

**Year 11 Double  
Award Science  
Physics Revision  
Booklet**

**(exam date: Wednesday 22<sup>nd</sup> May PM)**

Name

Please use test results, feedback and self-assessment to colour code each section red, amber or green, and ensure that where you need to do extra work to improve, you use Prep time to do so.

	Understood	Revised
<b>Unit 6.1 Distance, Speed and Acceleration</b>		
Calculate speed, velocity and acceleration		
Draw distance-time graphs and use them to calculate velocity		
Draw velocity-time graphs and use them to calculate acceleration <b>and distance travelled.</b>		
Explain the factors that affect the safe stopping of vehicles		
Use data to discuss traffic control		
<b>Unit 6.2 Newton's Laws</b>		
Inertia		
Newton's first law of motion		
Newton's second law of motion		
The difference between mass and weight		
Calculating weight		
Calculating gravitational potential energy		
Describe the forces on objects moving through the air		
Terminal Velocity		
Newton's third law of motion.		
<b>Unit 6.3 Work and Energy</b>		
The conservation of energy		
Work done		
Different types of energy		
<b>Calculating kinetic energy and the change in gravitational potential energy</b>		
The relationship between force and extension for a spring (Hooke's law)		
<b>The work done in stretching a spring from a force-extension graph</b>		
How energy efficiency of vehicles can be improved		
Car safety in terms of forces and energy		
<b>Unit 6.4 Stars and Planets</b>		
The main features of our Solar System		
The features of the observable Universe		
Using Astronomical Units and Light Years		
The life cycle of stars of different masses		
The stability of stars		
How heavier elements are ejected and form new objects		
The origin of the solar system		
<b>The Hertsprung-Russell Diagram</b>		
<b>Unit 6.5 Types of Radiation</b>		
The nucleus and what causes radioactivity		
Background radiation		
Nuclear Waste		
The random nature of radioactive decay		
The differences between alpha, beta and gamma radiation		
<b>Producing</b> and balancing nuclear equations for radioactive decay		
<b>Unit 6.6 Half-Life</b>		
The random nature of radioactive decay and how to model it		
How to plot or sketch decay curves for radioactive materials		
Determine the half-life from a decay curve		
Simple calculations to find half-life or activity		
Carbon Dating		
The uses of different types of radiation and why		

# Unit 6.1 - Motion

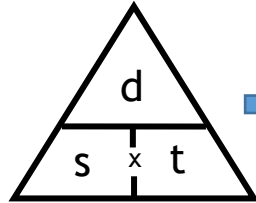
## Calculating Speed

Speed is defined as the distance moved per unit time, and hence, the equation for speed is :

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

...and the other two forms of the equation are :

$$s = \frac{d}{t}$$



$$d = s \times t$$

$$t = \frac{d}{s}$$

Distance is measured in metres (m)  
Time is measured in seconds (s)  
Speed is measured in metres per seconds (m/s)

### Example 1

If a school bus moves 1600 metres at an average speed of 12.5 m/s, how long did the journey take ?

$$t = \frac{d}{s} = \frac{1600}{12.5} = 128 \text{ s}$$

Look !! Since it's **time** we're calculating, the answer must have units of **seconds**.

### Example 2

An electron in orbit around an atom moves at a speed of 2500 km/s !  
How far would it travel (in a straight line) if it moved at this speed for 1 minute ?



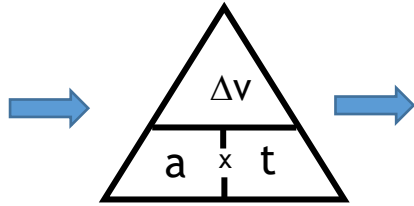
$$d = s \times t = 2\,500\,000 \times 60 = 1.5 \times 10^8 \text{ m} \quad (\text{Almost 4 times around the Earth !})$$

Look !! It's safer to use all values in metres and seconds (rather than km and minutes).  
So, 2500 km/s = 2500 x 1000 = 2 500 000 m/s

## Calculating Acceleration

Another equation you'll need is the one for acceleration.  
Acceleration is defined as the change in velocity (or speed) per second :

$$a = \frac{\Delta v}{t}$$



...and the other two forms of the equation are :

$$\Delta v = a \times t$$

$$t = \frac{\Delta v}{a}$$

**Info. !** Notice the triangle symbol ( $\Delta$ ) in front of the "v". It's the Greek letter 'delta'. In this case it means 'change in'.

Change in velocity is measured in **metres per second (m/s)**  
Time is measured in **seconds (s)**  
Acceleration is measured in **metres per second<sup>2</sup> (m/s<sup>2</sup>)**

### Example 1

A cyclist increases her speed from 5m/s to 19m/s in 7 seconds.  
What is her acceleration?

$$a = \frac{\Delta v}{t} = \frac{(19 - 5)}{7} = \frac{14}{7} = 2 \text{ m/s}^2$$



### Example 2

An oil tanker can decelerate at a maximum rate of 0.04 m/s<sup>2</sup>. How long will the tanker take to come to a complete stop if initially travelling at a speed of 12 m/s ?

$$t = \frac{\Delta v}{a} = \frac{(12)}{0.04} = 300 \text{ s} \quad (\text{A full 5 minutes !})$$

### Example 3

A football moving forwards at a speed of 12.4 m/s, is kicked forwards so that its speed increases. The acceleration of the ball is 48.0 m/s<sup>2</sup>, which lasts for 0.45 s. What's the final speed of the ball after this acceleration ?

$$\text{Change in speed, } \Delta v = a \times t = 48.0 \times 0.45 = 21.6 \text{ m/s}$$

$$\text{So, final speed} = 12.4 + 21.6 = 34.0 \text{ m/s}$$



## Motion graphs

The motion of an object can be shown on one of two types of graphs : distance-time or velocity-time graphs (sometimes called speed-time graphs).

### Distance - time graphs

There's ONE rule for a d-t graph :

*The 'steepness' (or more correctly 'slope' or 'gradient') of this graph indicates the speed of the object.*

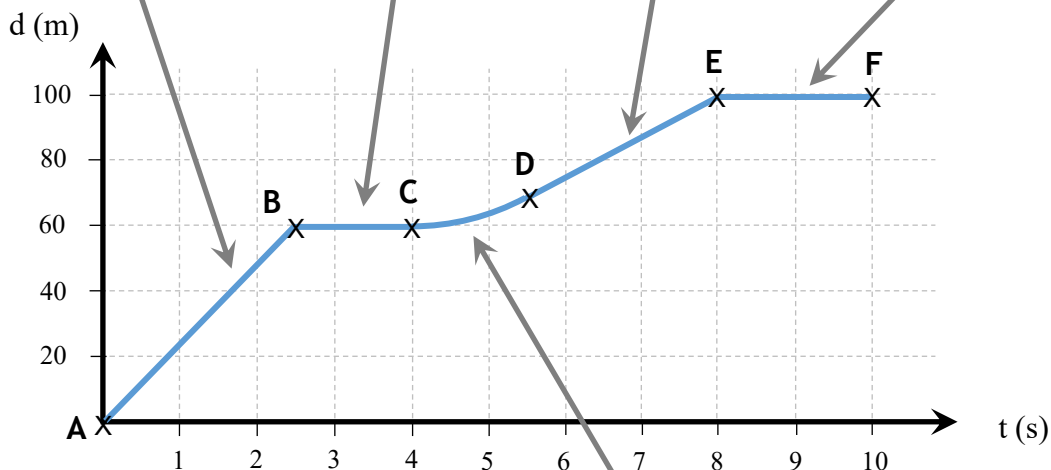
So,  
a STEEP line → a high speed  
a less steep line → a lower speed  
a flat/horizontal line → not moving

In the 1<sup>st</sup> section, the object is moving an equal distance each second. Hence, the object is moving at a 'constant speed'.

From B to C, the object is staying at a distance of 60m, so is not moving at all, i.e. **stationary**

This is a straight, diagonal line like section AB, and so is moving at a 'constant speed'. However, this is not as steep, so is moving **slower** than AB.

EF is again stationary.



This section is more difficult - since the slope is increasing, the speed is increasing, i.e. the object is **accelerating** !

## Motion graphs

### Velocity - time graphs (or 'speed-time' graphs)

There are TWO rules for a v-t graph :

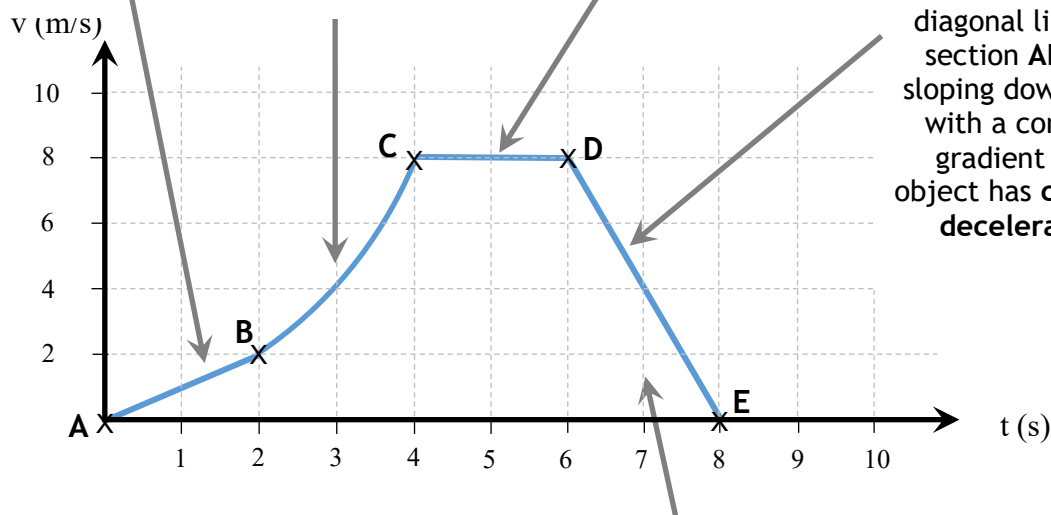
1. The slope/gradient is equal to the acceleration.
2. The area under the graph is equal to the distance travelled.

In the 1<sup>st</sup> section, the object is speeding up steadily since the gradient is constant (straight line), i.e. it has **constant acceleration**

Curved line shows non-constant acceleration. Gradient/steepness increasing, so acceleration is increasing.

