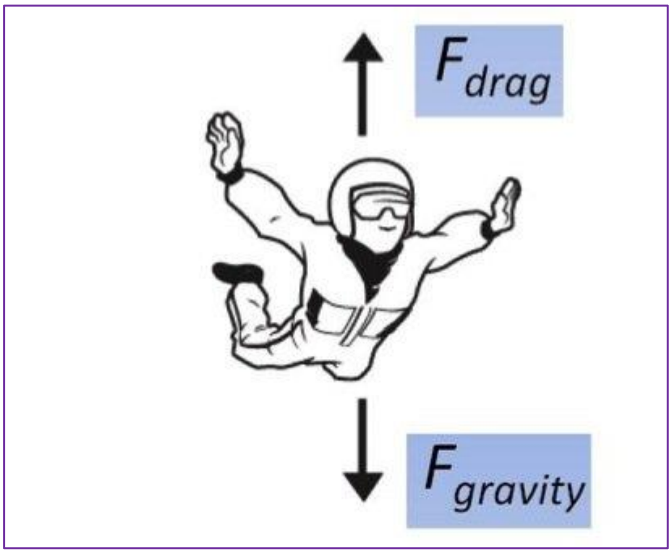
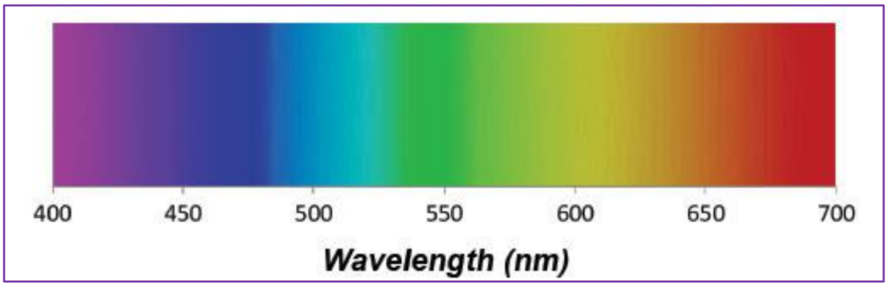


Edexcel GCSE Combined Science

Physics Paper 1

Revision Book



Select and Apply equations

Students may be asked to select and apply these equations in the exam papers. These equations will be given in a formulae sheet at the end of the exam papers.

Equations required for higher tier only are shown in bold text. Higher tier only equations will not be given in the formulae sheet for the foundation tier papers.

(Final velocity)^2 – initial velocity)^2 =2 x acceleration x distance $v^2 - u^2 = 2 \times a \times x$
Force = change in momentum ÷ time $\mathbf{F = \frac{(mv - mu)}{t}}$
Energy transferred = current x potential difference x time $E = I \times V \times t$
Force on a conductor at right angles to a magnetic field carrying a current = magnetic flux density x current x length $\mathbf{F = B \times I \times l}$
$\frac{\text{Voltage across primary coil}}{\text{Voltage across secondary coil}} = \frac{\text{number of turns in primary coil}}{\text{number of turns in secondary coil}}$ $\frac{V_p}{V_s} = \frac{N_p}{N_s}$
Change in thermal energy = mass x specific heat capacity x change in temperature $\Delta Q = m \times c \times \Delta\theta$
Thermal energy for a change of state = mass x specific latent heat $Q = m \times L$
Energy transferred in stretching = 0.5 x spring constant x (extension)^2 $E = \frac{1}{2} \times k \times x^2$

Topic 1: Motion- Revision

Vectors and scalars

We use many different quantities in physics; these quantities are split into two different groups- scalars and vectors.

Scalar quantities are quantities that have a size (magnitude) but no direction.

Vector quantities are quantities that have both size and direction.

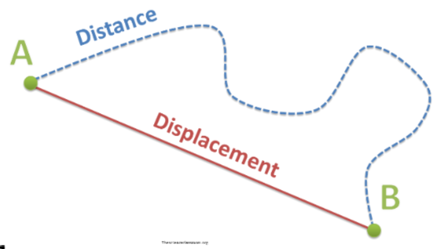
Some of these scalar and vector quantities are linked; **distance** and **displacement** are linked, as are **speed** and **velocity**.

Scalar quantities	Vector quantities
Distance (m)	Displacement (m)
Speed (m/s)	Velocity (m/s)
Time (s)	Acceleration (m/s^2)
Energy (J)	Force (N)
Mass (kg)	Weight (N)
	Momentum (kg m/s)

Distance and **displacement** are both measured in meters, distance is how far the journey is, and displacement is the distance covered in a straight line. Displacement is usually less than the distance travelled.

Speed and **velocity** are both measured in metres per second, speed is how far the object moves in a certain time and velocity is speed in a certain direction.

Acceleration tells us how **quickly velocity** is **changing**. An object is accelerating if it changes speed or changes direction.



Typical speed values

Typical Speeds	
Walking	1-3 m/s
Running	3-6 m/s
Cycling	6-8 m/s
Cars in town	13 m/s (30 mph)
Cars on the motorway	31 m/s (70 mph)
Trains	55 m/s
Aeroplanes	250 m/s
Wind	5 – 20 m/s
Sound in air	340 m/s
Light	300 000 000 (3×10^8) m/s

The **average speed** is calculated from the total distance travelled and the total time taken.

The **instantaneous speed** is the speed at any given point during the journey.

In the science lab we measure speed by measuring distance and time.

We often use a stopwatch to measure time but a light gate can measure time with much more accuracy.

Average speed (m/s) = distance (m) ÷ time (s)
s = d ÷ t

Distance travelled (m) = average speed (m/s) x time (s)
d = s x t

Distance/time graphs

A **distance/time graph** can be used to represent a journey; we can use a distance/time graph to find out different details about the speed during different parts of a journey.

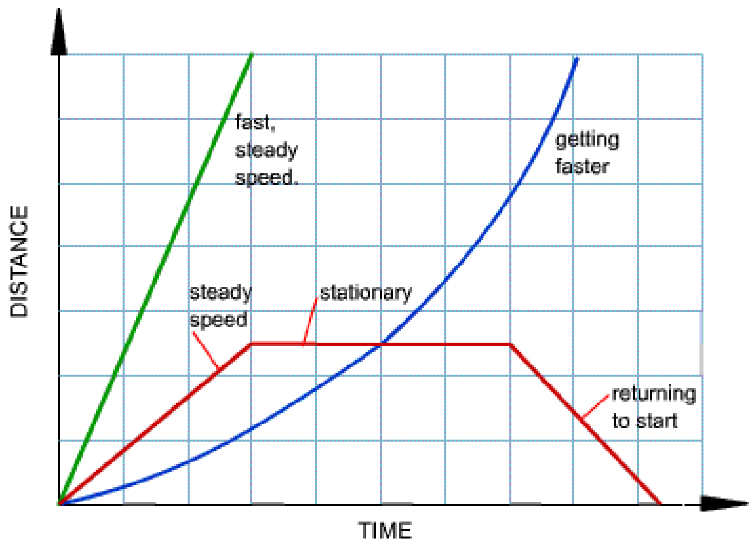
A horizontal line tells us that the object is **stationary.**

A straight sloping line tells us the object has a **steady speed.**

A steeper line indicates a **higher speed.**

A curved line tells us that the **speed is changing** (getting steeper = getting faster).

The **speed** can be calculated from the **gradient** of the line.



Acceleration

Whenever an object changes velocity (speed or direction), it is accelerating.
Acceleration is the **rate of change of velocity** (how quickly velocity is changing).
On Earth, objects fall because gravity accelerates them towards the centre of the Earth. The acceleration due to gravity is represented by the symbol '**g**' and is **10 m/s²**.

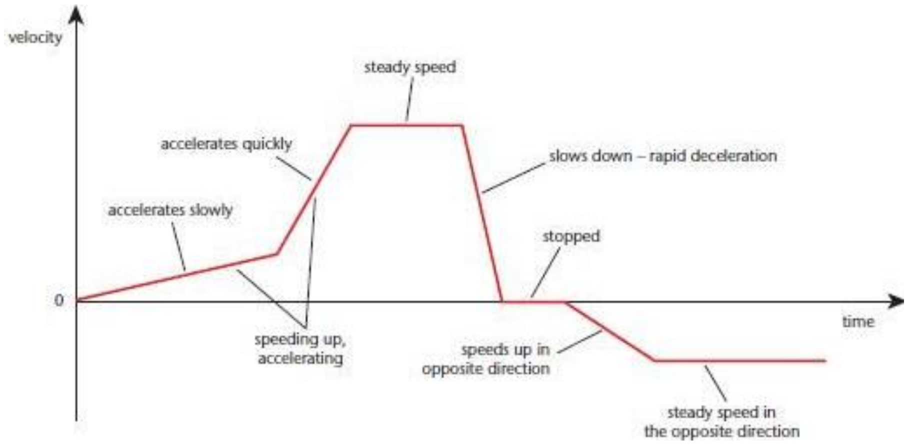
> Acceleration (m/s²) = change in velocity (m/s) ÷ time (s)
> $$\mathbf{a = (v - u) \div t}$$

To work out the change in velocity you need to know the initial velocity '**u**' and the final velocity '**v**'. If the object is speeding up the 'v – u' will give you a positive change in velocity and a positive acceleration. If the object is slowing down then 'v – u' will give you a negative change in velocity and negative acceleration (or a deceleration).
We can also calculate the acceleration if we know the distance travelled whilst accelerated as well as the initial and final velocities.

> Final velocity² (m/s) – initial velocity² (m/s) = 2 × acceleration (m/s²) × distance travelled (m)
> $$\mathbf{v^2 - u^2 = 2 \times a \times x}$$

Velocity/time graphs

A velocity/time graph can be used to show how the velocity of an object changes during a journey.
A horizontal line tells us the object is travelling at a **constant speed**
A straight sloping line tells us the object is **accelerating at a steady rate**
A steeper line indicates **higher acceleration**
A curved line tells us the **acceleration is changing** (getting steeper = increasing acceleration)



Acceleration can be calculated from the **gradient** of the line
Distance travelled can be found from the **area beneath** the line.

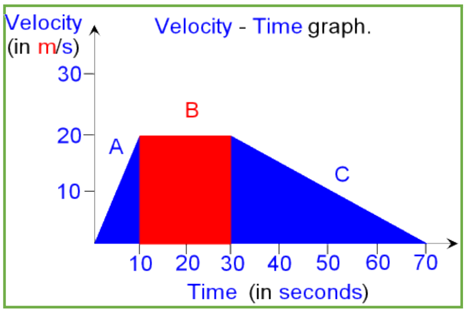
Calculating the area beneath the line

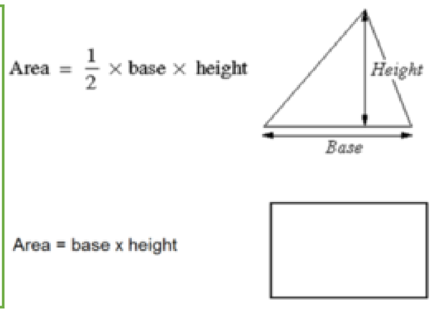
The area beneath the line will be a rectangle, a triangle or may even be a combination of both.
To work out the area of a rectangle

Area = base x height

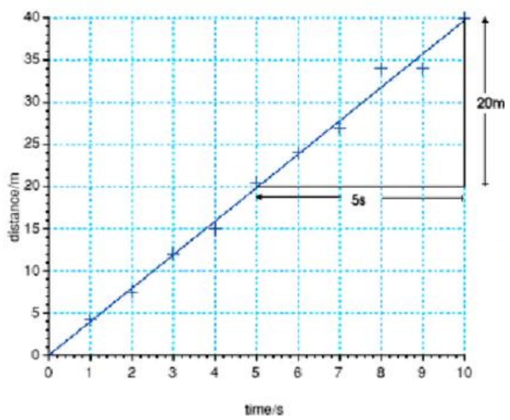
To work out the area of a triangle:

Area = ½ x base x height





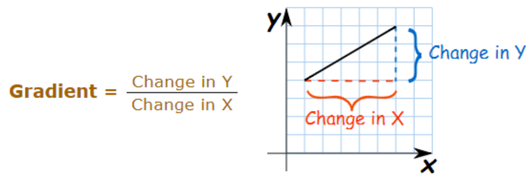
Calculating the gradient of a line



When you have a straight line, you can easily find the gradient of the line.

- Make a large triangle with the line.
- Work out how much the Y axis changes by.
- Work out how much the X axis changes by.
- Calculate the gradient using the equation:

Gradient = change in y ÷ change in X



Topic 2a: Forces- Revision

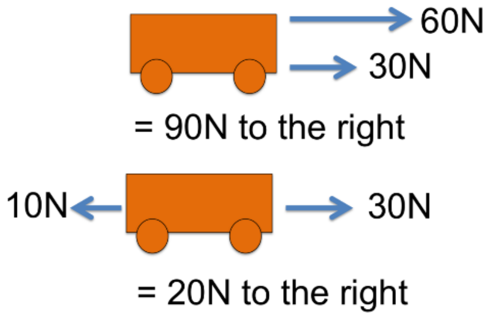
Scalars and vectors

Scalar values have **magnitude** whilst **vector** quantities have both **magnitude and direction**. An object can be moving in a circle, at a constant speed, and will be changing velocity because it is changing direction. If an object is changing velocity, then it is accelerating. A centripetal force is needed to make an object move in a circle, this may come from friction, tension or gravity. Forces are examples of vector quantities, it is important to know the size of the force and the direction in which it is acting.

Resultant forces

Usually there is more than one force acting on an object, the overall effect of these forces is called the **resultant force**. To calculate the resultant force:

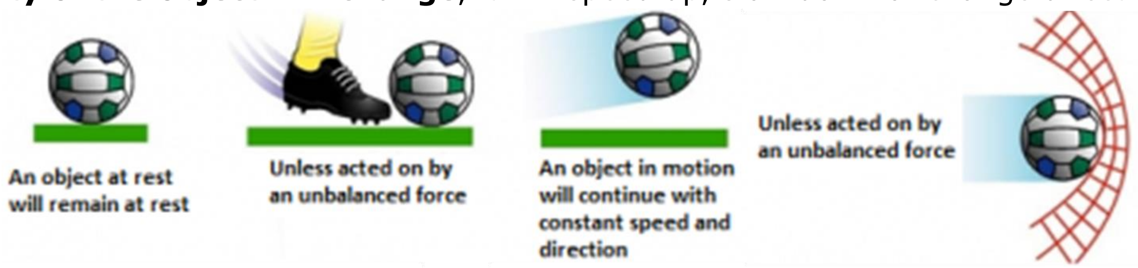
- If forces act in the **same direction**, you should **add them** together
- If forces act in **opposite directions**, you should **subtract one from the other**
- If the forces are acting at right angles, we work out the two separate sets of resultant forces separately.



