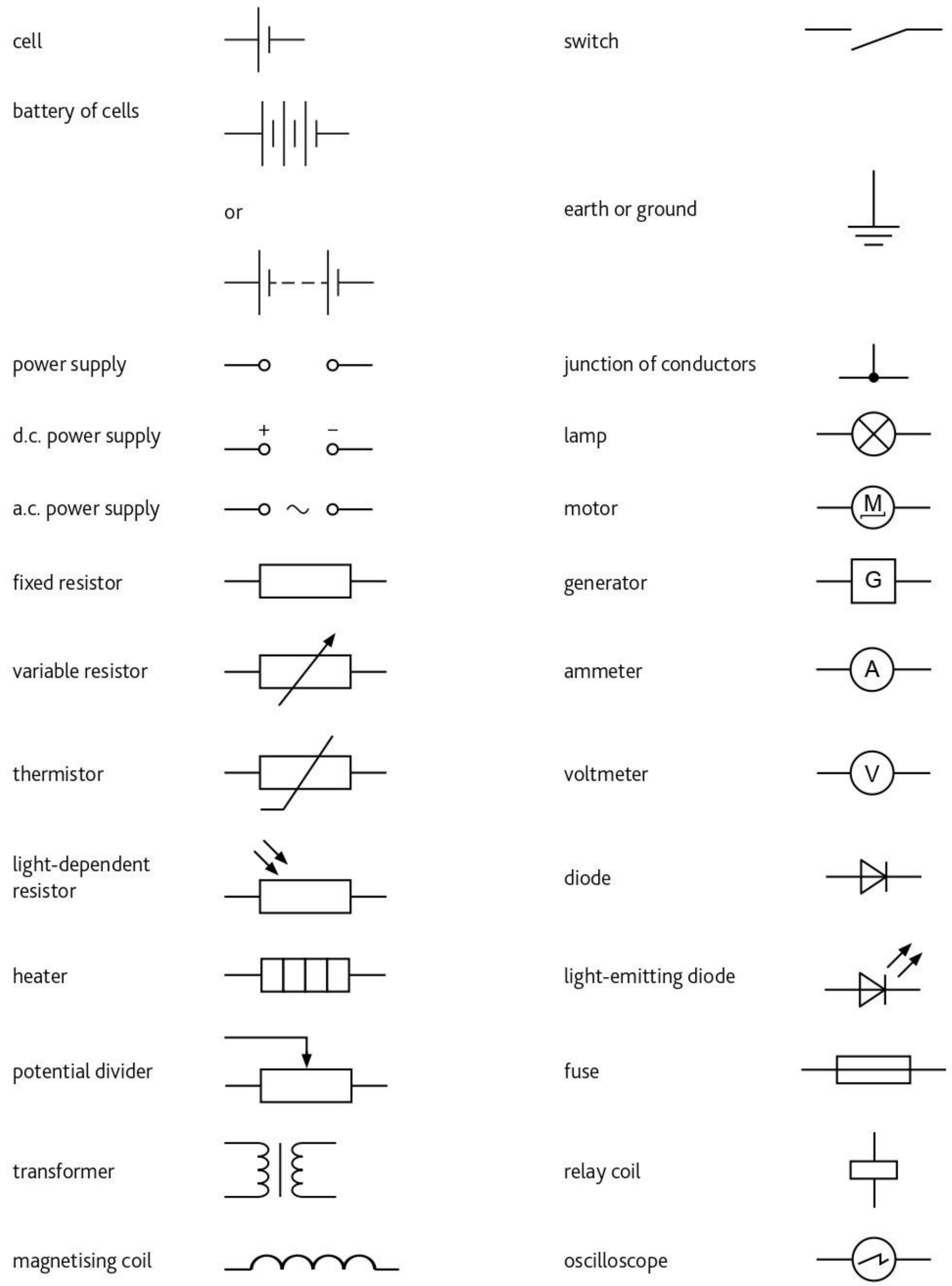
- Electrical Energy

➜ Energy is transferred from the power source to the components when current flows.
➜ Energy transferred = Current x Voltage x Time
➜ Energy is measured in Joules.

- Electrical Power

➜ Power is the rate of energy transfer.
➜ Power = Current x Voltage
➜ P=IV
➜ The unit of power is Watt (W)
➜ 1 Watt = 1 Joule / Second
➜ Energy = Power x Time
➜ E=Pt

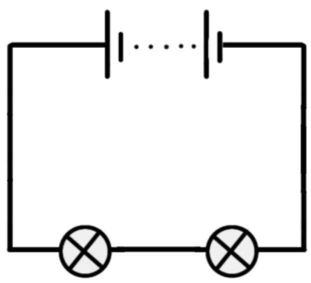
Electrical symbols



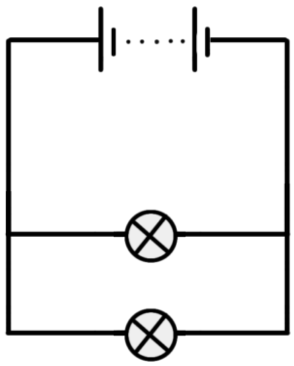
From [Cambridge Syllabus]

- Series Circuits

➔ Components are connected next to each other in series.
➔ The current is the same at all points in a series circuit.
➔ The total e.m.f.for batteries connected in series is the sum of their individual e.m.fs.
➔ In a series circuit, the sum of the p.d of individual components is equal to the total e.m.f.
➔ If one component stops working, the whole circuit doesn't work.
➔ The total resistance in a series circuit is the sum of all individual resistances.



Series Circuit



Parallel Circuit

- Parallel Circuits

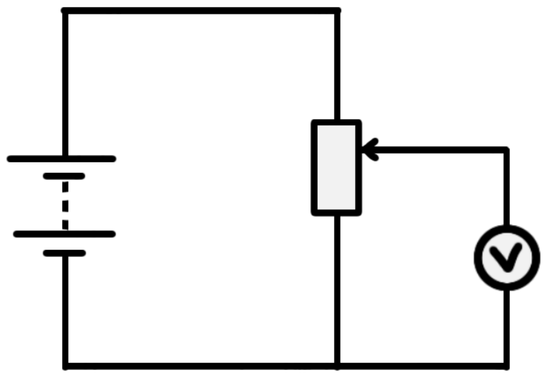
➔ The components are attached on separate branches.
➔ Components can be individually controlled.
➔ If one component stops working, the rest will continue to function.
➔ The current splits up in parallel circuits.
➔ The sum of currents in each branch gives the total current in the circuit.
➔ The current does not split equally always; it depends on the resistance in each branch; the higher the resistance, the lower the current. The sum of the currents entering a junction in a parallel circuit is equal to the sum of the currents that leave the junction.
➔ The potential difference is the same in every branch.
➔ Resistors connected in parallel have overall decreased resistance.
➔ If two identical resistors are attached in parallel, the resistance is will be half of one resistor
➔ The reciprocal of the total resistance is equal to the sum of the reciprocals of the individual resistances of the resistors .
➔ $1/R_t = 1/R_1 + 1/R_2 \ldots + 1/R_n$

- Advantages of connecting lamps in parallel

➔ The voltage across each bulb will be the same, so every bulb will be equally bright.
➔ Each component is independent of the others.
➔ Each component can be independently controlled by a switch.

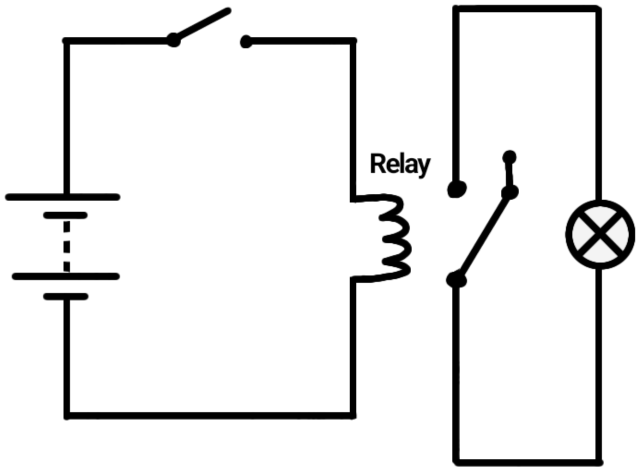
- Potential Dividers

➜ When two resistors are connected in series, voltage is shared between them.
➜The larger the resistance of a resistor, larger its share of the potential difference.
➜ Increasing the resistance of one resistor will increase the voltage across it and reduce the voltage across the other resistor, as the sum of their voltages remains the same.
➜ A potentiometer consists of a coil of wire with a sliding contact.
➜ Moving the sliding contact changes the resistance as it changes the length of the coil the current has to pass through.
➜ Adjusting the slider can be used to control the voltage across components in series; this phenomenon is used in a device known as the Potential Divider.



