Motion

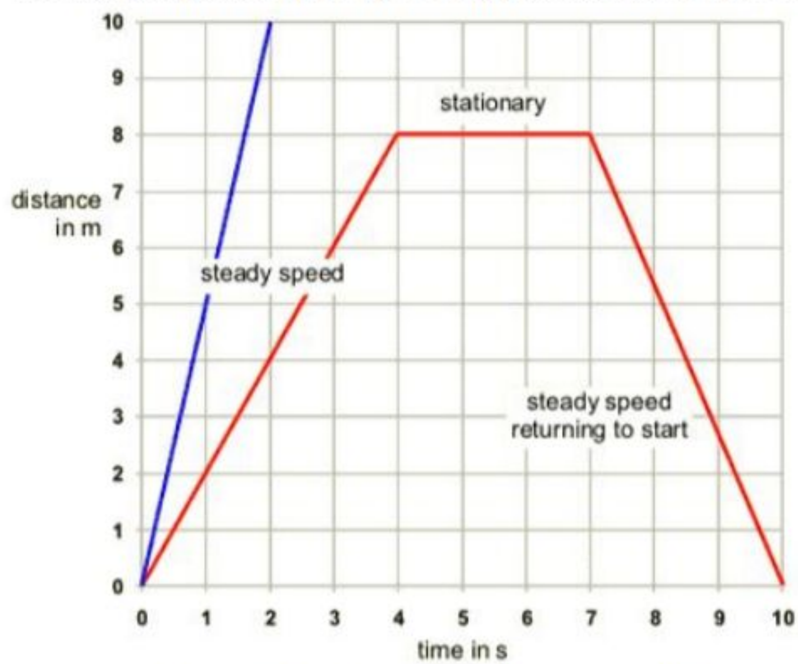
Distance-time and Speed-time Graphs

You need to know how to interpret **distance-time graphs** and **speed-time graphs.**

Distance-time graph

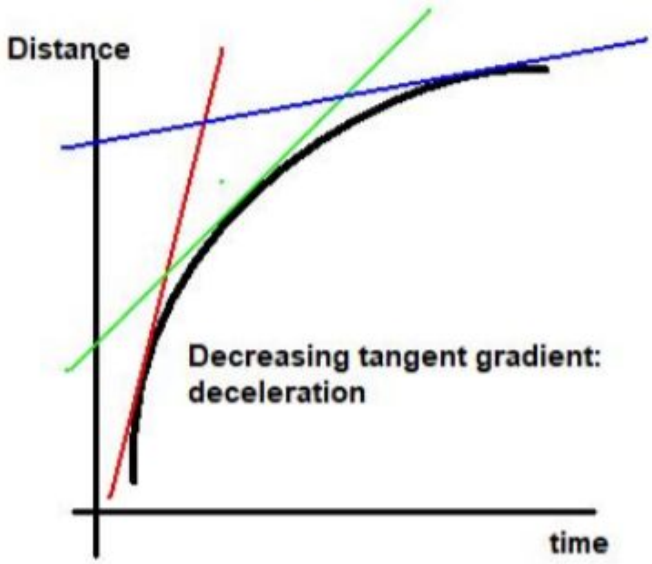
- Time is plotted on the x axis
- **Displacement** from the starting point in plotted against the y-axis,
    - This means at y value of 0, the object is at the starting point

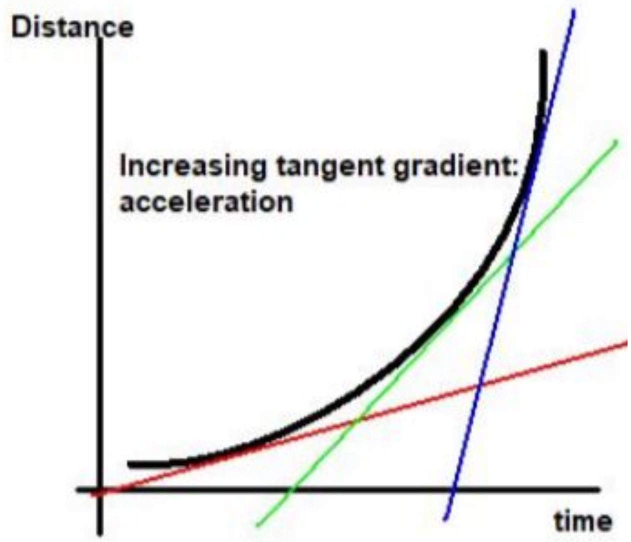
- The **gradient** of the graph, is calculated by **rise over run**, which is **distance / time.**
    - **This is the formula for speed, so: Gradient of a distance-time graph = speed of the object**
        - This means the gradient, the speed can be positive or negative (meaning it is a velocity)
            - Where positive is the forwards direction, and negative is the backwards direction
            - Meaning **negative speed (velocity)** means the **reverse direction**



- The steepness of the gradient also tells us the value of the velocity
    - Steeper the gradient, higher the value, so: **Steeper gradient = faster speed**
- The gradient tells us the speed, so what if the **gradient is 0**?
    - This means **no speed**, which means the object is **not moving (stationary)**.

- **A curved gradient**, instead of a straight line, means there is non-constant velocity
  - Velocity is changing which **means: there is acceleration (or deceleration)**

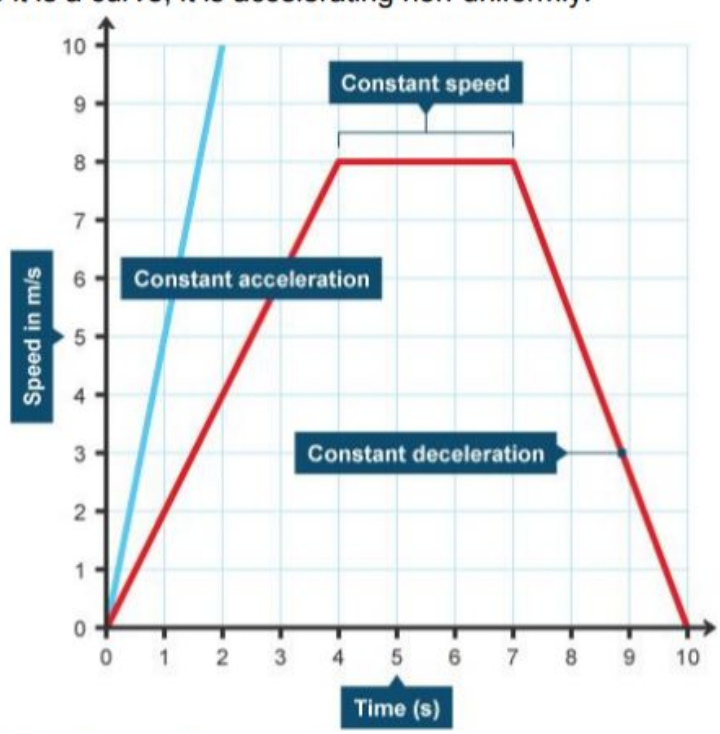




<u>**Speed-time graph**</u>

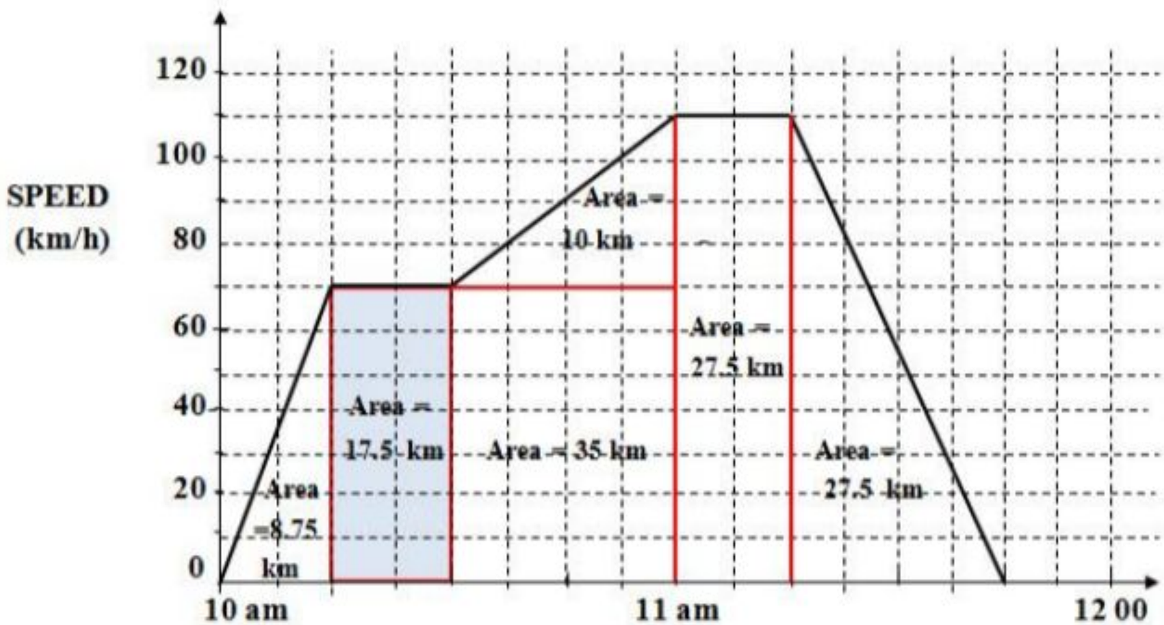
- Time is plotted on the x axis
- **Speed** of the object is plotted against the y-axis,
  - This means at y value of 0, the object is at speed 0m/s.

- The **gradient** of the graph, is calculated by **rise over run**, which is **speed / time.**
  - **Which is formula for acceleration: gradient of a speed-time graph = acceleration of the object**
    - This means the gradient, the acceleration can be positive or negative.
      - Where positive is the acceleration, and negative is the deceleration.
    - Again, the acceleration is constant if the gradient is straight,
      - If it is a curve, it is accelerating non-uniformly.



- Same as the distance time graph, steeper gradient means faster acceleration.
- However, a gradient of 0 **does not mean stationary**, it means **constant velocity**
  - Because there is **no acceleration.**

- We can find the **total distance** travelled from a speed-time graph by
  - **finding the area underneath the graph**.
- To the find area, we would need to multiply velocity by time, and this means
  - **velocity x time = distance.**



Check if you can

- Define speed and calculate average speed from: total distance / total time
- Distinguish between speed and velocity.
- Recognise linear motion for which the acceleration is constant and calculate the acceleration.
- Recognise motion for which the acceleration is not constant.
- Demonstrate a qualitative understanding that acceleration is related to changing speed.
- Plot and interpret a speed-time graph and a distance-time graph.
- Recognise from the shape of a speed-time graph when a body is:
  - at rest
  - moving with constant speed
  - moving with changing speed.
- Calculate the area under a speed-time graph to work out the distance travelled for motion with constant acceleration.

Energy, Work, and Power

You need to know what energy, work, and power is, and the units for energy and power.

Energy, E is **the capacity to perform work.**

- Energy is measured in units of **joules (J)**
- There are many different types of energy
  - They can either be **stored** energies or **"moving" active** energies.
- Energy can **neither** be created **nor** destroyed; rather, it can be **transformed** from one form to another.
  - This is the **Law of Conservation of Energy**

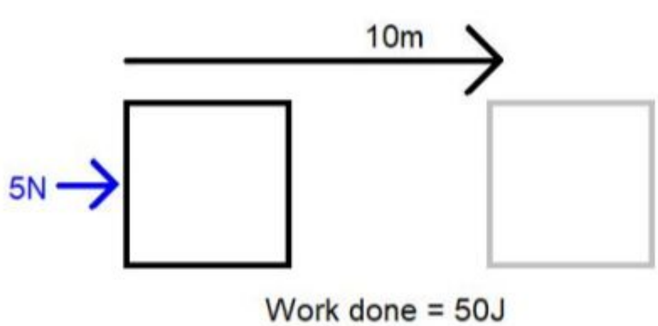
Type of Energy	State	Description	Found in / Uses
Kinetic (KE)	Moving	Energy in moving objects, a.k.a movement energy	All moving objects have KE
Gravitational Potential (GPE)	Stored	Energy stored in objects raised from the ground	All objects above ground have KE
Sound	Moving	Energy released by vibrating objects	Microphone, voice, etc
Thermal (Heat)	Moving	Energy of vibrating particles in an object	All objects at temperature above 0K
Electrical	Moving	Energy in moving or static electric charges	Electronic device, nervous system
Light	Moving	Only visible form of energy, part of the ER spectrum.	Vision, laser beams
Elastic Potential	Stored	Energy stored in stretched or squashed objects	Springs, rubber bands
Chemical	Stored	Energy stored in molecular bonds	Stored in food, fuels, and batteries
Nuclear	Stored	Energy stored in the nuclei of atoms	Nuclear reactor

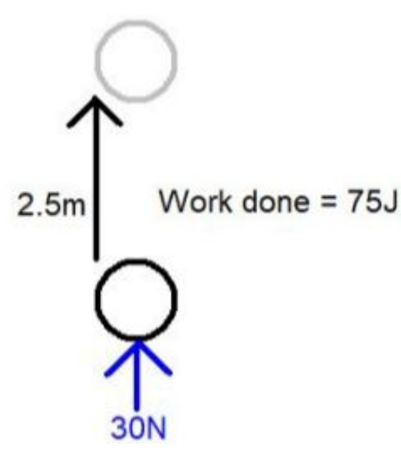
Work is done when a **force is applied to an object to move it through a distance**

- When work is done, energy is transferred
- So the unit of work is also joules, J.

To calculate work done, use the formula:

- The force and the distance moved must be in the **same direction**
  - **Work done = force x distance**
  - **W = F x d**
  - J = N x m
- **1 joule is the energy transferred by a force of 1 newton when it moves through a distance of 1 metre**





Power is the rate of doing work (Work done per unit time or energy transferred per unit time)

- **Power = work done ÷ time taken**
- **P = W ÷ t**
- W = J ÷ s

The unit of power is the **watt (W),** and it is equivalent to **J/s**

- **A power of 1 watt means that 1 joule of energy is being transferred every second**

Energy Transformations

You need to know energy transformations in simple systems.

According to the Law of Conservation of Energy:

- Energy can **neither** be created **nor** destroyed; rather, it can be **transformed** from one form to another.

When there is an energy transformation, there is an **input energy** and an **output energy.**

- Input energy ---transformation--> output energy

For the output energy, there is **useful energy**, which is what we want to use, and **waste energy.**

- For example, in a light bulb,
    - The goal is to convert **electrical energy** into **light energy**
    - **Electrical energy is the input energy, and light energy is the useful output energy**
    - However, a light bulb will also produce **heat energy which is the waste energy.**
- Not all 100% of the input energy is transformed into output energy.

You need to know what efficiency is, and how to calculate efficiency.

Efficiency is the **percentage ratio of useful output energy to total input energy**

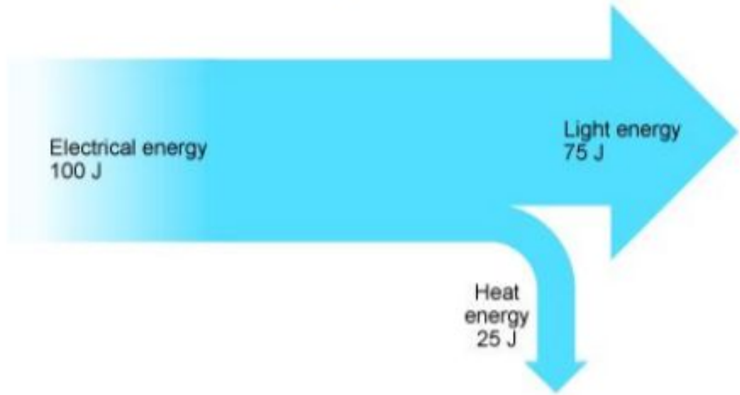
- **(Useful Energy ÷ Input Energy) x 100% = Efficiency**

No device has an energy transformation of 100% efficiency

e.g. 5000J of electrical energy is put through a light bulb and 3500J of light energy is emitted,

- what is the bulbs efficiency?
- (Useful Energy ÷ Input Energy) x 100% = Efficiency
- (3500/5000) x 100% = **70% efficiency.**

Sankey diagrams are a way to show energy transformations, along with efficiency.
- They look like arrows, with input energy coming from the **left**
- Useful energy continues straight on to the **right**, whereas the waste energy curves off **downwards.**
- The thicknesses of the arrows show the percentages.



Filament Lamp :
- Electrical -> **Light**, Heat

Television :
- Electrical -> **Light, Sound**, Heat

Microphone to amplifier:
- Sound -> **Electrical** -> **Sound**, Heat

Car:
- Chemical -> **Kinetic**, Heat, Sound

A man jumping off a cliff:
- Gravitational Potential -> **Kinetic** -> Sound, Heat

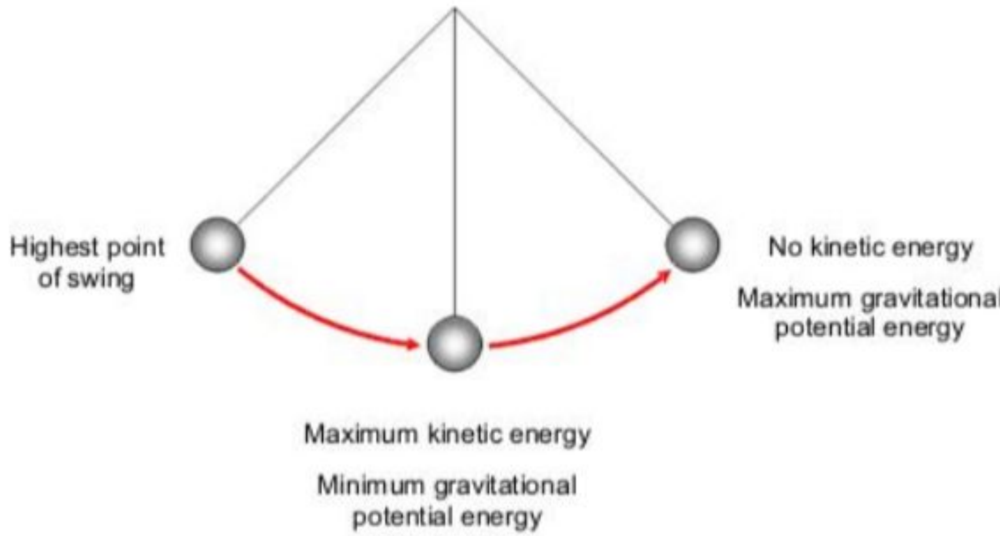
MP3 Player with screen:
- Chemical -> **Electrical** -> **Sound, Light**, Heat

Coal Power Station:
- Chemical -> **Heat** -> **Kinetic** -> **Electrical,** Heat

Nuclear Power Station:
- Nuclear -> **Heat** -> **Kinetic** -> **Electrical,** Heat

Pendulum:

- **Gravitational Potential** -> **Kinetic,** Heat -> **Gravitational Potential** -> **Kinetic,** Heat -> etc..



Kinetic Energy (K.E.)