If the **resultant force is zero**, we say the forces are **balanced**.
If the **resultant force is non-zero**, we say the forces are **unbalanced**.

Newton's first law

Newton's 1st law describes the relationship between the forces acting on an object and its motion.
If the **forces** acting on an object are **balanced** (zero resultant force) then the **velocity of the object will not change**, it will stay at rest or continue moving with the same velocity.
If the **forces** acting on an object are **unbalanced** (non-zero resultant force) then **velocity of the object will change**, it will speed up, slow down or change direction.



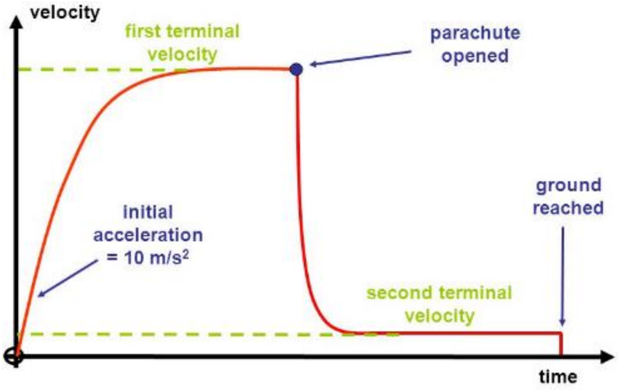
Falling objects

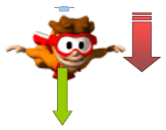
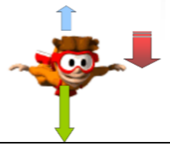
An object's mass (measured in kg) only changes if the object itself changes but the object's weight (measured in N) depends on the mass and the gravitational field strength. Objects fall towards the centre of the Earth due to gravity, on Earth objects every 1 kg of mass is pulled towards Earth with a force of 10 N. The Earth's gravitational field strength **'g' is 10 N/kg,** this is different on different planets and moons.

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

Terminal velocity

When objects fall, they accelerate and get faster, this increases the air resistance acting on them- until eventually they reach a terminal velocity when the forces acting on them are balanced.



			The skydiver will eventually open their parachute and the increased air resistance will cause them to decelerate, air resistance will decrease until the forces are again balanced, and a new terminal velocity is reached, but this time terminal velocity is at a much lower speed.
Just after jumping Very little air resistance Resultant force is high Acceleration is large	**A few seconds after jumping** Air resistance is increasing Resultant force is reducing Acceleration is reducing	**A while after jumping** Air resistance equals the weight Resultant force is zero There is no acceleration	

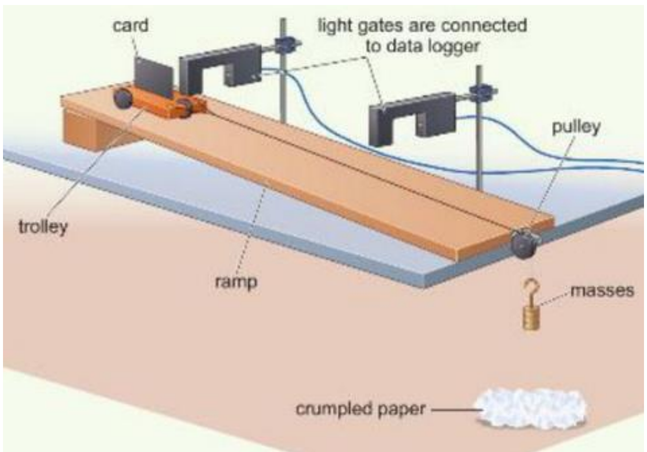
Newton's second law

Newton's second law tells us how the size of the resultant forces acting on an object affects its acceleration. The **bigger the resultant force**, the **bigger the acceleration**. The **larger the mass** of the object, the **smaller the acceleration**.

Force (N) = mass (kg) x acceleration (m/s^2)
F = m x a

Investigating acceleration

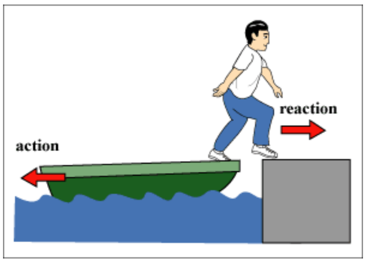
You can investigate acceleration using a motion trolley and a pair of **light gates**. As the card passes through the light gates the **speed** of the trolley is calculated using the **length of the card** and **the time it took the card to pass through**. The **time** taken to travel **between each gate** and the **change in velocity** between the gates can be used to calculate **acceleration**.
You can **change** the **mass** of the trolley by **adding masses** to it -keep the pulling force the same.



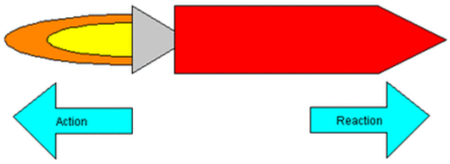
You can **change** the **force** pulling the trolley by **adding masses to the hanger**- keep the mass the same by having masses on the trolley and taking each mass you add to the hanger from off of the trolley.

Topic 2b: Collisions- Revision

Newton's third law



All forces require **interaction** between **two objects**, Newton's third law tells us about the forces acting on two different objects when they interact with each other. These two forces are called **action-reaction forces**. Action-reaction forces are always the **same size** and act in **opposite directions**, they act on **different objects** and are the **same type of force**. In the diagram here, the boy pushes backwards on the boat and the boat pushes forwards on the boy with the same size force. The rocket applies a force to the air moving out of the rocket, the air applies and equal and opposite force to the rocket.



Momentum (H)

Momentum tells us how **hard it is to stop** an object moving, it depends on **mass** and **velocity**.

Momentum (kg m/s) = mass (kg) x velocity (m/s)

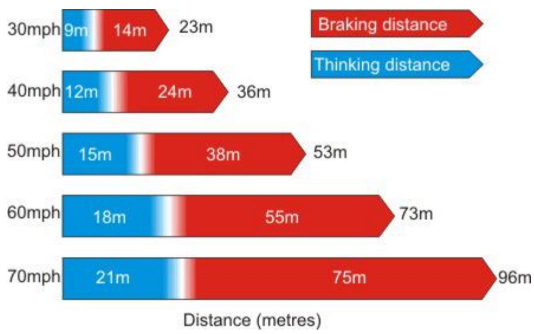
$$p = m \times v$$

A **resultant force** is needed to get **momentum to change**. The force needed to change momentum can be calculated, the quicker the momentum is changed, the more force is needed.

Force (N) = (mass(kg) x change in velocity(m/s)) ÷ time (s)

$$F = \frac{m(v-u)}{t}$$

As long as no external forces are acting then **momentum is always conserved during a collision**. The total **momentum before** the collision is **equal** to the total **momentum after** the collision.

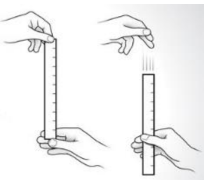


Stopping distance

When a driver sees a problem up ahead they must first react to the problem and then take action. The **distance** they travel whilst **reacting** is called the **thinking distance**, the distance they travel **once the brakes** are applied is called **the braking distance**.

Total stopping distance = thinking distance + braking distance

The **thinking distance** depends on your **reaction time** (typical **reaction time is 0.25 seconds**): factors that can increase reaction time are drugs, alcohol, age, tiredness and distractions (e.g. mobile phone).



The **braking distance** depends on the amount of **friction** between the brakes, tyres and road: factors that can increase braking distance are poor brakes, poor tyres, wet, icy or oily roads. The mass of vehicle can also affect braking distance. Both of these distances **increase with speed**- as shown in the chart. **Reaction time** can be **measured** in the classroom using the **ruler drop test**.

Car safety features

Car crashes can cause **serious injuries** due to the **huge forces** involved. The quicker a car slows down (the **bigger the deceleration**) **the greater the forces** are. A lot of safety features are designed to make objects **slow down slower**- reducing the deceleration and the forces involved. **Crumple zones** reduce the force because they take time to crumple, **air bags** increase the time taken for a person's head to stop and **seat belts** stretch to increase the time taken for a person's body to stop.

Topic 3a: Energy transfers- Revision

Energy can be stored in different ways

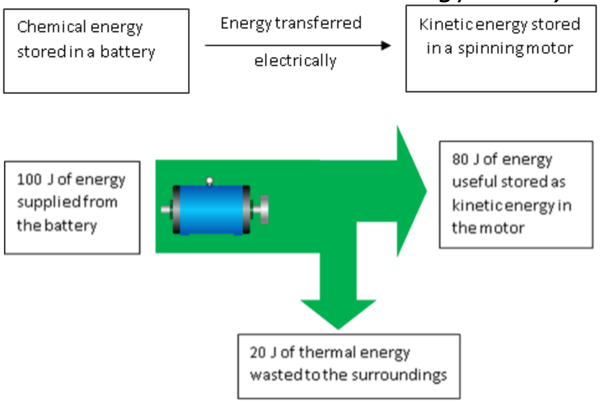
Thermal	The hotter an object, the more thermal energy it stores	Today
Kinetic	Any moving object has a kinetic energy store	Kids
Chemical	Can release energy through a chemical reaction (e.g. fuels, foods)	Can
Elastic	Anything stretched or compressed (e.g. elastic band or spring)	Easily
Magnetic	In two magnets that are attracting or repelling	Memorise
Gravitational	Due to an objects position within a gravitational field	GCSE
Electrostatic	In two electric charges that are attracting or repelling	Energy
Nuclear	Released from the nucleus (e.g. decay, fission or fusion)	Names

Energy can be changed from one store to another through different energy transfers

Mechanically	A force acts on an object through a distance
Electrically	An electric charge moves through a potential difference
By heating	Energy moves from a hotter object to a colder object
By radiation	Transferred by waves (e.g. light, sound)

Conservation of energy

Energy, measured in **joules (J), cannot be created or destroyed**. It can only be transferred from one place to another. (The energy before a transfer is the same as the total energy after.)



Energy transfer diagrams

We can represent energy stores and transfers using simple diagrams.
A **Sankey diagram** is used to show **what amount** of energy is transferred.
The width of the arrow represents the amount, or percentage, of energy being transferred.
Observe that the sum of the useful and wasted energy equal the energy supplied.

Energy is wasted during energy transfers

During energy transfers many machines become hot, energy is transferred to the surroundings by heating. The energy dissipates (spreads out) and is no longer useful, we say it is wasted. Friction between moving parts causes heating and is often the reason for energy being dissipated to the surroundings.

Reducing unwanted energy transfers

Lubricants, such as oil, can be used to **reduce friction** and therefore reduce the amount of energy wasted to the surroundings. **Insulation** can also reduce the amount of energy wasted from a system. Think about keeping the heat in your house, materials with a **low thermal conductivity** slow down the energy transfer, so the house cools down more slowly- less energy is wasted. **Thicker materials** will also **slow down the rate of energy transfer**.
Some machines transfer **most of their energy into useful forms** and do not waste much, we say these machines are **efficient**. Machines that **waste** a lot of **energy** are **inefficient**.
To **improve the efficiency** of a machine you have to **reduce** the amount of **energy** that is **wasted**. All machines will waste some energy so the efficiency is always below 1 (or 100 %).

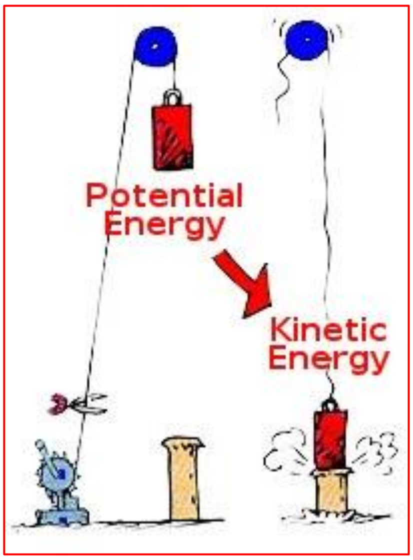
$$\text{Efficiency} = \frac{\text{useful energy transferred by device}}{\text{total energy supplied to device}}$$

Energy Transfer by Heating

It costs money to heat our houses, so we want to stop the heat escaping to the outside. (In the summer, we want to stop the heat getting in so that we can keep our houses cool.) Insulation slows down the rate of energy transfer to the surroundings. Heating can transfer energy in different ways:
Conduction passes energy from particle to particle in solids. Metals are good thermal conductors; wood is a poor thermal conductor (or a good thermal insulator).
Convection transfers energy through fluids, warmer fluids rise, colder fluids fall and this sets up a convection current.
Radiation can transfer energy through a vacuum. Infrared energy is absorbed and emitted best by dark, dull surfaces (and poorly by light, shiny surfaces).

Topic 3b: Energy resources- Revision

Gravitational Potential Energy



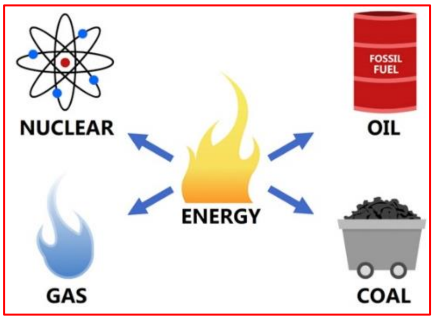
GPE is energy that is stored due to an object's position within a gravitational field. The higher and object, the stronger the gravitational field or the greater the mass the more energy is stored. On Earth, g is 10 N/kg.
GPE is often transferred into KE and vice-verse e.g. a falling object gains KE equal to the GPE lost.