From C to D, the gradient is zero, and so, from rule 1 above, the acceleration is zero. This means the object is staying at the same speed (8 m/s), i.e. **constant velocity**

This is a straight, diagonal line like section AB, but sloping downwards with a constant gradient - the object has **constant deceleration**



The distance travelled in any section can be calculated from the area below the line, in this case the area of the shaded triangle :

$$\text{Distance} = \text{area} = \frac{\text{base} \times \text{height}}{2} = \frac{2 \times 8}{2} = \frac{16}{2} = 8 \text{ metres}$$

Calculating the average/mean acceleration in section BC :

$$a = \frac{\Delta v}{t} = \frac{8 - 2}{2} = \frac{6}{2} = 3 \text{ m/s}^2$$

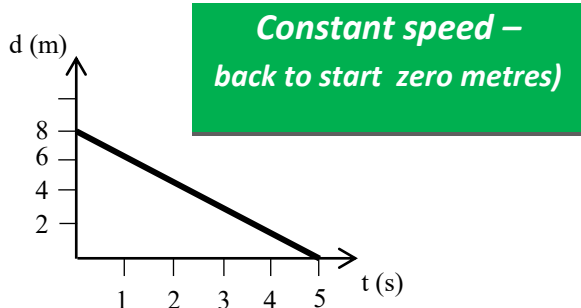
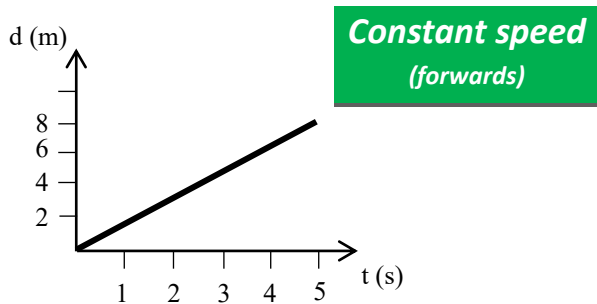
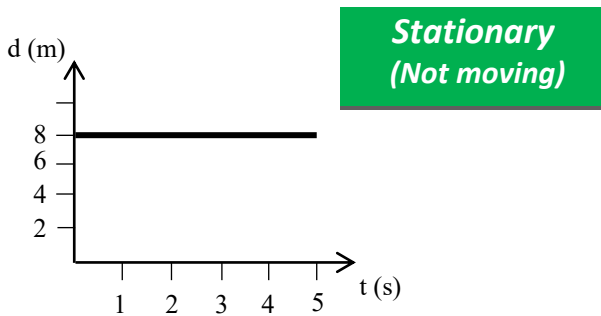
*NOTE : Calculating the average speed in a sloping section is easy !! Since only straight line sections are used for this, it's simply half way between the start and end speed for that section e.g. for section DE, the average speed is 4 m/s (half way between 8 m/s and 0 m/s )*

## Motion graphs

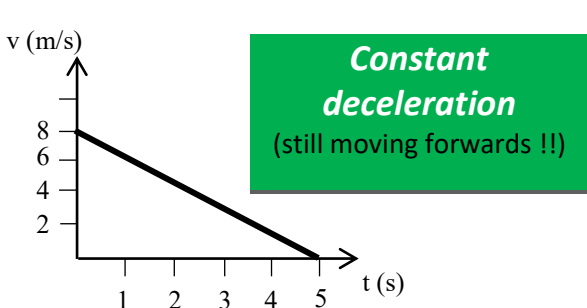
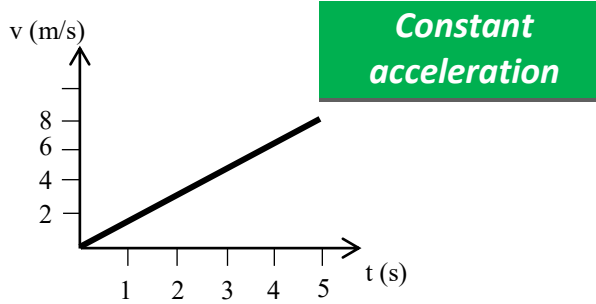
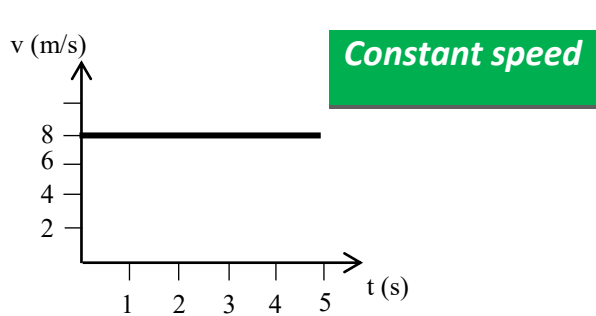
The motion of an object can be shown on one of two types of graphs : distance-time or velocity-time graphs (sometimes called speed-time graphs).

It's important that you learn what the shape of each type of graph tells you about the object's motion :

### Distance - time graphs



### Velocity - time graphs



## Stopping distance & Car Safety

Many road accidents happen because people often underestimate the distance needed to slow a car until it stops - **the stopping distance**.

The stopping distance is in two distinct parts :



$$\text{Stopping distance} = \text{Thinking distance} + \text{Braking distance}$$

**Thinking distance** = the distance travelled whilst reacting to a situation (before the driver applies the brakes)

**Braking distance** = the distance travelled whilst the brakes are applied (car is slowing down)

Reaction **time** is closely linked to thinking distance as follows :

$$\text{Thinking distance} = \text{speed} \times \text{reaction time} \quad (d = s \times t)$$

So, although a person's reaction time is not much affected by speed, the thinking distance is - look at these calculations at two different speed, 20 m/s, and 40 m/s, with a typical reaction time of 0.4 s,

$$\text{@ 20 m/s} \quad \text{Thinking distance} = 20 \times 0.4 = 8\text{m}$$

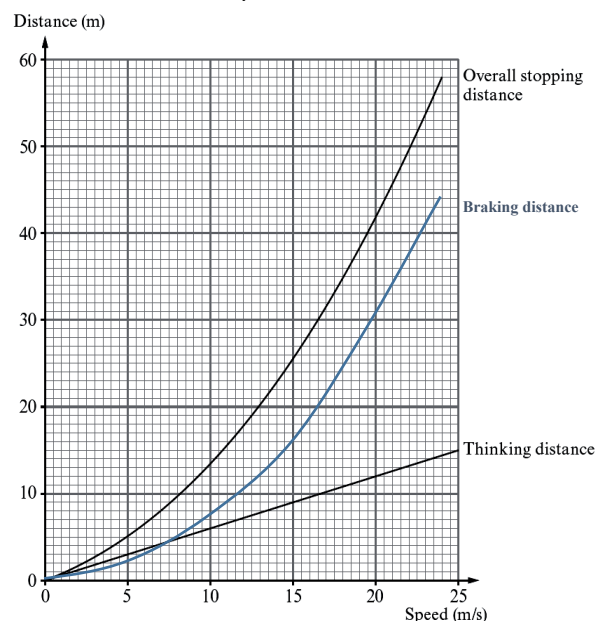
$$\text{@ 40 m/s} \quad \text{Thinking distance} = 40 \times 0.4 = 16\text{m}$$

So, thinking distance is directly proportional to the vehicle's speed.

Braking distance also increases with the vehicle's speed. However, they're not proportional (see the blue line on the graph → ).

(In fact, doubling the vehicle's speed quadruples the braking distance, since the speed is squared in the KE equation).

To find the overall stopping distance at a particular speed, just add the thinking distance and the braking distance values at that speed.



## Unit 6.2 - Newton's laws (Forces)

### Forces

A force is a **push** or a **pull** acting on an object. There are many different types of force, e.g. friction, air-resistance, weight, upthrust, **but they are always measured**



Sir Isaac Newton came up with three laws of motion, all of which describe the effect that forces have on things.

Before looking at these three laws, it's necessary to understand the term 'resultant force' first.



### Resultant force

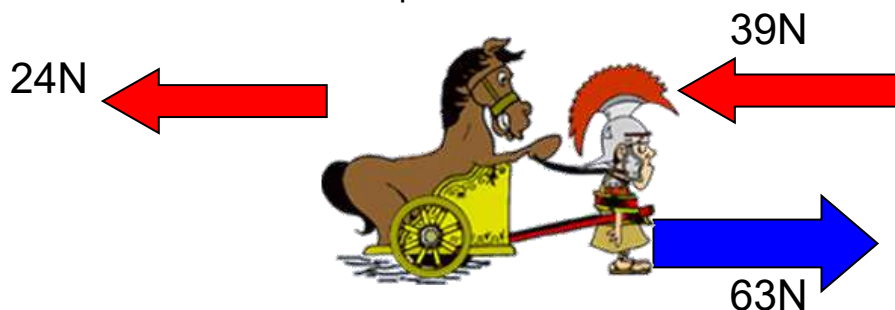
Usually, more than one force is acting on an object, like in the 'tug-of-war' below. In order to work out the effect of these forces on the object, we need to calculate what's known as '**resultant force**'.



Remember that all forces have a direction, unless of course they're zero. If forces act in the same direction  $\rightarrow$  add; if opposite  $\rightarrow$  subtract.

In the above example, the **resultant force**,  $RF = 490 - 450 = 40N \leftarrow$

What's the **resultant force** in the example below?



Answer :  $RF = 0$  (zero) N,  $39N \leftarrow + 24N \leftarrow = 63N \leftarrow$  (then  $63-63 = 0$ )

## Newton's laws

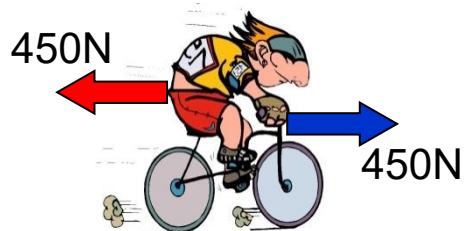
### Newton's 1<sup>st</sup> law

A body will remain at rest or continue to move at a constant velocity unless acted upon by an external (resultant) force.

In effect, this is like saying that if the forces are balanced, the object will remain stationary or keep moving at a constant velocity.

In the example on the right the cyclist keeps a steady forwards force by pushing on the pedals.

If the backward forces like air-resistance are equal to the forward force, the resultant force is then zero, and so the cyclist will keep moving at a constant speed.



This law also brings about the idea of '**inertia**'. **Inertia** is the resistance of any object to any change in its motion (including a change in direction). In other words, it is the tendency of objects to keep moving in a straight line at constant speed. So, a large object with a lot of mass, e.g. a cruise ship, will be very difficult to move, accelerate, decelerate, change its direction, etc. (because of its '**inertia**').