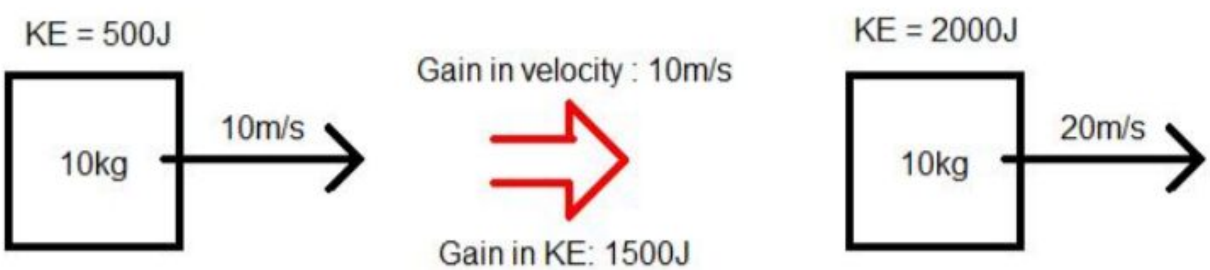
You should be able to calculate kinetic energies of moving objects.

An object possesses a certain amount of kinetic energy at a certain speed.

- **KE = $\frac{1}{2}mv^2$**
- **Kinetic Energy = ½ x mass x $(\text{velocity})^2$**

From this we can see that the **kinetic energy is dependant on both the mass and velocity** of the object

- Doubling the mass doubles the kinetic energy
- Doubling the velocity **quadruples** the kinetic energy.

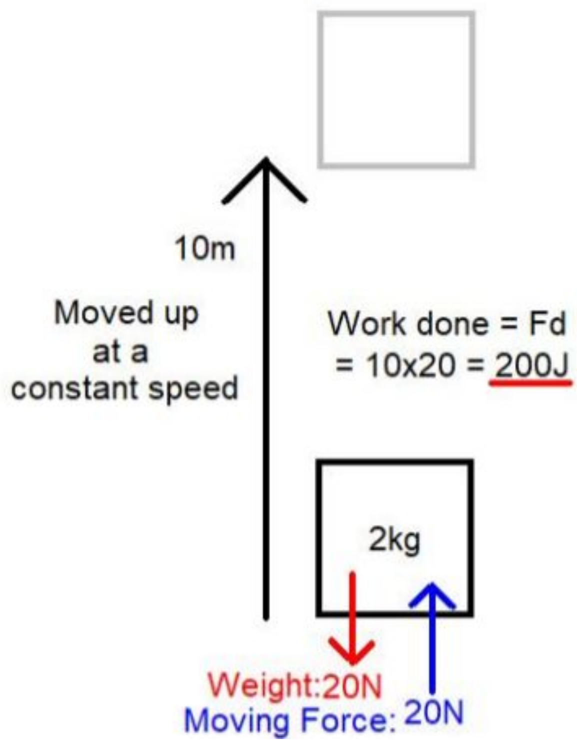


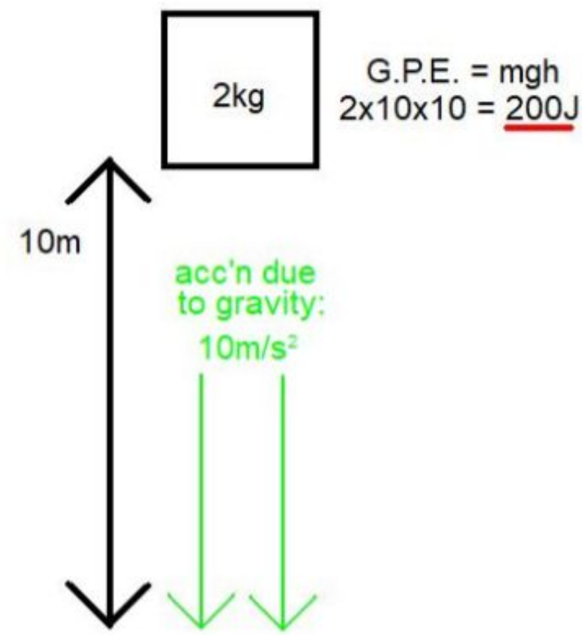
Gravitational Potential Energy (G.P.E.)

You should be able to calculate gravitational potential energies of objects.

Gravitational potential energy is the stored energy possessed by an object by its position in a gravitational field.

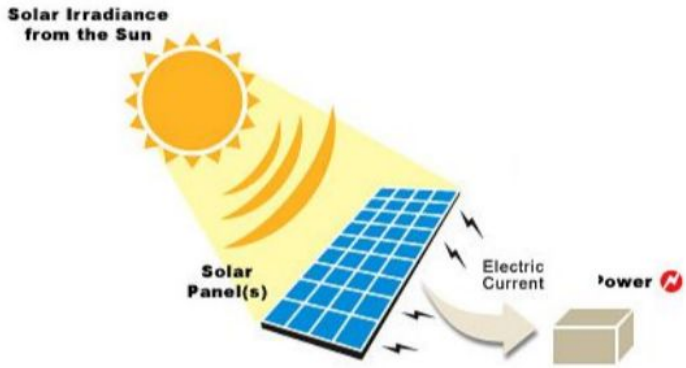
- It is calculated by:
    - **GPE = mgh**
    - **Gravitational Potential Energy = mass x gravity**(acc'n due to gravity) **x height**
        - For acceleration due to gravity, we take the rounded value $10m/s^2$ (rather than 9.81)
- It is also equal to the energy that is required to move the object against gravity to that position.





Solar

- Two methods:
  - Using the light energy from the sun
    - Solar panels containing photovoltaic cells convert light energy into electrical energy
  - Using the heat energy from the sun to turn water into steam and turn turbines to generate electricity.



You neec

Humans I

- **C** **nuclear.**

Fossil fu

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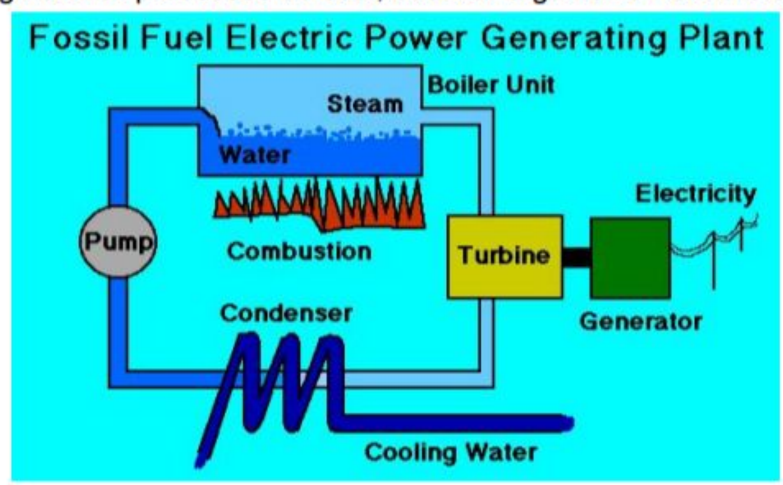
Oil & Natural Gas

- Formed through similar processes as coal, but with organisms from the sea.



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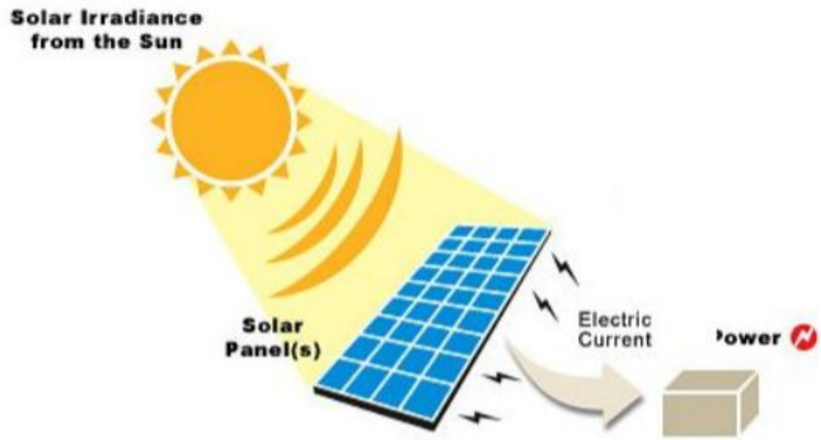
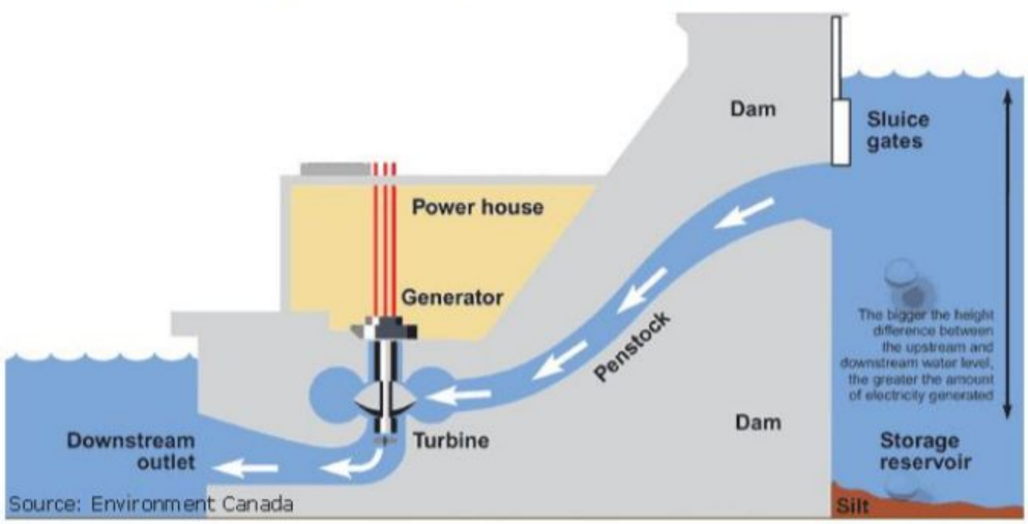


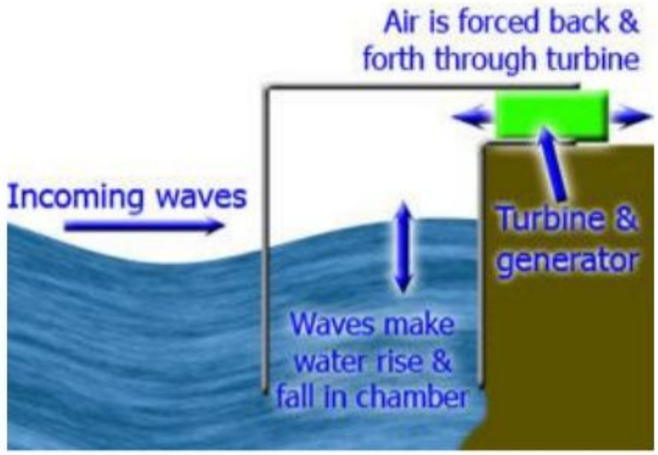
Hydroelectricity

- Water is stored at a height in a reservoir by a dam.
- The water is released from height, so the GPE of water is converted into kinetic energy.
- Water turns turbines as it is dropped down to generate electricity.



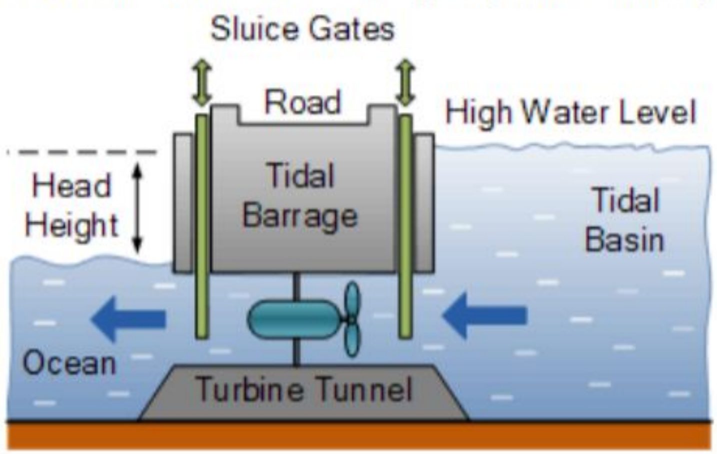
Wave

- Wind of the sea creates waves.
- Turbine- like devices on the surface of the water convert kinetic energy of the waves into electrical energy.

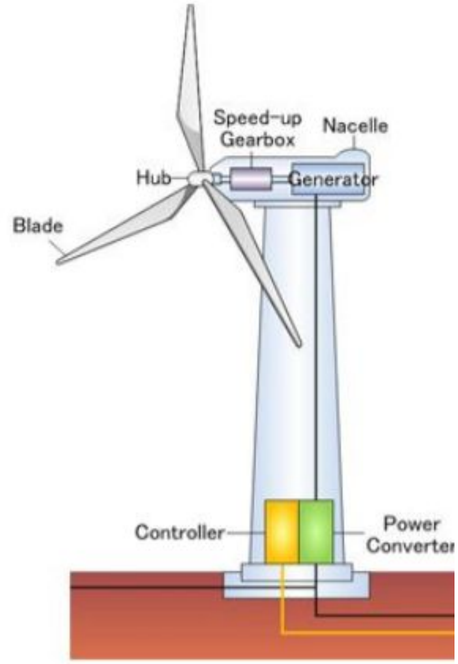


Tidal

- A barrage is built across an estuary.
- The gravity of the sun and the moon causes the oceanic water to move as tides
- THe water moves in and out of the turbines in the barrage to produce electricity.

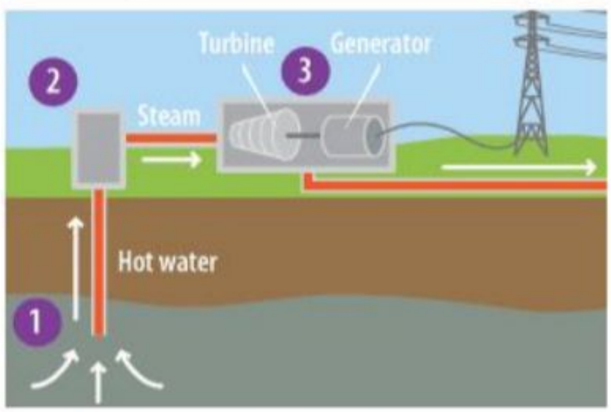


Wind
- Wind turbines high up in the air are turned by the force from the wind.
- Turbines are connected to electrical generators used to produce electricity.



Biomass
- Energy from living organisms or their waste.
- Wood from trees, ethanol fermented from sugar canes, cow dung, methane from landfill sites etc.
    - Can be burned like fuel.

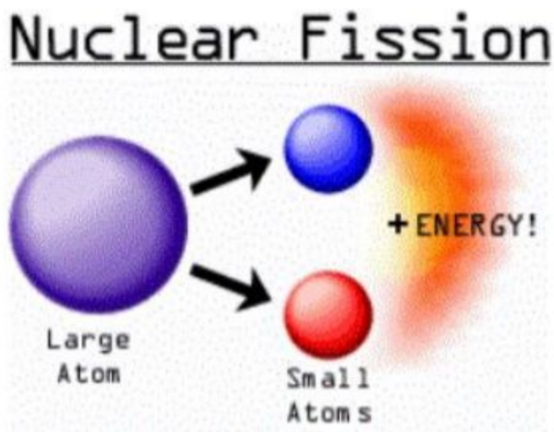
Geothermal
- Heat from the Earth occurs at plate boundaries or where the crust is thin.
    - Or can dig into the Earth closer to the heat.
- Heat is either used directly for heating, or used to heat water into steam and turn turbines for electricity.

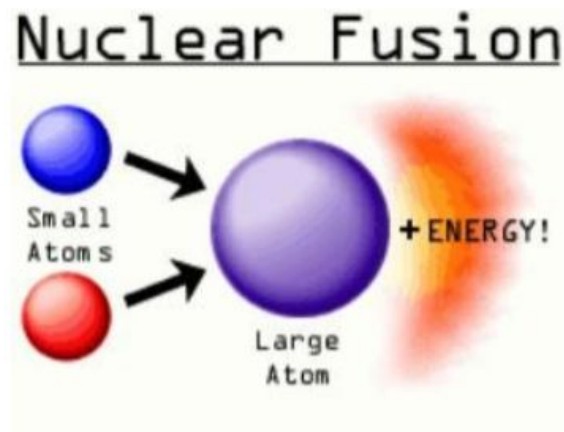


Nuclear

- Energy stored in the nucleus of unstable isotopes of elements.

- **Nuclear Fission**
    - The nucleus is hit with a particle and it splits (fission) releasing vast amounts of energy
- **Nuclear Fusion**
    - Nuclei are combined, and this fusion releases vast amounts of energy
    - This requires extreme environments, like the sun, where two hydrogen nuclei are fused into helium
        - This is how the sun is powered.





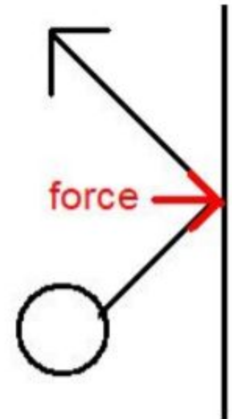
You need to know the difference between renewable and nonrenewable resources.

- **Renewable sources**
    - Will **effectively** last forever (will not run out)
    - Can be renewed (make more of the source)
- **Non-renewable sources**
    - Will run out at some point
    - Cannot be renewed in a reasonable time span.

- The 11 energy resources can be sorted into either of the two categories.

Renewable	**Non-renewable**
Solar	**Coal**
Hydroelectricity	**Oil**
Wave	**Natural Gas**
Tidal	**Nuclear**
Wind	
Biomass	
Geothermal	

Temperature and Pressure



You need to know temperature and pressure of gases

Temperature and **heat** are different quantities.

- **Heat** is a form of energy *(from Unit P3.1)*
- **Temperature** is a measure of the average speed of the particles in a substance
    - This means as the gas particles gain more kinetic energy, they will move faster.
    - Faster average speed means higher temperature of the gas.

Pressure, from Unit P2, is **force/area**.

- For a gas, this is the same, where:
    - The force is: **total force of all the collisions of the particles against the walls of the container.**
    - The area is : **the total surface area of the inner walls of the container in contact with the gas**.

Temperature and **pressure** are a gas's important properties along with volume and mass.

- They are important factors in calculations with gases.

The Gaw Laws

You need to know the three gas laws.

- Gas laws are connected by the properties of a gas. **Temperature, pressure, volume, and mass.**
    - In the 3folloing three **gas laws,**
        - Mass of gas is **always constant.**
        - One other property is **kept constant**,
        - One of the properties is **changed**.
        - And the **effect of that change** in the remaining property is **measured**.