Kinetic energy

Energy stored in moving objects is called kinetic energy. The more mass an object has and the faster it is going the more kinetic energy it stores.
Note: if you double the mass then the KE will double. If you double the velocity, then the KE will quadruple (x4) this is because of the velocity² in the equation.
Often these two energy stores are transferred between each other. (In reality some energy would be dissipated to the surroundings by heating).

GPE (J) = mass (kg) x gravitational field strength (N/kg) x change in vertical height (m) **GPE = m x g x Δh**
KE (J) = ½ mass (kg) x velocity² (m/s) **KE = ½ m x v²**

Non-Renewable energy resources



We currently get most of our energy from **fossil fuels** and **nuclear fuel**. These resources are **non-renewable** and will **soon run out**.
Fossils fuels are **coal, oil and natural gas**. Typically, we burn them to release the chemical energy stored within the fuel. Nuclear fuels are uranium and plutonium the nuclear energy is released during a process called nuclear fission.

Fuel	Advantages	Disadvantages
Fossil	Reliable Provide enough energy to meet our demands Cost to extract them from the ground is low Power stations are cheap to build and maintain	Are slowly running out Produce greenhouse gases- adds to global warming Produce sulphur dioxide- causes acid rain Oil spillages damage to the environment
Nuclear	Reliable Provide enough energy to meet our demands Clean- produces no greenhouse gasses or sulphur dioxide Not many accidents	Costly to build and decommission the nuclear power plant Produce nuclear waste-difficult to dispose of Risk of nuclear meltdown, e.g. Chernobyl or Fukushima

Trends in Fuel use

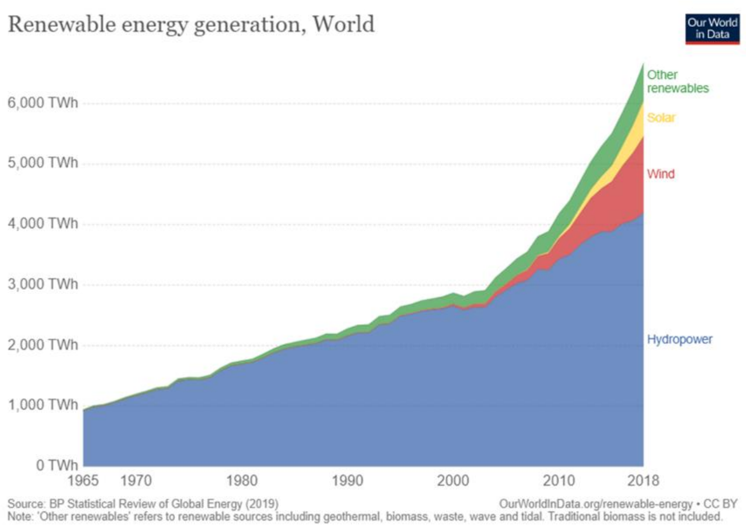
Over the 20th century populations around the world increased rapidly, so did the use of electricity. **Most of electricity** is produced from **fossil fuels**; we **also** use fossil fuels for **transport and heating**. During the 20th century, the use of fossil fuels increased but in the 21st century, most countries are trying to reduce the use of fossil fuels.

Renewable energy resources

More and more countries are turning to renewable sources of energy, these will not run out and most do not produce pollution or greenhouse gases as no fuel is burned.

Resource	Description	Advantages	Disadvantages
Solar	Use the energy transferred by light to create an electric current	No pollution, no running costs, can be used in remote places, won't run out	Initial costs high, not always light, do not produce much electricity
Wind	When the blades rotate, a generator is turned which induces an electric current	No pollution, low running costs, won't run out	Initial costs high, spoil the view, not always windy, do not produce much electricity
Hydro-electricity	A dam stores GPE in water, water is allowed to flow through turbines, turning a generator	No pollution, can respond very rapidly to energy demands, won't run out	Initial costs are high, damage the environment and destroy habitats
Biofuels	Plant material or animal waste is burnt to produce electricity	Reliable, carbon neutral (only return CO_2 that they removed from the atmosphere), won't run out	Can be expensive to refine, forests and habitats often destroyed for the growth of biofuels
Tidal	A large tidal barrage is built across the estuary of a river. As the tide flows in or out turbines are turned	No pollution, low running costs, reliable (tides are predictable), won't run out	Initial costs are high, can damage the environment and alter habitats, don't always produce electricity

Trends in renewable energy



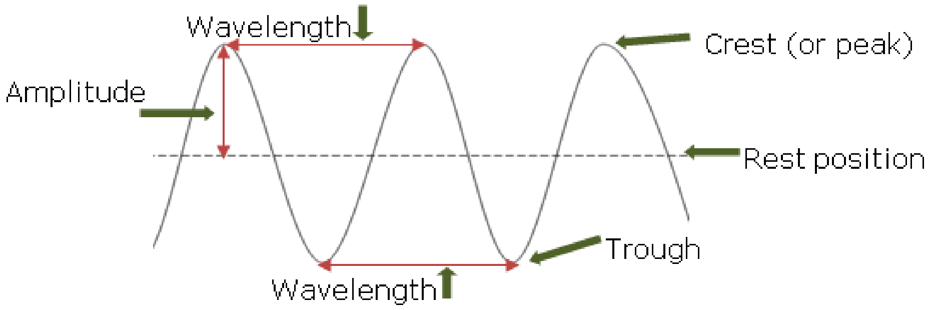
Whilst the use of **renewable energy resources** in **on the rise** we still rely heavily on non-renewable resources. **Renewable energy resources** are still **expensive** and **cannot provide enough energy** to **meet our demands**. Many of them are also **unreliable**, such as wind turbines and solar cells. **Research** into improving the reliability and cost of renewable resources is underway but is itself **expensive** and **takes time**.

Topic 4a: Waves- Revision

Wave transfer energy

All waves transfer energy, they do not transfer matter. E.g. water waves move energy from one place to another, but the water doesn't move- boats bob up and down as the waves pass but the boats do not move.

Key parts of a wave



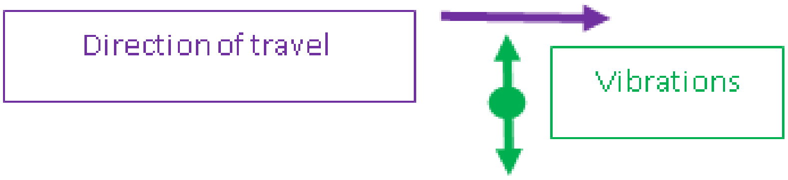
The **wavelength** is the distance from one point to the next identical point e.g. from peak to peak.
The **amplitude** is the displacement from the rest position to a crest or trough.
The **frequency** is the number of waves which pass a point every second, it is measured in **hertz** (Hz). 1 Hz means 1 complete wave every second.
The **period** is the time taken to complete one wave (Period = 1 ÷ frequency).

Types of wave

There are two main types of wave, **transverse** and **longitudinal**. Water waves and all electromagnetic waves, such as light & radio waves are transverse. Sound waves are longitudinal waves. Earthquakes produce both longitudinal and transverse waves.

Transverse waves

In **transverse waves** the **particles** vibrate at **right angles** (perpendicular) to the **direction of wave travel**.



Transverse waves (look at the T shape)

Longitudinal waves

In **longitudinal waves** the **vibrations** are **parallel** with the **direction of wave travel**. The particles are squashed together in a compression (area of high pressure) and then spread out in a rarefaction (area of low pressure).

Longitudinal waves (vibrations are aLONG the same direction)

Wave speed

Wave speed is quite simply the speed a wave is travelling at. There are two equations that allow you to calculate wave speed.

Wave speed (m/s) = distance (m) ÷ time (s)

$$V = x \div t$$

Wave speed (m/s) = frequency (Hz) x wavelength (m)

$$V = f \times \lambda$$

Measuring the velocity of waves

To measure the speed of sound waves you should use a **tape measure** or **trundle wheel** to measure out a **distance of at least 300 m**, get a partner to produce a sound with a visible signal. **Start the stopwatch** when **you see the signal** and **stop it** when you **hear the sound**.
Use the equation '**V = x ÷ t**' to calculate the speed.
You can use the same equation to calculate the speed of water waves, **measure the time taken** to **travel a known distance** between two fixed points (e.g. two floating buoys or ladders in a harbour).
To find the **frequency of a wave** you **count** how many complete waves **pass a point** in a certain amount of **time** (often 10 seconds) and then **divide the number of waves by the time taken** (frequency = number of waves ÷ time taken).

Measuring waves on water

You can find the speed of waves on water using both equations.
Set up a ripple tank producing waves with a wavelength about half the length of the tank- this way you will always see two waves. Attach a ruler along the side of the ripple tank so that you can clearly see the markings.

Using V = f x λ

1- Count how many waves are formed in 10 seconds
2- Divide this number by 10 to find the frequency of the waves (in Hz)
3- Use the markings of the ruler to estimate the gap between two waves- this is the wavelength
4- Use your value for f & λ to calculate the speed of the waves

Using V = x ÷ t

1- Measure the distance between two clear points in your ripple tank
2- Record how long it takes for a wave to travel between these two points
3- Use your value for x & t to calculate the speed of the waves

Measuring waves in solids

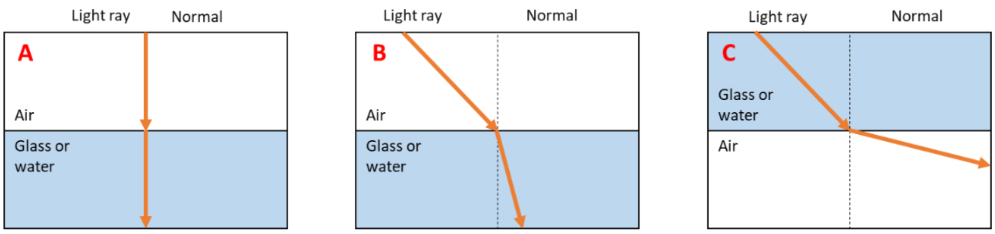
1- Suspend a metal rod using rubber bands
2- Use a hammer to hit one end of the rod, record the frequency of the sound produced (you will be able to use a data logger or even a frequency app on a smart phone to record this)
3- Measure the length of the rod
4- The wavelength is the length multiplied by two
5- Use your value for f & λ to calculate the speed of the waves

Topic 4b: Refraction- Revision

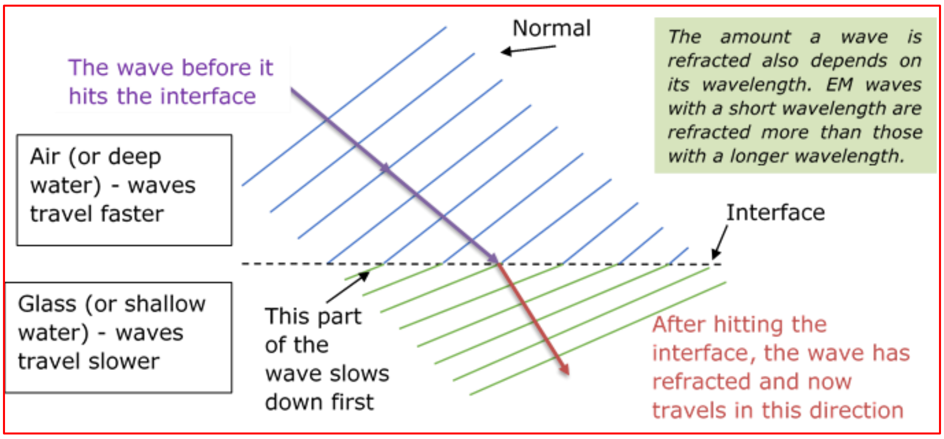
Refraction

Waves travel in straight lines, but they can **change direction** as they move from one medium to another. This change in direction is called refraction. Refraction happens at the **boundary** between to media- this is called the **interface**. The **normal** is an imaginary line at right angles to the interface.

- Light travelling along the normal as it hits the interface does not change direction, see diagram A below.
- Light moving from a **less dense to a more dense** medium (e.g. from air into glass) will **refract towards the normal**, see diagram B below.
- Light moving from a **more dense to a less dense** medium (e.g. from glass into air) will **refract away from the normal**, see diagram C below.

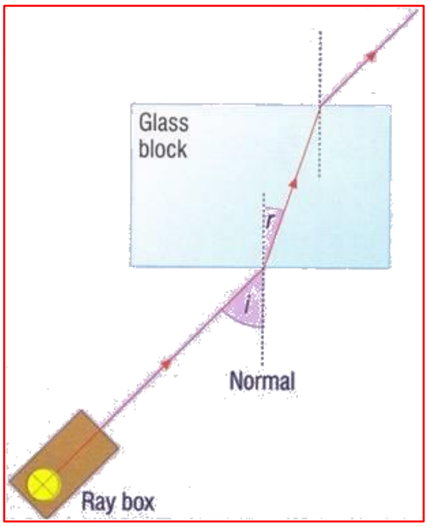


Why waves refract



Waves can travel through many different materials, but they will travel at different speeds (e.g. light travels faster in air than in glass and waves travel faster in deep water than they do in shallow water). As waves (e.g. light) **pass across the interface** of two materials the waves **change speed,** and this causes the **direction to change**. The greater the change in speed- the greater the change in angle. If the wave **slows down,** then it bends **towards the normal**- if it **speeds up** then it **bends away** from the normal.