## Newton's laws

### Newton's 2<sup>nd</sup> law

In situations where the **mass** is constant, Newton's 2<sup>nd</sup> law can be simplified :

$$F = \frac{\Delta (mv)}{t} = m \frac{\Delta v}{t} = m \times a$$

$$F = m a$$

So, the acceleration is directly proportional to the resultant force.  
If the resultant force doubles, the acceleration doubles.

Where  $F$  = **resultant** force,  $m$  = mass, and  $a$  = acceleration



### Mass & Weight

**Mass** is a measure of how much 'matter' or material an object has.  
It's measured in **kg**.

**Weight** is a measure of how large the force of gravity is on an object.  
It is measured in **N**.

Clearly, mass and weight are not the same !!



Mass does NOT depend on the location of the object, i.e. consider a 1 litre bottle of water - it has a mass of 1kg. If this bottle were taken to the surface of Mars, its **mass** would still be 1kg (as long as no water is taken out of the bottle !).

However, since there's less gravity on Mars, the **weight** of the bottle is less on Mars than here on Earth.

Since weight is a type of force, we can apply the force equation to calculate it :

$$F = m \times a$$

$$W = m \times g$$



Am I weightless, or massless; both or neither ??!

where  $W$  = weight = 'force of gravity

$m$  = mass

$g$  = gravitational field strength / acceleration due to gravity

Here on the Earth's surface the value of 'g' is 10 N/kg. You will have to learn this equation, as it does not appear in the equation list at the start of the examination paper !

$$W = m \times 10$$

## Newton's laws

### Example

A water rocket of mass 2.5kg is launched from the surface of the Earth. It produces a steady thrust of 75N. Calculate the acceleration at the start.

$$\text{Weight of rocket, } W = m \times g = 2.5 \times 10 = 25 \text{ N}$$

$$\text{So, resultant force on the rocket} = 75 - 25 = 50 \text{ N } (\uparrow)$$

$$\text{acceleration, } a = \frac{\text{resultant force}}{\text{mass}} = \frac{50}{2.5} = 20 \text{ m/s}^2$$

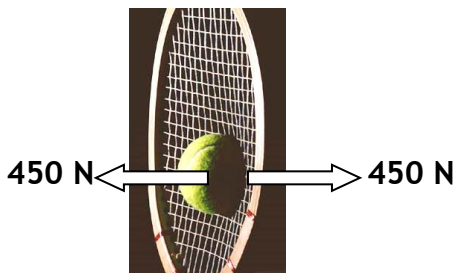


## Newton's 3<sup>rd</sup> law

In an interaction between 2 bodies, A and B, the force exerted by body A on body B is equal and opposite to the force exerted by body B on body A.

No force can act alone.

Remember that the action/reaction pair of forces are **always** on different objects, and so **never** 'cancel' out !

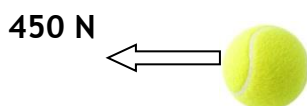


The racquet pushes the ball **forwards** with a force of 450N. Therefore, by Newton's 3<sup>rd</sup> law, the ball pushes the racquet **backwards** with an equal force.

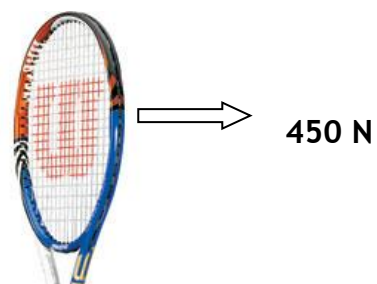
Note : one force is on the racquet, the other on the ball, so they don't 'cancel'.

The effect of these **two resultant forces** is that both objects **accelerate** in opposite directions. It may be easier to draw a **free body diagram** - a diagram that shows the forces acting on any **ONE** object at a time :

Here's the free body diagram for the tennis ball :



Here's the free body diagram for the racquet :



Note : Other forces like gravity and air-resistance have not been shown on these diagrams !

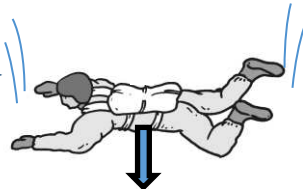
# Applying Newton's laws

Examination questions on forces often deal with the idea of 'terminal velocity'. This idea involves a situation whereby, initially, the forces may be unbalanced (so Newton's 2<sup>nd</sup> law is used) but later become balanced (→ Newton's 1<sup>st</sup> law).

A



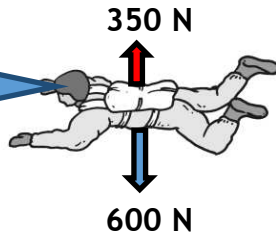
I've just jumped out of the helicopter, and so I'm hardly moving.



Air-resistance is zero, and so Newton's 2<sup>nd</sup> law states that the skydiver will **accelerate** downwards.

B

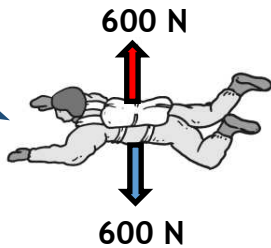
I'm now falling much faster – I can feel the air rushing past.



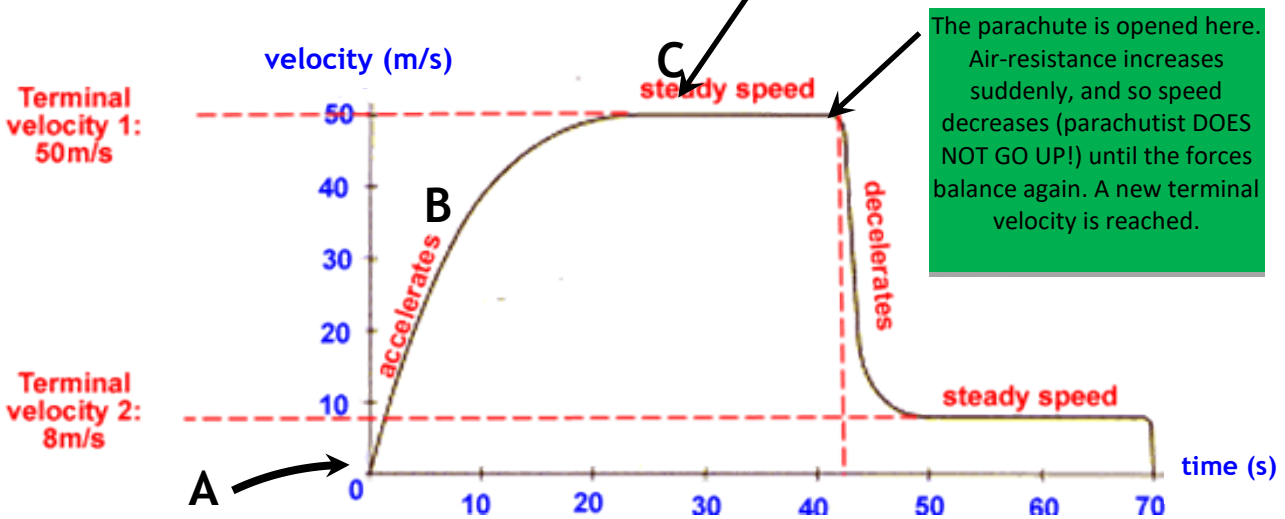
As the speed increases, so does the air-resistance. (The weight remains constant). Newton's 2<sup>nd</sup> law states that the skydiver will still **accelerate**, but not as much as before.

C

I'm now falling **very** fast - (about 50m/s or 115 mph !)



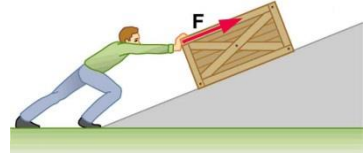
Eventually, the skydiver's speed is high enough such that the air-resistance is equal to the weight. Resultant force is zero, so zero acceleration. (Newton's 1<sup>st</sup> law) - **terminal velocity**



# Unit 6.3 - Work done & Energy

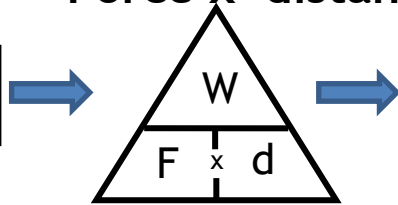
## Work Done

Doing 'work' in Physics means something very specific - it means a force is acting on an object causing some energy to be transferred. Work is calculated like this :



**Work done = Force x distance**

$$W = F \times d$$



...and the other two forms of the equation are :

$$F = \frac{W}{d}$$

$$d = \frac{W}{F}$$

Work, W, (or energy transferred) is measured in  
Force, F, is measured in  
Distance, d, is measured in

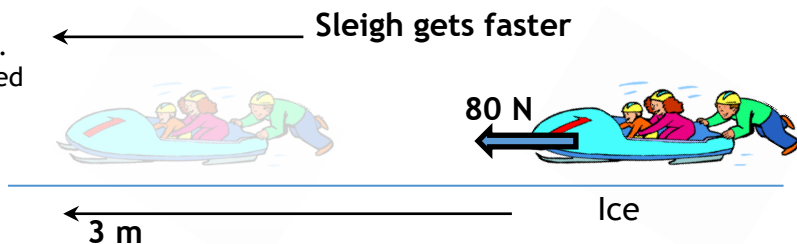
joules (J)  
newtons (N)  
metres, (m)

It's very important to remember the following fact :

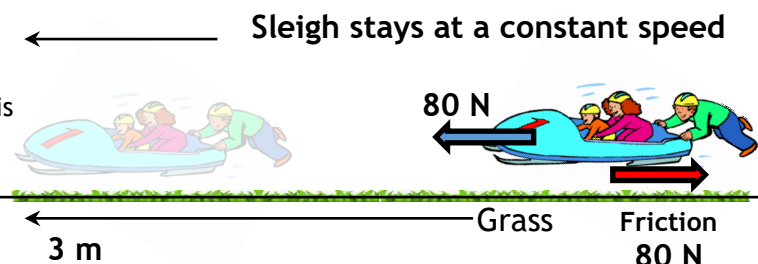
**Work done = energy transferred**

In correct terms, we should say that "Work done on an object is always equal to the energy transferred to or by the object". Here are 2 examples to explain this :

The force (by the person that's pushing) is doing work on the sleigh. This 240 J of work done is transferred to the sleigh, so it gains 240 J of kinetic energy - it speeds up.