Gay-Lussac's Law (or pressure law)

- For a fixed mass of gas at a constant volume, an **increase** in temperature **increases** the pressure.
- **Constant volume**, **increase in temperature**, **increase in pressure.**
    - **Pressure is directly proportional to temperature.**
    - **$p \propto T$,** or putting in a *constant of proportionality, k,* to make it an equation,
    - **$p = kT$,** which we commonly express as **$p/T = k$**
- This equation shows that for any fixed mass of gas, **p/T equals a constant.**

- As **temperature increases**,
    - The particles move faster, so they will collide with the walls **more often**
    - The particles have more kinetic energy, so they will collide with the walls with **more force.**
- Both of these observations lead to the conclusion:
    - As temperature increases, the pressure of the gas increases (if volume is constant)

Boyle's Law

- For a fixed mass of gas at a constant temperature, an **increase** in pressure **decreases** the volume.
- **Constant temperature**, **increase in pressure**, **decrease in volume.**
    - **Volume is inversely proportional to pressure**
    - **$V \propto 1/p$,** or putting in a *constant of proportionality, k,* to make it an equation,
    - **$V = k/p$,** which we commonly express as **$pV = k$**
- This equation shows that for any fixed mass of gas, **pV equals a constant.**
    - Also since this is for a fixed mass of gas, we can also say **$p_1V_1 = p_2V_2 = k$**
    - Where p_1V_1 is the pressure and volume before, and p_2V_2 is the pressure and volume after.
    - e.g. **Q**. A balloon rises through the atmosphere. On the ground, at 1 atmospheric pressure, it has a volume of $30cm^3$. It travels up until the pressure is 0.3 atmospheres, what is the new volume of the balloon?
        - $p_1V_1 = p_2V_2$
        - $1atm \times 30cm^3 = 0.3atm \times \mathbf{V_2}$
        - $\mathbf{V_2} = (1 \times 30) / 0.3 =$ **$100cm^3$**

Charles' Law

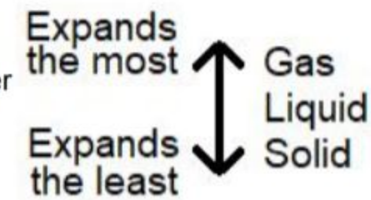
- For a fixed mass of gas at a constant pressure, an **increase** in temperature **increases** the volume.
- **Constant pressure**, **increase in temperature**, **increase in volume.**
    - **Volume is directly proportional to temperature**
    - **$V \propto T$** or putting in a *constant of proportionality, k,* to make it an equation,
    - **$V = kT$,** which we commonly express as **$V/T = k$**
- When you increase the temperature, the particles gain more energy and move faster and further apart.
    - This makes the gas occupy more volume.

Thermal Expansion

You need to know thermal expansions for solids, liquids, and gases, and their applications.

Thermal expansion
- When a material is **heated,** the particles vibrate and move faster
  - The particles **move further away** from each other.
  - If they all move further away from each other, they **occupy more space**
    - Meaning, they **expand in volume**

All materials expand, whether they are solids, liquids, or gases.
- However, they all expand by different amounts
  - Gases expand the most,
    - because they have the least amount of force holding them together
    - They also already have a lot of energy, so it is easier
  - Solids expand the least,
    - because they are tightly bound by the intermolecular force.



Charles' Law of the gas laws relates to thermal expansion of gases.

State	Useful applications of thermal expansion	Problems with thermal expansion
Solid	Heat-sensored triggers (bimetallic strip),	Bridge, roads, rails (under expansions they can break)
Liquid	Thermometer	Rising sea level
Gas	Hot-air balloon	

Thermal Capacity

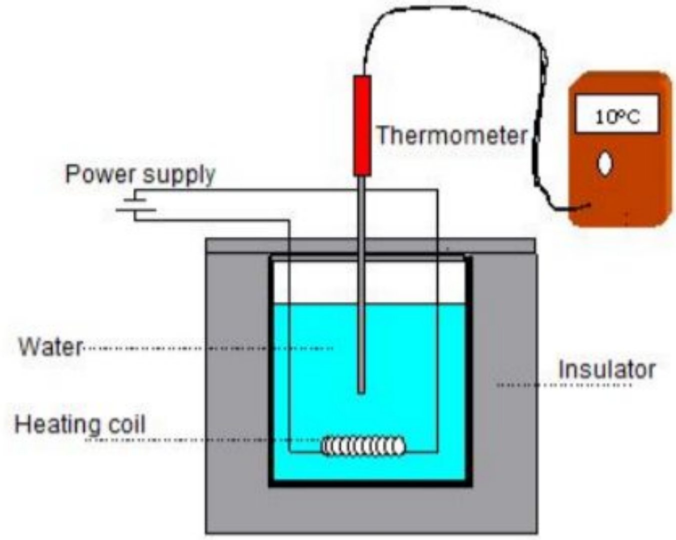
You need to know that **specific heat capacity** for a substance is:
- **The energy needed to raise the temperature of 1kg of the substance through 1°C.**

  - **Energy = mass x specific heat capacity x change in temperature**
  - $\mathbf{E} = \mathbf{m} \times \mathbf{c} \times \mathbf{\Delta t}$ **($E = mc\Delta t$)**
  - $J = kg \times J/kg°C \times °C$

Higher the specific heat capacity of a substance, more energy it needs to raise its temperature.
- For example, copper has the s.h.c. of 385 J/kg°C, whereas water has 4184 J/kg°C
- This shows **water has an extremely high specific heat capacity**
  - This is good for regulating temperature,
  - because it shows water is not easily affected by change of temperature in the environment.

You need to know how to experimentally find **specific heat capacity**.

- To find the specific heat capacity, we need to know:
    - Energy input
    - Change in temperature
    - Mass of the substance



1. Measure the volume of water ($1cm^3$ = 1g of water)
2. Measure the temperature at the beginning
3. Turn on the power and measure the power output
4. Measure the time of heating
    - (Power x time of heating = energy)
5. At the end of heating, measure the final temperature
6. Use the values to calculate.

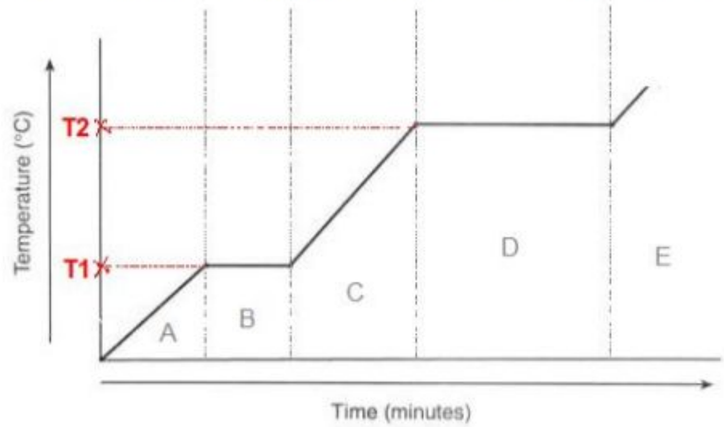
Start Temp	End Temp	Change in Temp	Mass of water	Power	Time of heating	Energy
25°C	50°C	35°C	0.2kg	250W	120s	30000J

- Energy = mass x specific heat capacity x change in temperature
- 30000 = 0.2 x s.h.c. x 25
    - Experimental value of s.h.c = 6000 J/kg°C
    - Real value is 4184 J/kg°C: the values are different because the experiment may have lost heat etc.

Heating and Cooling Curves

You need to know changes of state in terms of specific temperatures, **melting point** and **boiling point**.
You need to know latent heats of fusion and vaporisation.

In a **heating curve**, a substance is being heated, and the temperature is recorded on the y axis, against x, time.

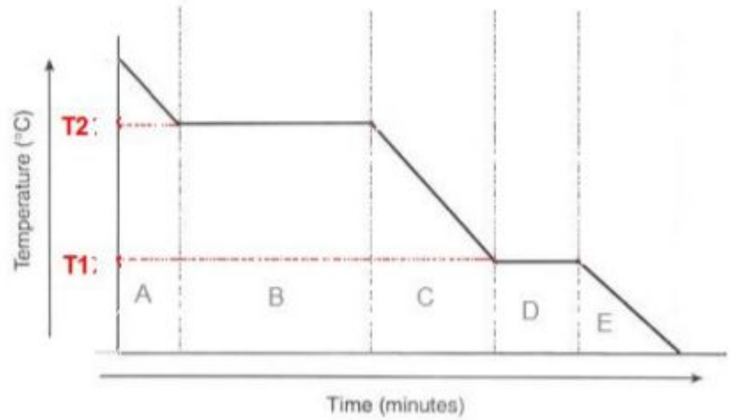


The curve shows important thermal properties of substances The graph has been divided into 5 areas.

- **A** : The substance is at **solid state**.
  - The energy input is being used to **raise the temperature -** Heat is converted to kinetic energy.
- **B** : The substance is **changing state from solid to liquid - is melting**
  - The energy input is **not** used to raise the temperature - so there is **no temperature increase**
    - **The temperature is constant at the melting point** (**T1** on graph)
  - The energy input is used to **break the forces of attraction** between the particles
    - The total energy input during this time is called **latent heat of fusion**
- **C** : The substance is at **liquid state**
  - The energy input is being used to **raise the temperature,** just like in area A
- **D** : The substance is **changing state from liquid to gas - is boiling**
  - The energy input is **not** used to raise the temperature - so there is **no temperature increase**
    - **The temperature constant at the boiling point** (**T2** on graph)
  - The total energy input during this time is called **latent heat of vaporisation**
    - Note that heat of vaporisation is **much more than** heat of fusion
      - Because the particles must be completely free of each other to be in gas.
      - Whereas in liquids, they are still very close together

- **E** : The substance is at **gaseous state**
    - The energy input is being used to **raise the temperature,** just like in area A and C

A **cooling curve** is exactly like a heating curve, except the other way around. Gas to liquid to solid.



And we can see that T2 is the condensation point, which is the same temperature as the boiling point, And that T1 is the freezing point which is the same temperature as the melting point.

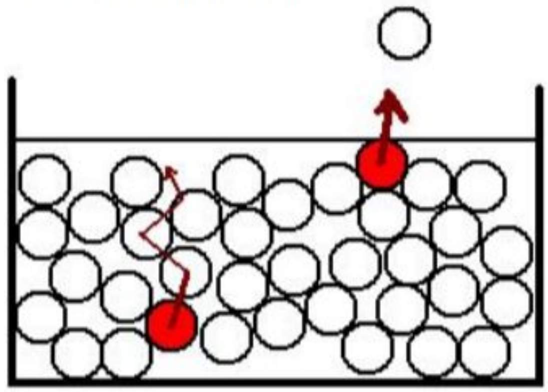
Evaporation

You need to know the process of evaporation, and the factors that affect evaporation.

Evaporation is **not the same** as boiling.

- Both are processes that change state from **liquid to gas.**
- **However they are not the same.**
    - Boiling occurs at the **boiling point of the liquid**
    - Evaporation **below the boiling point of the liquid**

- During **boiling,** all the particles have enough energy to break away from each other as a gas.
  - when the temperature reaches the boiling point.
- At evaporation, only some of the particles have enough energy to escape.
  - In a liquid, the temperature was said to be the average speed
    - "Average" means some particles will be at energies above the boiling point, and some below.
    - A particle will evaporate if they:
      - Have **high enough energy to escape the liquid**
      - Are **at the surface** of the liquid



  - If the particle is not at the surface, it will lose energy as it moves up the liquid.
    - And when it eventually reaches the surface, it won't have enough energy to evaporate.

- And when particles with high energy escape the liquid,
  - **average of speed of the remaining particles decrease** (as only the low energy particles are left)
    - Meaning the **temperature of the liquid decreases**
  - This shows the effect of cooling by evaporation,
    - This how sweat cools down the body, by evaporating and taking the heat away from the body.

Three factors affect evaporation:
- **Temperature**
  - Obviously, as the temperature increases, more particles will have high enough energy to escape
  - **As temperature increases, rate of evaporation increases**
- **Surface area of the liquid**
  - Larger surface area means the high-energy particles have more probability of being at the surface.
  - **As surface area increases, rate of evaporation increases**

- **Air movement**
  - Sometimes, the escaped particle has lost so much energy that it can fall back into the liquid.
    - This is reversing the evaporation process, so it will decrease the overall rate of evaporation.
  - A good flow of air **removes** the already-escaped particles, preventing it from falling back.
    - **As air movement increases, rate of evaporation increases**

Methods of Heat Transfer

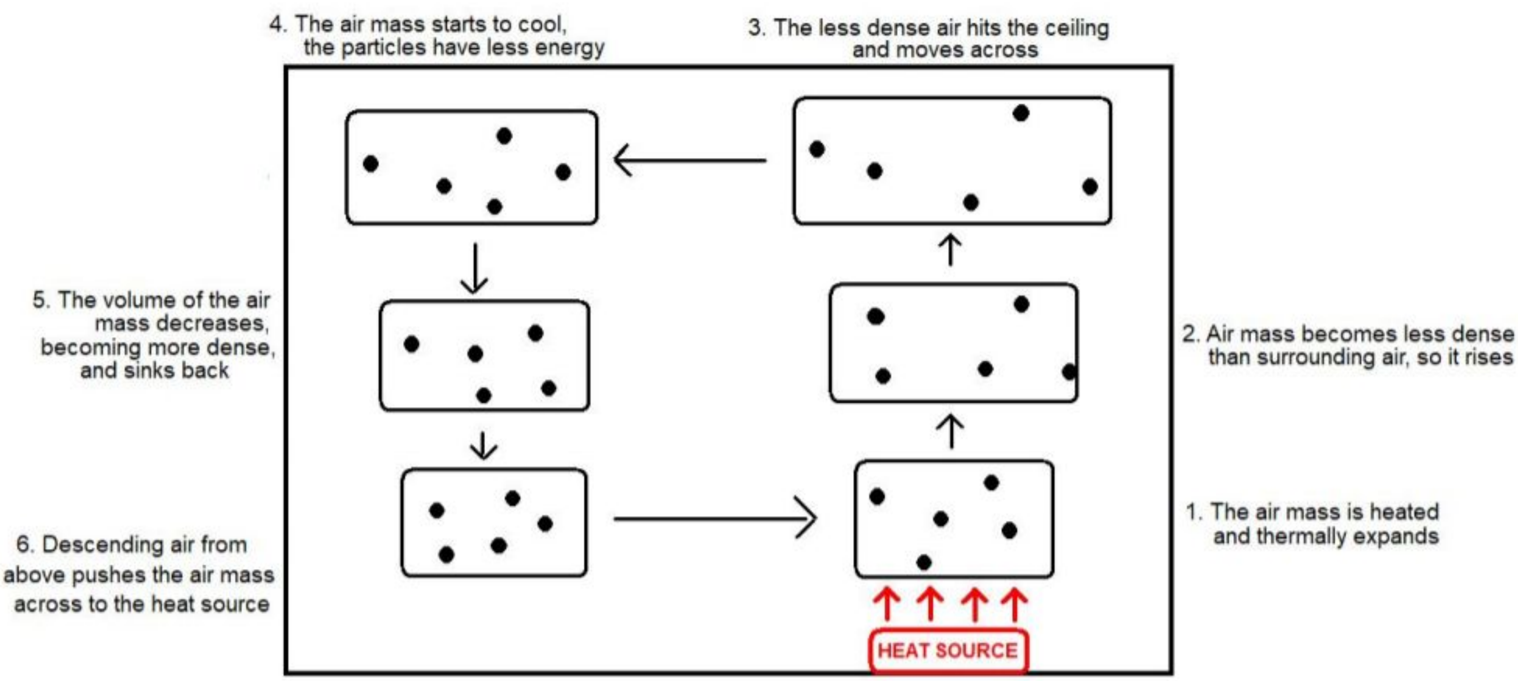
Convection

- This is occurs in fluids. - liquids and gases. **Not in solids.**

- Convection occurs by fluids changing density because of thermal expansion.
    - Take a 'pocket of air' with five particles as an example.
    - It thermally expands, occupying more volume - but the number of particles, hence the mass, is same.
        - This means the **density of the heated (expanded) gas is lower.**

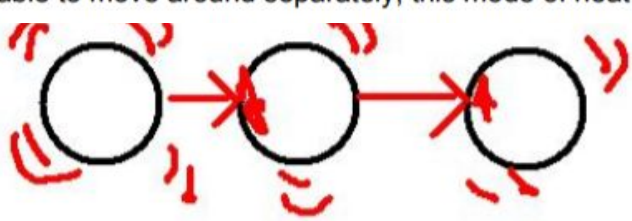
Conduction

- In a room with a heater, we can see 'convection current' cycles occurring because of the change in densities.



- The process is the same in a liquid, but except with 'pockets' of liquid particles

- As the particles must be able to move around separately, this mode of heat transfer is not possible in solids.



- Conduction is the main mode of heat transfer in solids because
    - In solids, the particles are close together, so collision is easy to happen.
- If it was a gas, the particles would be so far away from each other that they would not often collide.

- Some substances conduct heat better than others, they are called **good conductors** of heat
    - Like most metals.

- Some substances conduct heat poorly, and they are called **insulators** of heat
    - Like wood and styrofoam

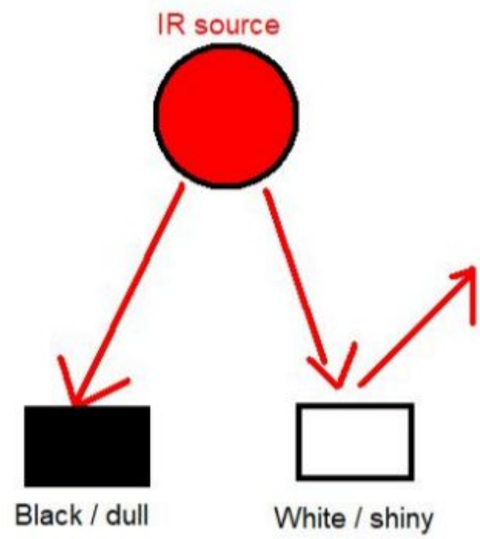
Radiation

- Radiation is a method of heat transfer through **infra-red** (IR) radiation *(more on Unit P9).*

- **Infrared** radiation an electromagnetic wave, meaning:
    - It travels at the speed of light (300,000,000m/s)
    - It **does not need a medium** to travel through (like light)
        - It does not need particles (like conduction) to transfer energy.
        - This is how the sun transfers heat energy to Earth,
            - Space is a vacuum, it cannot be through conduction or convection.

- All objects emit infrared radiation
    - And if hit by the radiation, the heat energy is **absorbed.**
    - Some substances can **reflect** IR radiation
    - And some are better **emitters** of IR radiation than others.

	Reflect	**Absorb**	**Emit**
White / shiny	Good	Bad	Bad
Black / dull	Bad	Good	Good



For example, if two cans were painted white and black,
and hot water of was put into both cans under the same conditions,
the black can would emit more heat, and therefore lose **cool down faster**

Type of heat transfer	**Applications**
Conduction	Heating up a frying pan, touching a hot surface
Convection	Heating a room with a heater, sub-oceanic currents
Infrared radiation	Heat from a light bulb, heat from the sun

Waves

You need to know a wave is:

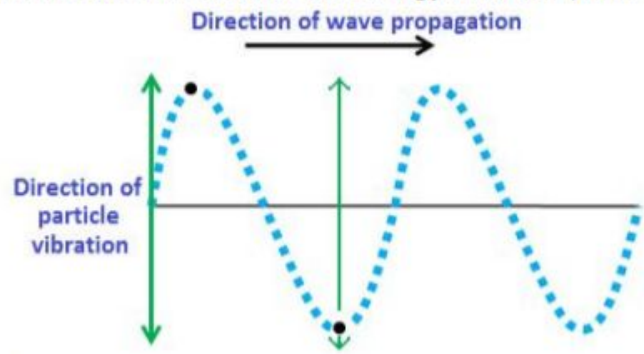
- **A method of transmission of energy without transferring matter in the direction of wave travel.**

Waves transfer energy through **vibrations of particles**.