- Relay

➜ A relay consists of an electromagnet and a magnetic switch.
➜ The switch is within the magnetic field range of the electromagnet.
➜ When there is current in the electromagnetic coil, it attracts the magnetic switch.
➜ Attracting the switch closes it, allowing the current to pass through the circuit.
➜ Turning the current off in the electromagnet opens the switch.



- Thermistor

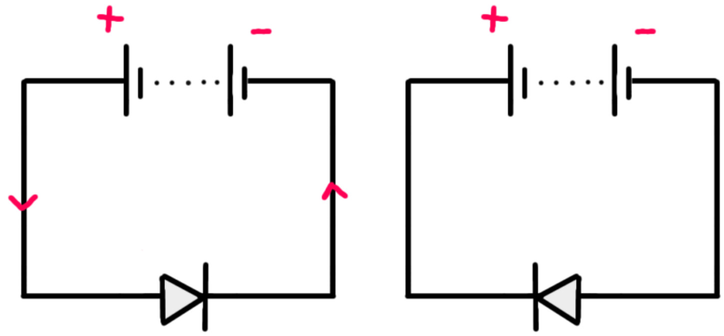
➜ Thermistors are resistors that have variable resistance depending upon the heat
➜ As the thermistor gets hotter, its resistance decreases.
➜ As the thermistor gets colder, its resistance increases.
➜ The temperature and resistance are inversely proportional.

- LDRs

➜ Light-dependant resistors change resistance according to the light falling on it.
➜ When more light shines on the LDR, the resistance decreases.
➜ When the light is lesser, the resistance increases.
➜ The light intensity and resistance are inversely proportional.

- Diode

➜ A diode is a component that allows current to pass in one direction only.
➜ If the current direction is opposite to the diode, it will not allow the current to pass through, and there will be no current.
➜ It converts a.c. current to d.c. current.
➜ There will be no current half the time with a.c current.



Current   No Current

- Hazards of Electricity

➜ Electricity can be lethal; a few volts of shock can be hazardous.
➜ Touching an exposed wire due to damaged insulation can cause an electric shock.
➜ Passing too much current through a wire can cause overheating and lead to fires.
➜ Moisture can come into contact with live wires in damp conditions, conducting electricity and causing a short circuit or even posing a risk of electrocution.

- Fuses

➜ Fuses are a safety measure to cut off electricity to an appliance if the current is too large.
➜ Fuses consist of a glass cylinder with a thin metal wire.
➜ If the current is too large, the wire will heat up and melt.
➜ The circuit will be broken and the current won't be able to pass through.

➜ Fuses have different ratings which are decided by the power of the appliance.
➜ The power of the component is found using P=IV.
➜ The rating of the fuse is the next size up - higher than the power rating.
➜ The power should lie within the range of the fuse.
➜ The fuse is attached to the live wire so that the current can not damage the device or cause a shock.

- Earthing

➜ Electrical appliances may have metal cases, which can cause hazards.
➜ If a live wire comes in contact with the metal case, touching it would cause a dangerous shock.
➜ The earth wire provides a low resistance path to the earth.
➜ If the current becomes too large, it will cause a surge in the earth wire, blowing the fuse.
➜ The fuse cuts off the supply of electricity, making the appliance safe.

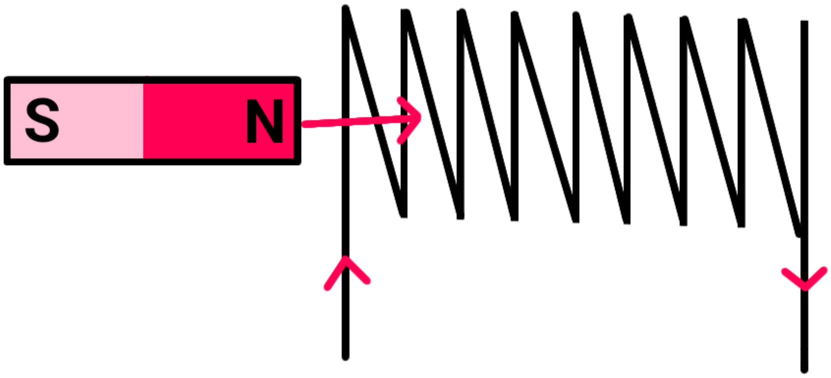
- Cost of electricity

➜ Energy is measured in homes and businesses in the kilowatt hour.
➜ The kilowatt hour is equivalent to one kilowatt of power expended for one hour.
➜ Energy in kWh = Power (in kilowatts) x Time (in hours)

Electromagnetism

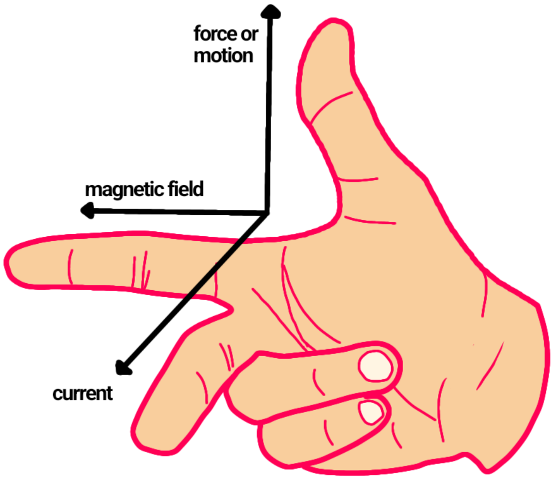
- Electromagnetic Induction

➜ When a conducting metal is moved in magnetic field lines, it induces an e.m.f.
➜ When a magnet is moved through a coil, the coil cuts through its magnetic field, producing an e.m.f.
➜ Whenever the magnetic field passing through a loop of wire changes, an e.m.f. is produced
➜ The size of the e.m.f. is proportional to the speed of field lines being cut
➜ The faster a magnet is moved through a coil or a conductor is moved through a field, the e.m.f. will be greater
➜ Using a stronger magnet increases the induced e.m.f.
➜ Adding more turns to the coil increases the induced e.m.f.



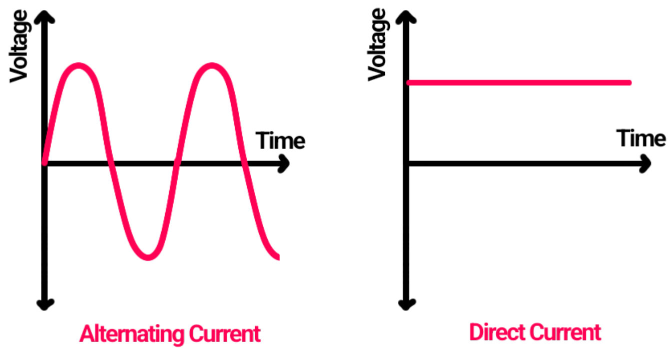
➜ According to Lenz's law, the direction of the e.m.f. always opposes the change that induced it.

➜ The direction of the e.m.f. can be determined by the right-hand rule, by holding your thumb index, and middle fingers perpendicular to each other. Point your index in the direction of the magnetic field and your thumb towards the direction of movement; the middle finger indicates the direction of current



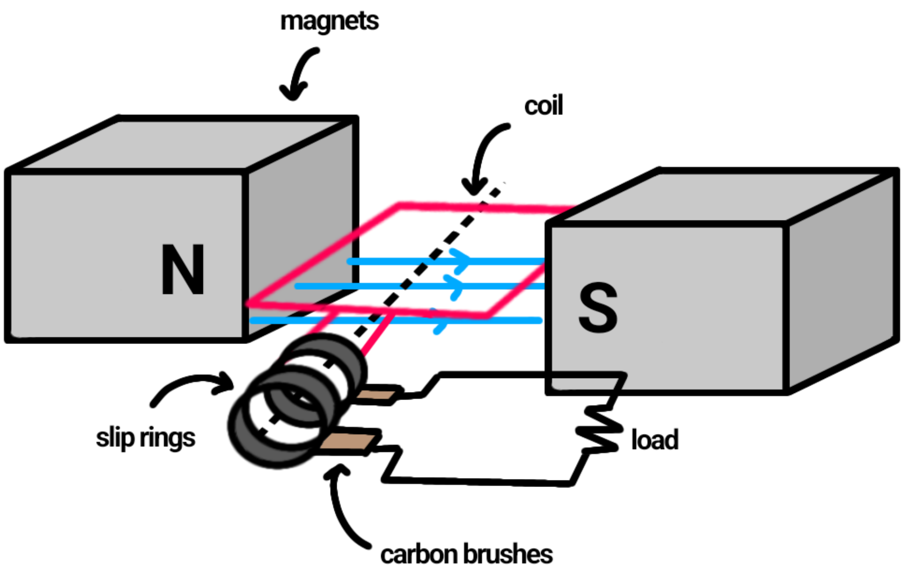
- Alternating vs Direct current

➜ Alternating current constantly changes direction, going back and forth in a circuit.
➜ A direct current flows in one direction only.
➜ A current time graph for DC current is a flat line.
➜ A current time graph for AC current is similar to a transverse wave.
➜ Batteries produce direct current.
➜ Mains electricity carries alternating current.