The force is again doing the same amount of work on the sleigh, and so 240 J of energy must have gone somewhere ! This time, however, there's friction. The frictional force is equal to the pushing force. The work done (240 J) is transferred/wasted as heat and sound (not extra kinetic).



## Work Done & Energy transfers

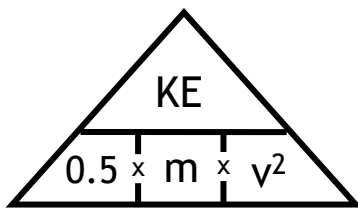
There are a number of different energy types, although all can be thought of as either kinetic or potential.

**Kinetic Energy (KE)** is the energy of a moving object.



Here's the equation to calculate KE :

$$\text{Kinetic energy} = \frac{\text{mass} \times \text{speed}^2}{2} \qquad \text{KE} = \frac{1}{2} m v^2$$



In order to find the speed of an object of known mass and KE, the above equation is re-arranged like this :

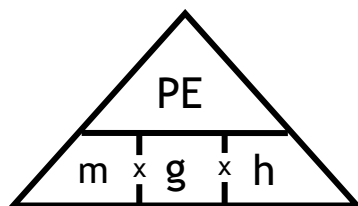
$$v = \sqrt{\frac{2 \text{ KE}}{m}} \qquad \text{or} \qquad v = \sqrt{\frac{\text{KE}}{0.5 m}}$$

Using the triangle

**(Gravitational) Potential Energy (PE)** is the energy an object has because of its position (usually its height above ground, or some other reference point).

Here's the equation to calculate PE :

$$\text{Change in potential energy} = \text{mass} \times \text{gravitational field strength} \times \text{change in height} \qquad \text{PE} = mgh$$



PE	is measured in	joules, J
m	is measured in	kilograms, kg
g	is measured in	N/kg (or m/s <sup>2</sup> )
h	is measured in	metres, (m)

## Work Done & Energy transfers

The **law of conservation of energy** states that energy can't be created or destroyed, only transferred from one form to another.

Hence, when an object, e.g. a ball, falls towards the ground, its gravitational potential energy (PE) decreases as it is transferred into kinetic energy (KE).



However, for all everyday situations, friction and air-resistance tend to act on moving objects, which change some of the energy into heat & sound. This is why a bouncing ball can never bounce back to the same height - some of its energy changes to heat and sound, mainly each time it strikes the floor, but also almost continuously by air-resistance.

For objects falling downwards

$$PE_{\text{loss}} = KE_{\text{gain}} + W$$

For objects thrown upwards

$$KE_{\text{loss}} = PE_{\text{gain}} + W$$

where **W** = work done by air-resistance and/or friction

Notice that the above are both 'conservation of energy' word equations. If the exam. question says that air-resistance and friction can be ignored, then just write one of the above word equation without the 'work done', '**W**'.

Also, remember that if there is some energy lost from the moving object through frictional forces, i.e. '**W**' is NOT zero, then you can also use this equation for work done :

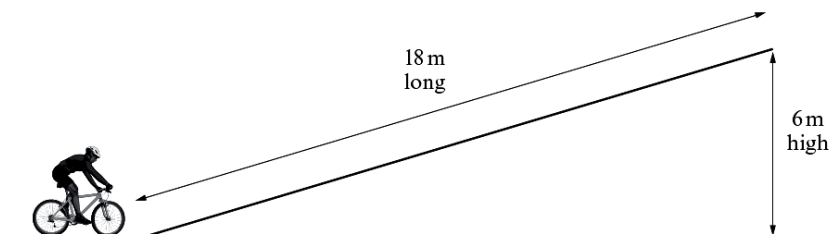
$$\text{Work} = \text{Force} \times \text{distance}$$

$$W = F \times d$$

## Work Done & Energy transfers

### Example 1 (P2, Jan 2012) - Answers at bottom of page !!

A cyclist and cycle have a total mass of 90 kg.  
 The cyclist reaches the bottom of a ramp at a speed of 13 m/s and stops pedalling. On reaching the top of the ramp the speed is reduced to 5 m/s.  
 The ramp is 18 m long and 6 m high.



(a) By using the equations

$$\text{kinetic energy} = \frac{mv^2}{2} \text{ and potential energy} = mgh$$

where  $g = 10 \text{ N/kg}$ , calculate:

(i) the kinetic energy of the cyclist (and cycle) at the bottom of the ramp. [2]

Kinetic energy = ..... J

(ii) the **total energy** at the top of the ramp. [4]

Total energy = ..... J

(b) Use your answers to part (a) and an equation from page 2 to calculate the frictional force acting against the cyclist up the ramp. [3]

Frictional force = ..... N

**HINTS !!**



Simply add the  $KE_{\text{top}}$  and the PE.

Find the difference between the energy of the cyclist at the bottom and at the top - this 'difference' is equal to the **work done** by frictional forces.

### Answers

(a) (i)  $KE_{\text{bottom}} = 0.5 m v^2 = 7610 \text{ J}$

(ii)  $E_{\text{total}} = KE_{\text{top}} + PE = 1130 + 5400 = 6530 \text{ J}$

(b) **Expected method**

$$W_{\text{friction}} = KE_{\text{bottom}} - E_{\text{total}} = 1080 \text{ J}$$

$$\text{Friction} = W_{\text{friction}} / \text{distance} = 60 \text{ N}$$

(b) **Alternative method**

$$KE_{\text{loss}} = PE_{\text{gain}} + W_{\text{friction}}$$

hence,  $W_{\text{friction}} = KE_{\text{loss}} - PE_{\text{gain}} = 1080 \text{ J}$

$$\text{Friction} = W_{\text{friction}} / \text{distance} = 60 \text{ N}$$

## Work Done & Energy transfers

### Example 2 ( P2, June 2012) - Answers at bottom of page !!

### HINTS !!



A cruise ship's engines produce a constant thrust of  $1.6 \times 10^6 \text{ N}$ . It has a mass of  $1.2 \times 10^8 \text{ kg}$ .

- (a) Use the equation

$$\text{acceleration} = \frac{\text{resultant force}}{\text{mass}}$$

to calculate the ship's initial acceleration. [2]

$$\text{Acceleration} = \dots\dots\dots \text{ m/s}^2$$

'Initial acceleration' means 'at the start', when the ship isn't moving fast enough to experience any friction or air-resistance. This means that you can assume the resultant force is equal to the 'thrust'.

- (b) Once at sea, the ship's speed increases from 5 m/s to 9 m/s over a distance of 2400m. By using the equations

$$\text{work} = \text{force} \times \text{distance}$$

$$\text{kinetic energy} = \frac{\text{mass} \times \text{speed}^2}{2}$$

- (i) calculate the work done by the ship's engines over the 2400 m travelled at sea, [2]

$$\text{Work done} = \dots\dots\dots \text{ J}$$

Look up the equation for 'work done'.

- (ii) calculate the increase in the ship's kinetic energy. [2]

$$\text{K.E. increase} = \dots\dots\dots \text{ J}$$

Calculate the KE **twice** - once for each speed, then find the difference.

- (iii) Use your answers to parts (i) and (ii) to calculate the mean work done against the ship as its speed increases. Hence find the value of the mean drag force acting against the ship. [3]

$$\text{Mean work done} = \dots\dots\dots \text{ J}$$

Calculate the difference between the work done by the engines and the KE gain. This is the work done by the frictional forces.

$$\text{Mean drag force} = \dots\dots\dots \text{ N}$$

### Answers

(a)  $a = 0.013 \text{ m/s}^2$

(b) (i)  $W_{\text{engine}} = 3.84 \times 10^9 \text{ J}$

(ii)  $KE_{\text{gain}} = KE_{\text{final}} - KE_{\text{initial}} = 3.36 \times 10^9 \text{ J}$

(iii)  $W_{\text{drag}} = 4.80 \times 10^8 \text{ J}$ ; hence, **Drag** =  $W_{\text{drag}} / \text{distance} = 2.00 \times 10^5 \text{ N}$

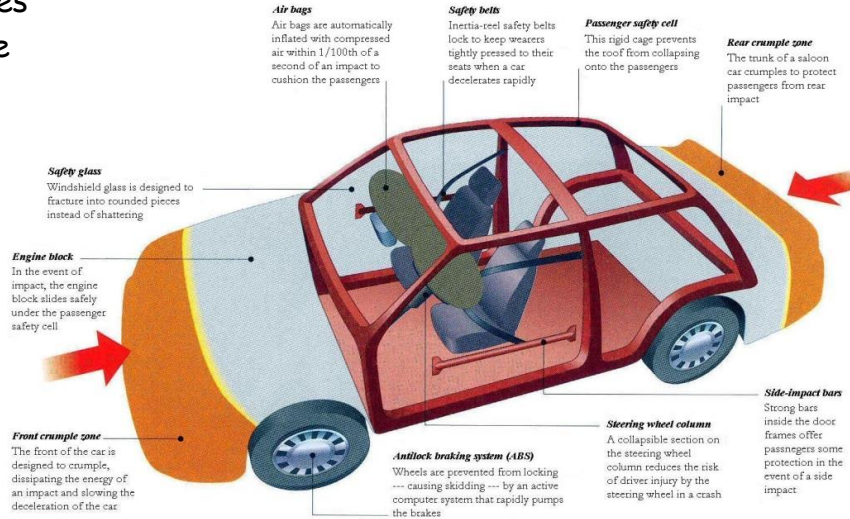


# Stopping distance & Car Safety

There are many safety features in modern cars/vehicles - some are shown in the picture. →

The main features are :

- 1) Seat belts
- 2) Crumple zones
- 3) Airbags
- 4) Side-impact bars
- 5) Passenger cell



Feature	What it is	How it works
Seat belt	A strong belt strapped around the body	Prevents the person being thrown forwards in a crash
Crumple zone	A section that deforms/compresses on impact	Decreases the deceleration, and so the force
Airbag	A bag that inflates rapidly in front of the person during a crash	Acts as a cushion to prevent the head of the passenger from hitting the front/side of the inside of the car
Side-impact	Strong bars inside the car doors	Strengthens the doors to better protect the passengers from another car hitting from the side
Passenger cell	A rigid cage around the passengers	Protects the passengers from impacts in all directions, but especially from a collapsing roof (when the car's upside-down)

Car manufacturers intentionally crash cars with dummies inside to assess the effectiveness of various safety features.



The idea behind crumple zones and airbags is to reduce the **force** on passengers during a crash.