- There are **two types** of waves, depending on the direction of the vibration of the particle.
    - **Transverse waves** and **longitudinal waves**.

Transverse waves

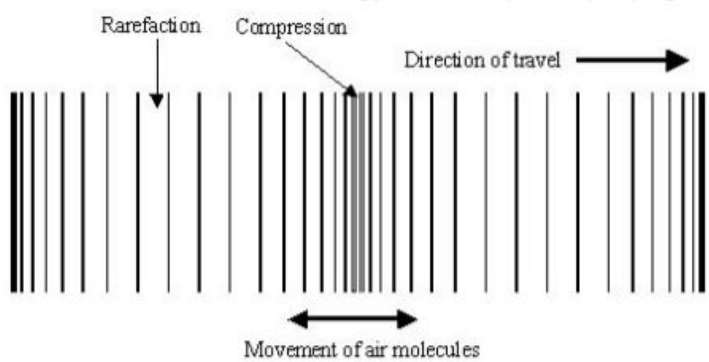
- Particles move **perpendicular** to the direction of the energy transfer (wave propagation).



- Transverse waves include light, radio waves, water waves.

Longitudinal waves

- Particles move **parallel** to the direction of the energy transfer (wave propagation).



- The area where the molecules are close together in an instant is called **compression**
- The area where the molecules are far apart in an instant is called **rarefaction** (pronounced rare-re-faction)

- Longitudinal waves include sound waves, seismic waves, and waves in compressed spring.

Some waves, like sound waves and water waves require a **medium:**

- **A medium** is the material which the wave travels through

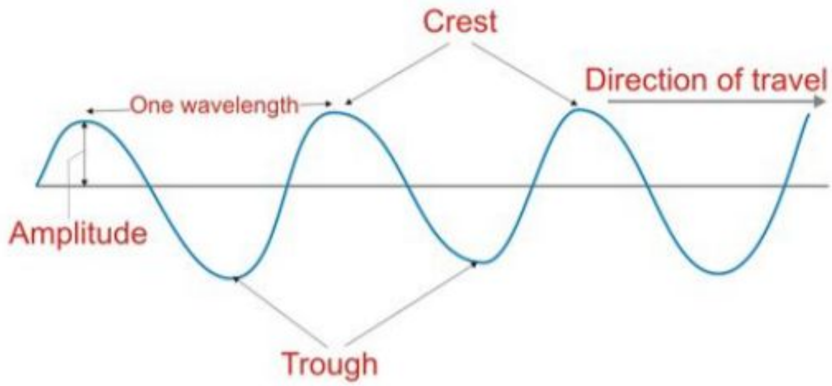
Without a medium, these waves cannot propagate since there are no molecules to vibrate.

However, some waves, like electromagnetic waves including **light** and radiowaves, can travel **without a medium**.

- This is why only electromagnetic waves can travel through space, and not sound
- In space there is a vacuum, so only waves that do not need a medium can travel

Wave Properties

You need to know what **amplitude**, **wavelength**, **frequency**, and **velocity** of a wave means.

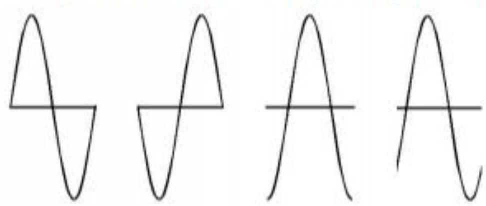


A **crest** is the highest point of a wave, and a **trough** is the lowest point of a wave.

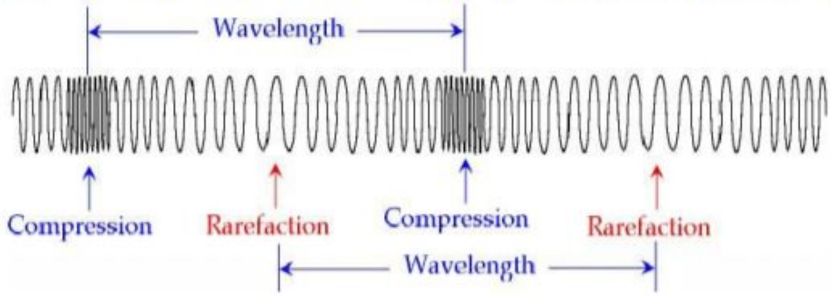
Amplitude : the maximum displacement of the particle from its "zero" position.
- Which means it is the distance from the "zero" middle line to either the crest of the trough.

- Amplitude in a sound wave determines the **volume.** Higher amplitude means a higher volume.

Wavelength : **the distance from one point on a wave to the same point on the next wave**
- usually denoted by the greek letter delta **(λ)**
- which is equal to the distance from one **trough** to next, or the from one **crest** to the next.
  - These are all one complete waves - all equaling the same length:



- On a longitudinal wave, the wavelength can be seen as the distance between the middle of compressions



Frequency : the number of waves passing a given point each second

- If in one second, 5 complete waves pass through, the frequency is 5waves/sec
- Frequency is measured in units of **hertz (Hz)** where **1Hz = 1wave/sec**

Velocity : **the speed of the travel of the wave - it can change depending on the medium.**

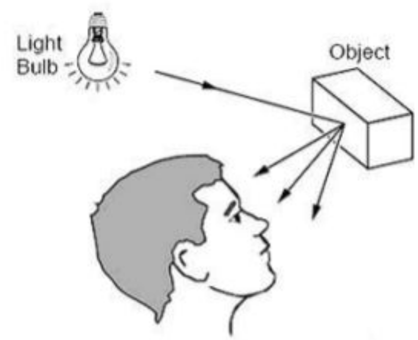
- If the velocity of the wave is 330m/s (the case for sound in air)
- Energy is transferred to a distance of 330m away each second.

You need to know that the **velocity** is related to the **frequency** and the **wavelength** with a formula: **$v = f\lambda$**

- **$v = f \times \lambda$**
- **Velocity = frequency x wavelength**

You need to know that light behaves like a **wave** and **therefore can be reflected and refracted.**

Reflection



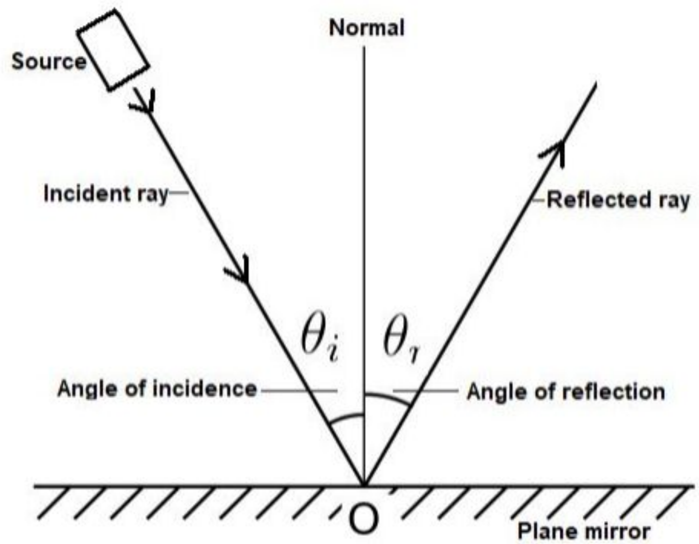
You need to know how light is **reflected.**

Reflection occurs when a light rayse hits a surface, and it changes direction.

For light, this is how we can see objects

- light rays from the sun hit objects and are reflected into our eyes.

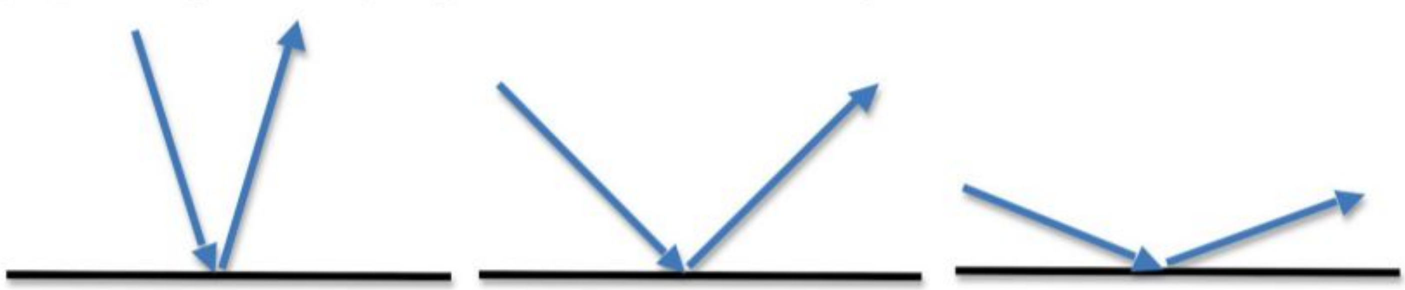
For light reflection on a **plane mirror (**straight mirror**)**, **you need to know:**



- **Incident ray** : original ray of light that is being reflected on the mirror (direction towards mirror)
- **Reflected ray** : the ray of light that has been reflected off the mirror (direction away from mirror)
- **Normal** : the **perpendicular** line to the surface of reflection at the point of reflection.
- **Angle of incidence (*i*)** : the angle between the **incident ray and the <u>normal</u>**
- **Angle of reflection (*r*)** : the angle between the **reflected ray and the <u>normal</u>**

The equation you need to know it quite simple : **angle of incidence = angle of reflection**

Meaning any incoming incident ray of light is reflected at the same angle - like so:



And if the incident ray is perpendicular to the mirror (angle = 0) the reflection is also perpendicular (angle = 0)

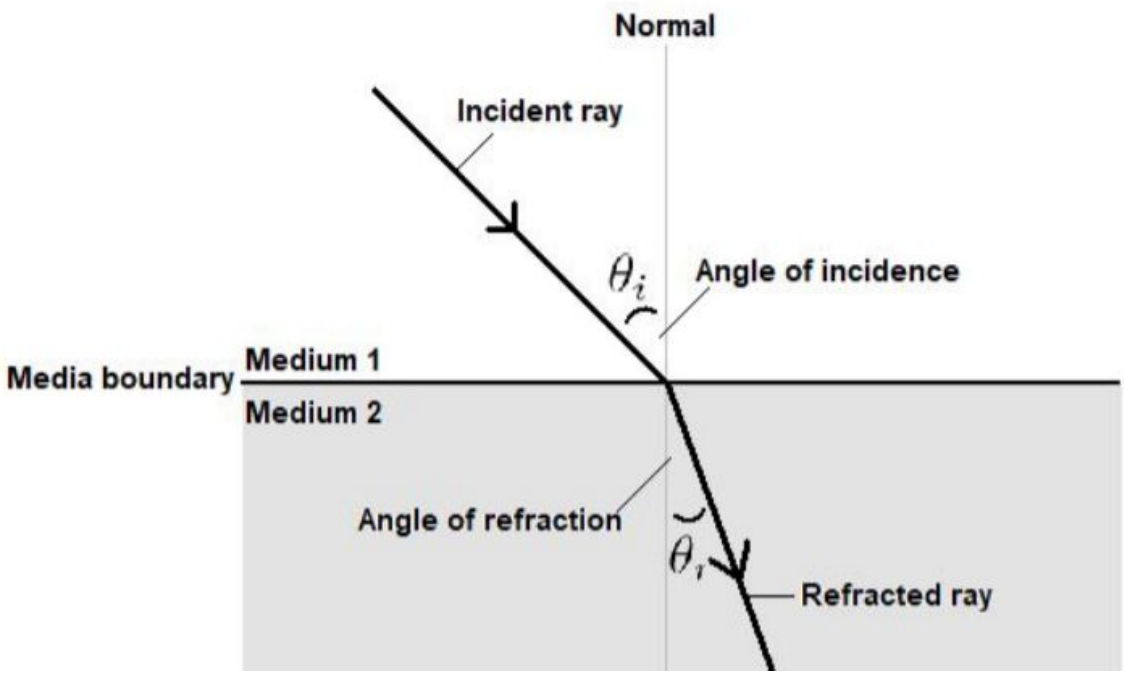
<u>Refraction</u>

You need to know how light is **refracted**.

Refraction is the **change in velocity** of light as it passes from one medium to another medium

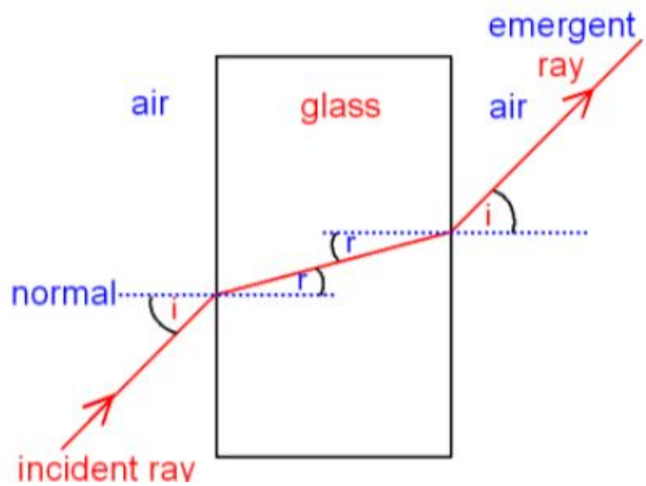
- Often results in change in direction (if incident ray is at an angle)

Light travels **more slowly in denser media -** e.g. velocity of light is higher in air than water.



- **Incident ray** : original ray of light that is being refracted (direction into the boundary of media)
- **Reflected ray** : the ray of light that has changed velocity - refracted (direction away from the boundary)
- **Normal** : the **perpendicular** line to the media boundary at the point of refraction.
- **Angle of incidence (*i*)** : the angle between the **incident ray and the <u>normal</u>**
- **Angle of refraction (*r*)** : the angle between the **refracted ray and the <u>normal</u>**

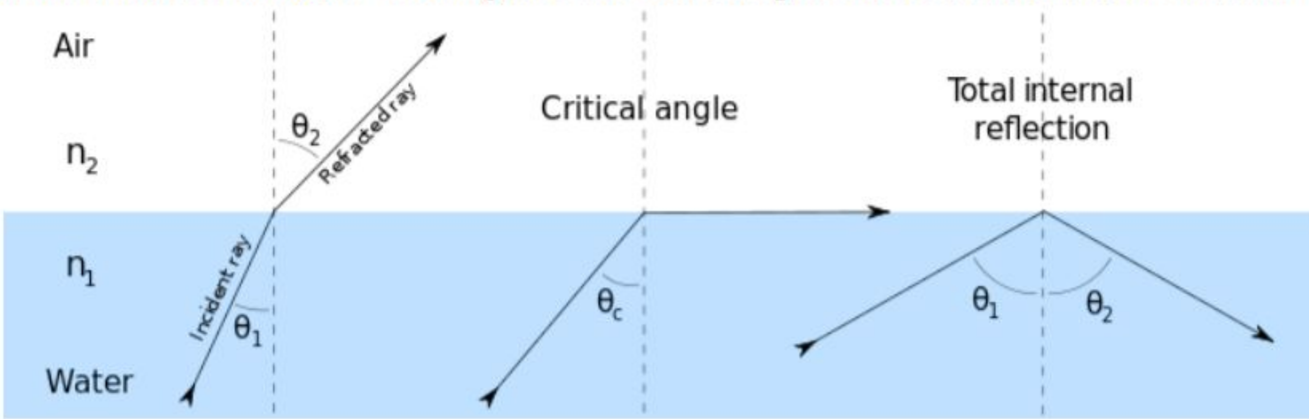
Of course, as the light ray changes direction: **angle of refraction ≠ angle of incidence.**
As light travels slower, it moves close to the normal (**decrease in angle of refraction in denser media**)
As light travels faster, it moves away from the normal (**increase in angle of refraction in less dense media**)



Total Internal Reflection (TIR)

You need to know what **total internal reflection** is.

If light travels from a **more dense** medium to **less dense** medium, (e.g. from water to air) a phenomenon called **total internal reflection** can occur - meaning **all of the incident light is reflected back into the medium**



When the angle of incidence is **equal** to the **critical angle (c)**,

- the ray is changes direction at the boundary so that it **travels parallel to the boundary**.

So total internal reflection occurs if **i > c** (angle of incidence > critical angle)

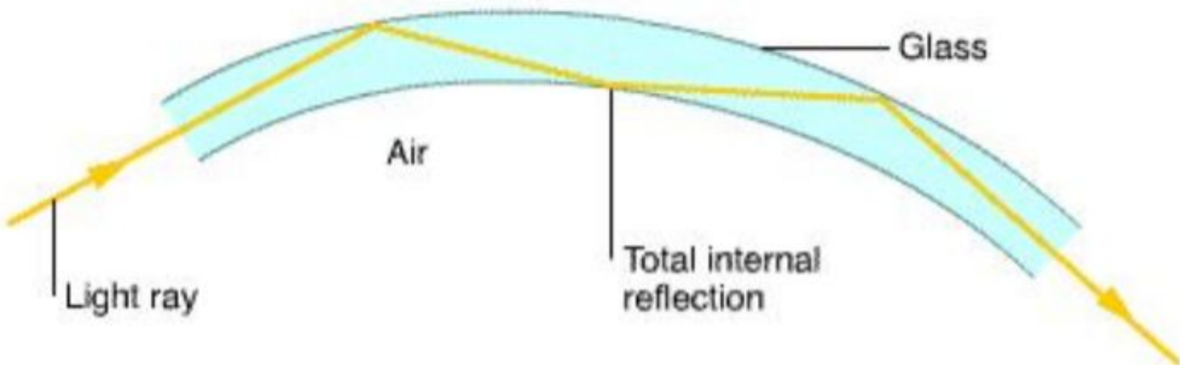
- If **i < c** (angle of incidence < critical angle) instead, normal refraction occurs.

Use of Total Internal Reflection

TIR is used in fibre optics technology,

- Which uses fibre optics cables made from glass
- And transfers data using light waves

TIR is important in fibre optics, as the light wave must all be reflected back into the wire without being lost. The wire is specially designed so the angle of incidence inside will never be less than the critical angle.



Fibre optics internet and endoscopes use this technology.