- A.C Generator

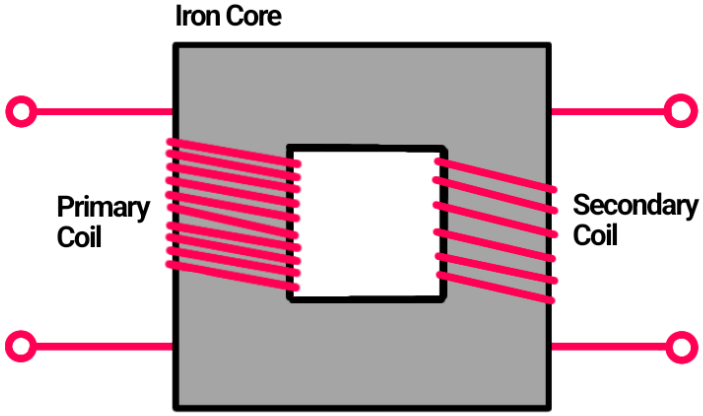
➜ An A.C. generator is spun mechanically instead of by being connected to a power supply.
➜ When a coil is spun in a magnetic field, a voltage is induced between the ends of the coil.
➜ Rotating the coil cuts the magnetic field, inducing an e.m.f.
➜ The e.m.f. can be increased by rotating the coil faster, using a stronger magnet, or adding more turns to the coil.
➜ Slip rings are attached to the end of the coil, which transfer current to brushes.
➜ The current produced as the coil rotates is A.C. that changes size and direction.
➜ When the coil is horizontal, the e.m.f. is greatest as it moves the fastest.
➜ When the coil is vertical, the e.m.f. is the smallest.



- Transformers

➜ Transformers are a device used to increase or decrease the voltage of alternating current.
➜ A step-up transformer is used to increase the voltage.
➜ A step-down transformer is used to decrease the voltage.
➜ The transformer consists of two coils wrapped around a soft iron core.
➜ The number of turns in the coils determines the size of the voltage.
➜ The secondary coil has more turns than the primary coil in a step-up transformer.
➜ In a step-down transformer, the secondary coil has fewer turns than the primary coil.

➜ When an alternating current passes through the primary coil, a magnetic field is produced.
➜ Due to the changing direction of the current, the field changes and a magnetic flux is generated.
➜ The field is strengthened by the soft iron core and passes through the secondary coil.
➜ The changing magnetic field induces an e.m.f. in the secondary coil.
➜ The ratio of the turns of the primary coil to the turns of the secondary coil is equal to the ratio of the voltage in the primary coil to the voltage in the secondary coil.
➜ Input voltage/Output voltage = No. of turns in the primary coil/No. of turns in the secondary coil
➜ The input power is equal to the output power if the transformer is 100% efficient.

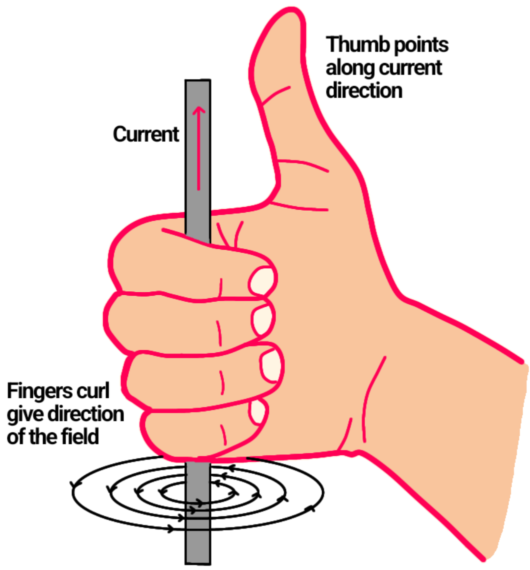


- Transmission of electricity

➜ Electricity is transmitted at high voltages through power cables.
➜ A step-up transformer is used at the power station to increase the voltage.
➜ A step-down transformer is used to reduce the voltage before it reaches homes.
➜ The high voltage reduces the current, reducing the energy loss.
➜ High current in wires heats them, causing energy loss.
➜ Raising the voltage transfers the same amount of power at a lower current.
➜ This reduces the energy loss during transmission.

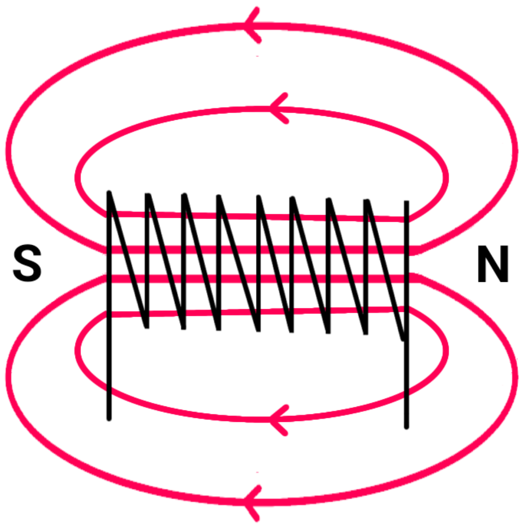
- Magnetic Effect of Current

➜ Concentric magnetic fields are generated around current-carrying wires.
➜ The right-hand grip rule gives the direction of the field lines.
➜ Make a fist around the wire and point the thumb in the direction of the current.
➜ The direction your fingers' curl shows the direction of the magnetic field.
➜ The direction of the magnetic field at a point is the direction of the force on the north pole of a magnet placed in the field.
➜ The greater the current in the wire, the stronger the magnetic field.
➜ Reversing the direction of the current reverses the direction of the field.
➜ The distance between field lines represents their strength; the closer the field lines, the stronger the magnetic field.
➜ Field lines are closer near the wire, and get further apart.



- Solenoid

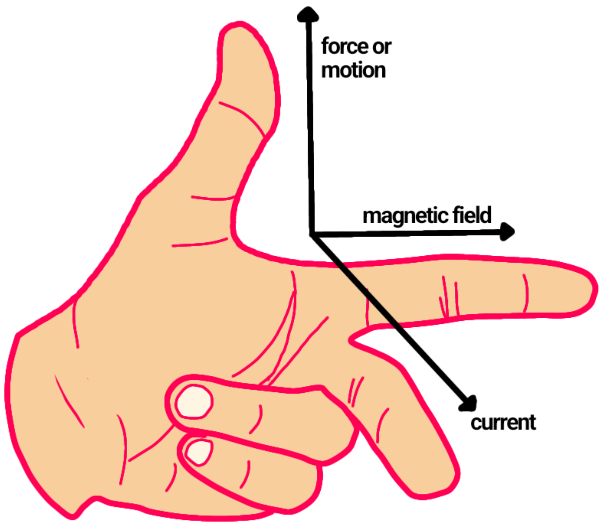
➜ The magnetic field of a solenoid is similar to that of a bar magnet.
➜ The solenoid develops a north pole at one end and a south pole at the other.
➜ The field lines on the inside of a solenoid are straight.
➜ Solenoids can be used as electromagnets.
➜ Their magnetic field can be strengthened using a soft iron core.
➜ These electromagnets are used in relays, doorbells, and electronic door locks.



- Motor effect

➜ A force is exerted on a current-carrying wire in a magnetic field.
➜ The direction of the force depends on the direction of current and the direction of the

magnetic field.
➜ If the direction of one of the two is reversed, the direction of the force will reverse.
➜ If both are reversed, the direction of the force will remain the same.
➜ The force is always perpendicular to both the current and the direction of the field.
➜ The left-hand rule can be used to determine the direction of the force.
➜ Hold your left hand with the thumb, index finger, and middle finger perpendicular to each other.
➜ The thumb is in the direction of the force, the index finger is in the direction of the magnetic field, and the middle finger is in the direction of the current.