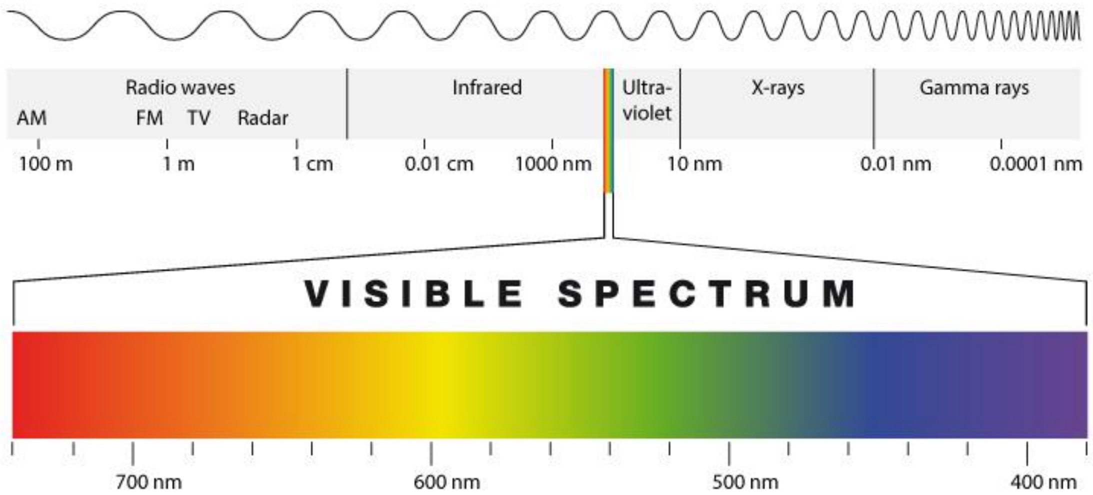
Investigating refraction



Refraction is the **bending of light** as it passes the **interface** between two materials, it occurs due to the change in wave speed. To investigate refraction, you need a thin beam of light from a **ray box**, a **ruler**, a **pencil**, a **glass block** and a **protractor.**
Shine light through the glass block, use a pencil to **mark the path** of the light **before and after** the glass block, remove the glass block and **use the ruler** to complete the rays of light. Use a **protractor** to **measure** the **angle of incidence** and the **angle of refraction**, repeat this for several angles over a **large range of angles**. Remember that angles are measured from the normal line.

Topic 5: Light & the Electromagnetic Spectrum- Revision

The electromagnetic (EM) spectrum



The EM spectrum is a family of waves with similar properties, however the waves have different wavelengths which means that they have different frequencies and different properties.
ALL EM waves are **transverse,** and they all travel at the **same speed through a vacuum**- the speed of light, which is **300 000 000 m/s.**
The electromagnetic waves, from longest wavelength to shortest, are: **radio waves, microwaves, infrared, visible light, ultra violet, X-rays and gamma rays.**
All of these EM waves transfer energy from their source to an observer, e.g. infrared waves can transfer energy from a heater to your skin. Many of these waves can be used to transfer information from their source to an observer, e.g. infrared waves can transfer information from a TV remote to the TV. You will need to remember the colours of visible light (the visible spectrum) from longest wavelength to shortest these are **red**, **orange**, **yellow**, **green**, **blue**, **indigo**, **violet**.

Producing and detecting electromagnetic waves

All EM waves are generated by **changes within the atom**, e.g. gamma rays are caused by changes in the nucleus of an atom and light rays are often produced by changes to an electron's energy level.
Radio waves are produced by ***oscillating*** *(vibrating)* ***charges****. An* ***a.c. supply*** *causes* ***electrons to oscillate*** *within a transmitter, these oscillations produce radio waves that have the* ***same frequency*** *as the a.c. supply.*
When the radio wave hits the receiver, ***electrons*** *inside the receiver* ***absorb the energy*** *and begin to* ***oscillate****, producing an a.c. with* ***the same frequency*** *as the radio waves.*

Frequency, wavelength and energy

As the wavelength of EM waves gets smaller, we see that the frequency gets larger so radio waves have a long wavelength but a low frequency whereas gamma rays have a short wavelength and a high frequency. The **higher the frequency** of a wave the **more energy** it transfers- this makes the higher frequency waves more dangerous to humans than the lower frequency waves.

Using the electromagnetic waves

Due to their different wavelengths and their different properties the EM waves have different uses.

Radio waves	Radio waves are used for **communication** such as **broadcasting television** and **radio**, and **satellite transmissions**. Radio waves are transmitted easily through air. They can be reflected to change their direction. Television and radio systems use this principle to broadcast information.
Microwaves	Microwaves are used for **cooking food**, **communications** and for **satellite communications**. Microwaves pass easily through the atmosphere, so they can pass between stations on Earth and satellites in orbit.
Infrared	Infrared (IR) light is used by **electrical heaters**, cookers for **cooking food**, **short-range communications like remote controls**, **optical fibres, security systems** and **thermal imaging** cameras which detect people in the dark. All objects emit infrared light. The human eye cannot see this light, but infrared cameras can detect it. 'Thermal imaging' is useful for detecting people in the dark.
Visible light	Visible light is the light we can see, so is used **in photography** and **illumination**. It is also used in **fibre optic communications**, where coded pulses of light travel through glass fibres from a source to a receiver.
Ultraviolet	**Fluorescent** substances are used in **energy-efficient lamps** - they absorb ultraviolet light produced inside the lamp, and re-emit the energy as visible light. Similar substances are used on bank notes to **detect forgeries** and **security markings.** The properties of UV mean it will **kill bacteria** and can be used for **disinfecting water.**
X-rays	X-rays are absorbed by dense structures like bones, which is why X-ray photos are used to help **identify broken bones**. X-ray imaging is also used for scanning the internal structure of objects and in **airport security** scanners.
Gamma rays	Gamma rays are used for **sterilising food and medical instruments**, and in the **treatment and detection of cancer**.

Dangers of the electromagnetic waves

The different wavelengths and properties of the EM waves means that they behave differently when they meet a boundary between two materials- this means they have different implications for human health when we come into contact with them.

Radio waves transmit (pass) through our body without being absorbed and cause **no damage**.

Microwaves can be absorbed by cells inside our bodies and cause **internal heating of our blood**.

Infrared is mostly absorbed or reflected by the skin and can **cause burns to the skin**.

Visible light is mostly absorbed or reflected by the skin and can cause **burns to the skin** (think lasers)

Ultraviolet is also absorbed by the skin but is a higher frequency so can be more dangerous. It can damage cells in our skin and lead to **skin cancer**, it can also cause **damage to the eyes**, even blindness.

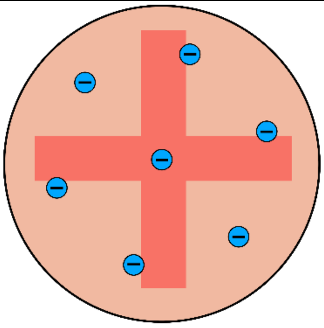
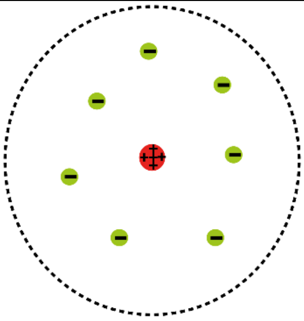
X-rays and **gamma rays** pass into the body and are absorbed by deeper tissues and can **damage cells**, **cause mutations** and **lead to cancer**.

Ultraviolet, X-rays and gamma rays are higher frequency waves and are known as **ionising radiations**. Their **high energy** can **knock electrons** out of atoms leaving charged particles (called ions) within the body. This damage can **lead to cancer**.

Topic 6: Radioactivity 1- Revision

The atom

An atom consists of a **nucleus**, containing **nucleons** (**protons** and **neutrons**), surrounding by **electrons** orbiting in **energy levels** or **shells**. **Protons** have a **relative mass** of **1** and a **relative charge** of **+1**. **Neutrons** have a **relative mass** of **1** and **no relative charge**. **Electrons** have a **negligible (1/1825) relative mass** and a **relative charge** of **-1. Atoms** and small molecules typically have a radius of around **1×10^{-10} m**. A nucleus typically has a radius of **1×10^{-15} m.** Our understanding of the atom has changed over time.

The plum pudding model		The nuclear model	
	The atom was thought to be a **region of positive charge** with **negative electrons spread throughout**.		The **nucleus** was proven to be **small** and **positive** and it was believed that the negative **electrons orbited** in the empty space surrounding the nucleus.

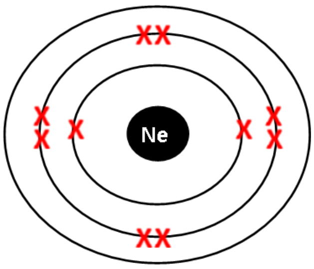
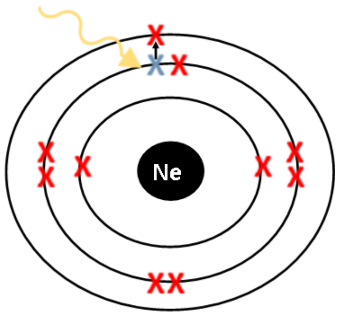
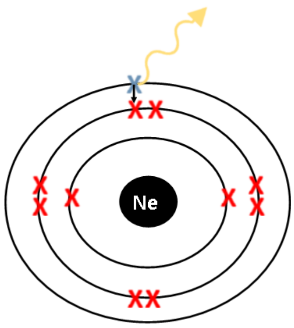
Rutherford's scattering experiment

Rutherford proved that the plum model was incorrect, he was firing **alpha particles through thin gold foil**. **Most** of the alpha particles **passed straight through**- proving that **the atom was mostly empty space**. **Some** of the alpha particles, which have a positive charge, **bounced back**- suggesting that the **nucleus** was not only **small** but had to be **positive**.

Nuclear symbols and isotopes

Nuclear symbols are used to describe atoms. The **bottom number**- the **atomic number**- tells us the **number of protons** in the nucleus. The **top number**- the **mass number**- tells us the **number of nucleons** in the nucleus (if you **subtract the atomic number from the mass number** you can find out **how many neutrons** there are). Two atoms of the **same element** will always have the **same number of protons**, Carbon-12 and Carbon-14 both have 6 protons, but they have a different number of neutrons. **Isotopes** of an element all have the **same number of protons** (atomic number) but a **different number of neutrons** (mass number). An **atom** is **neutral** (has no overall charge) because the **number of protons** in the nucleus is **equal** to the **number of electrons** orbiting, so the positive charges are balanced by the same number of negative charges.

Electron energy levels

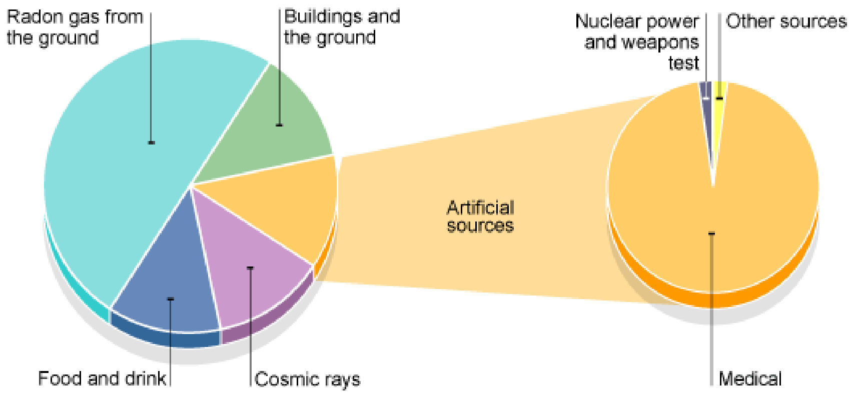
Electronic configuration	Absorbing energy	Emitting energy
		
Electrons in an atom exist in different energy levels around the nucleus, they are arranged differently for each type of atom, the arrangement is known as the electronic configuration.	When an **electron absorbs** the correct amount of energy it becomes **excited** and move to **higher energy levels.**	The electrons quickly want to **return to their original location** (**ground state**) and **emit electromagnetic radiation** in order to do so. This is often visible light.

The **wavelength of light** emitted **depends** on the **energy changes** made by the electrons, this depends of the electronic configuration.

Sometimes an outer electron gains **enough energy** it can **escape** the **atom** altogether, the atom has become an **ion**. There are now **more protons** than **electrons**, so a **positive ion** is produced.

Background radiation

Background radiation is **low level radiation** that always **surrounds us.** Background radiation is different in different areas- some areas have more rocks that produce radon gas. There are several sources of background radiation including radon gas, cosmic rays, medical sources, rocks & buildings and food & drink.



Investigating radioactivity

A **Geiger Muller (GM) tube** is used to **measure radioactivity**.
Photographic film can also be used to measure radioactivity.
When investigating radioactivity it is important to take a background count. To take a **background count** place the **GM tube away from any radioactive material** and record how many **counts there are in one minute**, **repeat** this three times and calculate the **mean average**.
To measure the radioactivity of a sample, **place the sample a set distance in front** of the **GM tube** and record how many **counts there are in one minute**- some of these counts will be from the background radiation so find the **actual count** you must **subtract** the **background count** from the **measured count**.

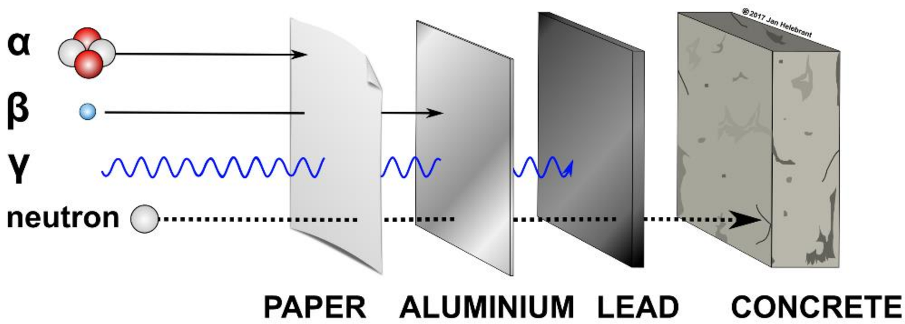
Types of radiation

The **nucleus** of a radioactive substance is always **unstable**, the nucleus will **decay** in an attempt to become more stable. When a nucleus will decay is **random**- you cannot predict when it will happen.
There are **different types** of radiation that can be emitted by a nucleus when it decays.

Radiation	Symbol		Nature	Realtive mass	Relative charge
Alpha	α	$^{4}_{2}He$	A helium nucleus (2 protons and 2 neutrons)	4	+2
Beta$^-$	β^-	$^{0}_{-1}e$	A high speed electron	1/1835	-1
Beta$^+$	β^+	$^{0}_{+1}e$	A high speed positron	1/1835	+1
Gamma	γ		High frequency EM radiation	No mass	No charge
Neutron	N		A high speed neutron	1	No charge

Properties of radiation

All of these radioactive particles are **ionising**- they cause atoms to **lose electrons**, creating **positive ions**.
The more energy they transfer the better they are at ionising. Particles that are very ionising lose their energy very quickly and are not very penetrating (do not travel very far and are easily stopped).