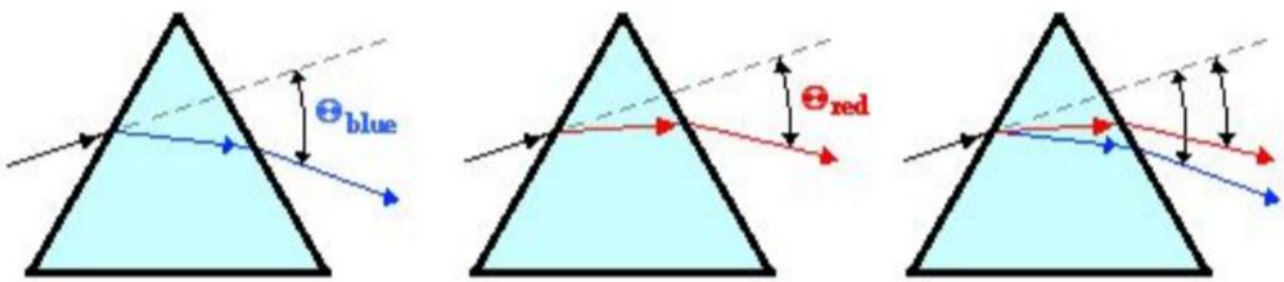
Dispersion of Light

You need to know how light can be **dispersed** through a prism

Dispersion is when white light (containing all wavelengths) separates into different wavelengths - due to refraction
Wavelengths of light characterises the colour of the light, making white light separate into different colours.

Rays with shorter wavelengths (therefore high frequencies) are refracted more than those with longer wavelengths

So, **blue** light will be refracted more (larger angle of refraction) than **red** light.



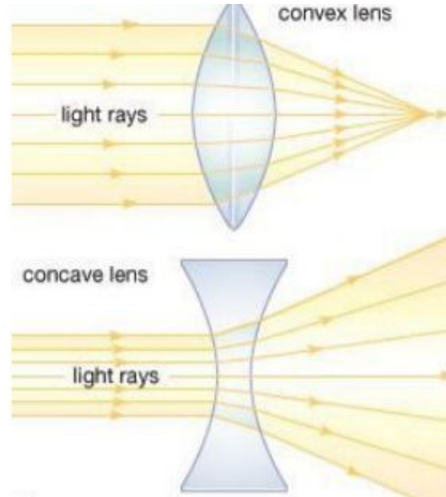
Blue light refracts more than red light due to the difference in wavelength. This causes blue light to deviate from its original path by a greater angle than the red light.

In a prism, there are two points of refraction, so the difference in angle will be greater in the end.

When this occurs with all the wavelengths of light, the colours spread out into a **spectrum of light.**

- Which has "rainbow colour" with ROYGBIV.
- Infrared and ultraviolet light - which are also part of sunlight are also refracted in the extreme ends.

Lenses



You need to know the behaviour of light through different lenses.

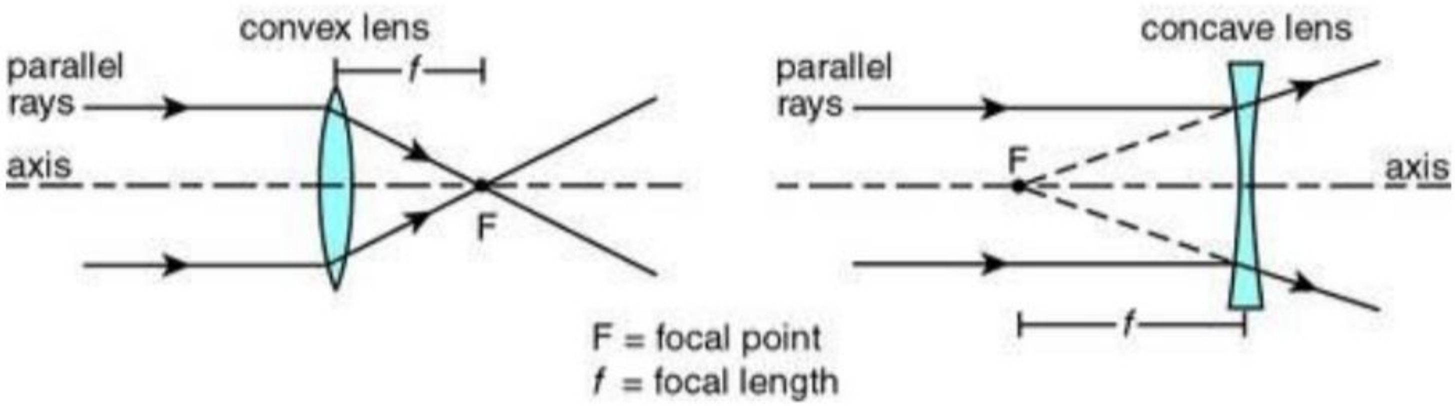
There are two different types of lenses

- **Convex** lenses: which **converge** light rays
- **Concave** lenses: which **diverge** light rays

You need to know how to draw ray diagrams for the lenses.

- **AND know** these vocabulary:

Focal point (principal focus)**:** point where the parallel light rays all focus to.
Focal length : the distance from the middle of the lens to the focal point
Image : the new image of the **object** formed by the light rays



Focal point for a **concave** lens is **behind** the lens - you have to extend the rays backwards to find this.
Draw a line from the middle of the lens and mark the focal point (F) and twice the focal point (2F) on either side

There were few words to describe the image formed:

- **Real** or **virtual**
  - **Real** images are formed on the opposite side of the object
    - They can be projected onto a screen
  - **Virtual** images are formed on the same side of the object
    - They cannot be projected onto a screen

- **Upright**(also called erect) or **inverted**
  - **Upright** images are "standing" in the same direction as the object
  - **Inverted** images are "standing" **upside down** to the object

- **Magnified** or **diminished**
  - **Magnified** images are larger than the object
  - **Inverted** images are smaller than the object

Convex lens

Light rays change direction at the lens as they go through - and goes through at the focal point

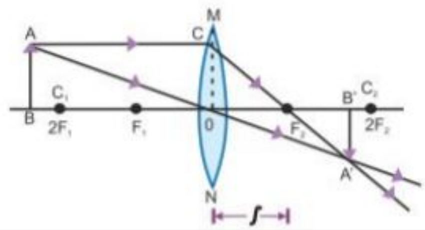
1. Draw a parallel line from the top of the image through the focal point
2. Draw another light ray going straight through the centre of the lens.

And depending on the distance of the image from the lens, the image changes

1) When object is placed beyond 2F.

The image is :

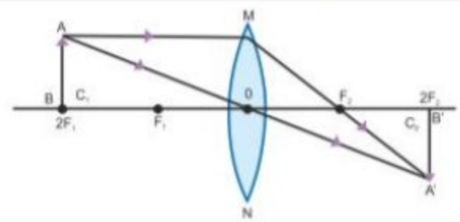
- formed between F_2 and $2F_2$
- real and Inverted
- diminished



2) When the Object is Placed at $2F_1$

The image is :

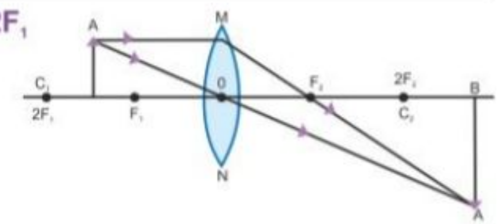
- formed at $2F_2$
- real and Inverted
- same size as the object



3) When the Object is Placed between F_1 and $2F_1$

The image is :

- formed beyond $2F_2$
- real and Inverted
- magnified



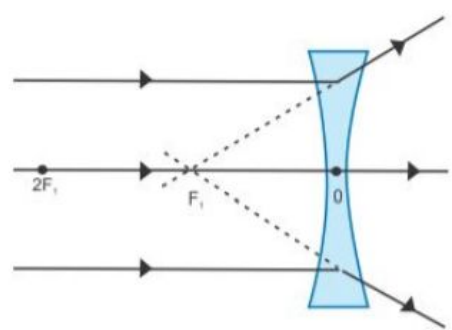
Concave lens

Focal point for a **concave** lens is **behind** the lens - you have to extend the rays backwards to find this.

1) When object is placed at infinity

Image is :

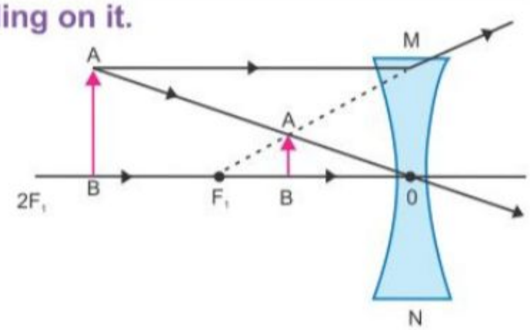
- formed at F_1
- virtual and erect
- highly diminished



2) A concave lens diverges all rays falling on it.

Therefore for all positions, image is :

- on the same side of object
- virtual and erect
- diminished



Simple phenomena of magnetism

Magnetic forces are due to interactions between magnetic fields. In a magnet, like poles repel and opposite poles attract.

Magnetic materials are materials that are attracted to magnets and can be magnetised (e.g. iron, steel, cobalt, nickel)
Non-magnetic materials are materials that are not attracted to magnets and cannot be magnetised (e.g. glass, plastic)

Induced magnetism:

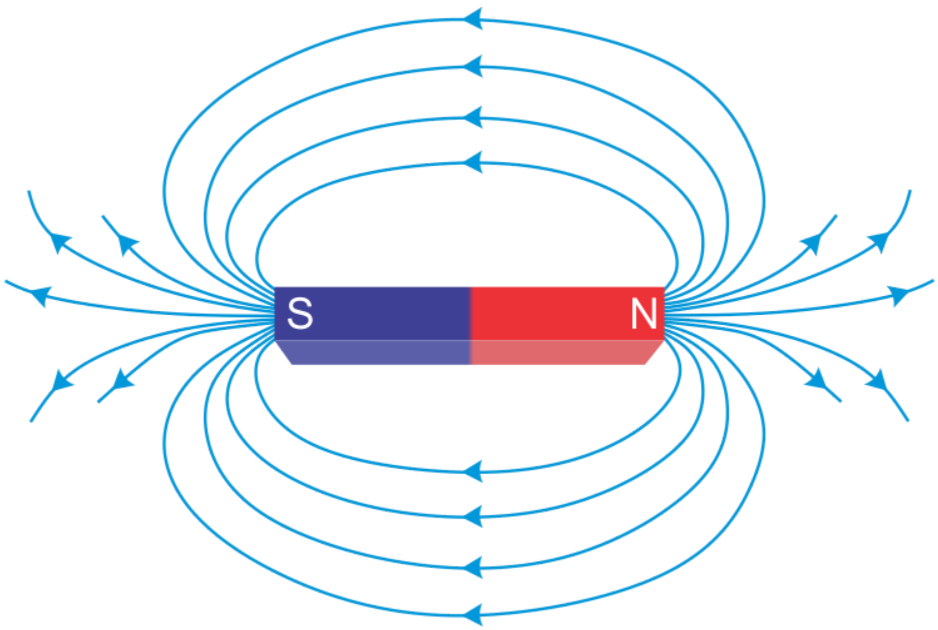
Magnetic materials can be magnetised by induced magnetism:

They can be magnetised by stroking them with a magnet, hammering them in a magnetic field, or putting them inside a coil with a direct current through it.
They can be demagnetised by hammering them, heating them or putting them inside a coil with an alternating current through it.

Magnetic materials that can be permanently magnetised are described as magnetically hard (e.g. steel). Magnetic materials that are only temporarily magnetised are described as magnetically soft (e.g. soft iron).

Permanent magnets vs electromagnets:

Permanent magnets are a hard-magnetic material that has been permanently magnetised whereas electromagnets consist of a coil of wire wrapped around a magnetically soft core and can be turned on and off.
Permanent magnets are more useful when they do not need to be turned off such as a fridge magnet, whereas electromagnets have the ability to be turned on and off so they can be used for situations such as moving scrap metal.



Magnetic fields:

Field lines around a bar magnet point from north to south

The direction of a magnetic field line shows the direction of the force on a north pole at that point.

Field strength decreases with distance from the magnet

Plotting compasses are small compasses which show the direction and shape of a magnetic field.

Electrical quantities

Electric charge

Charge is **measured in coulombs.** There are positive and negative charges; unlike charges attract and like charges repel.

Charging a body involves the addition or removal of electrons.

Conductors allow electrons to flow through them whereas insulators impede the flow of electrons.

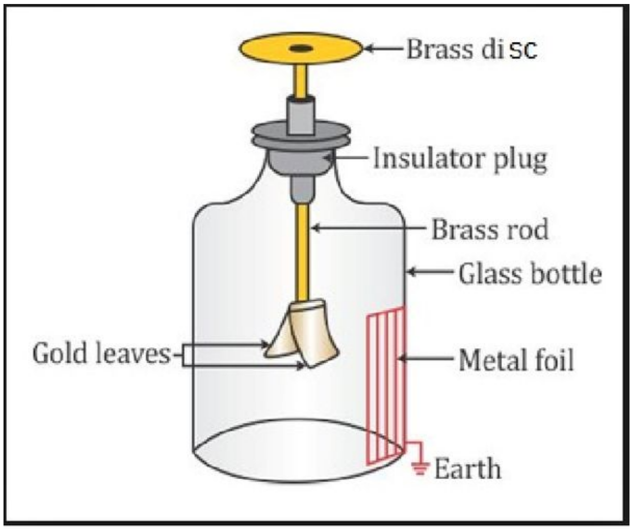
Conductors such as metals are used as wires in circuits.

When two insulators are rubbed together, electrons move from one to the other and they become charged. For example, when a rod is rubbed with a cloth, electrons are transferred from the rod onto the cloth and the rod becomes positively charged.

Charge can be detected using a gold leaf electroscope.

If a positively charged rod is brought close to the disc on top of the electroscope, electrons are attracted to the top of the disc, away from the bottom of the metal stem and the gold leaf. The gold leaf will then be repelled from the metal stem because they both become positively charged.

If someone then touches the disc, electrons flow from the ground into the disc as they are attracted to the rod, and the electroscope now contains a net negative charge. This is called charging by induction.

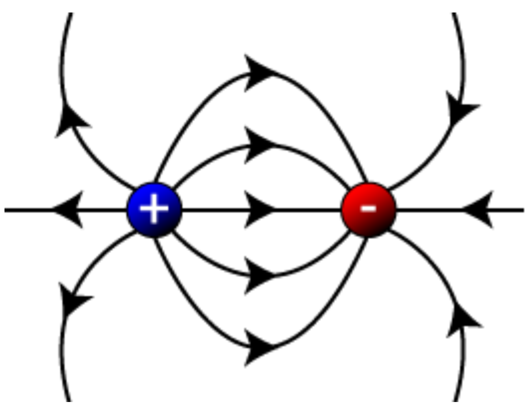


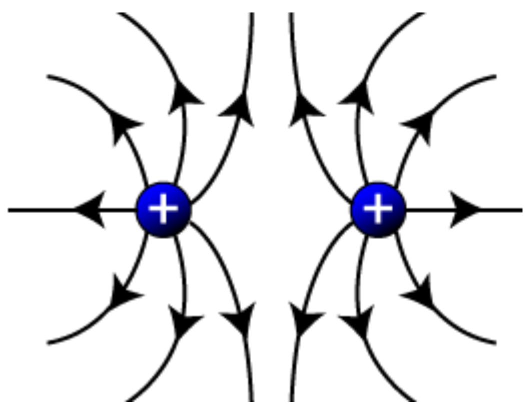
Charges create electric fields (regions in which an electric charge experiences a force); the direction of an electric field at a point is the direction of the force on a positive charge at that point.

Electric field lines point away from positive charges and towards negative charges.

The field lines around a charged conducting sphere are as if the charge was concentrated at the centre of the sphere.

The field lines between two charged plates go in straight lines from the positive plate to the negative plate and are equally spaced apart.





Electromotive force

The electromotive force (e.m.f) of an electrical source of energy is measured in volts and is the **energy supplied by the source per unit charge in driving the charge round a complete circuit.**

Potential difference

Potential difference V is measured in volts **(1 V = 1 JC^{-1}) and is the work done per unit charge in moving between two points in a circuit.**

It is measured with a voltmeter placed in parallel across the component.
The higher the potential difference, the greater the current.

Resistance

The resistance of a component is given by the potential difference across it divided by the current through it. The greater the resistance, the harder it is for current to flow through the component.

As the length of a resistor increases, the resistance increases.

The resistance is directly proportional to the length.

As the diameter of a resistor increases, the resistance decreases.

The resistance is inversely proportional to the cross-sectional area.

In an ohmic conductor, the current is directly proportional to the voltage (i.e. it has constant resistance). In a non-ohmic conductor (such as a filament lamp), the resistance changes as the voltage and current change.

As the current increases through a filament lamp, so does the temperature. This means electrons and ions vibrate more and collide more, increasing resistance.

Electrical working

Energy is transferred from chemical energy in the battery to electrical energy used by circuit components and then to the surroundings.
The power of a component is given by P=IV.
By using V=IR, this can be shown to be equivalent to $P=I^2R$ and $P=V^2/R$.

<u>Electric circuits</u>

Series:

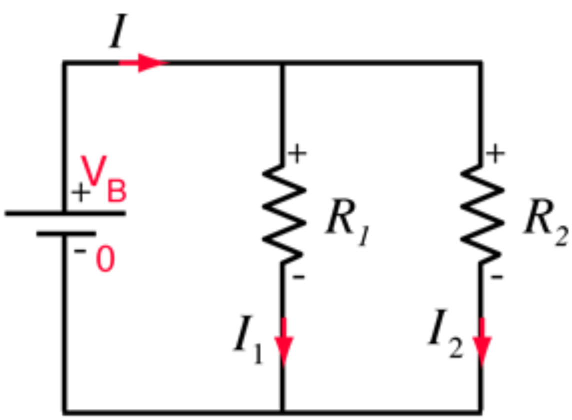
Components are connected end to end in one loop
The same current flows through every component
The potential difference is shared across each component (i.e. the sum of the p.d.s across the components is equal to the total p.d. across the supply).

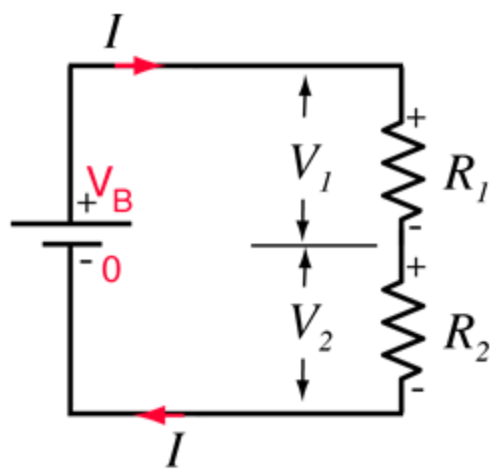
The total resistance is the sum of the resistances of each component $R_T = R_1 + R_2 + \ldots$

The combined e.m.f. of several sources in series is the sum of the individual e.m.f.s

Parallel

Components are connected to the power supply in separate branches
The current is shared between each branch (i.e. the sum of the currents in the separate branches is equal to the current through the source)





Parallel resistors

$$\frac{1}{R_{equivalent}} = \frac{1}{R_1} + \frac{1}{R_2}$$

Series resistors

$$R_{equivalent} = R_1 + R_2$$

A potential divider circuit divides the source voltage into smaller parts.
The voltage across a c*R*ertain component is source voltage, R is the resistance of the component and R_T is the total resistance.