Since Force =  $\frac{\text{work done}}{\text{distance}}$ , if you increase the distance over which the energy is transferred, it will reduce the force.

**Example:** a person is sitting inside a moving car. The car is moving with a speed of 30 m/s. The person's mass is 75kg. Calculate the person's kinetic energy.

$$KE = 0.5 m v^2 = 0.5 \times 75 \times 900 = 33\,750 \text{ J}$$





The car deforms a little during the collision. This means the passengers reduce their speed over a certain distance. In a car without a proper 'crumple zone', this distance is about 40cm. **With** a crumple zone it increases to 60cm. The seat belt also stretches a little, so increases these distances by 4cm. Calculate the force acting on the passenger in a normal car, and then in a car with a crumple zone. If the person travelling in the car has 33,750 J of kinetic energy before the collision. The work done happens over a distance of 0.64m with a crumple zone.

$$G_{\text{ym}} = W / x = 33750 / 0.64 = 52\,734 \text{ N} \quad (\text{With crumple zone})$$

$$G_{\text{ym}} = W / x = 33750 / 0.44 = 76\,705 \text{ N} \quad (\text{No crumple zone})$$

Therefore the force on the occupant is much less when a crumple zone is used.

### Improving the efficiency of vehicles.

Feature	Picture	How it works.
Aerodynamic losses		Cars are designed to reduce aerodynamic losses by using more streamlined designs. This allows the car to move through the air as easily as possible.
Rolling resistance		Rolling resistance is reduced by having correctly inflated tyres and using materials which don't heat up as much as they are squashed.
Idling losses		Stop-start systems reduce idling losses. If the car is stopped in traffic the engine shuts down automatically and then re-starts automatically when the accelerator is pressed
Inertial losses		Inertial losses are reduced by having lighter cars. Materials such as carbon fibre are used instead of metals for parts of the bodywork.

## Unit 6.4 - Stars and planets

### The Solar System.

The planets all move in an orbit around the Sun. The order of the planets is: **Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune**, (Pluto is a 'dwarf planet').



The planets seen above are shown to the correct scale according to their relative sizes, but are far from scale in terms of their distances from the Sun. (On the scale shown, the Earth should be about 15metres away from the Sun !!)

Mercury, Venus, Earth and Mars are rocky planets, the rest are gas giants. Most of the planets have moons which are in orbit around them. Saturn and Jupiter have the greatest number of moons because they have the strongest gravitational pull.

### Asteroids.

Asteroids are lumps of rock which are in orbit around the Sun but are too small to be called planets. The asteroid belt is located between Mars and Jupiter and contains a number of dwarf planets. Ceres is largest of these with a diameter of 587 miles.



### Comets.

Comets are lumps of ice and dust which are in a highly elliptical orbit around the Sun. They travel very far out of our solar system and take a number of years to return closer to the Sun. Halley's Comet is one of the most famous, it has an orbital period of about 75 years.

## Scale and distances in space.

**Astronomical Unit (AU):** The mean distance from the centre of the Earth to the centre of the Sun.

$$1\text{AU} = 1.496 \times 10^{11}\text{m}$$

**The light year (l-y):** the distance light travels in one year.

$$1\text{ l-y} = 9.46 \times 10^{15}\text{m}$$

The Earth - our home !

Diameter = 12,800 km.

The closest object to us in space is the Moon. (It's about 30 Earth diameters away).



<http://htwins.net/scale2>

X 100

Our star - the Sun. All objects in the solar system orbit around the Sun.

It's about 100 times as big as the Earth.



X 3000

Our solar system.

The picture at the top of this page shows what it contains. Diameter ~ 100 AU (1 AU = Earth-Sun distance,  $1.5 \times 10^{11}\text{m}$ )



X 40,000

Outside the solar system there's a lot of empty space. The nearest stars are about 4 light years away, and all spaced out about the same distance within the galaxy.



X 10,000

A cluster of stars is known as a galaxy. Our galaxy is called the 'Milky Way'. It's about 90,000 light years across. (1 l.y. = 63 000 AU =  $9.5 \times 10^{15}\text{m}$ ).



X 200

The picture (→), taken by the Hubble telescope shows a large 'cluster' of galaxies !



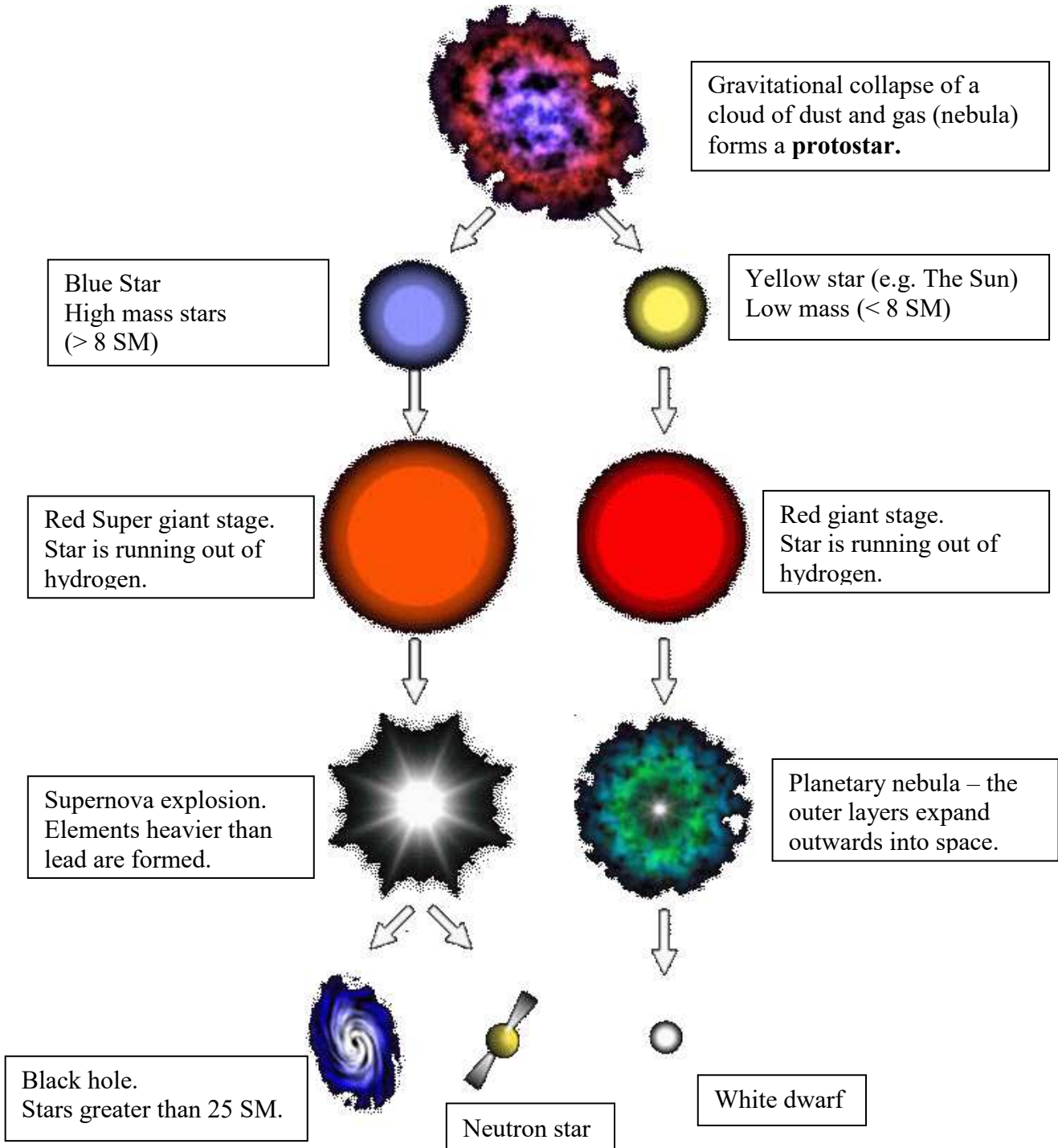
X 1000

The known universe is made of many billions of galaxies. The string-like patterns seen are called 'filaments' - colossal clusters of millions of galaxies !



## Life cycle of the stars.

The diagram below shows the possible life cycle for stars of different masses. **SM** stands for **Solar Masses**. If a star is 3SM then it is 3 times the mass of the Sun.



**Brown dwarfs** are failed stars that never have enough mass in order to get hot enough to achieve nuclear fusion.

**Red dwarf stars:** these are low mass stars that **do** achieve nuclear fusion. They are not very bright and have very long lifetimes. They are main sequence stars.

## Forces within a star.

There are 2 forces acting inside a star.

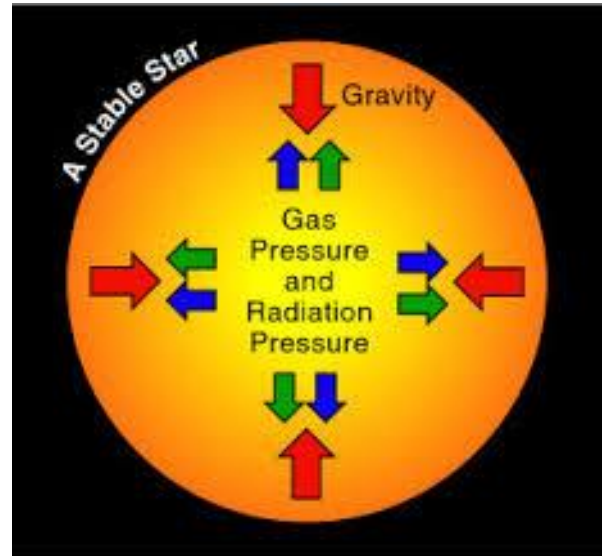
1. **Inward force of gravity**
2. **Outward: combination of gas and radiation pressure.**

**Gas pressure:** caused by rapid random motion of particles in the sun.

**Radiation pressure:** caused by light hitting the particles.

For most of the life of a star it is in a stable state in which the inward force of gravity on any part of the star is balanced (equal) by a force due to the increasing pressure towards the centre.