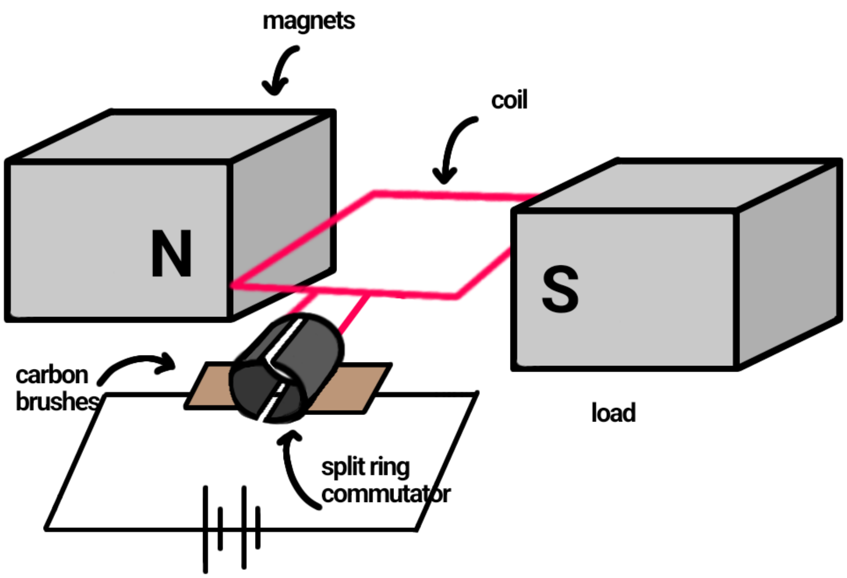


- Charged particles

➜ A charged particle will deflect when passing through a magnetic field.
➜ The moving charge forms a current, causing the deflection.
➜ The direction of the current is opposite to the flow of the negative charge.
➜ The deflection of particles can be demonstrated by a C.R.O.

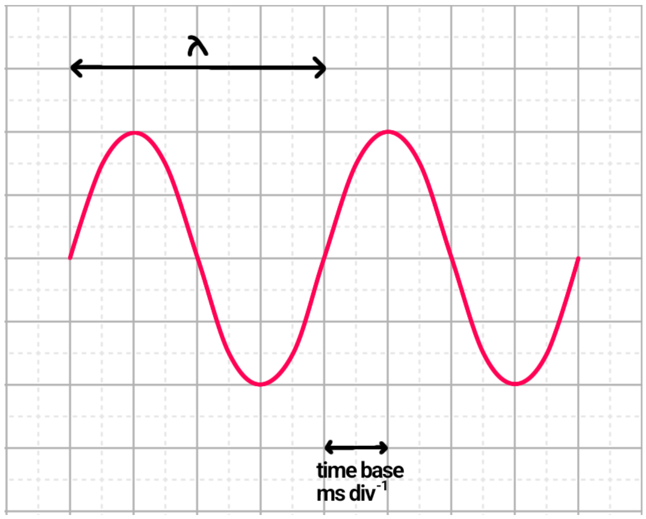
- D.C Motor

➜ A d.c motor consists of a coil in a uniform field.
➜ When current passes through the coil, it produces a turning effect.
➜ The turning effect can be increased by increasing the current, increasing the strength of the magnetic field, and/or adding more turns to the coil.
➜ As the current passes through the coil, it produces a magnetic field around the coil.
➜ The two magnetic fields interact and exert a force on the coil.
➜ One side is pushed up and one side is pulled down, causing it to rotate.
➜ A split-ring commutator is used to reverse the direction of current every half turn.
➜ The split-ring commutator allows the coil to keep rotating.



- Oscilloscope

➜ Oscilloscope is a laboratory instrument used to display, measure and analyse waveforms of electrical circuits.
➜ The x-axis (or timebase) is the time and the y-axis is the voltage (or y-gain).
➜ The period of the wave can be determined from the time-base. This is how many seconds each division represents, measured commonly in s div^{-1} or s cm^{-1}.
➜ Dividing the total time by the number of wavelengths will give the time period *T* (Time taken for one complete oscillation).
➜ The frequency is then determined through 1/T.



Section 5: Nuclear Physics

The Nuclear Atom

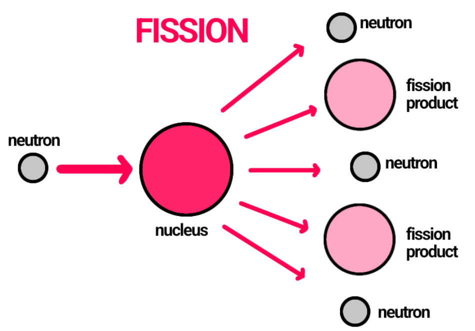
➜ Atoms are the tiniest particles with chemical properties.
➜ They consist of a nucleus with protons and neutrons and are surrounded by electrons.
➜ The protons and neutrons make up the positively-charged nucleus.
➜ Negatively charged electrons orbit the nucleus, making the overall charge neutral.
➜ Protons have a charge of +1 and a mass of 1.
➜ Neutrons have a charge of 0 and a mass of 1.
➜ Electrons have a charge of -1 and have a negligible mass of 1/1840.
➜ The mass number, or the nucleon number, is the total number of protons and neutrons in a nucleus of an atom.
➜ The proton number or the atomic number is the number of protons in an atom.
➜ The difference between the mass number and proton number gives the neutron number.
➜ In a neutral atom, the number of electrons is equal to the number of protons.
➜ A positive charge represents a loss of electrons.
➜ A negative charge represents a gain of electrons.
➜ Isotopes are different atoms of the same element with the same proton number but different neutron number.
➜ They have similar chemical properties as the number of electrons and protons are the same.

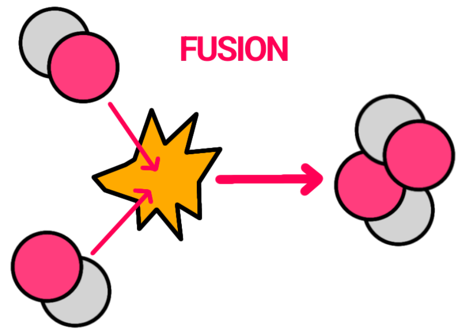
- Alpha-particle scattering experiment

➜ This experiment includes alpha particles fired at thin gold foil and a detector on the other side.
➜ Most of the particles went straight, which shows that the atom is mostly empty space.
➜ Some of them deflected, suggesting the existence of a small positive nucleus at the centre.
➜ Only a small number of particles were deflected back, showing the nucleus has most of the mass of the atom.

- Nuclear Fission and Fusion

➜ Some unstable nuclei break up in one go, known as fission.
➜ Fission requires energy which is given by hitting the nucleus with a neutron.
➜ The nucleus breaks up into two daughter nuclei along with a few neutrons.
➜ The products carry away the released energy as kinetic energy.
➜ Fusion involves the colliding of small nuclei at high speed to form larger nuclei.
➜ Fusion also releases energy.





- The Nuclear reactor

➜ A chain reaction takes place in a Nuclear reactor.
➜ The purpose of a coolant in the reactor is to remove or transfer heat.
➜The number of free neutrons in a reactor is controlled using control rods and moderators.
➜ Control rods absorb neutrons.
➜ The number of neutrons absorbed is controlled by varying the depth of the rods.
➜ Moderators are used to slow down neutrons by colliding with them.
➜ This helps to control the speed of the nuclear reaction.

Radioactivity

- Background Radiation

➜ There is some radiation always present around us in the environment.
➜ Most of it is natural, and some can be artificial, such as X-rays.
➜ It varies from place to place.

- Detecting radiation

➜ Radiation knocks out some electrons when it passes close to an atom.
➜ These atoms are ionised.
➜ Radiation detectors detect the presence of these ions to measure radiation.
➜ Geiger-Muller tube is an example of a detector.