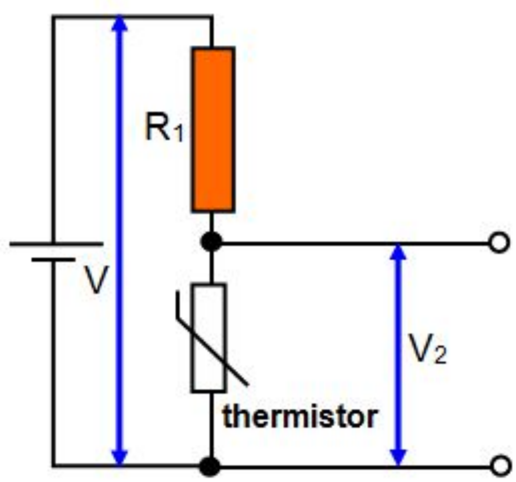
A thermistor is a resistor whose resistance decreases as the temperature increases.

A light dependent resistor is a resistor whose resistance decreases as light intensity increases.

A relay is an electromagnetically operated switch. When a small current passes through the electromagnet, it switches on and attracts an iron arm. This arm rotates about a pivot and pushes the contacts in another circuit together.

They are used to switch on a circuit with a high current using a circuit with a small current.

The above three components can be used in conjunction to operate light-sensitive switches and temperature-operated alarms.



Dangers of electricity

Hazards:

- Damaged insulation – contact with the wire due to gaps in the insulation can cause an electric shock or pose a fire hazard by creating a short circuit.
- Overheating of cables – high currents passing through thin wire conductors cause the wires to heat up to very high temperatures which could melt the insulation and cause a fire.
- Damp conditions – water can conduct a current so wet electrical equipment can cause an electric shock.

Fuses:

- A fuse is a thin piece of wire which overheats and melts if the current is too high, protecting the circuit.
- Fuses have a current rating which should be slightly higher than the current used by the device in the circuit. The most common are 3A, 5A and 13A.

Circuit breakers:

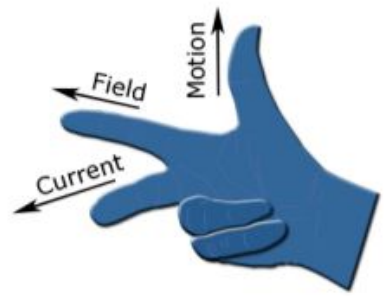
- Circuit breakers consist of an automatic electromagnet switch which which breaks the circuit if the current rises over a certain value.
- This is better than a fuse as it can be reset and used again, and they operate faster.

Earthing metal cases:

- Earth wires creates a safe route for current to flow through in the case of a short circuit, preventing electric shocks.
- Earth wires have a very low resistance so a strong current surges through them which breaks the fuse and disconnects the appliance.

Electromagnetic effects

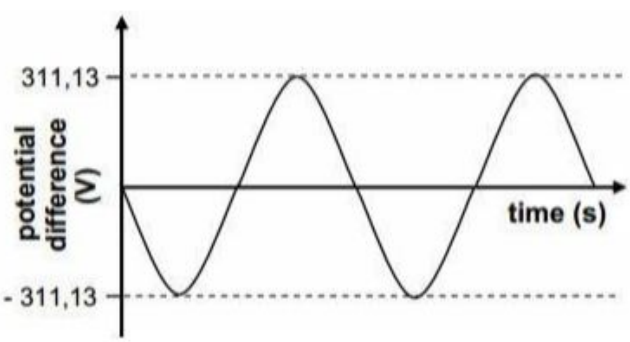
Electromagnetic induction

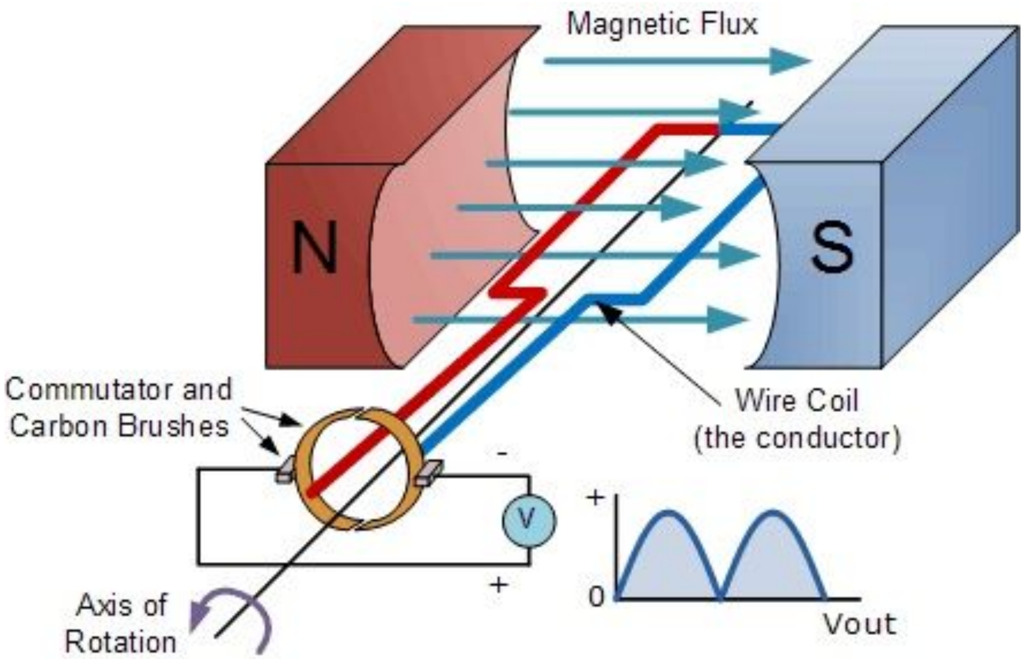


- When a wire moves across a magnetic field, an e.m.f. is induced in it. If it is part of a complete circuit, this causes a current to flow.
- **The induced current flows in such a direction that it opposes the change that produced it.**
- The induced e.m.f. can be increased by moving the wire more quickly, using a stronger magnetic field, or increasing the length of the wire.
- **The direction of the e.m.f. is determined by Fleming's right hand rule as shown in the diagram.**
- An e.m.f. is also induced if a changing magnetic field links with a conductor. For example, when a magnet is moved into a coil, the magnetic field through the coil changes and an e.m.f. is induced in it. The more quickly the magnetic field changes, the greater the e.m.f.

AC generator

- In a direct current, the current only flows in one direction whereas in an alternating current, the current continuously changes direction.
- **An AC generator consists of a coil of wire between two permanent magnets. They generate AC current because a slip ring commutator is used.**
- **As the coil rotates, the magnetic field through the coil changes, which induces an e.m.f. in the coil.**
- **The magnitude of the e.m.f. is maximum when the coil is horizontal as the field lines are cut the fastest, and zero when vertical as no field lines are being cut.**
- **The e.m.f. can be increased by increasing the number of turns on the coil, increasing the area of the coil, using a stronger magnet or increasing the speed of rotation.**





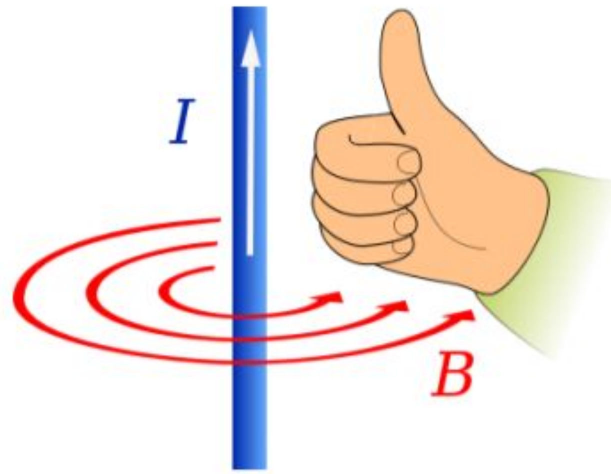
Transformer

- A transformer consists of two coils wrapped around a soft iron core and is used to transform voltages.
- **An alternating current in the primary coil creates a changing magnetic field; this changing magnetic field links with the secondary coil and induces an alternating e.m.f. in it.**

- A step up transformer has more turns on the secondary which means the voltage of the secondary is greater than that of the primary. A step down transformer has fewer turns on the secondary which means the voltage of the secondary is less than that of the primary.
- $\frac{number\ of\ coils\ on\ primary}{number\ of\ coils\ on\ secondary} = \frac{pd\ of\ primary}{pd\ of\ secondary}$ $\qquad \frac{N_{primary}}{N_{secondary}} = \frac{V_{primary}}{V_{secondary}}$
- **For a 100% efficient transformer, because the power used is constant,** $I_p V_p = I_s V_s$
- Transformers are used to step up the voltage in power lines which reduces power loss**. This is because a higher voltage means a smaller current and the loss of power due to $P=I^2R$ will be lower.**

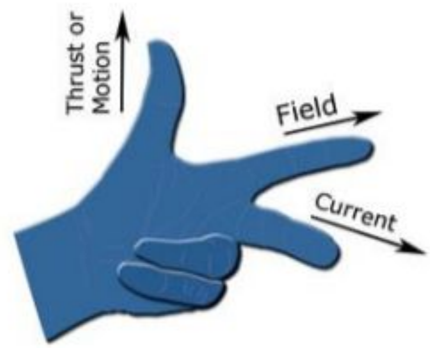
The magnetic effect of a current

- The right hand grip rule determines the direction of the magnetic field produced by a current carrying wire.
- The magnetic field created by a solenoid is like the field produced by a bar magnet.
- **Increasing the current through the wire increases the strength of the magnetic field, and reversing the direction of the current through the wire reverses the direction of the magnetic field.**
- The magnetic effect of current is used in relays.



Force on a current-carrying conductor

- A force acts on a current-carrying conductor in a magnetic field. **Fleming's left hand rule shows the relative directions of the force, field, and current.**
    - If a current-carrying wire is fixed in place between two magnets which rest on a balance, the wire will exert an equal and opposite force on the magnets and the reading will change, showing that a force is acting.
- If the current is reversed or the magnetic field is reversed, the force will be reversed.
- **A force is also exerted on charged particles moving in a magnetic field (because moving charged particles are current). If a beam of charged particles moves through a magnetic field, it will be deflected, showing that there is a force.**



Atomic Physics

An atom consists of:

- A positively charged nucleus made of:
  - Positive protons
  - Neutral neutrons
- Surrounded by negatively charged electrons which orbit the nucleus

The radius of the nucleus is a lot smaller than the radius of the entire atom. Almost all the mass of the atoms lies in the nucleus.

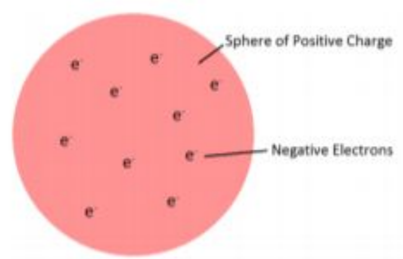
Particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	0.0005	-1

Atoms of the same element have the same number of protons. Isotopes are forms of an element's atom with the same number of protons but a different number of neutrons.

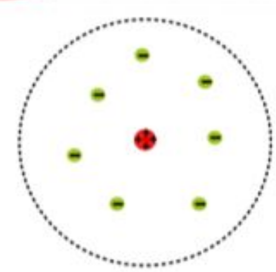
For a given nuclide $^{A}_{Z}X$:

- X is the symbol of the element
- A is the nucleon number (number of neutrons and protons)
- Z is the proton number (number of protons)

Alpha particle scattering:



- **An early model of the atom proposed by JJ Thomson was the plum pudding model - that the atom consisted of a cloud of positive charge with negatively charged electrons dotted around inside it.**
- **In Rutherford's scattering experiment, he aimed a beam of alpha particles at a thin gold foil. He concluded that:**
  - **The atom was composed primarily of empty space because most alpha particles passed straight through.**
  - **It had a nucleus which was massive and contained most of the mass of the atom because it deflected some alpha particles straight back.**
  - **The nucleus was positively charged because it repelled the positively charged alpha particles.**



upload.wikimedia.org

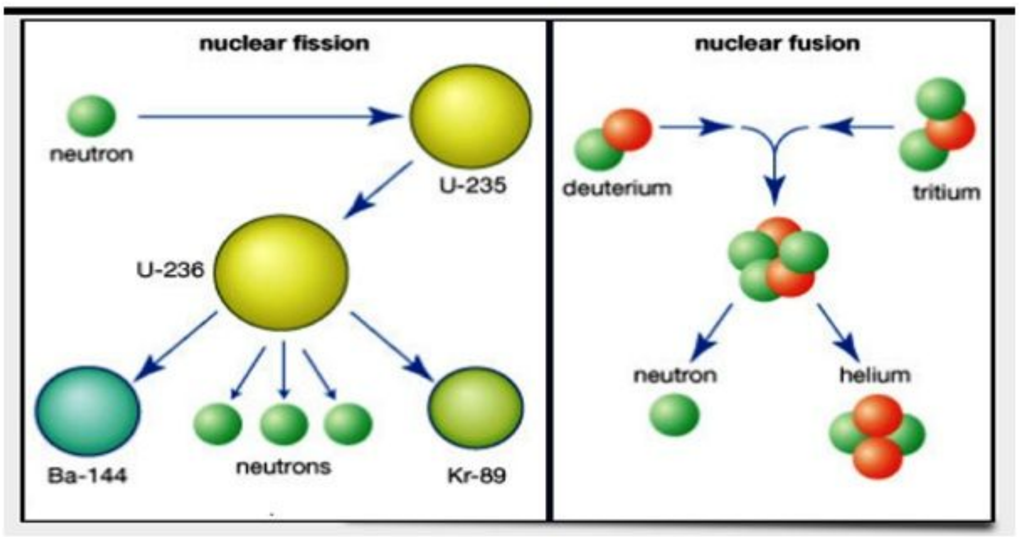
Nuclear fission:

- The process of splitting a nucleus is called nuclear fission
- Uranium-235 is a commonly used isotope as the fuel in nuclear reactors
- When a Uranium-235 nucleus absorbs a neutron, it splits into two daughter nuclei and 2 or 3 neutrons, releasing energy in the process
- The neutrons then can induce further fission events in a chain reaction

Nuclear fusion:

- The process of fusing two nuclei to form a larger nucleus is called nuclear fusion
- Energy is released during this process
- Nuclear fusion is how the sun and other stars release energy

Nuclear Fission and Nuclear Fusion



Radioactivity

Radioactive decay is the spontaneous transformation of an unstable nucleus into a more stable one by the release of radiation. It is a random process which means one cannot know what nucleus will decay and when it will decay because it is down to chance.

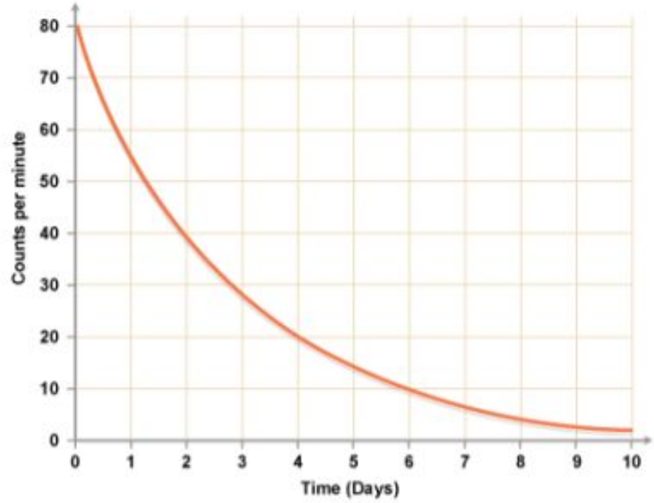
Decay processes:

- Alpha:
  - A heavy nucleus emits an alpha particle (helium nucleus).
  - The nucleus changes to that of a different element **according to the following equation:** $^{A}_{Z}X \rightarrow \; ^{A-4}_{Z-2}Y + \; ^{4}_{2}\alpha$
  - They are highly ionising and weakly penetrating. **They are stopped by a sheet of paper.**
  - **They are slightly deflected by electric and magnetic fields.**
- Beta:
  - A neutron turns into a proton and emits a beta particle (electron)
  - The nucleus changes to that of a different element **according to the following equation:** $^{A}_{Z}X \rightarrow \; ^{A}_{Z+1}Y + \; ^{0}_{-1}e^{-}$
  - They are moderately ionising and moderately penetrating. **They are stopped by a thin sheet of aluminium.**
  - **They are greatly deflected by electric and magnetic fields.**
- Gamma:
  - After a previous decay, a nuclei with excess energy emits a gamma particle.
  - Gamma particles are a form of electromagnetic radiation.
  - They are lowly ionising and highly penetrating. **They are stopped by many centimetres of lead.**
  - **They are not deflected by electric and magnetic fields.**

Weak radiation that can be detected from external sources is called background radiation. Sources of background radiation include:

- Cosmic rays
- Radiation from underground rocks
- Nuclear fallout
- Medical rays

- The half-life of an isotope is the time taken for half the nuclei to decay, or the time taken for the activity to halve.
- In the graph, the count rate drops from 80 to 40 counts per minute in 2 days, which means the half-life is around 2 days.
- **Background radiation has to be subtracted before attempting to perform half-life calculations**



Uses of radioactivity:

- **Smoke detectors**
  - **Long half life alpha emitters are used in smoke detectors.**
  - **Alpha particles cause a current in the alarm.**
  - **If smoke enters the detector, some of the alpha particles are absorbed and the current drops, triggering the alarm.**
- **Thickness monitoring**
  - **Long half life beta emitters can be used for thickness monitoring of metal sheets.**
  - **A source and receiver are placed on either side of the sheet during its production. If there is a drop or rise in the number of beta particles detected, then the thickness of the sheet has changed and needs to be adjusted.**
- **Sterilisation of equipment**
  - **Gamma emitters are used to kill bacteria or parasites on equipment so it is safe for operations.**
- **Diagnosis and treatment**
  - **Short half life gamma emitters such as technetium-99m are used as tracers in medicine as they concentrate in certain parts of the body.**
    - **The half life must be long enough for diagnostic procedures to be performed, but short enough to not remain radioactive for too long.**
  - **Other gamma emitters such as cobalt-60 can be used to destroy tumours with a high dose of radiation.**

Exposure to radiation can destroy living cell membranes by ionisation, causing the cells to die, or damage DNA which causes mutations that could lead to cancer.

Safety measures include:

- Minimising the time of exposure to radiation. For example, radioactive tracers with a short half life should be used.
- Keeping as big a distance from the radioactive source as possible. They should be handled using tongs and held far away from people.
- Using shielding against radiation, such as the concrete shielding around a nuclear reactor. Radioactive sources must also be kept in a lead-lined box.

Criteria B: Experimental Design and set up

Key Terms

Independent variable (IV): the thing you are going to **change**
Dependent variable (DV): the thing you are going to **measure** (it is dependent on the independent variable)
Control variables: the things you are going to **keep the same** (so that the results are as reliable as possible.)