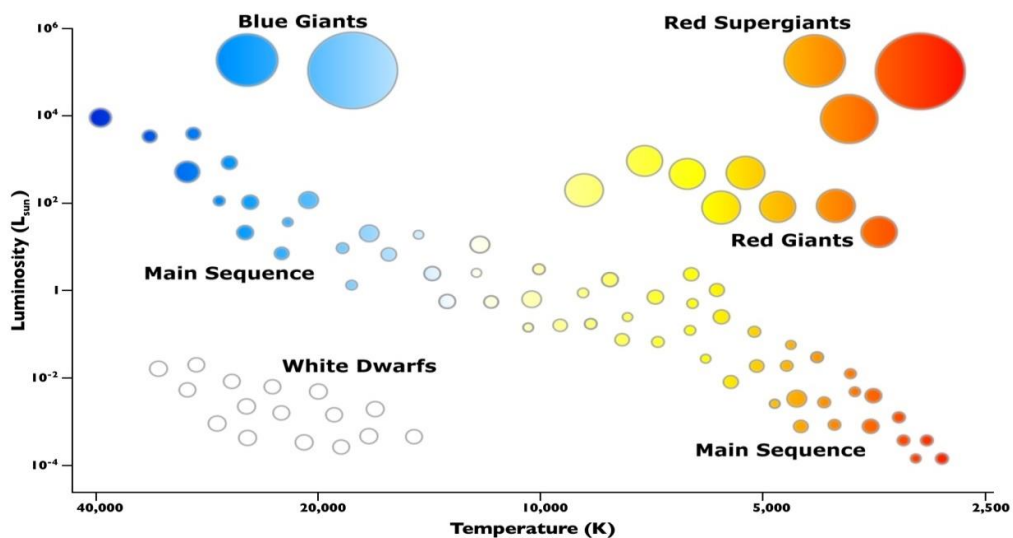
If the pressure in the middle **falls**, this will cause a star to **shrink** – this will cause the pressure to rise once more until a new equilibrium is established with the smaller core. If the pressure increases, the star will **expand**.



## Main sequence stars.

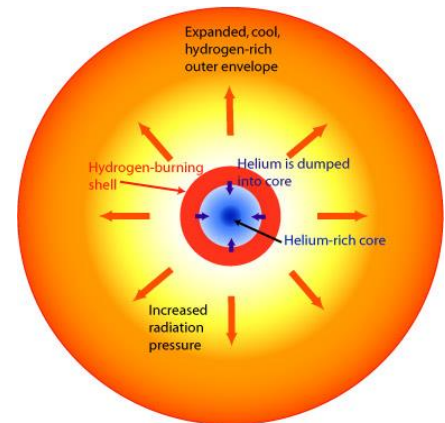
Main sequence stars fuse **hydrogen** to **helium** in their cores.

The colour of a star depends upon the temperature of the star. Our sun is a yellow star which is one of the most common type. Surface temperature is 5800°C. Stable lifetime is around 10,000 million years. The diagram below is a Hertzsprung-Russell diagram. In general, where a star is on the diagram relates to which stage of its life cycle it's currently in.



## End of main sequence stage.

Once a star has exhausted (run out) of its supply of hydrogen the temperature of the star's core will decrease as nuclear fusion ceases. This means that the gravitational force is greater than the gas and radiation pressure causing the core to shrink. Fusion of helium will then soon start in the core as the temperature increases due to gravitational collapse, once again resulting in an increase in gas and radiation pressure. The fusion reactions are now much more 'fierce' than before (higher temp.), and so the increased gas and radiation pressure causes the star's outer layers to expand – the star is now a **red giant**.



Hydrogen Shell Burning on the Red Giant Branch

### At the end of the main sequence stage of our Sun the:

- Light elements (Hydrogen and Helium) fuse in the centre
- Centre is exhausted of light elements – nuclear reactions stop, causing pressure to drop
- Star nucleus shrinks, making density and temperature go up, allowing heavier elements to fuse
- Meanwhile the lighter elements continue fusing in a shell around the nucleus
- Stars like the Sun never reach sufficient temperatures to fuse elements heavier than oxygen
- The outer layers of the star are pushed off by the radiation pressure of the core – enriching the interstellar medium with heavier elements.
- A very dense core remains known as a white dwarf (1 teaspoon has a mass of 5 tons).

Useful website <http://aspire.cosmic-ray.org/Labs/StarLife/>

### A new beginning !

All the material from a supernova mixes up with interstellar dust and gas. The shockwave from a supernova can also 'kickstart' the collapse of a nebula. The effect then is that the dust and gas in a nebula (now enriched with heavier elements from the supernova) contracts over time.

As the nebula (or part of it) contracts, the 'gravitational collapse' converts gravitational potential energy into kinetic energy, i.e. the dust and gas becomes hotter and hotter.

Eventually the temperature at the heart of the nebula reaches a sufficiently high temperature and density for fusion to start – a star is born !

During formation rocks tended to gather close to the Sun and formed the rocky planets whilst gaseous substances gathered together at distances further away and formed the gas planets.

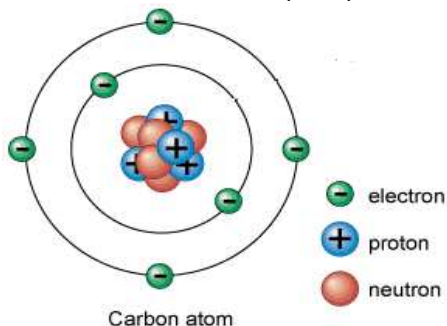


M16 : AKA "The eagle nebula – pillars of creation".

## Unit 6.5 - Types of radiation

### Nuclear physics.

To understand what radioactivity is you must understand what makes an atom radioactive.

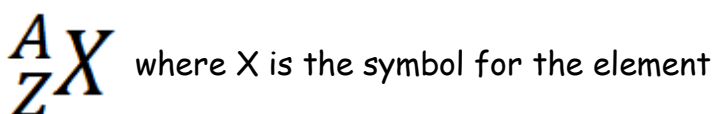


The atom consists of:

6 protons

6 neutrons

6 electrons



**Proton number (or Atomic number) ( Z )** - This tells us the *number of protons* in the atom/nucleus.

**Nucleon number (aka Mass Number) ( A )** - This tells us the number of *protons and neutrons* in the atom/nucleus.

A mathematical formula to calculate the number of neutrons 'N' in terms of A and Z.

$$N = A - Z$$

Example:  ${}^7_3\text{Li}$  of protons = 3



Number of neutrons 'N' =  $A - Z = 7 - 3 = 4$

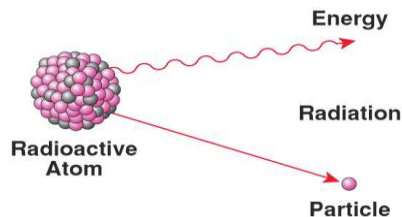
**Isotopes:** These are atoms of the same element which have the same number of protons but a different number of neutrons. They have the same proton number and differing nucleon number.

Example. Iodine-123  ${}^{123}_{53}\text{I}$  and iodine-131  ${}^{131}_{53}\text{I}$  are isotopes. Iodine-123 has 53 protons and 70 neutrons whereas iodine-131 has 53 protons and 78 neutrons.

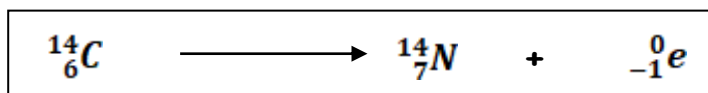
The higher the proton number of the element the more neutrons the element will have compared to protons.

## RADIOACTIVE DECAY

Why is an atom radioactive? **If an atom has an imbalance of protons and neutrons in the nucleus it will be also be UNSTABLE.** (This does not mean an equal number of protons and neutrons).






The nucleus tries to become stable by breaking up into stable fragments: **RADIOACTIVE DECAY**. Carbon has three common isotopes  $^{12}\text{C}$ ,  $^{13}\text{C}$  and  $^{14}\text{C}$ . Carbon-14 is radioactive because it has an **imbalance of protons and neutrons**.



Carbon will **emit radiation** to try and make itself stable, a nitrogen nucleus is formed in the process. This process is called **RADIOACTIVE DECAY**.

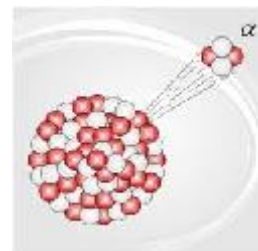
There are 3 types of radiation emitted from the nucleus.

Information	Alpha ( $\alpha$ )	Beta ( $\beta$ )	Gamma ( $\gamma$ )
Symbol	$^4_2\text{He}$	$^0_{-1}\text{e}$	$\gamma$
What is it?	 A helium nucleus (2 protons and 2 neutrons).	 Fast moving/ high energy electron.	 High energy electromagnetic wave.
What can stop it? Penetrating power.	Thin sheet of paper, skin or few cm of air	Few mm of aluminium or up to a metre of air.	Several cm of lead or very thick concrete.
Ionising power	Very high - most damaging inside the body.	Medium	Low (compared with alpha and beta). Easily passes through the body.

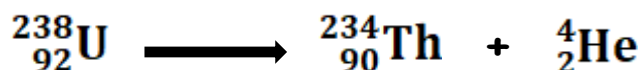
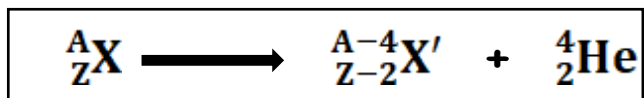
## Balancing nuclear equations.

### Alpha decay ${}^4_2\text{He}$

During alpha decay the number of protons decreases by 2 and the number of neutrons decreases by 2. Therefore the proton number decreases by 2 and the nucleon number decreases by 4.