- Alpha, Beta and Gamma particles

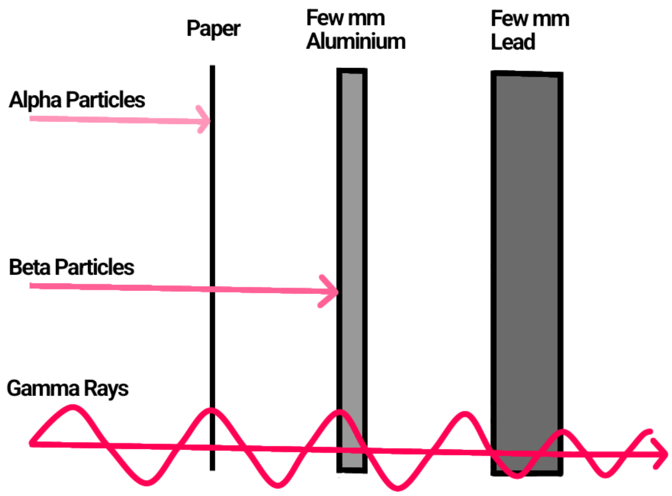
➜ Radiation consists of high-energy particles emitted from a nucleus.
➜ Alpha particles are high-energy particles made up of 2 protons and 2 neutrons.
➜ Alpha particles are the same as a helium nucleus.
➜ Beta particles are high-energy electrons.
➜ Gamma rays are high-energy electromagnetic waves.

➔ These particles can hit atoms and knock out electrons, ionising the atom.
➔ Ionisation can cause chemical changes and damage or kill living cells.

Alpha:
➔ Alpha particles have a charge of +2.
➔ They can travel a few centimetres in air.
➔ They can be stopped by a piece of paper.
➔ They have the highest ionisation ability.
➔ Low danger due to their very small range and penetration ability.
➔ When emitted, the atom loses 2 protons and a total of 4 nucleons.

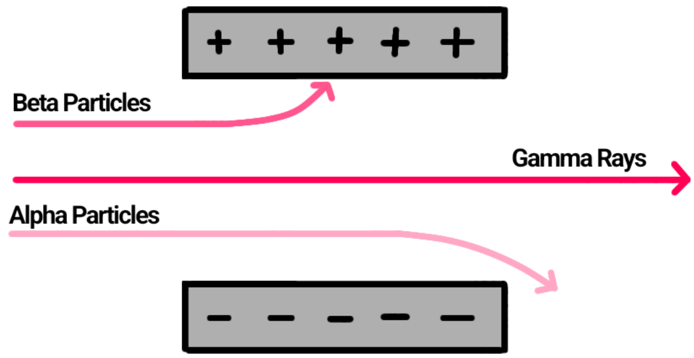
Beta:
➔ Beta particles have a charge of -1.
➔ They can travel a few 10s of centimetres in air.
➔ They can not pierce through a few millimetres of aluminium.
➔ They have medium ionisation ability.
➔ More dangerous than alpha, due to their higher penetration and range, and can kill cells.
➔ Can be used to measure the thickness of sheets by measuring the effect on the count rate.
➔ Particles gain a proton number by each beta emission.

Gamma:
➔ Gamma rays have a charge of 0.
➔ They can travel infinite distances in the air.
➔ A few centimetres of lead can reduce them
➔ They have low ionising ability.
➔ Can be hazardous due to high range and penetration.
➔ Used to sterilise medical equipment.
➔ Can be used to treat cancer.
➔ Emission of gamma ray does not affect the proton or the mass number of atom.



- Deflection

➜ In electric fields, alpha particles are slightly deflected towards the negative plate due to the positive charge; they deflect slightly because they have a mass of 4.
➜ Beta particles are attracted towards the positive plate and deflect completely as they have a charge of -1 and negligible mass.
➜ Gamma rays pass through unaffected as they have no charge.



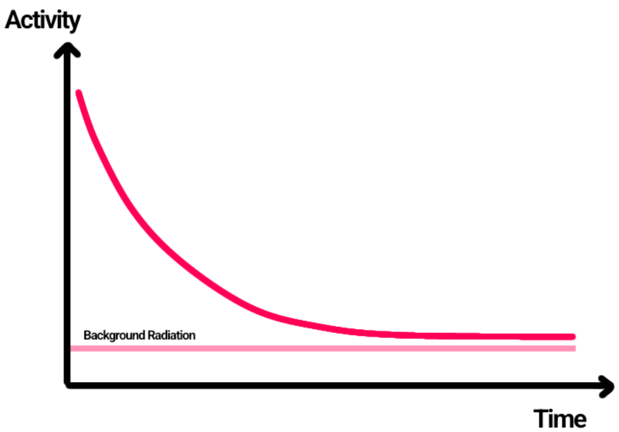
Half life and Hazards

- Half life

➜ Half-life is the time taken for the number of atoms of a radioactive isotope to half.
➜ With every half-life passing, the number of nuclei of that isotope and activity will half.
➜ Half-life varies from isotope to isotope and can be extremely short or extremely long.

- Calculations

➜ If the half-life of an isotope is given, along with the number of atoms and time of decay, find out the number of half-lives passed by dividing the time by the half-life, and half the number of atoms that many times to get the final number of atoms. If you start off with the final count, double it that many times.
➜ If you are given the initial number of atoms, the final number of atoms, and the time taken, and need to calculate the half-life, find out how many times the half-life passed by dividing the initial count by 2 till it reaches the final count, the number of times you halve it is the number of half-lives passed. Divide the time taken by this number to get the half-life of the isotope.
➜ If you need to find the time taken, get the number of half-lives passed by halving the initial count till it reaches the final count, and multiply the number with the half-life to get the time taken.
➜ If the background radiation is mentioned in the question, make sure to subtract the background radiation before doing anything else, and then carry out the required calculations and add the background radiation again at the end.



- Hazards of radiation and safety

➜ The ionisation of atoms caused by radioactive decay can cause chemical changes.
➜ It can cause cancer, mutations, or kill living cells.
➜ The radioactive sources should be stored in lead-lined boxes, away from people.
➜ It should be stored away right after use.
➜ Keep yourself away from the sources and handle with tongs.
➜ Minimise the time of exposure to radiation.

Section 6: Space Physics

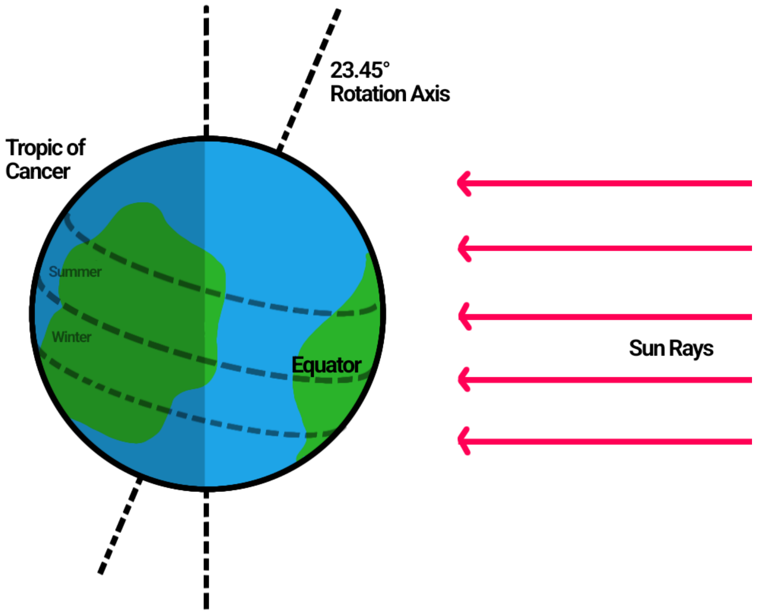
Earth and the Solar System

- The Earth

➜ The Earth is the Sun's third planet.
➜ It travels in a nearly circular, ellipse orbit around the Sun.
➜ There is an imaginary line going through the Earth's north and south poles, which is its axis.
➜ The axis is a little tilted at an angle of 23.4° from the vertical.
➜ The Earth spins on its axis like a top.
➜ Earth's spinning on its axis is called **rotation.**
➜ It takes 24 hours to turn all the way around its axis (completing one full rotation), hence, a single **day.**
➜ It orbits the Sun and takes approximately 365 days (a **year**) to travel around the orbit.
➜ The Moon orbits the Earth as a satellite.
➜ The motion of the Earth and the Moon cause natural events.
➜ It takes approximately 500s for light from the Sun to reach the Earth.

- Day and night

➜ Since the Earth is rotating on its axis, one half of it is always facing the Sun.
➜ The other half is facing away from the Sun.
➜ The side of the Earth facing the Sun experiences daytime.
➜ The other half away from the Sun has night.



➜ In an **equinox,** the Sun rises **exactly** at the East and sets exactly at the West.