Planning the Experiment

When planning an investigation, the first step is to **identify your variables**: What are you going to change? What are you going to measure? What is going to stay the same?
The **control variables** in an experiment are incredibly important in ensuring the test is **fair**.

Before starting the experiment you must also **evaluate the dangers** in a **risk assessment** (detailed in a previous section) to ensure that it is safe to continue.

Conducting the Experiment

During the experiment, make sure all control variables are kept constant, and take care to follow the precautions set out in your risk assessment.

In order to make the results as reliable as possible, you should **repeat the experiment a few times** so that you have more data to work with. This will allow you to easily identify any anomalous results (and remove them from the data set so they do not affect any further calculations), and determine the mean for each set of readings. Repeating the experiment will also give an idea of how reliable your results are: if repeat readings are all very different, it is likely they are unreliable. You should also use the best equipment available – instruments with the **highest resolution** – to **maximise precision**.

Reflecting on how well your plan worked

Did you choose the right range of values for your IV? Was your DV affected by your IV in the way you expected? Was your measuring equipment sensitive enough to detect the change? Were there any confounding variables that you were unaware of, or unable to control for? Did you choose the right apparatus for your needs?

Suggesting improvements

Here are some common issues that can affect the results of experiments;

- Small **sample size**
- Experiment was **not repeated**
- Equipment **not precise**
- Certain variables were **not controlled**

Recording Measurements

When conducting an experiment, you must **record all measurements taken** (e.g. temperature, mass or time), and in most cases this should be **presented in a table**. This table should have the independent variable in the left-hand column and the dependent variable should go along the top, with the recorded data filling the main body of the table. The headings should be in the format **'quantity/unit'**.

An example table is shown below:

	Potential Difference / V (dependent variable)			
Length / m (independent variable)	**Trial 1**	**Trial 2**	**Trial 3**	**Mean**
0.00	0.00	0.00	0.00	0.00
0.10	0.09	0.15	0.12	0.12
0.20	0.22	0.22	0.25	0.23
0.30	0.30	0.35	0.40	0.35
0.40	0.51	0.43	0.47	0.47

Setting Up Apparatus

When setting up the apparatus for an experiment, ensure you follow **all instructions** carefully so as to minimise the chances of somebody getting hurt or of making a mistake and getting inaccurate results. For example, when creating a circuit, ensure the **power is always off** before making any changes, and be sure to connect everything in the **correct places** so that you get the right measurements.

Using Apparatus Safely

As with setting up the experiment, ensure that you **follow the method carefully** all the way through. There may also be a **risk assessment** within the instructions which you should be aware of and follow all precautions. If one does not already exist, then you should carry out your own risk assessment, detailing all **possible hazards**, why they are hazardous (what is the risk?), and then what you can do to **minimise the risk**. For example:

Hazard	Risk	Precautions
Using a Bunsen burner	Can start a fire or burn someone	Ensure all loose or hanging clothing is removed or kept away from the Bunsen burner (e.g. ties or blazers) and **hair is tied up**. The flame should be off or on the **safety flame** when not in use. **Heatproof mats** should also be placed under the Bunsen burner.
Using hanging masses	Masses can fall and hit someone	Stand away from the hanging masses and wear protective, closed-toe shoes.
Stretching a spring	The spring may break and hit someone	**Wear goggles** to protect your eyes from any sharp pieces of metal and do not overload the spring.

Measurements and Observations

Two methods of recording data are **observations** and **measurements**. Both can be recorded using different methods e.g. tables, written statements, drawings, tally charts. When using tables ensure you use a ruler and a pencil, and include headings with units.

Observations

Observations are a more **qualitative** form of recording results. This involves writing down **exactly** what you **see** happening during the experiment. There is **always** something to observe; even if nothing happens you can write 'no change'. A good tip is to use four of your **senses** when recording observations;

1. What can you **see**? This is the most obvious one, and therefore easiest to spot. Does anything change colour? Is there fizzing?
2. What can you **smell**? Is there a nice smell, like fruit? Or a less pleasant smell, like rotten eggs?
3. What can you **feel**? Is something getting warmer, or colder?
4. What can you **hear**? This is the trickiest one as experiments rarely produce noise. Listen carefully, and you may hear popping or whistling if gas is being produced.

Measurements

Measurements are a more **quantitative** form of recording results. This involves exact numbers, either obtained from apparatus such as scales, or counted frequencies. Some examples of things you can measure include weight, length, volume (of liquid or gas), temperature, pH.

It is important to be as **accurate** as you can when taking measurements; ask someone else to check if you are not sure. Record results to the **same precision** as your equipment e.g. if using a measuring cylinder with $1cm^3$ increments, do not record $0.5cm^3$. Always use SI units, e.g. millimetres not inches.

Variables

Independent: The one that you change (normally plotted on the x-axis)

Dependent: Changes because of the changes you make in the independent variable (y-axis)

Control : What you keep the same to ensure that the experiment is fair. (Tip: Imagine you doing the experiment, don't just say keep the same measuring cylinder, keep using the same stop watch – those things are assumed and will not get you mark!)

Example: When investigating the rate of cooling , controls would be keeping the room temp constant, start temperature of water the same, ensuring there are no draughts, keeping the amount of liquid the same and keeping the amount of stirring constant.

Drawing a graph

First get yourself familiarised with the tools for drawing graphs in Assessprep

Draw axes correct way round, label axes and include units e.g. Resistance / Ω (Don't write Resistance (Ω), use the forward slash "/")

Use appropriate scales so that the graph takes up most of the graph paper available. If your range of values is, for example, 89 to 170, Plot all points to within ½ small square (examiner checks this very carefully!)

Ensure line of best fit (as many points above as below the line). Don't force a line through 0,0 unless the graph should go through the origin (for example this is fine in the case of someone starting a stopwatch at a start line if you're plotting time against displacement).

Draw a single, continuous and sharp line.

Always proper tools given in assessprep to plot points correctly and to draw a sharp line.

A straight line shows that x is proportional to y. A straight line through the origin shows that x is directly proportional to y.

Calculating a gradient

Always draw a gradient triangle which takes up over half the length of the line. **Show your working out – put numbers into $y_2 - y_1 / x_2 - x_1$ using proper tool as given in assessprep.**

Gradients have units (unit on the y axis divided by unit of x axis, so for a speed – time graph the unit of the gradient is m/s / s which is m/s^2 which is the unit of acceleration (as you would expect!))

Column headings in tables

Column headings in tables of readings must be headed with the quantity/unit as in these examples: I/A, or t/s, or y/m.

Calculations

Always show answers to 2 or 3 significant figures. Double check all calculations at the end of the test and check that you have given the correct unit.

How to Improve Accuracy / Reliability

When carrying out practical work there are usually measurements that are in some way difficult to take in spite of taking great care. You **should comment about these difficulties when asked about precautions taken to improve accuracy.**

TIP: Try and imagine or picture yourself carrying out the experiment.

Top tips to improve accuracy:

How to measure something accurately from a scale: Avoid parallax error!

Check for zero error. Eg If you're measuring the length of something, make sure the start of the object is in line with the zero on your ruler. Or if using a stopwatch, check it is zeroed first.

Repeat experiments to identify anomalous errors or to calculate an average.

Some more specific examples:

Hooke's Law experiments / Experiments involving springs

Avoid parallax error / line of sight error by reading the ruler at eye level

Always measure from the same point on spring (top or bottom of ring)
Wait for spring/weight to stop bouncing
Use of horizontal aid/ensure ruler is vertical

In experiments involving the measurement of a length

Explain how to avoid parallax error
When measuring heights ensure that the rule is held perpendicular to the base
Explain how to arrange apparatus so that it is parallel or perpendicular to a bench

In experiments using objects, lenses and a screen

Ensure each item is aligned so that the centre of each item is at the same height and on the same horizontal straight line.
Mark the middle of the lens on the bench or on holder
Perform the experiment in a shaded part of the laboratory
Avoidance of parallax error

In ray tracing experiments

Space marker pins so they are at least 60mm apart
Ensure the pins are vertical
Draw neat thin lines

In heat experiments

Choose volume / mass values of the quantities that give large changes in the temperature
Insulate the container, cover the container
Position the eye so that the mercury thread appears to touch the scale
Stir and wait for the highest temperature after stopping heating – wait for thread of mercury to stop moving. Ensure the thermometer bulb is in the liquid while you take the reading.

In electrical experiments

Check for a zero error
Always check that connections are clean
When measuring resistance use low currents / voltages to avoid heating and changing the resistance you are measuring

For oscillations (of a pendulum or vibrating rule) be able to define a complete oscillation
Time N oscillations, usually $N>10$ and use the terminology periodic time $T = t / N$
Explain where the eye should be placed to avoid parallax error.

"Within the limits of experimental accuracy"

There will no doubt be a question on the exam paper asking you if your result is accurate / correct:
Example: You calculate the voltage V_A across 3 lamps to be 1.9V. A student says that V_A should equal V_B which is 2.0V.

A few sample questions and the answers you should provide are shown below:

State whether the results support this suggestion and justify your answer with reference to the results.

statement .....**if it is close to the published value say "Yes", if not "No**

……..……………..

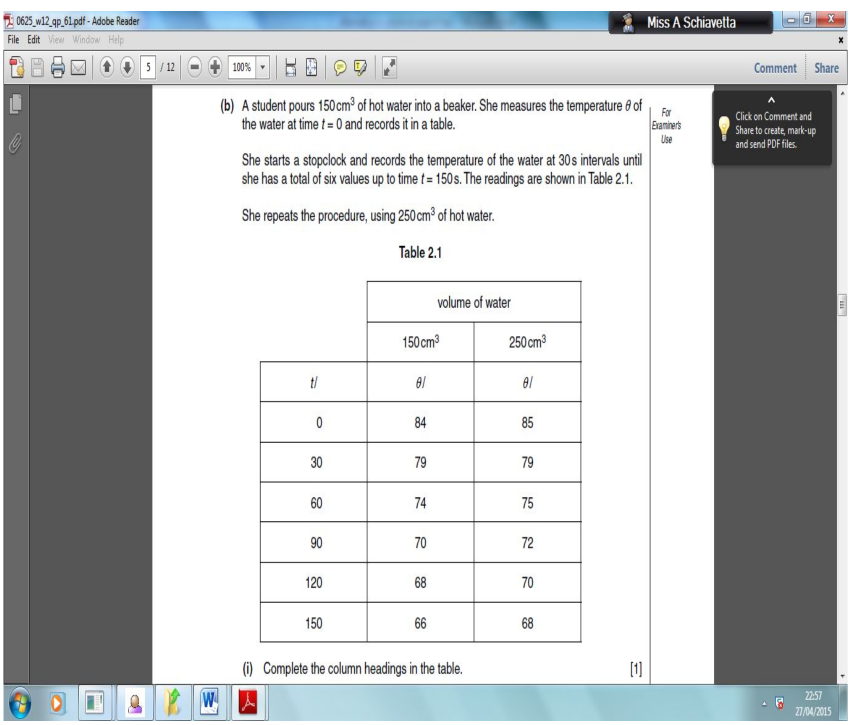
justification…… **It is (not) within the limits of experimental accuracy**................................

Justification

If you are asked to justify a statement that you have made it must be justified by reference to the readings. A theoretical justification in a practical test will not gain marks.

For example:

You are shown the following table which shows the temperature of two different volumes of water.



(b) A student pours 150 cm^3 of hot water into a beaker. She measures the temperature θ of the water at time $t = 0$ and records it in a table.

She starts a stopclock and records the temperature of the water at 30 s intervals until she has a total of six values up to time $t = 150$ s. The readings are shown in Table 2.1.

She repeats the procedure, using 250 cm^3 of hot water.

Table 2.1

	volume of water	
	150 cm^3	250 cm^3
t/	θ/	θ/
0	84	85
30	79	79
60	74	75
90	70	72
120	68	70
150	66	68

(i) Complete the column headings in the table. [1]

Q: State whether the rate of cooling is significantly faster, slower, or about the same when using the larger volume of hot water. Justify your answer by reference to the readings.
Statement: **The rate of cooling is about the same**
Justification: **The 150cm^3 beaker cools from 84^{o}C to 66^{o}C in 150 seconds, which is an 18^{o}C drop and the 250cm^3 beaker cools from 85^{o}C to 68^{o}C which is a 16^{o}C drop.**

Precaution is different from safety.

Precaution to achieve a reliable result

A safe thing to say is "Repeat 3-5 times and take the average".

Criteria C sample questions

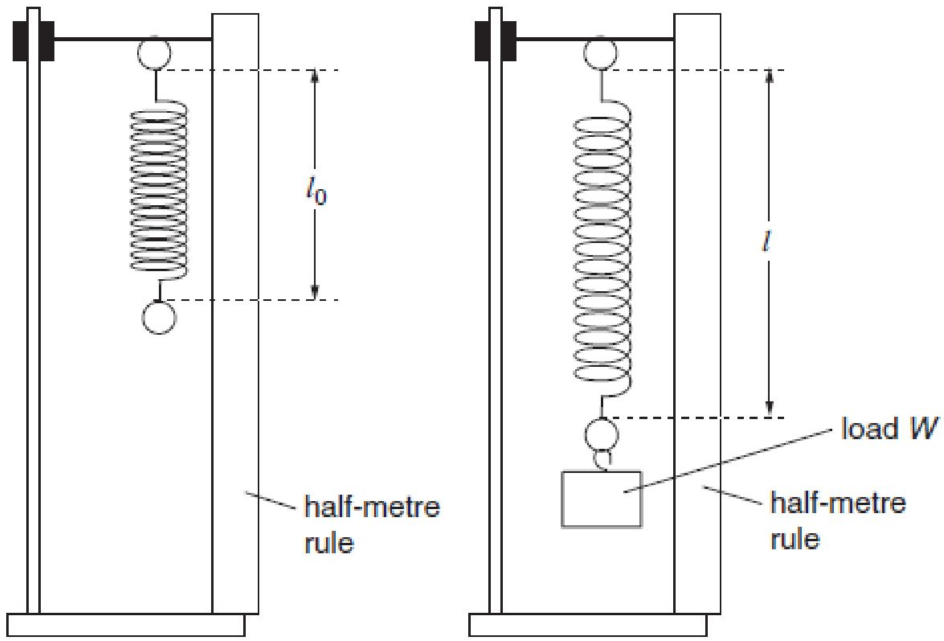
1. A student performing an experiment to study how does light behave when reflected of the mirror and prove an important law of light behavior. Your task is to help him collect the data and study the investigation

Hypothesis by a Student: Since light bounces back of any plane surface it will make an angle on incidence equal to angle of reflection.
use simulation link given below to collect data in suitable table.
https://simpop.org/reflection/reflection.htm

You should -
Accurately interpret data and describe results using correct scientific reasoning
Draw a line graph to represent the data for the investigation.

Discuss the validity of the hypothesis based on the results obtained.
Describe improvements or extensions to the method that would benefit the scientific investigation.

2. A student carried out an experiment to find the spring constant of a steel spring. The apparatus is shown in figure below



The student recorded the unstretched length l_0 of the spring. Then she added loads W to the spring, recording the new length l each time. The readings are shown in the table below.

W/N	l/mm	e/mm
0	30	
1	32	
2	33	
3	36	
4	39	
5	40	
6	42	

l_0 = 30 mm

Calculate the extension e of the spring produced by each load, using the equation $e = (l - l_0)$ and record the values of e in the table. [2]

Accurately interpret data and describe results using correct scientific reasoning by plotting the graph of e / mm (y-axis) against W/N (x-axis) you may also calculate gradient for your reasoning and analysis. [7]

Discuss the validity of the method based on the outcome of a scientific investigation. [2]

Describe improvements or extensions to the method that would benefit the scientific investigation. [2]

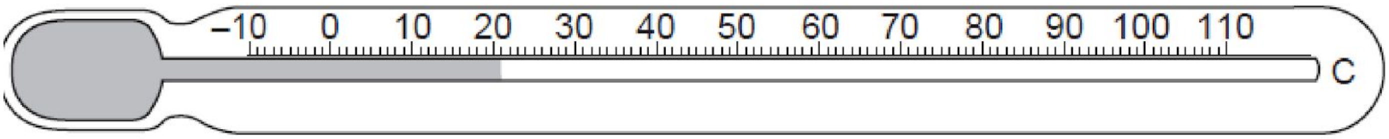
3. A student wish to prove ohms law which states that voltage is directly proportional to current.
Hypothesis by a Student: As the voltage increases more and more energy is given to electrons and so value of current will increase in same proportion and so the ratio of voltage and current should remain constant.
Your task is to help him prove the given law and verify the hypothesis stated.
Use simulation link given below to collect data in suitable table.
https://phet.colorado.edu/sims/html/ohms-law/latest/ohms-law_en.html

You should -
Accurately interpret data and describe results using correct scientific reasoning [2]
Draw a line graph to represent the data for the investigation. [2]

Discuss the validity of the hypothesis based on the results obtained. [2]
Describe improvements or extensions to the method that would benefit the scientific investigation. [2]

4. A class is investigating the change in temperature of hot water as cold water is added to it. The students are provided with 100 cm^3 of hot water and a supply of cold water at room temperature.

The thermometer in figure below shows the temperature of the cold water.



a. Record the temperature of the cold water, as shown in figure above

[1]

____

b. A student records the temperature of the hot water. He then pours 20 cm3 of the cold water into the beaker containing the hot water. He records the temperature θ of the mixture of hot and cold water and the volume V of cold water added. He then repeats the process four times until he has added a total of 100 cm3 of cold water. The table shows the readings.