General equation:



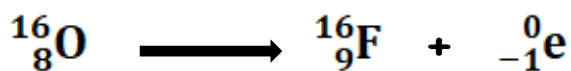
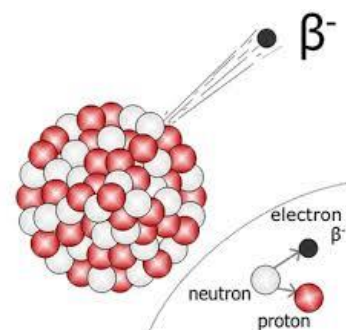
Balance the following nuclear equations by calculating the value of a, b, c and d.



a=237, b=93, c=232, d=82

### Beta decay.

During beta decay the number of protons increases by 1 and the number of neutrons decreases by 1. Therefore the proton number increases by 1 and the nucleon number stays the same



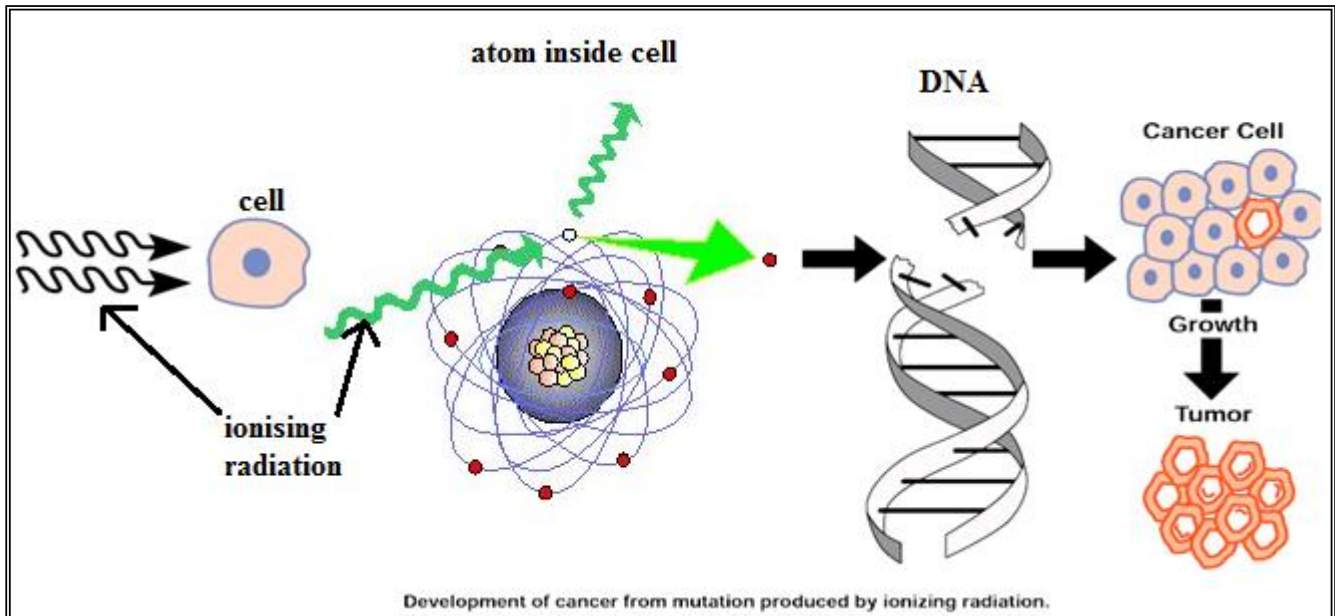
Balance the following nuclear equations by calculating the value of a, b, c and d.



a=2, b=1, c=63, d=29

## Ionising radiation.

**Ionising:** - some particles and electromagnetic waves (both are radiation) have enough energy to rip electrons away from atoms and molecules. Ions are formed which can interact with cells in the body and **damage DNA/cells**. This damage can lead to the formation of cancer.

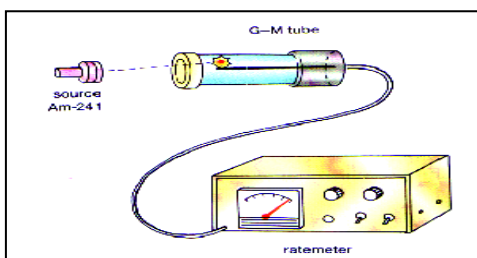
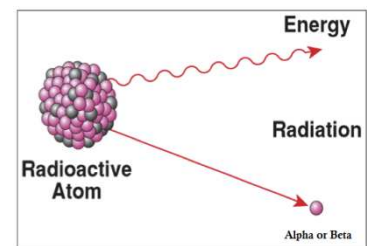


**Ionising radiation include:** alpha, beta, gamma, x-rays and ultraviolet.

**Non-ionising radiation:** visible light, infrared, microwave and radio waves.

## Radioactive decay:

Some atoms are unstable and so we say that they are radioactive. They try to become stable emitting alpha, beta or gamma radiation. The process of atoms undergoing radioactive decay is totally **random** and **spontaneous**. There is no way of telling **when** or **which** atom will decay in a radioactive material.

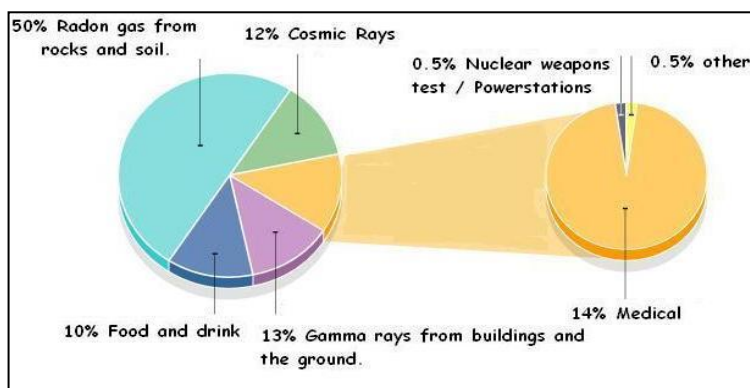


A Geiger counter can be used to measure the ionising radiation. To gain greater accuracy when measuring radioactive decay we must do 2 things:

1. Repeat the experiment and calculate the average.
2. Carry out the experiment over a longer period of time.

## Background radiation.

**Background radiation:** background radiation is all around as radioactive atoms emit alpha, beta and gamma radiation. Most of the background radiation comes from natural sources. The pie chart shows the sources of background radiation.



**Natural sources:** Radon, Cosmic radiation (from space), radon, rocks, food and buildings. Background radiation varies with altitude as at higher altitudes there will be more cosmic radiation.

**Artificial sources:** medical and nuclear industry.

**Correcting for background :** If the background count was 30 counts per minute (30 count/minute) then if we are measuring the activity of a radioactive source we must **subtract** the background count rate. If the count rate was therefore measured to be 150 count/minute what is the count rate from the radiation source?

$$\begin{array}{rccccccc} \text{Radiation from source only} & = & 150 & - & 30 & = & 120 \\ & & (\text{total}) & & (\text{background}) & & (\text{radiation from source}) \end{array}$$

## Determining the type of radiation emitted by a radioactive source

**Example question:** Various materials are placed between the Geiger tube and the radioactive material. The following information is recorded about the radioactive material. The count rate has **not been corrected** for background.

	No absorber	Paper absorber	Sheet of aluminium	20cm of lead
Count rate detected (counts/s)	250	50	50	0.5

**Question:** determine the type and amount of each radiation emitted by the radioactive material.

**1<sup>st</sup> point:** the count drops from 250 to 50 with a shielding of paper. This indicates the presence of alpha radiation. Count rate alpha = 250 – 50 = 200 count/s.

**2<sup>nd</sup> point:** placing aluminium in front has no effect so there's no beta present.

**3<sup>rd</sup> point:** the lead decreases the count/s so must be gamma radiation present.  
Count rate gamma = 50 – 0.5 = 49.5 count/s.

**4<sup>th</sup> point:** Background count = 0.5 count/s. All (almost) gamma radiation should be stopped by 20cm of lead.

**Summary:** alpha = 200 count/s, beta = 0 count/s, gamma = 49.5 count/s, background = 0.5 count/s



## Radiation dose.

**Measuring the received dose of radiation:** The higher the radiation received can increase your risk of developing cancer. Scientists can measure the dose in units of **sievert (Sv)**. One sievert is a large dose and therefore they use **milisievert (mSv)**.



The higher the dose received the more damage has been done.

The dose received depends upon two things:

1. The type of radiation (alpha, beta or gamma)
2. The amount of radiation received.

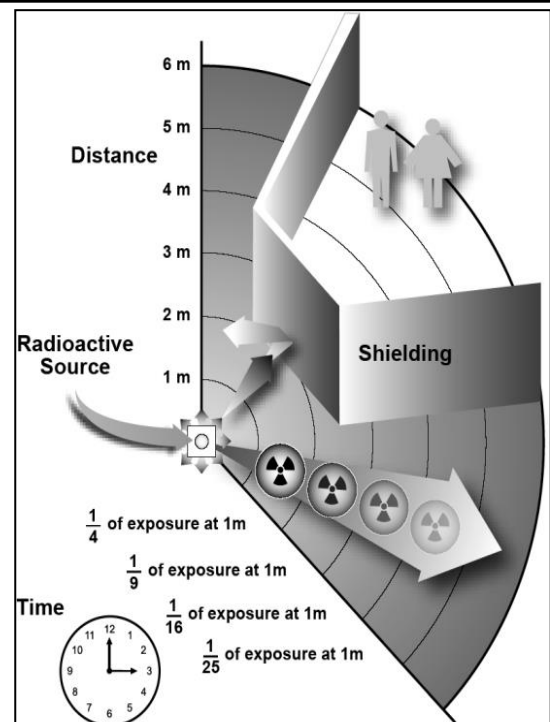
Over the world the average dose received is 2.4 milisievert (0.0024Sv) a year. Some places in Cornwall receive doses of 7.8 mSv.

Available scientific evidence does not indicate any cancer risk or immediate effects at doses below 100 mSv a year. At low levels of exposure, the body's natural repair mechanisms seem to be adequate to **repair radiation damage** to cells soon after it occurs.

## Protecting against radiation

There are **four ways** in which people are protected from identified radiation sources:

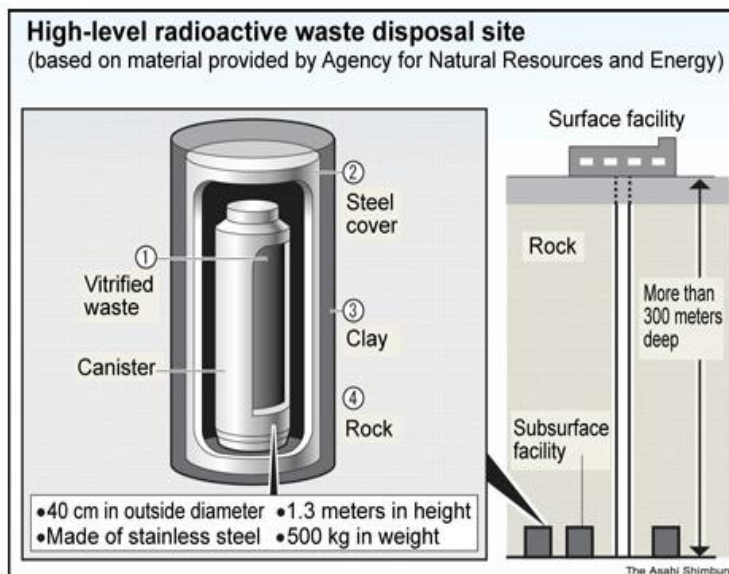
1. **Limiting time.** In the workplace situations, dose is reduced by limiting exposure time.
2. **Distance.** The intensity of radiation decreases with distance from its source.
3. **Shielding.** Barriers of lead, concrete or water give good protection from high levels of penetrating radiation such as gamma rays. Intensely radioactive materials are therefore often stored or handled under water, or by remote control in rooms constructed of thick concrete or lined with lead.
4. **Containment.** Highly radioactive materials are confined and kept out of the workplace and environment. Nuclear reactors operate within closed systems with multiple barriers which keep the radioactive materials contained.