Alpha particles are **very ionising**, but will only travel a **few centimeters** in air. They are **stopped** by **paper or skin**.
Both types of **beta particles** are much **less ionising** than alpha so will travel a **few metres** in air. They are **stopped** by a **thin sheet (3 mm) of aluminium**.
Gamma rays are **much less ionising** than beta particles and will travel **a few km** in air. They are only **stopped** by **several meters of lead or concrete**.
Neutrons are the **least ionising** and similary to gamma rays will only be **stopped** by **thick layers of lead or concrete**.

Topic 6: Radioactivity 2- Revision

Radioactive decay

When an unstable nucleus undergoes **radioactive decay,** the nucleus gets rearranged- this often means that the **atomic number changes**. When the **atomic number changes** a **different element** has been formed.
During **alpha** decay **2 protons and 2 neutrons** are **emitted**, so the **mass number** goes **down by 4** and the **atomic number** goes **down by 2**.
During **beta$^-$** decay a **neutron changes into a proton and an electron** (which is ejected), so the **mass number** stays **the same** and the **atomic number** goes **up by 1**.
During **beta$^+$** decay a **proton changes into a neutron and a positron** (which is ejected), so the **mass number** stays **the same** and the **atomic number** goes **down by 1**.
During **gamma** decay **electromagnetic energy** is **emitted**, so the **mass number** and **atomic number** remained **unchanged**.
During **neutron** decay a **neutron** is **emitted**, so the **mass number** goes **down by 1** and the **atomic number** stays **the same**.

Nuclear equations

The above decays can be represented by nuclear equations, some examples are shown here. The important thing to watch out for is that the **mass numbers** on either side of the equation must **be equal** and the **atomic numbers** on either side of the equation must **be equal**.
Look at the mass numbers for alpha decay they equal 235 on both sides of the equation, and the atomic numbers equal 92 on both sides of the equation. The beta decay shown is beta$^-$.
What would the new element be here? $^{187}_{78}\text{Pt} \rightarrow {}^{0}_{+1}\text{e} + ?$

Alpha decay

$$^{235}_{92}\text{U} \longrightarrow {}^{231}_{90}\text{Th} + {}^{4}_{2}\text{He}$$

Beta decay

$$^{235}_{92}\text{U} \longrightarrow {}^{235}_{93}\text{Np} + {}^{0}_{-1}\text{e}$$

Gamma decay

$$^{235}_{92}\text{U} \longrightarrow {}^{235}_{92}\text{U} + {}^{0}_{0}\gamma$$

The mass number would stay the same, so will remain at 187. The proton number will go down by 1, so will be 77. Element 77 is iridium (Ir).
The new element would be: $^{187}_{77}\text{Ir}$

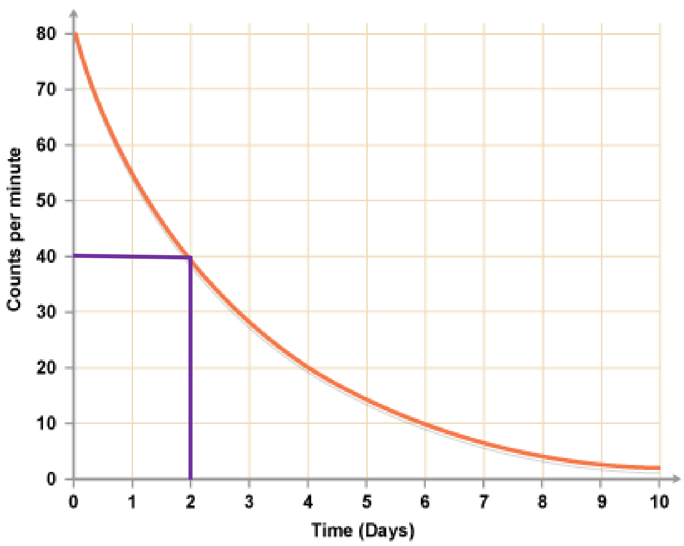
Activity

We measure the activity of a radioactive source in Becquerels (Bq), 1 Bq is 1 radioactive decay every second. Radioactive decay is a random process, you cannot predict when any given nucleus will decay. We can, however, use probability to predict the activity of a large number of nuclei. Some isotopes decay at a much greater rate than others.

Half-life

Radioactive **half-life** is the **time taken** for **half of the unstable nuclei to decay** or half-life is the **time taken** for the **radioactivity to reduce by half**. Different radioactive isotopes have different half-lives, but the half-life of a given isotope never changes.

Finding half-life from a graph

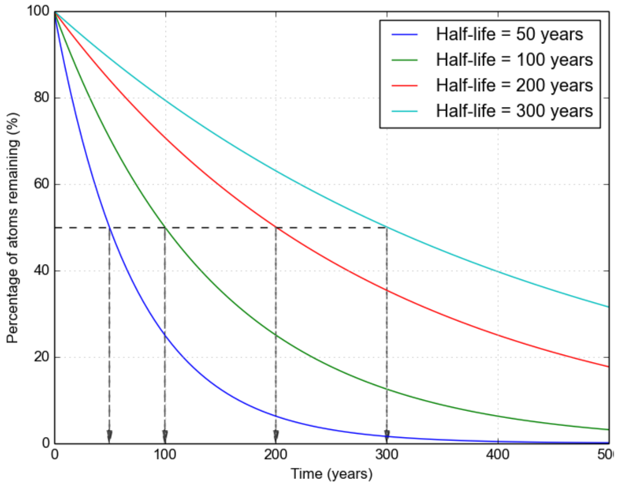


A half-life graph is an exponential decay curve, like the one shown here. You can use this graph to find the half-life of the substance.

1. Where does the curve meet the Y-axis (what is the starting count rate?) 80 cpm
2. What is half of this value? 80 ÷ 2 = 40 cpm
3. Draw a horizontal line from this value (40) until it meets the curve
4. Draw a vertical line down from the curve to the x-axis
5. What time is this? 2 days

The half-life for this isotope is always the same, no matter what the activity is, it will half every 2 days. This will be different for a different isotope.

Comparing half-life on a graph



Different isotopes have different half-lives, this means their respective half-life graphs look different. The **shorter** the **half-life**, the **steeper** the **curve** will be. The graph to the right shows a comparison of isotopes with different half-lives.

Calculating half-life

Half-life calculations can be really straight forward, if you work through them step-by-step. You can be asked to calculate the half-life of an isotope or the total time taken for a given decay to occur. You could also be asked to calculate a new activity or the original activity. Whatever the question is asking you to calculate, all you have to do is break it down into steps- every half-life the activity will half (÷2), so all you really have to do is ÷2.

Example: A radioactive isotope has an activity of 320 Bq. 4 hours later is has an activity of 20 Bq. Calculate the half-life of this isotope.

First thing to do is work out how many half-lives there were:

Initial count 320 Bq	÷ 2	After 1 half-life 160 Bq	÷ 2	After 2 half-lives 80 Bq	÷ 2	After 3 half-lives 40 Bq	÷ 2	After 4 half-lives 20 Bq

There are four half-lives and the total time taken was 4 hours. To find the half-life you divide the total time by the number of half-lives: 4 hours ÷ 4 half-lives = 1 hour.

You may have been told the half-life and asked to calculate the activity after 2 hours.

First thing to do is work out how many half-lives there are. This time you divide the total time by time for 1 half-life: 2 hours ÷ 1 hour = 2 half-lives. So we half the activity (÷ 2) twice and you can see in the table above that this gives us an activity of 80 Bq.

Work through this type of question step-by-step and you will find them very easy.

Dangers of radioactivity

Radiation can cause visible damage- reddened skin- due to **radiation burns** but can do a lot of unseen damage. Over a long period of time even small doses of radiation can **damage the DNA** inside a cell- this is called a **mutation**. Some mutations can cause cells to malfunction and can lead to **cancer**. Cells can repair themselves from some mutations, if the radiation was a very low dose. The background radiation we are exposed to is very low dose, so the risk is very low, people who work with radiation have to take certain precautions to limit the risks.

Reducing the risks

Some people, such as medical staff, work with radioactive sources and they have to **limit their exposure** as much as possible.

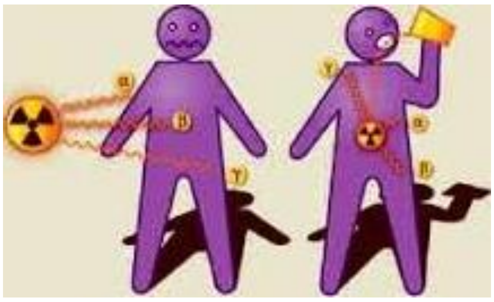
Using **tongs** to hold sources because intensity of radiation **decreases with distance**. **Don't point** the sources at people and store them in **lead-lined containers**.

Keep **exposure time** as **short** as possible and **monitor exposure** using a **dosimeter**.

Sometimes **patients** are exposed as part of their **diagnosis or treatment**, this is only done if the benefits outweigh the risks. **The smallest dose** possible is used and sources with a **short half-life** are chosen to limit the exposure time for patients.

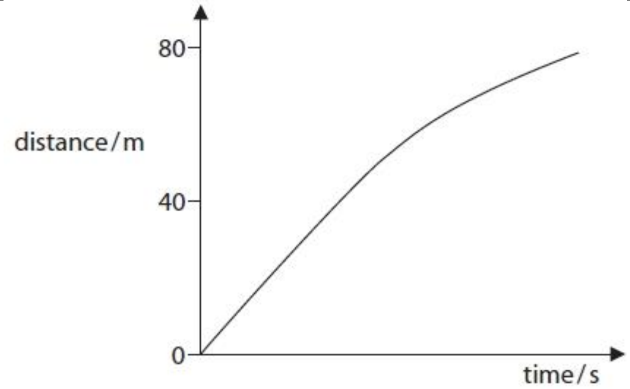
Irradiation and contamination

If you are **close to a radioactive source** you may get **irradiated**, this means you are **exposed to alpha, beta or gamma** particles emitted by that source- when you move away from the source the irradiation stops.

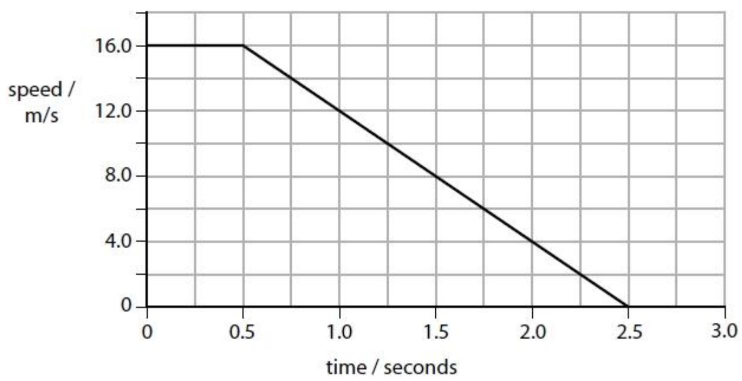


If somebody gets a **radioactive source on their skin** (or in their **hair**) or **inside their body**, then they have been **contaminated**. A person who has been contaminated will continue to be exposed to radiation until the radioactive source has been removed or has all decayed. After a nuclear accident water supplies and soil can become contaminated, so the contamination can spread through the food chain. People wear suits, gloves and masks to prevent the risk of contamination.

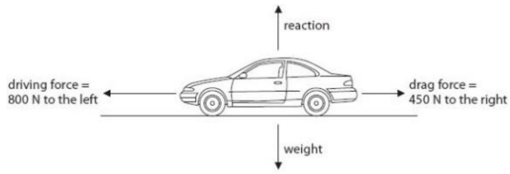
1a	Quantities in physics can be classed as scalar or vector. **Describe the difference between scalar and vector quantities. (2)**
1b	Speed and velocity are examples of quantities measured in physics. **i. List 2 scalar quantities (1)** **ii. List 2 vector quantities (1)** **iii. Compare speed and velocity (2)**
2a	Speed tells us has far an object moves in a certain time. **State the typical speeds of:** **i. A person walking (1)** **ii. A car on the motorway (1)** iii. **Sound waves in air (1)**
2b	Speed tells us has far an object moves in a certain time. **State the equation used to calculate speed. (1)**
2c	Sid often calculates average speed during his science lessons, but not instantaneous speed. **Describe the difference between average speed and instantaneous speed.** (2)
2d	Some students use a telescope to view the Moon. Light from the Moon takes 1.3 s to reach the students. The speed of light is 300 000 km/s. **Calculate the distance to the Moon. Give your answer in kilometres. (2)**
3a	This is a distance-time graph for a car. **Describe what the graph shows about the speed of the car as it travels the 80 m. (2)**
3b	The car travels the first 40 m in 5 seconds. **Calculate the average speed of the car over the first 40 m. (2)**



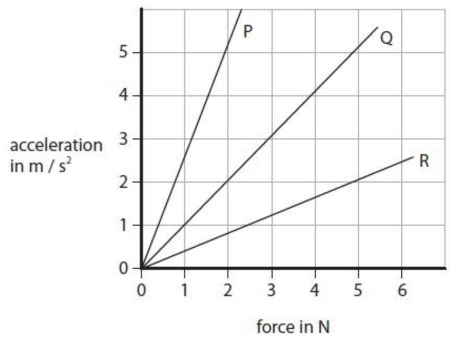
4a	Acceleration is another quantity that is measured in physics. **i. What does the term acceleration mean? (1)** **ii. State the equation that links acceleration, change in velocity and time (1)** **iii. What is the acceleration due to gravity on Earth? (1)**
4b	A car accelerates at a constant rate of 1.83 m/s^2 along a flat straight road. The car accelerates from rest for 16 s. **Calculate the speed of the car after 16 s. (3)**
5a	A car driver sees a rabbit on the road. The driver makes an emergency stop after he sees the rabbit. This graph shows the speed of the car from the time the driver sees the rabbit until the car stops. **Calculate the deceleration of the car between 0.5 and 2.5 seconds (2)**
5b	**Calculate the distance travelled during the first 0.5 seconds (2)**
5b	**Calculate the total distance travelled from seeing the rabbit to completing the emergency stop (3)**