V/	θ/
0	80.0
20	58.0
40	48.0
60	40.5
80	34.0
100	29.0

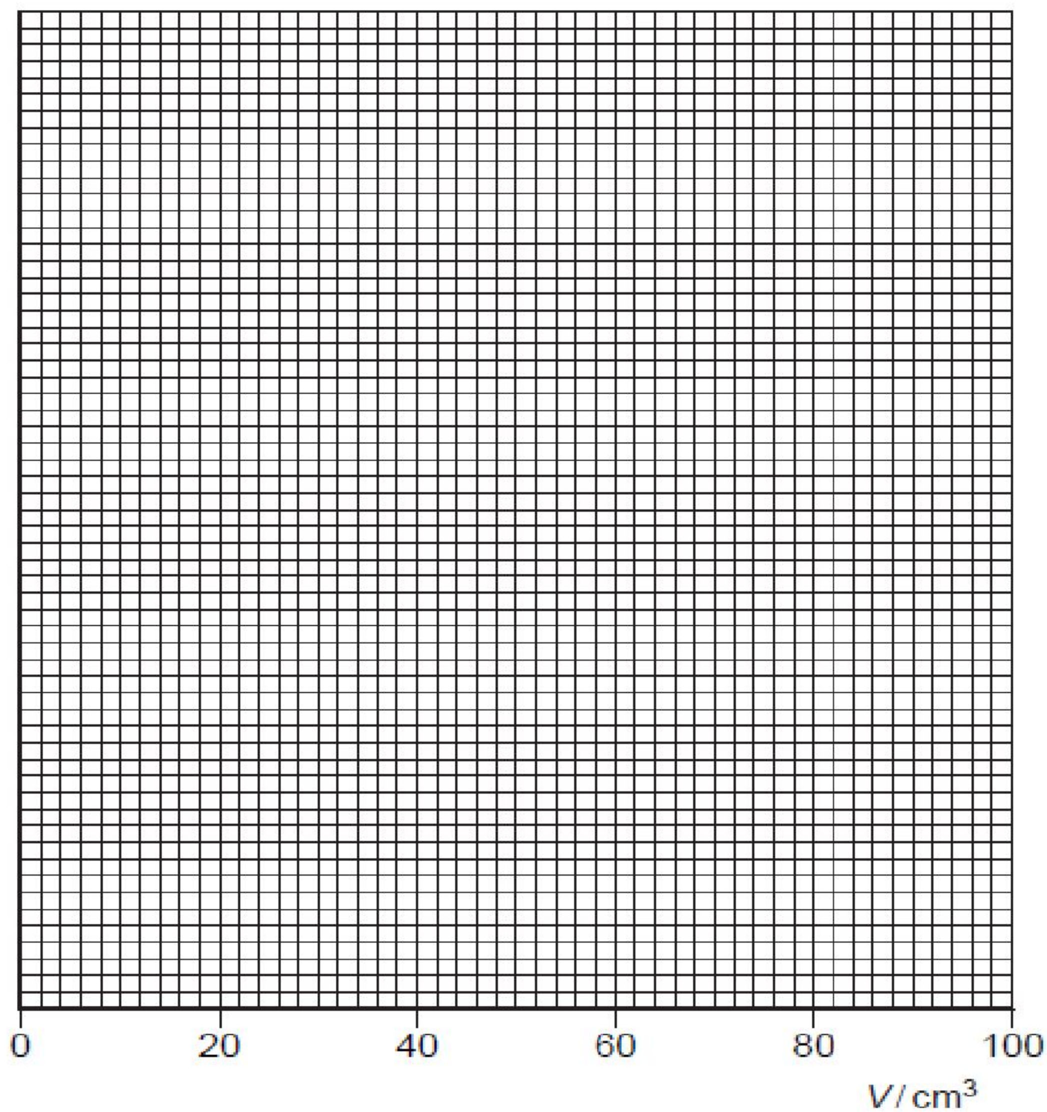
Write the units in the table above for the quantities measured.

[2]

____

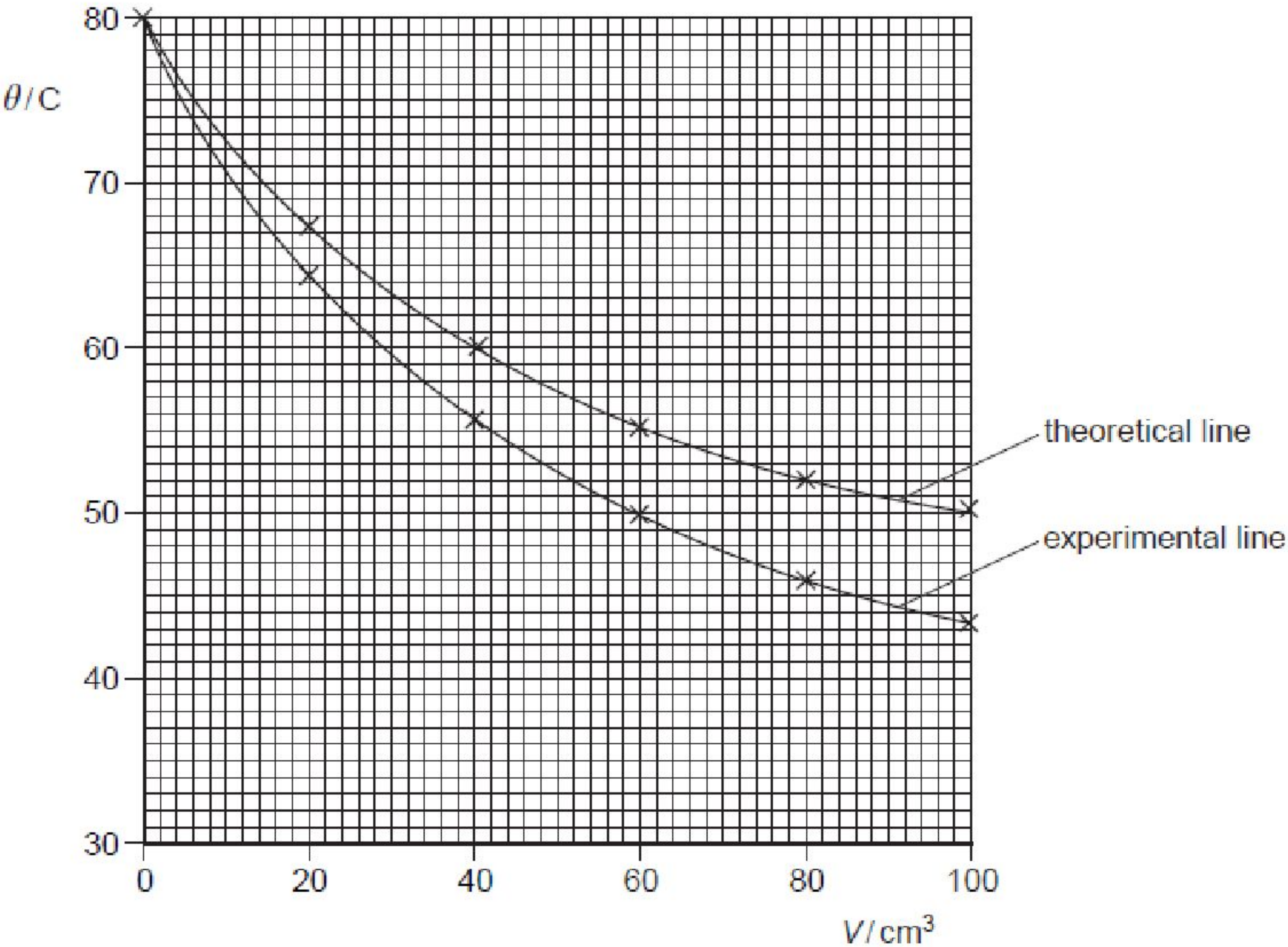
c. Use the data in the table to plot a graph of temperature θ (*y*-axis) against volume V (x- axis)

[4]



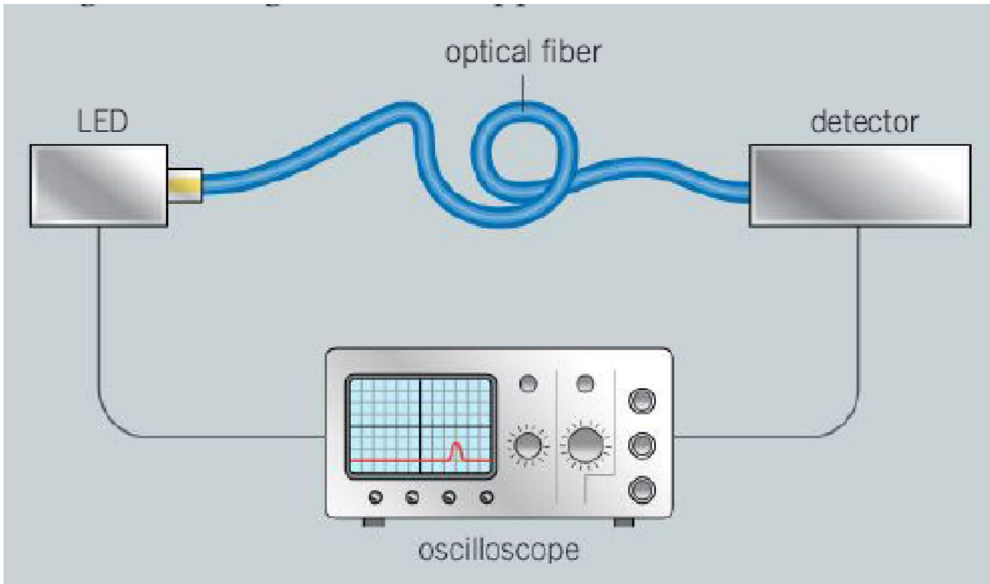
d. A sketch graph of the readings taken by another student carrying out a similar experiment is shown in figure below. The theoretical line shows the results expected by the student after calculating the values of θ. The student assumed that all the heat lost by the hot water was gained by the cold water when the cold water was poured into the beaker.

The other line shows the experimental results

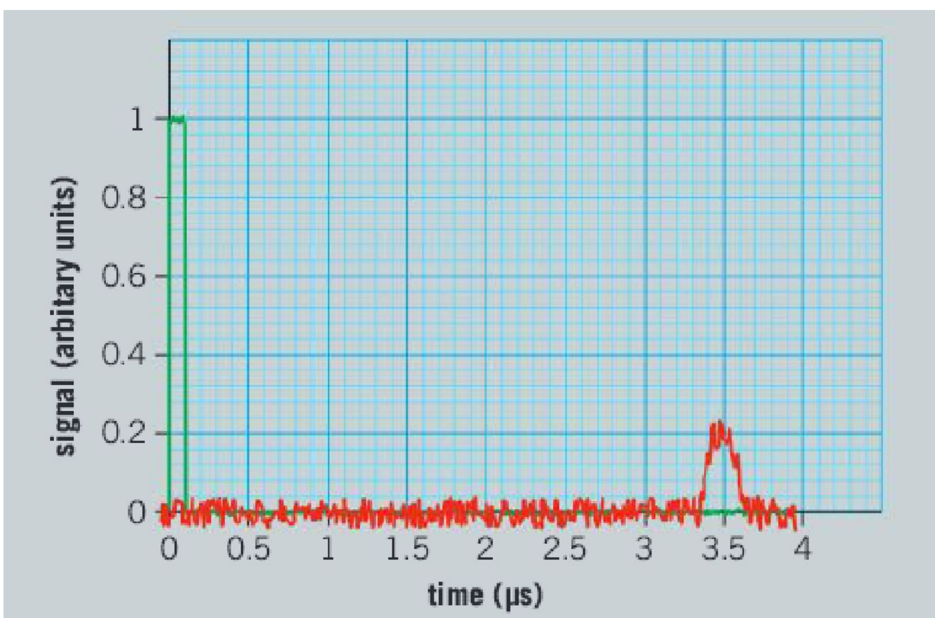


The student carried out the experiment with care. Suggest a practical reason why the experimental line differs from the theoretical line. [2]

5. An experiment was conducted to determine the speed of light through a fiber optic cable. An electrical signal was sent to an LED. The light from the LED was transmitted down the optical fiber and a pulse was detected at the other end. An oscilloscope was used to measure the time delay between the initial electrical pulse and the detected signal. A diagram of the apparatus is shown below.

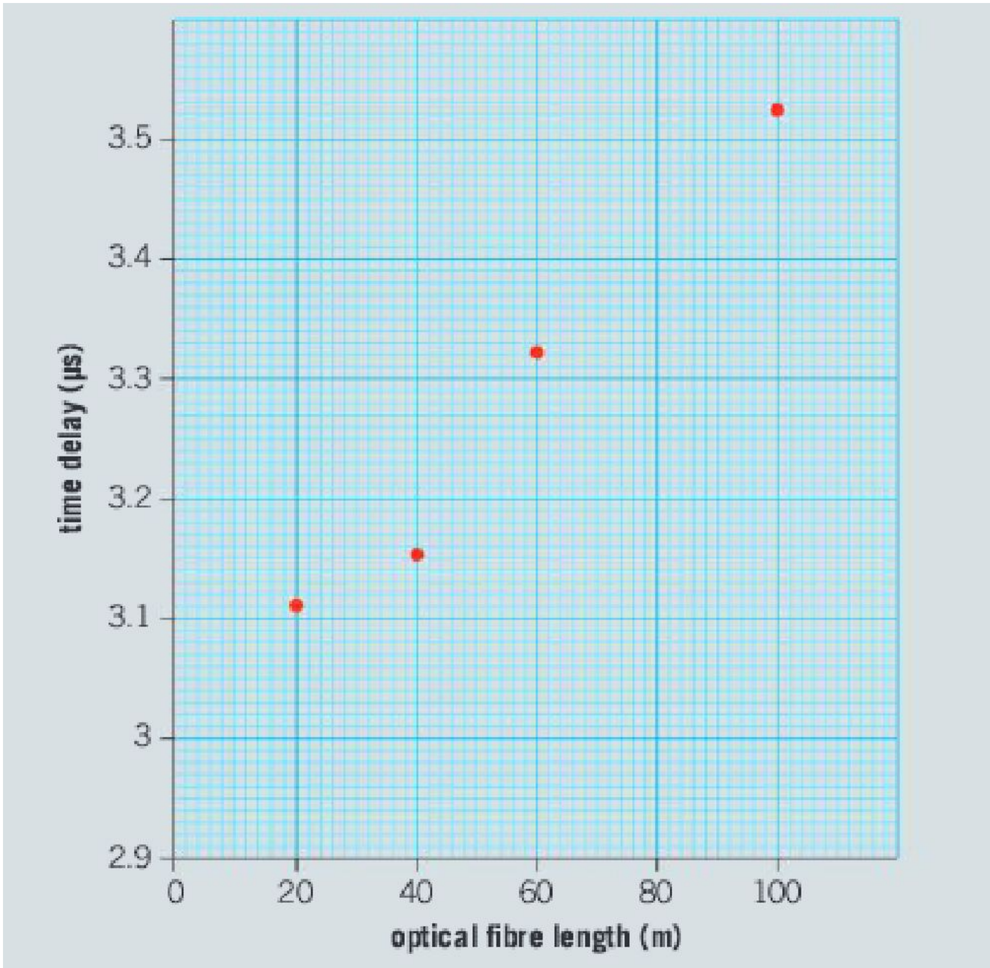


When the length of optical fiber is 80 m, the signal on the oscilloscope appears like this.



a. Measure the time delay between the initial signal and the detected signal. [2]

The length of the optical fiber is varied and the delay between the signals is measured. A graph of the results is shown below.



b. On the graph above, add the result from when the optical fiber was 80 m long. [2]

c. Add a line of best fit of the graph. [1]

d. Find the gradient of your line of best fit. [2]

Source: Physic Year 4 and 5 By William Heathcote

For Criteria D you just have to follow the strands in L:7-8 and check if you have satisfied the same.

i. **explain** the ways in which science is applied and used to address a specific problem or issue . Don't beat around the bush or write general applications. Be specific and focussed.

ii. **discuss and evaluate** the implications of using science and its application to solve a specific problem or issue, interacting with a factor iii. consistently apply scientific language to communicate understanding clearly and precisely

iv. **document** sources completely. (author, title, page no, publication and year)

Applying science:
This task requires you to explain how science is used to address a real-life issue. This task will be assessed against **criterion D**, but there may be occasions when marks are also awarded against the other three criteria when this is appropriate for the question. You should expect to write extended responses.

You gain global understanding of science by evaluating the implications of scientific developments and their applications to a specific problem or issue. Varied scientific language will be applied in order to
demonstrate understanding. You are expected to become aware of the importance of documenting the work of others when communicating in science.
You must reflect on the implications of using science, interacting with one of the following factors:
moral, ethical, social, economic, political, cultural or environmental, as appropriate to the task.
Your chosen factor may be interrelated with other factors.

A few sample questions are given below for your practise;
Essay on Energy

1. Write **an essay**(1000/1200 words)**,** which include the following:
   a. Application of energy transformation in daily situations. Give at least 5 appropriate examples and explain each using scientific words.
   b. Choose any machine/invention related to energy transformation.

Discuss and analyse the implications of this machine/invention to society, in terms of the benefits and the limitations, interacting to one of the following factors: moral, ethical, social, economic, political, cultural or environmental.

Citations is must. . (Provide **at least three authentic or reliable** sources.)
You may include diagrams/images /figures/graphs appropriately.

2 Essay on Electrical Energy

Let there be light

INSTRUCTION

Write an essay (1000/1200 words) to show your understanding of how Science is used to fulfil the electricity demand and what implications it has.

To do this you need to

1. Choose **ONE** particular region anywhere in the world and describe how an energy resource is used to produce electrical energy to fulfil the electricity demand within this region, and how the energy is transferred to homes/businesses. Explain the reason for this choice of energy production.
2. Discuss and evaluate the implications of this method of energy production in your chosen region. Your evaluation should relate to **one** of the following factors: moral, ethical, social, economic, political, cultural or environmental.

You are expected to include appropriate scientific language, charts, tables, and graphs. Check that you have carefully read the descriptor for the highest level of criteria D.
Cite facts or information copied or paraphrased from resources appropriately

3. Scientists think that some animals are able to help themselves navigate by detecting the Earth's magnetic field. However, they are not certain about how animals are able to detect magnetic fields. In 2008, some Czech scientists analyzed images from Google Earth and found that cows and deer seemed to prefer to align themselves with

the Earth's magnetic field. The following text is from the introduction to a paper published in the Proceedings of the National Academy of Sciences of the United States of

America, volume 105 on 9 September 2008. The paper was written by Sabine Begall, Jaroslav ˇCervený, Julia Neef, Oldrˇich Vojteˇch and Hynek Burda.

We demonstrate by means of simple, noninvasive methods (analysis of satellite images, field observations, and measuring "deer beds" in snow) that domestic cattle (n = 8,510 in 308 pastures) across the globe, and grazing and resting red and roe deer (n = 2,974 at 241 localities), align their body axes in roughly a north–south direction. Direct observations of roe deer revealed that animals orient their heads northward when grazing or resting. Amazingly, this [widespread] phenomenon does not seem to have been noticed by herdsmen, ranchers, or hunters. Because wind and light conditions could be excluded as a common denominator determining the body axis orientation, magnetic alignment is the most [convincing] explanation. […]. This study reveals the magnetic alignment in large mammals based on statistically sufficient sample sizes. Our findings […] are of potential significance for applied [ethics] (husbandry, animal welfare). They challenge neuroscientists and biophysics to explain the [underlying] mechanisms.

a. Write a bibliography reference for this paper. [1]
b. Discuss why non-invasive techniques are preferable when studying animal behaviour. [3]
c. Imagine that you are one of the scientists involved in this research. Write a report suggesting why you should be given more funding to continue this research. Explain the potential benefits of understanding why cows and deer prefer to align themselves to the Earth's magnetic field. [5]
d. It is believed that some animals use magnetic fields to navigate while migrating. Suggest one other way that animals might navigate, and compare the advantages and disadvantages of this with sensing the Earth's magnetic field. [3]
e. It is clear that migrating must take a lot of energy so animals would not do this if they did not have to. Give three motivations for animal migration. [3]

Source: Physic Year 4 and 5 By William Heathcote

4. Many industrial processes now use automated robots to carry out various tasks. Some manufacturers are increasing the number of robots they use on production lines.

a. Describe the advantages of using robots in industry. [5]

b. Some manufacturers are removing some robots in their factories and employing people to do these jobs instead. Explain what advantages there might be to employing a human workforce rather than using robots. [5]

c. For centuries machines have been used to make certain tasks easier. Pick one machine, describe what it does and explain how it makes that task easier. Try to use simple scientific terms effectively. [5]

Source: Physic Year 4 and 5 By William Heathcote