➜ An equinox means ‘equal night’, meaning that the day’s length and the night’s length is the same.
➜ It usually occurs on 20th March and 23rd September.
➜ In the northern hemisphere, during summer, the Sun rises north of east and sets north of west.
➜ During winter, it rises and sets north of these points respectively.
➜ It's highest above the horizon at noon.
➜ In the northern hemisphere, the daylight hours are longest until 21st June.

- Seasons

➜ The Earth’s movement around the Sun (its orbit) and **its tilt** cause seasons.
➜ Due to this tilt, one part of the Earth leans away from the Sun.
➜ Consequently, the solar energy from the Sun reaching the Earth is not constant, but varies throughout the year.
➜ Summer and winter occur simultaneously on Earth’s surface.
➜ When the northern hemisphere is tilted towards the Sun, there is spring and summer - days are longer than nights.
➜ When the southern hemisphere is tilted away from the Sun, there’s autumn and winter - days are shorter than nights.
➜ This cycle continues vice versa throughout the year.

- The Moon and its phases

➜ The Moon is lit by the Sun.
➜ It doesn’t produce its own light.
➜ The Sun gives off light and the Moon reflects it, so we’re able to see it.
➜ It takes one month for the Moon to orbit the Earth.
➜ It revolves on its own axis, so it always has the same side of it facing the Earth.
➜ The Moon’s appearance changes over each month’s course; it has **phases.**

- The new moon phase

➜ The Moon is between the Earth and the Sun.
➜ The sunlight is on the opposite side of the Moon.
➜ This side isn’t visible from Earth.

- The waxing crescent

➜ A thin crescent appears as the Moon travels in its orbit.
➜ It’s partially illuminated by the Sun’s rays.
➜ More of the Sun’s rays are reflected off the Moon towards the Earth.

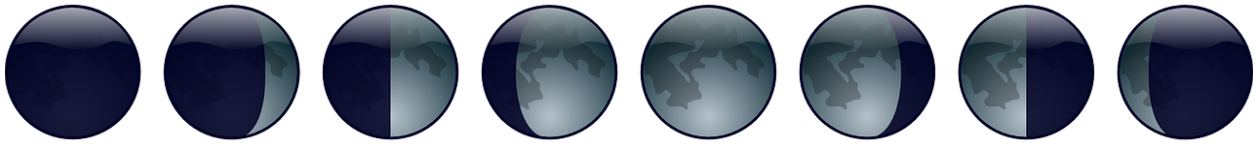
- First quarter

➜ Half of the Moon’s surface can be seen.

- Full Moon

➜ The Earth is between the Moon and the Sun.
➜ The Sun's rays are reflected fully back to the Earth.
➜ It's seen as fully lit from Earth.

➜ After this, the Moon slowly starts waning and we see less of its surface until we can see the old crescent again.

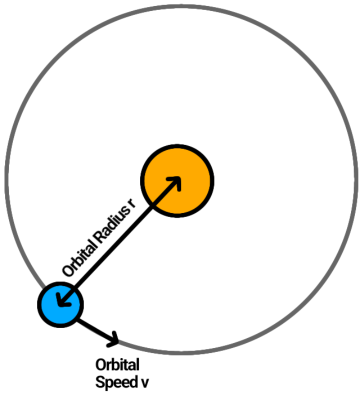


- Average orbital speed

➜ The formula for average orbital speed is:
$v = 2\pi r/T$, where:

$$v = \frac{\text{circumference of orbit}}{T} = \frac{2\pi r}{T}$$

v = average orbital speed
r = average radius of the orbit
T = time taken to complete one orbit (orbital period)
Always measure the orbit radius r from the centre of the object being orbited to the orbiting object.



The Solar System

- The Solar System contains

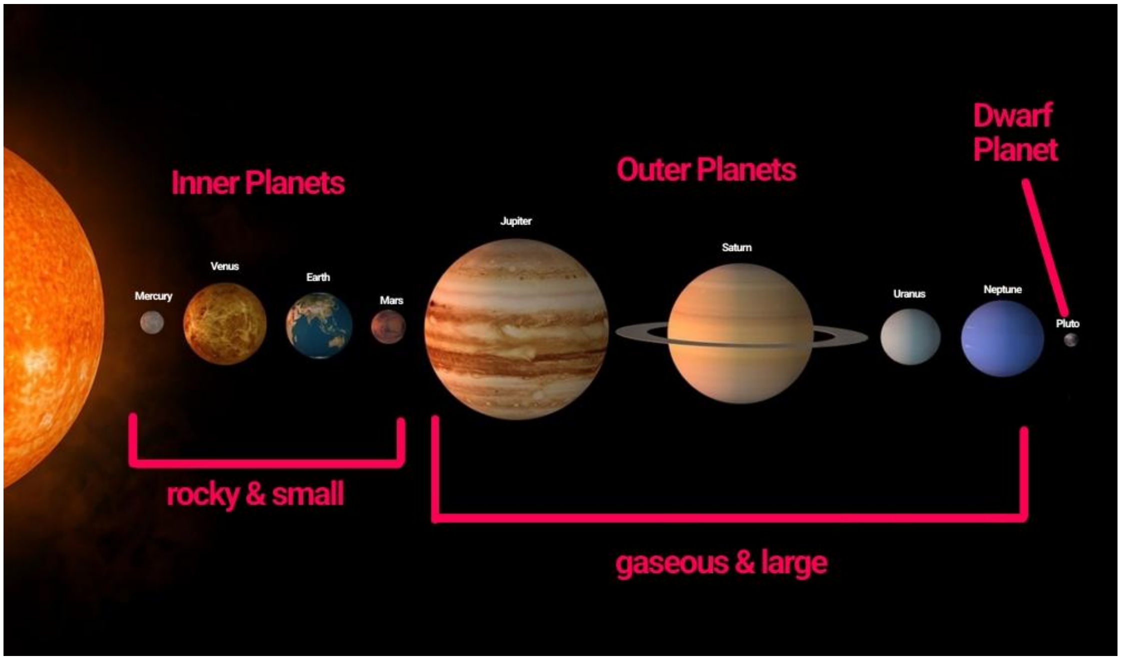
➜ One star, the Sun.
➜ The eight planets.
➜ Asteroids and dwarf planets, also known as minor planets.
➜ Moons, which orbit planets.
➜ Comets and natural satellites.

- Satellites

➜ Objects that orbit a planet.
➜ The Sun is a star and produces its own light.
➜ It is not at the centre of the **elliptical** orbit, but just at one focus of the orbit.
➜ An elliptical orbit means it isn't a perfect circle.
➜ It only sits at the centre of a planet's orbit if it's approximately circular.
➜ The more elliptical orbit of a planet, the less that the Sun will sit at the centre of the orbit.
➜ The order of the 8 planets are:

Mercury, **V**enus, **E**arth, **M**ars, **J**upiter, **U**ranus, **N**eptune.

➜ The four **inner** planets (Mercury, Venus, Earth and Mars) are nearest to the Sun.
➜ They're rocky and small with a high density and similar sizes.
➜ The four **outer** planets (Jupiter, Saturn, Uranus and Neptune) are further away from the Sun.
➜ They're gaseous, large and comparatively colder.



- Dwarf Planets

➜ These have high densities.
➜ Mainly composed of rock and ice.
➜ The best known of them is Pluto.
➜ They are too small to be counted as a major planet.

- Asteroids

➜ Also known as **minor planets.**
➜ A body orbiting a star, the mass of which is not large enough to be pulled into a sphere by gravity.
➜ Their density is similar to that of the inner planets.
➜ If they enter the Earth's atmosphere, they fall as shooting stars or meteors into Earth.
➜ The asteroid belt lies between Mars and Jupiter.

- Comets

➜ Consist of dust and ice made of water and methane.
➜ Have very elliptical orbits.
➜ Density is similar to that of the outer planets.
➜ Often travel to the very outskirts of the solar system.