## Storing Nuclear Waste

Nuclear waste is produced by the nuclear industry in **nuclear power stations** and **nuclear medicine**. Nuclear waste is very difficult to get rid of and make safe.

Only **time** can reduce the radiation emitted because they can remain radioactive for a long period of time (**thousands of years** with some materials). It is very **costly** to **process, store** and **guard** the nuclear waste.



Nuclear power stations produce the vast majority of the nuclear waste. Due to the radiation emitted the waste is very hot and so must be cooled. It is then turned into a glass so that it cannot flow. The waste is placed inside steel drums and then sealed in concrete. **Deep underground** is one possible idea for storage. Care must be taken that the waste does not pollute the local water source if it were to leak.

## Unit 6.6 : Half-life

There are billions upon billions of atoms in a small amount of a radioactive sample so the chance that one atom will undergo decay is high.

Is it possible to determine **which** radioactive nuclei/atom will decay next in the sample? No, because the process is **random**. Is it possible to determine when the next radioactive nuclei will decay? No, because the process is **spontaneous**. Since its random and spontaneous process we can get more accurate information/results by:

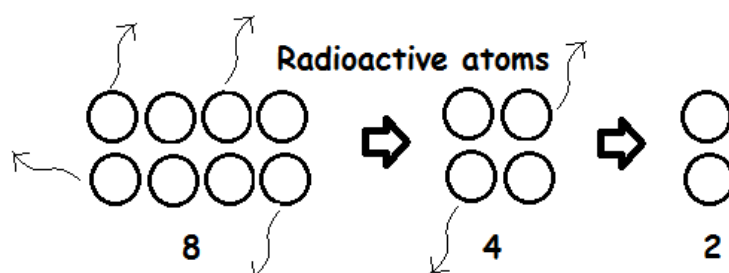


1. Repeating.

2. Measuring over a long time.

### The half life.

Each half life the number of unstable atoms halves. The half life remains constant.



**The half life is the time it takes for half the unstable atoms to decay.**

**The half life is the time it takes for the activity to halve from its original value.**

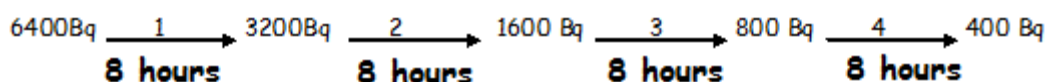
**Activity.** The activity is a measure of number of radioactive decays per second. It is measured in becquerel, Bq. So an activity of 1 becquerel is equivalent to 1 radioactive decay per second. The activity of a sample of radioactive material will depend on 2 things:

**1. The number of radioactive/unstable atoms present.**

**2. The half life of the atoms.**

The more atoms present the greater the activity. The shorter the half life the greater the activity.

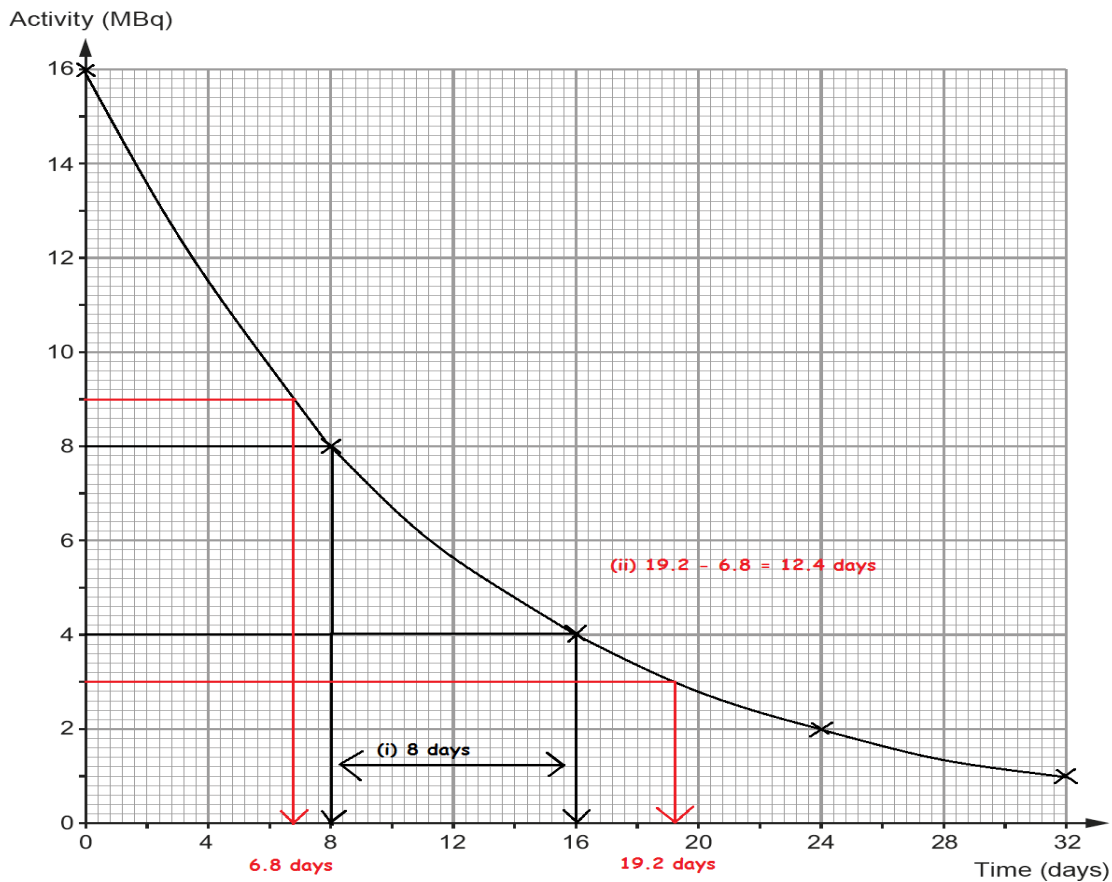
Example. A radioactive isotope has an activity of 6400Bq. The half life of the isotope is 8 hours. What is its activity after 32 hours?



There have been 4 half lives totalling 32 hours (8 hours x 4).

## Radioactive decay curves.

Whether you are plotting a graph of activity or the number of radioactive atoms the curve/line of the graph is the same. In this example the activity of the isotope iodine-131 has been plotted against time. The sample has a starting/initial activity of 16 MBq (16,000,000Bq).



(i) We can calculate the half life using the method shown above. You must choose one activity value and then halve it. In the example the activity has halved from 8MBq to 4MBq. This has taken 8 days so we can say that the **half life of iodine-131 is 8 days**.

(ii) We can also calculate how long it will take for the activity to fall a certain amount, e.g. from 9 MBq to 3 MBq. The activity was 9 MBq after 6.8 days and the activity was 3 MBq after 19.2 days. Therefore by calculating the time difference we can calculate how long this took.

$$19.2 - 6.8 = 12.4 \text{ days.}$$

(iii) How long would it take for the activity to fall from 1 MBq to 250,000 Bq?

It is not possible to continue the graph so we must use the same method as on the previous page.

$$1 \text{ MBq} = 1,000,000 \text{ Bq} \xrightarrow[8 \text{ days}]{1} 500,000 \text{ Bq} \xrightarrow[8 \text{ days}]{2} 250,000 \text{ Bq}$$

$$\text{Total time} = 8 + 8 = 16 \text{ days}$$

## Uses of radioactive materials

There are many uses of radioactive materials; carbon dating, sterilising medical equipment, killing cancer cells, smoke alarms and controlling the thickness of aluminium foil.

What is required is that you can select from a given list and explain which isotope is suitable for use in a specific case. Consider: 1. **Penetrating power.** 2. **Half life.** 3. **Biological effect.**

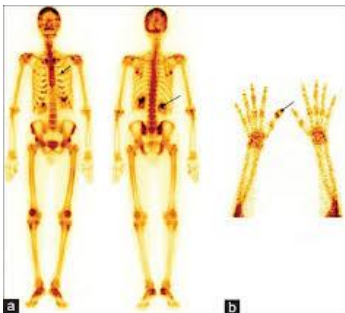
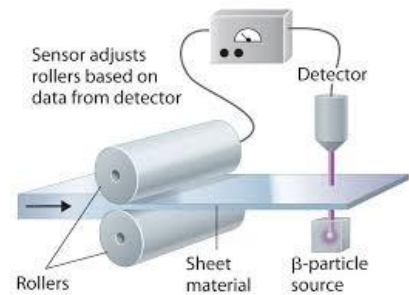
In this case we will choose one of the isotopes for a particular use and explain our reasoning.

Example of radioactive isotope. The half life given in brackets ( )		
Gamma – $\gamma$	Beta ${}_{-1}^0e$	Alpha ${}_{2}^4He$
Technetium-99 (6.01hrs)	Iridium-192 (74 days)	Polonium-210 (138days)
Cobalt-60 (5.27 yrs)	Strontium-90 (28.5 yrs)	Americium-241 (432 yrs)
	Carbon-14 (5730yrs)	Plutonium-238 (87.7 yrs)

(a) Monitoring the thickness of aluminium sheet in a factory.

**Isotope chosen :** Strontium – 90 (beta emitter).

**Reason:** because **fewer** beta particles will pass through when the thickness of aluminium increases. The half life is fairly long so the source will last a reasonable amount of time.



(b) Medical tracer in monitoring internal organs by using a camera outside the body.

**Isotope chosen:** Technetium-99 ( $\gamma$  – emitter)

**Reason:** because it's a gamma emitter, it passes out of the body easily. The half life is short so it will not remain in the body for a long time.

(c) A smoke detector.

**Isotope chosen:** Americium-241 (alpha emitter)

**Reason:** Gamma more penetrating than alpha so it would not be blocked by smoke. It has a longer half life so detector stays active / keeps working for a longer period of time. (Polonium-210 has too short a half life so it would not last very long and therefore it's not suitable).