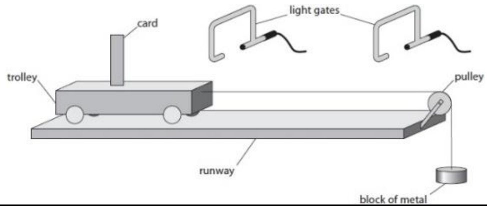


1a	**Tick the correct box to complete this sentence:** A driver sees a rabbit in the road, the distance travelled by the car from the time the driver sees the rabbit to when the car starts to slow down is called the (1)			
	A. average distance	B. braking distance	C. thinking distance	D. stopping distance
1b	**Tick the correct box:** Which of these factors affects the thinking distance when a car has to stop (1)			
	A. condition of the road	B. mass of the car	C. reaction time	D. worn brakes
1c	The resultant force on the car is 350 N. **In which direction is the force acting?** (1)			
	A. down	B. to the left	C. to the right	D. up
1d	**Tick the correct box:** The car is…. (1)			
	A. accelerating	B. decelerating	C. moving at constant speed	D. not moving

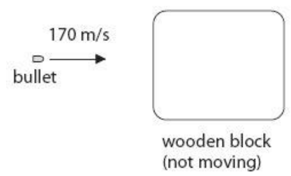


1e	The mass of the car is 625 kg. Gravitational field strength = 10 N/kg. **Calculate the weight of the car.** (1)
1f	The car accelerates due to a force of 2.5 kN. **Calculate the acceleration of the car.** (3)
2a	A student investigates the motion of a trolley along a horizontal runway using the equipment shown. **Describe how the student could increase the accelerating force applied to the trolley** (2)
2b	**Describe how the mass of the moving system can be kept constant.** (2)
2c	**Explain how the student could improve the procedure to compensate for the effects of frictional forces acting on the trolley. (2)**
2d	Three different trolleys are investigated, the graph is shown here. **Calculate the mass of trolley Q.** (2)
2e	The trolleys all had different masses. **Explain which trolley has the greatest mass.** (2)

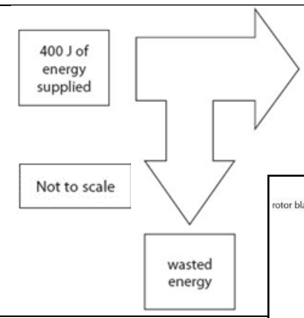
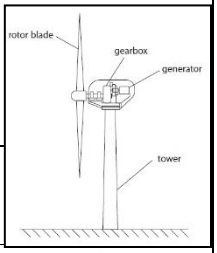




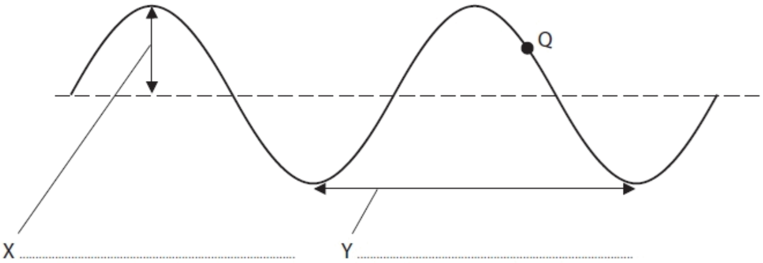
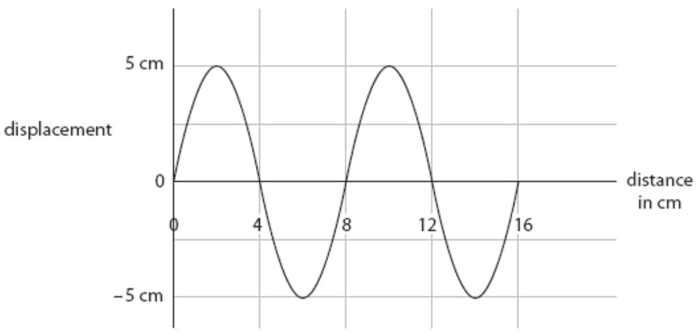
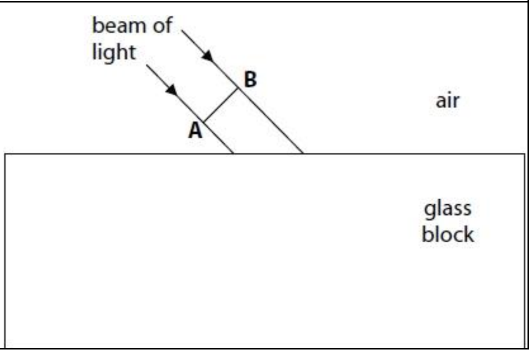
3a	A student drops a stick from a bridge, the stick accelerates before reaching a terminal velocity. **Describe the forces acting on the stick change whilst it is accelerating.** (3)
3b	The student uses a stopwatch to measure how long it takes for the stick to fall, she realises that there will be some uncertainty in her measurements, due to reaction time. **State a typical value for human reaction time.** (1)
3c	**Draw a free body diagram to show the forces acting on the stick when it is travelling at terminal velocity.** (3)
3d	Eventually the stick lands and comes to rest in the ground. The stick pushes downwards on the ground with 7 N of force. **Describe the reaction forces that completes this action-reaction pair.** (2)
4a	A pilot flies his plane at a constant velocity. **What do we know about the forces acting on the plane when it travels at a constant velocity?** (1)
4b	(H) The plane has a mass of 130 000 kg and a velocity of 75 m/s. **Calculate the momentum of the plane** (2)
4c	(H) The aircraft lands and comes to a stop. **State the change in momentum when the panes stops.** (1)
4d	(H) The plane takes 6.5 seconds to come to a complete stop. **Calculate the forces needed to cause this change in momentum.** (3)
4e	(H) **Explain why large aircraft need a very long runway to land safely.** (2)
5a	(H) A bullet is moving with a velocity of 170 m/s. The mass of the bullet is 0.030 kg. **Show that the momentum of the bullet is about 5.0 kg m/s.** (2)
5b	(H) The bullet collides with the wooden block and sticks in it. The bullet and the wooden block move off together. The mass of the wooden block is 0.80 kg. **Calculate the velocity of the wooden block and bullet immediately after the collision.** (3)



Topic 3: Conservation of Energy- Exam Questions

1a	When energy is supplied to a motor, all of the energy is transferred into different forms. This statement is an example of: **Tick the correct box?** (1) A. Renewable energy | B. conservation of energy | C. non-renewable energy | D. sustainable energy
1b	Sue uses her kettle to boils some water. **What type of energy is stored by a kettle and water?** (1)
1c	Sue later burns some coals on her barbeque to heat some food. **What type of energy is stored within the coal?** (1)
1d	When of these is a NOT a non-renewable energy source? **Tick the correct box?** (1) A. geothermal | B. natural gas | C. coal | D. petrol
1e	**Name two renewable energy resources.** (2)
2	This diagram shows how much energy is usefully transferred by a solar powered battery charger. 
2a	**Calculate the amount of energy wasted.** (1)
2b	The charger uses energy from the sun to charge a battery used by a mobile phone. **State how energy is stored in the battery.** (1)
2c	**Describe how energy is transferred from the battery to the mobile phone.** (1)
2d	**Calculate the efficiency of the battery charger.** (2)
2e	A wind turbine generates electricity by using the kinetic energy of wind to drive a gear box and make a generator spin. **Explain how unwanted energy transfers could be reduced in the gear box.** (2) 
3a	A house has a boiler to provide hot water. One type of boiler burns natural gas. The hot water is stored in the copper cylinder until it is needed. A foam jacket helps to keep the water hot. **Explain how the foam helps to keep the water hot.** (2) 
3b	A company has developed a new material which they think could be used instead of foam around the cylinder. **Plan an investigation to find out if the new material (X) is better than the foam at keeping water hot.** (6)
4a	A skier is at the top of a 200 m high slope. The skier's mass is 65 kg. Gravitational field strength, g, is 10 N / kg. **Calculate the change in gravitational potential energy**. Use the equation: $\Delta GPE = m \times g \times \Delta h$ (2)
4b	**State the work done in getting to the top of the slope.** (1)
4c	**Calculate the skier's velocity at the bottom of the slope.** (3) Assume all gravitational potential energy is transferred to kinetic energy. Use the equation: $KE = ½ \times m \times v^2$
4d	At the bottom of the slope the skier bring herself to a sudden stop. **Describe the energy changes that take place to allow her to stop.** (2)
5a	A fly wheel is a heavy revolving wheel that is designed to store energy as it spins. **Identify the energy stored in the spinning fly wheel.** (1) 
5b	**State one way to increase the amount of energy stored in the flywheel.** (1)
5c	Many countries are starting to use more renewable energy resources. **Explain why renewable sources provide an increasing fraction of the electricity supply for many countries.** (2)
5d	There are several large-scale energy resources which are suitable alternatives to fossil fuels in some situations. Two of these alternatives are hydro-electric power and solar power. **Compare hydro-electric power with solar power as energy resources for the large-scale generation of electricity.** (6)

Topic 4: Waves- Exam Questions

1a	A student is standing 600 m from a firework display. A firework explodes with a loud bang, and a flash of light is seen. **Describe how a student can measure the time it takes for the sound wave from the loud bang to travel 600 m.** (2)
1b	A man throws a stone into a pond. **Devise a method of measuring the frequency of the waves.** (2)
1c	A man throws a stone into a pond. On the other side of the pond, the water becomes very shallow. In the shallow water, the wave is slower, but the frequency does not change. **State what happens to the wavelength when a wave reaches the shallow water.** (1)
2a	There is a piece of music called "The Flight of the Bumble Bee." This takes 4 minutes to play. During this time, a bee flies 1608 m. **Calculate the average speed of the bee.** (3)
2b	The distance between the Earth and the Sun is 1.50×10^{11} m. Light takes 500 s to travel from the Sun to the Earth. The wavelength of red light is 670 nm. **Calculate the frequency of red light, using only the data provided.** (4)
3a	Water waves are transverse waves. (i) **Give one other example of a transverse wave**. (1) (ii) **Give one example of a longitudinal wave.** (1)
3b	There are many different types of waves. Waves on the surface of water are transverse waves. **Describe the difference between transverse waves and longitudinal waves.** (2)
3c	**What type of waves are produced by earthquakes?** (1)
3d	Explain the differences between longitudinal and transverse waves. **Your explanation should refer to ultraviolet, ultrasound and seismic waves.** (6)
4a	The diagram shows a transverse wave. **Label the distances X and Y.** (2) 
4b	 i. **State the amplitude and wavelength of the wave.** (2) ii. 20 waves are sent out in 4 seconds. **Calculate the frequency of the wave** (1)
5	Figure 13 shows a beam of red light approaching one side of a rectangular glass block. The beam of light will pass through the block and leave through the opposite side. **AB** is a wave front. **Discuss the path of the wave front AB as it enters and leaves the glass block.** (6) 

Topic 5: Light & the Electromagnetic Spectrum- Exam Questions

1a	**Give two properties that all EM waves have in common** (2)
1b	The electromagnetic spectrum includes seven different waves, radio waves have the longest wavelength and gamma rays have the shortest. **List electromagnetic waves in order from longest wavelength to shortest.** (3)
1c	Visible light can be split into seven colours, known as the visible spectrum. **Complete the list of the visible spectrum below** (2) Red, ____, yellow, ______, ______ , indigo, violet
2a	**Explain what happens to the wavelength of light when it passes from air into glass** (2)
2b	A student investigates what happens when light travels from air into glass. **Describe an experiment that could be used to investigate the refraction of light through a glass block.** You should identify the equipment needed and explain how you will collect your results and you may use a diagram if you wish. (6)
3a	Genuine bank notes contain special ink that is not visible under normal light. **Explain why the ink glows when ultraviolet radiation is shone on it (2)**
3b	Microwaves are used to send and receive television signals from high orbit satellites. **Describe why microwaves rather than radio waves are used** (2)
3c	**Describe a use of gamma radiation** (2)
4a	**State one use and one danger of infrared radiation** (2)
4b	**Ultraviolet radiation is ionising, name two other EM waves that are ionising** (2)
4c	Infrared and ultraviolet are both types of light that we can't see. **Explain why ultraviolet light is more harmful to humans than infrared light is** (3)
5	Radiation from different regions of the electromagnetic spectrum can affect the human body in many ways. **Discuss the different ways in which excessive exposure to electromagnetic radiations of different frequencies may cause damage to the human body** (6)

Topic 6: Radioactivity 1- Exam Questions

1a **Which of these statements is correct?** (1)

A. alpha radiation has no charge	B. alpha radiation is very ionising	C. alpha radiation travels very far in air	D. alpha radiation is an EM wave

1b When an atom emits an alpha particle its nucleus changes.
Which describes the changes in the nucleus? (1)

	A	**B**	**C**	**D**
Proton number	Decreases by 2	Increases by 2	Decreases by 2	Increases by 2
Mass number	Decreases by 4	Decreases by 4	Increases by 4	Increases by 4

1c Alpha, beta and gamma are types of ionising radiation.
State two ways in which gamma radiation is different from alpha radiation. (2)

1d Ionising radiations are emitted by unstable nuclei.
Which particle has the same mass as but opposite charge to a β+ particle? (1)

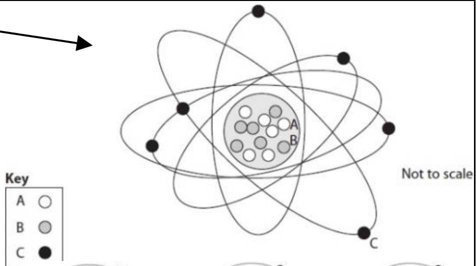
A. electron	B. positron	C. proton	D. neutron

1e **Suggest why a beta particle will travel further in air than an alpha particle.** (2)

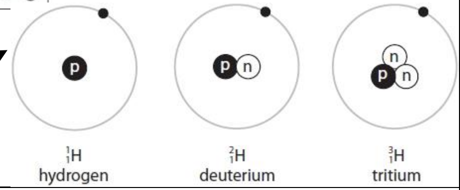
2a i. **Name the 3 particles shown in this diagram.** (3)
A = _______, B = _______, C = _______
ii. **What is the mass number of this carbon atom**? (1)
iii. **What would be the approximate size of this atom**? (1)