- Accretion model

➜ There was a vast cloud of hydrogen, helium, and dust (nebulae).
➜ Nearby, a hot star burned up its fuel and destroyed itself.
➜ This explosion is a supernova.
➜ The supernova caused the nebula to collapse.
➜ Due to gravity, the nebula flattened into an exploding disc.
➜ In the disc's centre, a protostar revs up.
➜ This protostar then went through nuclear fusion, ignited and expanded.
➜ As a result, it became our Sun.
➜ Material in the nebula that wasn't absorbed by the Sun swirled around in a rotating disc of dust and gas.
➜ It was held in orbit by the Sun's high gravitational attraction.
➜ This disk is called the **accretion disk.**

➜ Gases rotating around a star lead to the formation of orbiting planets.
➜ It explains the range of elements in rocky planets.
➜ Each planet began as microscopic grains of dust in the accretion disk.
➜ The atoms and molecules in it stuck together and they formed balls and then objects
➜ These objects were large enough to attract other objects by gravity.
➜ Whilst the planets were forming, the Sun sent out energy and particles known as the stellar winds.
➜ It would have been too hot for light molecules like hydrogen, helium, water, and methane to exist in a solid state in the region of space, where the inner planets were forming

➜ As a result, the inner planets are made of materials with high melting points, like metals (including iron) and silicates.
➜ Due to this, Mercury, Venus, Earth and Mars are smaller and rocky.
➜ The four outer planets were so far away from the Sun that these stellars winds couldn't blow away their ice and gases.
➜ In the Solar System's cooler regions, further from the Sun, light molecules may exist as solid ice.
➜ Because the light elements are more common than the heavier ones, the outer planets could grow big enough to absorb even the lightest element: hydrogen.
➜ Hence, they're gaseous and large.
➜ They're made up of lighter elements e.g. hydrogen, as the Sun's gravity pulls heavier elements of the original accretion disc to the Sun's surface.

- Calculating travel times

➜ The time it takes light to travel a significant distance:
➜ total time = total distance/speed

- Gravitational field strength

➜ The strength of a planet's gravitational field at its surface depends on its mass.
e.g. Jupiter's gravitational field strength will be higher compared to the Earth's gravitational field, because Jupiter's mass is larger (**not** in terms of size, but mass).
➜ It is nearly constant across its surface.
➜ As one gets away from the planet, gravitational field strength weakens.
➜ Increasing the distance decreases the gravitational field strength.
➜ The Sun has the largest mass in our solar system and therefore has the largest gravitational field strength, which explains why all celestial bodies orbit it.
➜ The majority of the solar system's mass is in the Sun.
➜ The strength of the gravitational field there is stronger than that of the gravitational field on the surfaces of the planets.

➜ **Gravitational attraction:** the force that keeps an object in orbit around the Sun.
➜ **Atmosphere:** the envelope of gases surrounding a planet.
➜ **Surface temperature:** the temperature of the air near the planet's surface.

- Analysing and interpreting planetary data

➜ The following are tables for the Sun, Earth, Moon and other planets.
➜ This data indicates factors that affect conditions on the surface of the planets and environmental problems that a visit (using manned spaceships or robots) would encounter.
➜ You don't need to memorise it, but you should carefully analyse it to see if there's any trend between the values
➜ e.g. if a value increases whilst the other one decreases, and then develop this analysis with what you've already learnt about the topic.

▼ **Table 6.1.1** Data for the Sun, Earth and Moon

	Mass/kg	Radius/m	Density kg/m³	Surface gravity /N/kg	Orbital duration
Sun	2.0×10^{30}	7.0×10^{8}	1410	274	
Earth	6.0×10^{24}	6.4×10^{6}	5520	9.8	365 days (around Sun)
Moon	7.4×10^{22}	1.7×10^{6}	3340	1.7	27 days (around Earth)

▼ **Table 6.1.2** Data for the planets

Planet	Av distance from Sun /million km	Orbit time round sun /days or years	Surface temperature /°C	Density /kg/m³	Diameter /10^3 km	Mass /10^{24} kg	Surface gravity /N/kg	No. of moons
Mercury	57.9	88 d	350	5427	4.8	0.330	3.7	0
Venus	108.2	225 d	460	5243	12.1	4.87	8.9	0
Earth	149.6	365 d	20	5514	12.8	5.97	9.8	1
Mars	227.9	687 d	−23	3933	6.8	0.642	3.7	2
Jupiter	778.6	11.9 y	−120	1326	143	1898	23.1	79
Saturn	1433.5	29.5 y	−180	687	120	568	9.0	82
Uranus	2872.5	84 y	−210	1271	51	86.8	8.7	27
Neptune	4495.1	165 y	−220	1638	50	102	11.0	14

➜ The greater the distance the longer it takes for a year to complete.
➜ This is because as we move further away from the Sun, the size of the orbit around it increases.
➜ The orbital speed decreases with distance from the Sun.
➜ Neptune travels slower than Mercury due to greater distance from the Sun.
➜ Objects farther from the Sun move slower due to a weaker gravitational pull.
➜ Surface temperature decreases with the distance from the Sun **except** for Venus.
➜ Venus has a hot atmosphere of carbon dioxide gas and a high surface temperature.
➜ Mars has longer seasons than Earth due to:
- its axis being tilted at 24°
- its distance from the Sun is longer

➜ The first 4 planets have heavier elements, thus increasing their density.

- Orbits and the Conservation of Energy

➜ As a comet orbits the Sun, its orbit's radius increases as it moves further away from the Sun.
➜ A comet travels the fastest when it's the closest to the Sun.
➜ Its speed decreases as it moves away from the Sun.

Stars and the Universe

- The Sun

➜ Medium-sized star.
➜ Mainly contains hydrogen and helium.
➜ Emits radiant energy.
➜ This radiation is given off by glowing hydrogen which is heated by the Sun's nuclear reactions.

➜ It radiates most of its energy in the infrared, visible and ultraviolet regions of the electromagnetic spectrum.

- Nuclear fusion in stars

➜ Stars are powered by nuclear reactions which release energy.
➜ **Stable stars** are hot and dense enough in the centre (core) for nuclear fusion to occur.
➜ This hot temperature in their centre is required for nuclear fusion.
➜ The energy that nuclear fusion releases maintains the temperature at their core.
➜ Some of the heat from the core is transferred to the star's outer layer.
➜ This transferred energy is relatively cooler and less dense, but it's enough to make the hydrogen gas glow and give off electromagnetic radiation into space.
➜ White and blue stars are hotter and brighter than the others.
➜ Surface temperature: 6000 to 25 000°C.
➜ Red or yellow ones are the coolest.
➜ Surface temperature: 3000 to 6000°C.

Stars

- Basics

➜ Galaxies are each made up of many billions of stars.
➜ The Sun is a star in the Milky Way galaxy.
➜ Other stars that make up the Milky Way are much further away from the Earth than the Sun is from the Earth.
➜ **Light-year:** the distance travelled in a vacuum by light in one year.
One light-year = 9.5×10^{12} km = 9.5×10^{15}m

- The life cycle of a star

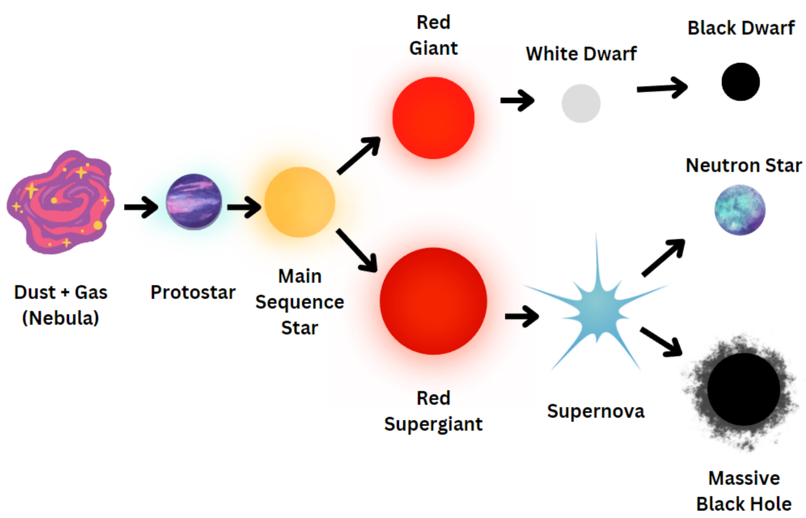
➜ It starts with a big cloud of dust and gas (nebula) containing hydrogen.
➜ Overtime, the attractive force of gravity pulls the dust together and forms a **protostar.**
➜ As more and more particles collide and join the protostar, it gets bigger and bigger.
➜ Therefore, its force of gravity gets stronger, which allows it to attract more dust and gas.
➜ The gravity squeezes the protostar, which causes the particles to collide more, and make it denser.
➜ This increases the temperature of the protostar.
➜ When the temperature's high enough, nuclear fusion occurs.
➜ The outward pressure, caused by nuclear fusion, and the inward pressure, caused by gravity, are perfectly balanced.
➜ This thermal pressure arises from the kinetic energy of the nuclei.
➜ The star is stable due to the balance.
➜ At this point, it's a **main sequence star.**
➜ At some point, the star will start to run out of hydrogen as fuel for the nuclear fusion
➜ The inward pressure contracts the star into a small ball, until it's so hot that nuclear fusion can start again, causing it to expand again.