A. 10^{-3} m	B. 10^{-10} m
B. 10^{-19} m	C. 10^{-31} m

iv. **Explain how this atom could become ionised by radiation**. (2)



2b This diagram shows three isotopes of hydrogen.
Give reasons why these atoms are isotopes. (2)



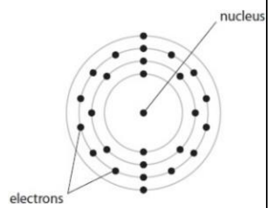
3a Everyone is exposed to background radiation. Some of this radiation comes from natural sources, such as radon gas, and some comes from sources that do not occur naturally.
State one other source of background radiation that occurs natural and one that does not occur naturally. (2)

3b In some parts of the country, a lot of the background radiation comes from radon gas.
Explain why there is no radon gas in some other parts of the country. (2)

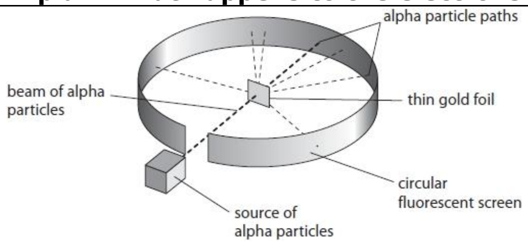
3c A teacher measures background radiation and the reading is 34 counts per minute.
The teacher puts a source of beta radiation 15 cm in front of the Geiger-Müller tube. The reading on the counter tube is now 468 counts per minute.
i. Calculate how much radiation detected by the Geiger-Müller tube comes from the source of beta radiation. (1)
A thick sheet of aluminium is placed between the source of beta radiation and the GM tube.
ii. **Estimate the reading on the counter tube**. (1)

3d Some scientists carry out an experiment to measure the radioactivity from a source to be used in a factory. They measure the background radiation before and after their experiment. They take the background count at the same place as they do their experiment. **Explain how this procedure helps ensure that the results of the experiment are valid**. (6)

4a This diagram shows an atom of iron with its electron orbits.
When iron is heated it glows red.
Explain what happens to the electrons during this process. (3)



4b

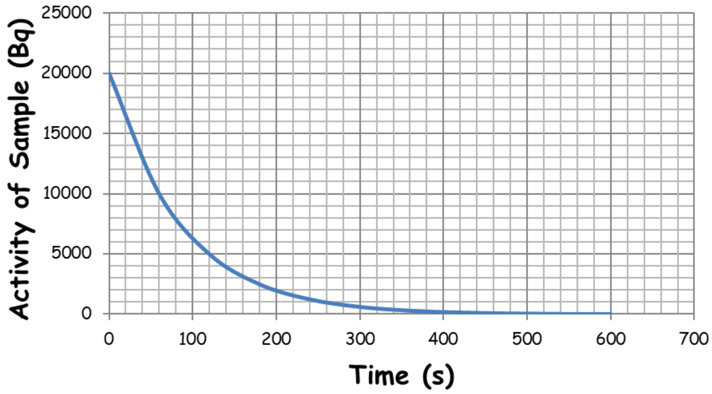


Early in the twentieth century, scientists fired a beam of alpha particles at thin gold foil.
This diagram shows the main parts of their experiment with some results.

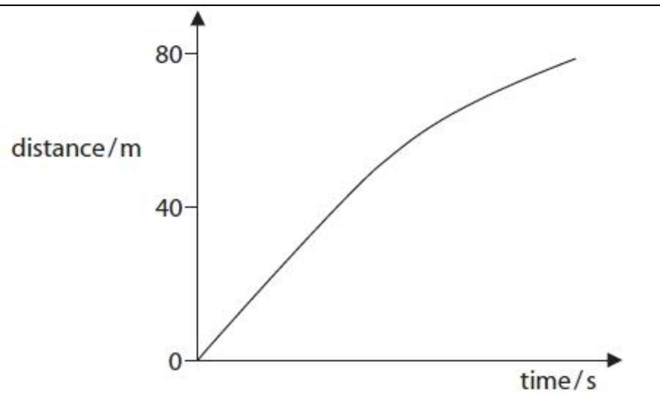
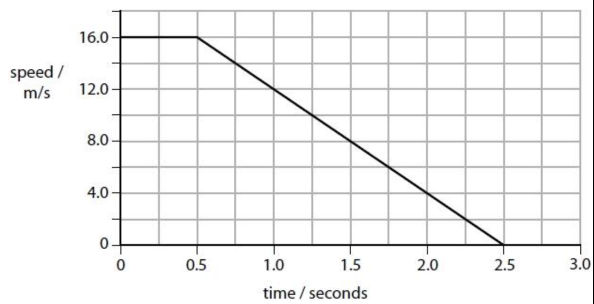
Explain how the results of the experiment shown in Figure 2 support the nuclear model of an atom. (3)

Topic 6: Radioactivity 2- Exam Questions

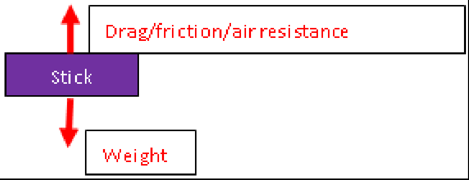
1a	**Which of these statements is correct for half-life?** (1) A. The time it takes for half of the undecayed nuclei to decay | B. The time it takes for all of the undecayed nuclei to decay | C. Half the time it takes for all of the undecayed nuclei to decay | D. Half the time it takes for half of the undecayed nuclei to decay
1b	**Which of these statements best describes half-life?** (1) A. It is half the time for all the atoms to decay | B. It is the time it takes for an atom to half decay | C. It is the time it takes for half an atom to decay | D. It is the time it takes for half the atoms to decay
1c	Radioactivity can be measured using a GM tube. **State the units used to measure radioactivity.** (1)
1d	**Following the radioactive decay of a nucleus, the nucleus might undergo some rearrangement, losing energy as …** (1) A. gamma radiation | B. a proton | C. a neutron | D. an X-ray
1e	**State two ways in which radiation from radioactive sources can harm people.** (2)
2	Staff who work with radioactive materials have to protect themselves from irradiation and contamination.
2a	**Describe the differences between irradiation and contamination.** (2)
2b	**Describe some precautions that medical staff take to reduce the risks of working with radioactive sources.** (3)
2c	**Explain how the radiation can be dangerous to people.** (2)
3a	**Describe the process of β^- emission.** (3)
3b	**Explain what happens to the mass number and the atomic number of a nucleus when β^- emission occurs.** (3)
3c	Technetium-99 (Tc) has an atomic number of 43 and a mass number of 99. It undergoes β^- decay to become an isotope of ruthenium (Ru). **Write a balanced nuclear equation to show this decay.** (3)
3d	Potassium-37 (K) has 19 protons and 18 neutrons. It undergoes β^+ decay to become an isotope of argon (Ar). **Write a balanced nuclear equation to show this decay.** (3)
4a	**Calculate the half-life shown in this graph.** (2)
4b	**The count rate of a material is 2016 Bq. After 15 days it has fallen to 252Bq. What is the half-life?** (2)
4c	**A radioactive isotope has a half-life of 30 years. It has an initial count rate of 36000 Bq. What will the count rate be after 120 years?** (2)
4d	A radioactive sample has a half-life of 5 hours and an activity of 1600 Bq. **Sketch a graph to show the decay curve over the next 15 hours.** (2)
4e	A radioactive sample of the same isotope as in Q4d has an activity of 800 Bq. **Add a curve to your graph to show the decay over the next 15 hours.** (2)
4f	A different radioactive sample has a half-life of 10 hours and an activity of 1600 Bq. **Add a curve to your graph to show the decay over the next 20 hours.**



Topic 1: Motion- Exam mark scheme

<table>
<tr><td>1a</td><td colspan="2">Scalar quantities have only size (magnitude) (1) whereas vector quantities have size (magnitude) and direction (1)</td></tr>
<tr><td>1b</td><td colspan="2">i. Distance, speed, mass, time, energy
ii. Displacement, velocity, acceleration, force, weight, momentum
iii. Speed is scalar (1) velocity is vector (1) or velocity is speed in a straight line (2) or speed only has size (1) but velocity has size and direction (1)</td></tr>
<tr><td>2a</td><td colspan="2">i. 1-3 m/s (1)
ii. 31 m/s (1)
iii. 340 m/s (1)</td></tr>
<tr><td>2b</td><td colspan="2">Speed = distance ÷ time (1)</td></tr>
<tr><td>2c</td><td colspan="2">The average speed is calculated from the total distance travelled and the total time taken. (1)
The instantaneous speed is the speed at any given point during the journey. (1)</td></tr>
<tr><td>2d</td><td colspan="2">Distance = speed x time
Distance = 300 000 x 1.3 (1)
Distance = <u>390 000 km</u> (1)
Correct answer on its own gets both marks</td></tr>
<tr><td>3a</td><td>At first (for the first 50-60seconds) the car is travelling at a steady speed (1)
the car then slows down (in between 50 and 60 seconds) (1)
and then continues at a slower (steady) speed (1)</td><td rowspan="2">
</td></tr>
<tr><td>3b</td><td>Speed = distance ÷ time
Speed = 40 ÷ 5 (1)
Speed = 8 m/s (1)
Correct answer on its own gets both marks</td></tr>
<tr><td>4a</td><td colspan="2">i. Rate of change of velocity (how quickly velocity changes) (1)
ii. Acceleration = change in velocity ÷ time (1)
iii. g = 10 m/s^2 (1)</td></tr>
<tr><td>4b</td><td colspan="2">Acceleration = change in velocity ÷ time
1.83 = change in velocity ÷ 16 (1)
1.83 x 16 = change in velocity (1)
Change in velocity = 29.28
As started from rest, the speed of the car after 16 s will be <u>29.28 m/s</u> (1)
Correct answer on its own gets all 3 marks</td></tr>
<tr><td>5a</td><td>Acceleration = Gradient
Gradient = $\frac{\text{change in Y}}{\text{change in X}}$
change on Y = 16 – 0 = 16
change in X = 2.5 – 0.5 = 2
acceleration = 16 ÷ 2 (1)
acceleration = <u>8 m/s^2 (1)</u>
Correct answer on its own gets both marks</td><td rowspan="3">
</td></tr>
<tr><td>5b</td><td>Distance travelled = area below line
Area = base x height
Distance = 16 x 0.5 (1)
Distance = 8 m (1)
Correct answer on its own gets both marks</td></tr>
<tr><td>5b</td><td>Distance travelled = area below line
Area (of triangle) = ½ base x height
Distance = ½ x 16 x 2 (1)
Distance = 16 m (1)
Total distance = 8 + 16 = <u>32 m</u>
Correct answer on its own gets both marks</td></tr>
</table>

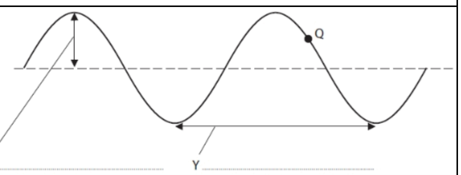
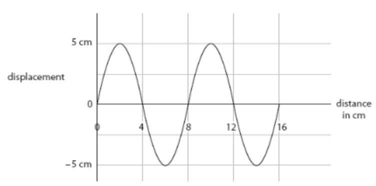
Topic 2: Forces- Exam mark scheme

1a	c. thinking distance (1)
1b	c. reaction time (1)
1c	b. to the left (1)
1d	a. accelerating (1)
1e	Weight = mass x g W = 625 x 10 (1) W = 6250 N (1) Correct answer gains all marks
1f	2.5 kN = 2500 N F = mass x acceleration 2500 = 625 x a (1) a = 2500 ÷ 625 a = 4 m/s^2 (1) correct answer gains all marks (0.004 m/s^2 gains 2)
2a	Add weight/mass (1) to the hanger (NOT the trolley) (1) Allow incline the runway (1) so larger component of gravity acts (1)
2b	Transfer weight/mass (1) between trolley and hanger (1)
2c	Raise one end of the runway (1) to reduce the effects of friction (1) so that the trolley rolls at a constant speed (before hanger is attached) (1)
2d	Any two correct points from graph substituted into equation e.g. mass = 2÷ 2 or mass = 3 ÷ 3 (1) Mass = 1 kg (1)
2e	Trolley **R** has the largest mass (1) because it has the largest force and smallest acceleration (1) and m = F ÷ a (1)
3a	Weight will stay the same throughout (1) drag/air resistance/friction will increase (as the stick gets faster (1) the resultant force will gradually reduce (1)
3b	0.25 s (0.2-0.3 s) (1)
3c	1 mark for each correctly drawn and labelled arrow 1 marks for arrows being the same size 
3d	The ground pushes upwards on the stick (1) with 7 N of force (1)
4a	Forces are balance (resultant force = zero) (1)
4b	(H) ρ = mass x velocity ρ = 130 000 x 75 (1) ρ = 9,750,000 kg m/s (1)
4c	(H) 9,750,000 kg m/s (1) Same answer as given in 4b, even if 4b is incorrect
4d	(H) Momentum change = 9,750,000 (1) F = change in momentum ÷ time F = 9,750,000 ÷ 6.5 (1) F = 1,500,000 N (1.5 x 10^6 N) (1.5 MN) (1) Correct answer gains all marks
4e	(H) Larger mass means more momentum (to change) (1) longer runway means a longer time (to change momentum) (1) so force is reduced (1) large forces could cause injury/discomfort to passengers (1)
5a	(H) ρ = mass x velocity ρ = 0.03 x 170 (1) ρ = 5.1 kg m/s (1) Show that question, so answer on own gets no marks
5b	(H) Idea of conservation of momentum (momentum before = momentum after) (1) $\text{Momentum}_{\text{before}} = \text{mass}_{\text{after}} \times \text{velocity}_{\text{after}}$ 5 = 0.83 x v (1) v = 5 ÷ 0.83 v = 6.1 m/s (1) Correct answer gains all marks

Topic 3: Conservation of Energy- Exam mark scheme

1a	B. conservation of energy (1)
1b	Thermal energy (1)
1c	Chemical energy (1)
1d	A. Geothermal (1)
1e	Two from: solar, wind, hydroelectric, bio fuels, tidal, wave, geothermal. (2)
2a	400- 50 = **350 J** (1)
2b	Chemical energy (1)
2c	Electrically (1)
2d	Eff = useful energy ÷ total energy input Eff = 50 ÷ 400 (1) Eff = **0.125** or **12.5 %** (1) Correct answer = (2)
2e	Reduce friction (1) by using lubrication / oil (1)
3a	Acts as insulation (1) and reduces the amount of heat transferred/dissipated (1) to the surroundings (1)
3b	Maximum of 6 marks from: Maximum of **two marks** for equipment Beakers (1) thermometers (1) stopwatch (1) foam and new material (1) hot water (1) Maximum of **three marks** for method Wrap material around a beaker (1) fill beaker with hot water (1) measure starting temperature (1) measure temperature after a period of time (1) Repeat for both materials (1) Maximum of **two marks** for analysis of data Work out the change in temperature (1) the better insulator will cool down slowest (1)
4a	$\Delta GPE = m \times g \times \Delta h$ $\Delta GPE = 65 \times 10 \times 200$ (1) $\Delta GPE =$ **130,000 J** (1) Correct answer = (2)
4b	130,000 J (same answer as given for 4a) (1)
4c	$KE = \frac{1}{2} \times m \times v^2$ $130{,}000 = \frac{1}{2} \times 65 \times v^2$ (1) $130{,}000 \div 32.5 = v^2$ $v = \sqrt{4000}$ (1) v = **63 m/s** (1) Correct answer = (3)
4d	Kinetic energy (1) is transferred into thermal energy (1) mechanically (1)
5a	Kinetic energy (1)
5b	Make it spin faster (1)
5c	Non-renewable supplies are running out (1) renewable resources are becoming more efficient (1) To reduce the greenhouse gases released from burning fossil fuels (1) Renewable resources don't produce carbon dioxide (1) NOT renewable is better for the environment (needs the details on how it is better)
5d	A discussion including some of the following points Both HEP (hydroelectric power) and Solar power are renewable (1) Both HEP and Solar power would save fossil fuels (1) HEP only possible in some locations (1) HEP requires reservoirs and damming of rivers (1) This can damage environment /takes a lot of land out of use (1) Energy from solar power installation is currently much less than energy from fossil fuel powered station (1) Solar power only suitable in certain locations (1) Solar power reliability dependent on constant sunshine (1) Neither of them cause atmospheric pollution (1)

Topic 4: Waves- Exam mark scheme

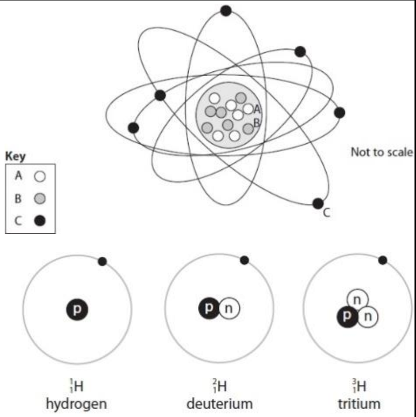
1a	Use a stopwatch (1) and start timing when the flash is seen (1) stop timing when bang is heard (1)	
1b	Using a stopwatch (1) count the number of waves that reach the bank is a given time (1)	
1c	Wavelength gets shorter/decreases (1)	
2a	Convert minutes to seconds (4 x 60 = 240) (1) Speed = distance / time (1608 / 240) (1) Speed = 6.7 m/s (1) 6.7 on its own scores all 3 marks	If forgot to convert minutes to seconds: Speed = distance / time (1608 / 4) (1) Speed = 402 m/s (1) 402 on its own scores 2 marks
2b	You have to use distance and time to calculate velocity, then use velocity and wavelength to calculate frequency. Velocity = 1.5 $\times 10^{11}$ / 500 (1) Velocity = 3 x 10^{8} m/s (1) Velocity = frequency x wavelength 3 x 10^{8} = f x 670 X 10^{-9} f = 3 x 10^{8} / 670 X 10^{-9} (1) f = 4.5 x 10^{14} Hz (1)	V = 3 x 10^{8} m/s will score 2 marks on its own F = 4.5 x 10^{14} Hz will score all 4 marks on its own
3a	(i) Example of a transverse wave- any transverse wave (1) (ii) Example of a longitudinal wave- sound/ultrasound/infrasound. (1)	
3b	Transverse waves have vibrations at right angles to the direction of wave travel (1) Longitudinal waves have vibrations in the same direction as the wave travel (1)	
3c	Earthquakes produce both transverse and longitudinal waves (1)	
3d	An explanation including some of the following points: 1 correct point = 2 marks, 2-3 correct points = 3-4 marks, 4+ correct points = 6 marks Longitudinal vibrations are along the same direction of wave travel (1) Transverse vibrations are at right angles to the wave travel (1) Ultraviolet waves are transverse (1) ultrasound waves are longitudinal (1) seismic waves can be either longitudinal and transverse (1) Longitudinal waves need a material to travel through (1) whereas electromagnetic waves can pass through a vacuum (1)	
4a	X = amplitude (1) Y = wavelength (1)	
4b		i. amplitude is 5 cm (1) wavelength is 8 cm (1) ii. 20 / 4 = 5 Hz (1)
5	An explanation including some of the following points: 1-3 correct point = 1-2 marks, 4-5 correct points = 3-4 marks, 6+ correct points = 6 marks Point A reaches the glass before point B (1). A moves into the glass and slows down (1) because light travels more slowly in glass than in air (1). B is still in air so is travelling faster than A (1) By the time B reaches the block it has travelled further than A (1) therefore the whole wave front changes direction/refracts towards the normal (1) At the other face (leaving the block) A exits first so the whole process is reversed (1) and the wave front refracts away from the normal (1) it returns to its original direction (1)	

Topic 5: Light & the Electromagnetic Spectrum- Exam Mark Scheme

1a	All EM waves transfer energy (1), they are all transverse (1) they all travel at the same speed in a vacuum (1) which is 300 000 000 m/s (1)	
1b	1 mark if the 5 correct waves are given (don't need to be in correct order) 1 mark if 3 waves in the correct place, a further mark if 5 are in the correct place **Radio waves**, microwaves, infrared, visible light, ultraviolet, X-rays, **gamma rays** (3)	
1c	1-2 correct = 1 mark, all 3 correct = 2 marks Red, orange, yellow, green, blue, indigo, violet (2)	
2a	(As light passes from air into glass) the wavelength decreases (1) because wavelength is the ratio of wave velocity to frequency ($V = f \times \lambda$) (1) and at the boundary waves slow down but frequency stays the same (1)	
2b	1-3 correct point = 1-2 marks, 4-5 correct points = 3-4 marks, 6+ correct points = 6 marks Shine a thin beam of light through a glass block (1) use a pencil to mark the light rays that enter and leave the glass block (1) remove the glass block and use a ruler to complete the light rays (1). Use a protractor to measure the angle of incidence (1) and the angle of refraction (1) measure the angles against the normal line (1) Repeat this process for several angles of incidence (1) within the range of 0° to 80° (any sensible range greater than 40 degrees would be acceptable (1)	
3a	It fluoresces (1) ink absorbs energy from the UV light transfers (1) the energy (from UV) (re)- emitted by ink at lower frequency/as (visible) light (1)	
3b	Radio waves will not reach the satellites (1) because they are reflected by the atmosphere/ionosphere (1) ORA for microwaves	
3c	One use with a matching explanation from: To sterilise medical equipment (1) the high energy radiation kills the bacteria (1) Sterilise food (1) the high energy radiation kills the bacteria (1) Treat cancer (1) the high energy radiation can be used to destroy cancer cells (1) Detect cancer (1) gamma rays can be used as medical tracers (1)	
4a	One use from: (1) electrical heaters, cookers for cooking food, short-range communications like remote controls, optical fibres, security systems	Danger: cause burns to the skin (1)
4b	X-rays (1), gamma rays (1)	
4c	Ultraviolet waves are higher frequency than infrared (1) so they have more energy (1) they are ionising (1) and can cause cancer (1) ORA for infrared being lower frequency than ultra violet	
5	One mark for each wave dangers correctly identified up to four marks maximum: No dangers (radio waves), Internal heating of body cells (microwaves), Skin burns (infrared), Damages skin cells/sunburn (UV), Damages eyes (UV), Can cause skin cancer (UV), Can cause cataracts (UV), Damage to cells inside the body (X-rays and gamma rays), Damages DNA (X-rays and gamma rays) A maximum of two marks for these points: As the frequency increases/wavelength decreases (1), greater frequency means the waves transfer more energy (1) (radio → gamma) the waves do more damage/danger as they have more energy (1)	

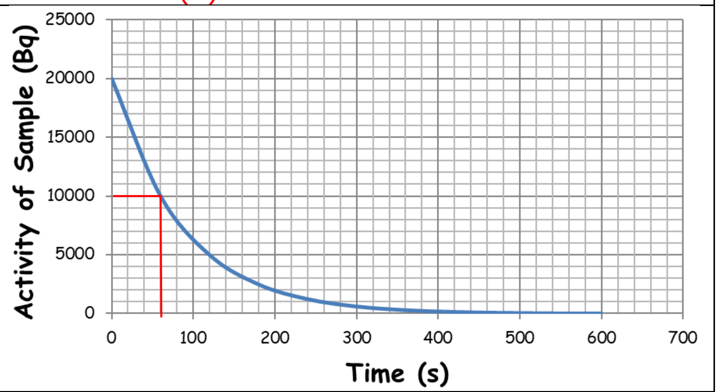
Topic 6: Radioactivity 1- Exam mark scheme

1a	B. alpha radiation is very ionising (1)
1b	A. Proton number decreases by 2, mass number decreases by 4 (1)
1c	**Any two of:** Gamma is a wave (1) Alpha is a helium nucleus (1) Alpha is charged (1) Alpha has a mass (1) Gamma penetrates further (1) Gamma weakly ionising (1) Gamma travels faster (1)
1d	A electron (1)
1e	**two of:** the ionisation is different (1) correct difference in ionisation (e.g. alpha is more ionising = 2 marks) (1) the masses are different (1) alpha is bigger than beta (1) alpha hits more (air) particles (1) alpha loses its energy in shorter distance (1)
2a	i. A = proton or neutron (1) B = proton or neutron (1) C =electron (1) ii. Mass umber = 12 (1) iii. B. 1 x 10^{-10} m iv. atom/electron can absorb enough energy (1) so that an electron can escape (1)
2b	1 from: same atomic number (1) same number of protons (1) or same element (1) 1 from: different number of neutrons (1) different mass numbers (1)
3a	Naturally: cosmic rays (1) food and drink (1) rocks and buildings (1) Man-made: medicine (1) nuclear industry (1)
3b	Comes from granite / rocks (1) none/ less of these (rocks) in some areas (1)
3c	i. 468 - 34 = 434 (1) ii. 34 (any answer between 29 and 39) (1)
3d	An explanation including some of the following ideas **Need for measurement** Background radiation is always present/all around us (1) has (natural) source(s) exemplified by space, living things, rocks, food, nuclear/medical sources etc. (1) would give false reading in experiment (1) **How and why to measure** Measurement is taken at site of experiment because it is different in different places (1) Measurement is taken with all apparatus except source in place (1) Measurement is taken before and after because it can change with time / they need an average (1) Measurement must be worked out for same time as (or longer than) experiment / rate found so analysis is simpler (1) It is taken several times/ averaged because it is random **Analysis** Background radiation measurement must be subtracted from measurements with source /main count rate (1)
4a	Heat energy is gained/absorbed by an electron (the atom) (1) Electon becomes excited/ moves to a higher orbit (1) Electron returns to ground state/lower energy level (1) Releases EM radiation (1)
4b	Some alpha particles go straight through (1) Some alpha particles scattered (1) Mass/positive charge concentrated in a nucleus (1) Most of atom is empty space (1)



Topic 6: Radioactivity 2- Exam mark scheme

1a	A. the time it takes for half of the undecayed nuclei to decay (1)
1b	D. it is the time it takes for half the atoms to decay (1)
1c	Becquerel (Bq) (1)
1d	A. gamma radiation (1)
1e	Two from: Ionising, damage tissue, kill cells, burns, mutations, cancer/tumours (2)
2a	1 from: Irradiation is when you are near to a radioactive source (1) irradiations end when the source is moved away/you move away from the source (1) 1 from: Contamination is when the radioactive source is on or in your body (1) you are exposed to radiation until the source has decayed (1)
2b	3 from: Keep distance away from the source, limit the time exposed to the source, used lead shielding when handling, use tongs when handling, dispose of radioactive material safely, wear <u>lead-lined</u> apron/clothing/gloves, monitor exposure (3) (ignore clothing or gloves unless lead-lined or stated that it would prevent contamination)
2c	1 from: It is ionising, it has high energy it is high frequency (1) 1 from: Damage tissue, kill cells, burns, mutations, cancer/tumours (1)
3a	A neutron (1) turns into a proton (1) and an electron (1) Allow 1 mark for correct description of beta$^+$ decay (proton turns into a neutron and a positron)
3b	Atomic number goes up by 1 (1) because there is an extra proton in the nucleus (1) mass number does not change (1) because no change in number of nucleons (or proton has the same mass as neutron) (1)
3c	${}^{99}_{43}Tc \rightarrow {}^{0}_{-1}\beta^- + {}^{99}_{44}Ru$ (3)
3d	${}^{37}_{19}K \rightarrow {}^{0}_{+1}\beta^+ + {}^{37}_{18}Ar$ (3)
4a	20000 ÷ 2 = 10000 (1) <u>60 years</u> = (1) Correct answer gets both marks
4b	2016 ÷ 2 = 1008 ÷ 2 = 504 ÷ 2 = 252 3 half-lives (1) 15 ÷ 3 = <u>5 days</u> (1) Correct answer gets both marks
4c	120 ÷ 30 = 4 half-lives (1) 36000 ÷ 2 = 18000 ÷ 2 = 9000 ÷ 2 = 4500 ÷ 2 = <u>2250 Bq</u> (1) Correct answer gets both marks



For each of these graphs check points are plotted in correct place and curve is smooth	
4d	Blue line (2)
4e	Green line (2)
4f	Red line (2)