➜ Potential energy is transferred to kinetic energy, so the core becomes hotter.
➜ What will happen next depends on the size of the star at the beginning.

If it was a small/medium star, it'll expand into a red giant:
➜ The remaining hydrogen gets burned and the star turns into a red giant.
➜ Shortly afterwards, the red giant becomes unstable and expels its outer layers.
➜ This leaves behind a planetary nebula with a hot, dense, white dwarf at its centre.
➜ Nuclear fusion doesn't occur in the white dwarf.
➜ Overtime, the white dwarf gets cooler and darker as it emits all of its energy.
➜ It transitions into a black dwarf, which can't give off light.

If it was a truly massive star, it'll explode and expand into a red supergiant:
➜ Red supergiants star shining brightly again due to more nuclear fusion and eventually explode into a supernova.
➜ A supernova forms a nebula of elements even heavier than iron, with a neutron star at its ➜ centre.
➜ If the star was absolutely massive, it'll collapse on itself and become a black hole.
➜ Black Holes are so dense that their gravity pulls in any light that passes nearby.
➜ The nebula from a supernova may form new stars with orbiting planets.

Life Cycle of Stars



- The Universe

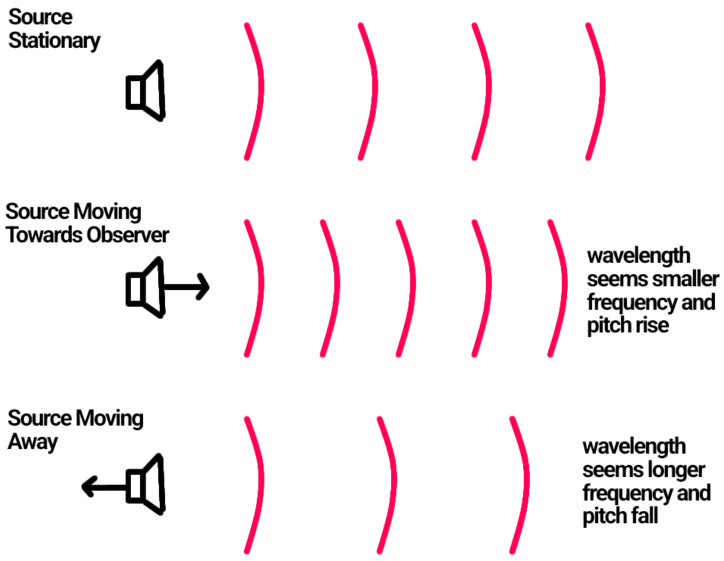
➜ The Milky Way is one of the billions of galaxies making up the Universe.
➜ Its diameter is 100,000 light years.

- The Big Bang Theory

The Big Bang Theory states that:
➜ If the universe is currently expanding, it must have been smaller in the past.
➜ Initially, the universe was densely packed.
➜ The universe was formed 14 billion years ago from one place with a massive explosion (the Big Bang).
➜ It started to expand after that and still continues to.

- Redshift and the Doppler Effect

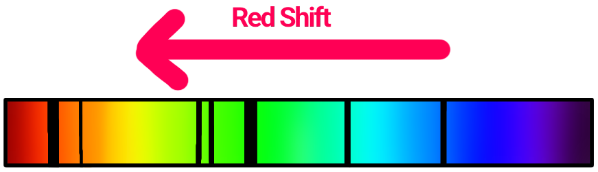
➜ In sound, a wavelength defines its pitch.
➜ The shorter the wavelength is, the higher the pitch. The longer it is, the lower the pitch.
➜ When a police car gets closer to you, the sound waves get compressed and become shorter, causing the pitch to rise so its sirens sound more high-pitched.
➜ When it passes you, the sound waves get longer, lowering the pitch so it sounds more far off and distant. This is the **doppler effect.**



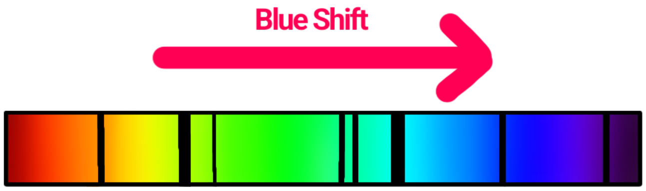
➜ The same phenomenon occurs in the case of light..
➜ When an objec heads towards you, the wavelength of the wave it emits gets shorter. In that case, we say it's blue shifted.
➜ As it heads away from you, the wavelength gets longer and it's redshifted.
➜ If you apply that to a spectrum, you can measure that shift to see if an object is moving toward or away from you.
➜ In the electromagnetic spectrum, the red end of the spectrum has a longer wavelength, and the blue-violetish end has a shorter wavelength.

➜ Wave being emitted by an object heading towards you gets **blue**-shifted (gets a **shorter** wavelength). Wave being emitted by an object heading away from you, gets **red-**shifted (gets a **longer** wavelength).

➜ In the diagram here, we can see that the black lines are moving towards the red end of this absorption spectrum shown. This depicts the object moving away.



➜ Over here though, the black lines are more towards the blue end. This shows us that the object is moving towards the observer.



➜ If the object is stationary (in this case we'll relate it to space, hence the 'object' is a galaxy), then the black lines will be evenly distributed toward both ends:

➜ When we analyse light from distant galaxies, its waves get stretched hence the light stretches to the red end of the spectrum.
➜ This process of the light shifting to the red end of the spectrum is redshift.
➜ The light waves get stretched when they reach the Earth.
➜ That's because the space between Earth and the galaxies which are giving off/emitting light are expanding.
➜ Because of the distance, we end up further away from the galaxy and the light waves get stretched.
➜ The galaxies aren't travelling away from us through space, the space between Earth and the galaxy is expanding.

- Evidence supporting the Big Bang Theory

➜ If it wouldn't have been expanding, then the light waves would stay exactly the same to Earth too as they travel from galaxies.

Redshift:
➜ The increase in the observed wavelength of electromagnetic radiation emitted from receding stars and galaxies

IGCSE ONLY

- Cosmic background microwave radiation (CMBR)

➜ The Big Bang produced a radiation energy which still exists in the Universe.
➜ It was produced shortly after the Universe was formed.
➜ It exists in the form of CMBR.
➜ It's present in all corners of the universe.
➜ Initially, it was high energy radiation towards the gamma end of the spectrum.
➜ As the universe expanded more and more, it expanded into the microwave region of the electromagnetic spectrum.
➜ It's present everywhere in the form of background radiation.
➜ It has maximum intensity at a wavelength of 1.1mm.

- Evidence for the Big Bang Theory

➜ Because of it being so evenly distributed at all points of the universe, it became evident that it's because the universe is expanding.

Recessional velocity:
➜ The velocity at which something moves away from the observer.

- Hubble's law

➜ Hubble's law states that recessional velocity is proportional to its distance from the Earth.
➜ It can be written as: $v = H_0/d$, where:
v = recessional velocity (km s^{-1})
H_0 = Hubble's constant (km s^{-1} Mpc^{-1})
d = distance between the object and the Earth (Mpc)
recessional velocity = Hubble's constant x distance away
➜ Edwin Hubble discovered that the further a galaxy is away, the faster it's moving away from us.
➜ Hubble constant isn't actually constant; it keeps changing because it represents the **current** rate of expansion.
➜ Its current agreed value is: 2.2×10^{-18} per second.
➜ H_0 is defined as the ratio of the speed at which the galaxy is moving away from the Earth to its distance from the Earth.

- The age of the universe

➜ The equation:
$d/v = 1/H_0$
represents the estimated age of the universe ever since the Big Bang, where:
d = distance
v = recessional velocity
➜ This is evidence that all the matter in the Universe used to exist at a single point.

A Note from Mojza

These notes for Physics (5054/0625) have been prepared by Team Mojza, covering the content for GCE O levels and IGCSE 2023-25 syllabus. The content of these notes has been prepared with utmost care. We apologise for any issues overlooked; factual, grammatical or otherwise. We hope that you benefit from these and find them useful towards achieving your goals for your Cambridge examinations.

If you find any issues within these notes or have any feedback, please contact us at support@mojza.org.

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