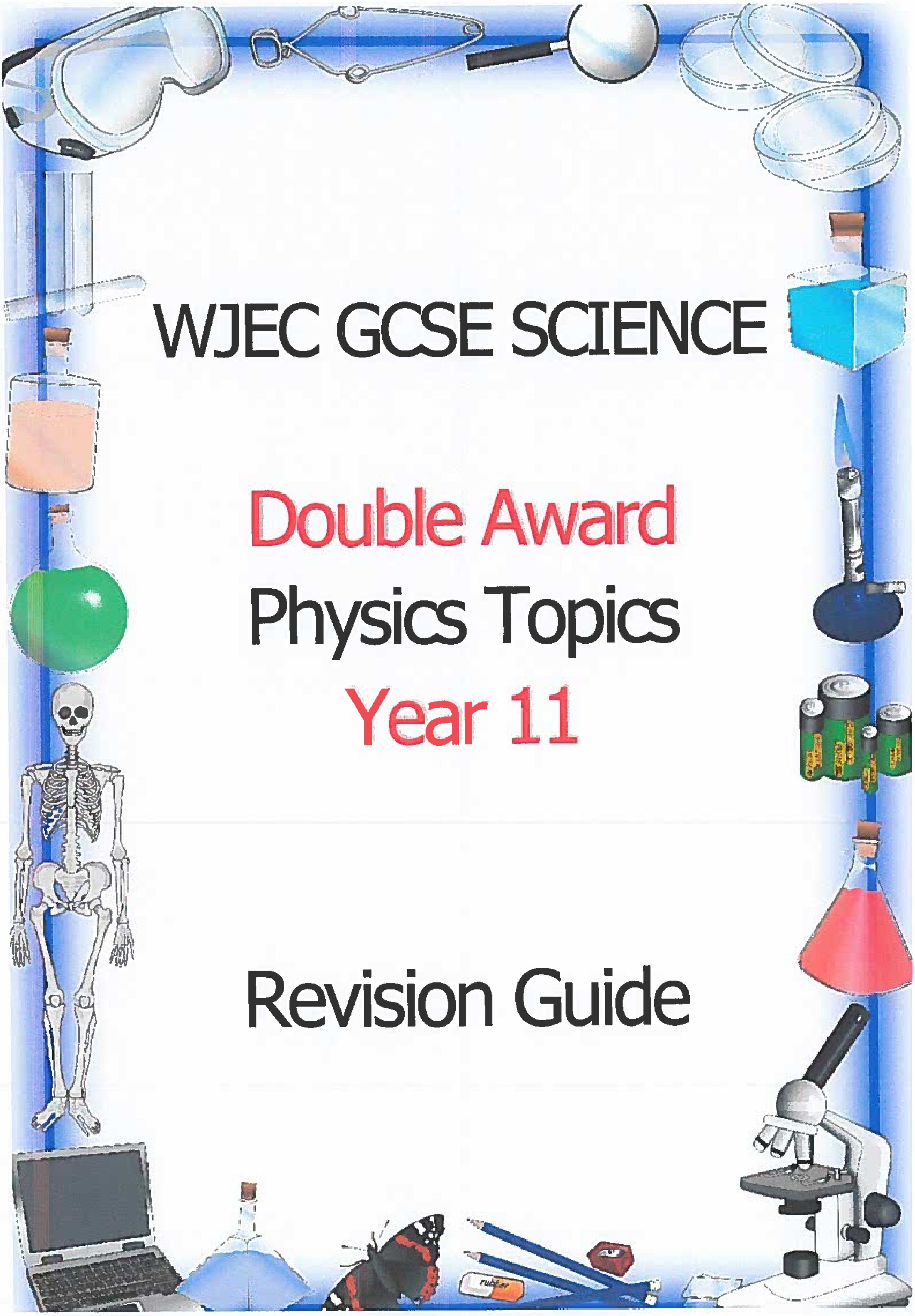


WJEC GCSE SCIENCE

Double Award
Physics Topics
Year 11

Revision Guide

GCSE PHYSICS Unit 2 Foundation

Equations

$\text{speed} = \frac{\text{distance}}{\text{time}}$	
$\text{acceleration [or deceleration]} = \frac{\text{change in velocity}}{\text{time}}$	$a = \frac{\Delta v}{t}$
acceleration = gradient of a velocity-time graph	
resultant force = mass × acceleration	$F = ma$
weight = mass × gravitational field strength	$W = mg$
work = force × distance	$W = Fd$
force = spring constant × extension	$F = kx$
momentum = mass × velocity	$p = mv$
$\text{force} = \frac{\text{change in momentum}}{\text{time}}$	$F = \frac{\Delta p}{t}$
u = initial velocity v = final velocity t = time a = acceleration x = displacement	$v = u + at$ $x = \frac{u + v}{2}t$
moment = force × distance	$M = Fd$

SI multipliers

Prefix	Multiplier
m	1×10^{-3}
k	1×10^{3}
M	1×10^{6}

GCSE PHYSICS Unit 2 Higher

Equations

speed $= \dfrac{\text{distance}}{\text{time}}$	
acceleration [or deceleration] $= \dfrac{\text{change in velocity}}{\text{time}}$	$a = \dfrac{\Delta v}{t}$
acceleration = gradient of a velocity-time graph	
distance travelled = area under a velocity-time graph	
resultant force = mass × acceleration	$F = ma$
weight = mass × gravitational field strength	$W = mg$
work = force × distance	$W = Fd$
kinetic energy $= \dfrac{\text{mass x velocity}^2}{2}$	$\text{KE} = \frac{1}{2}mv^2$
change in potential energy = mass × gravitational field strength × change in height	$\text{PE} = mgh$
force = spring constant × extension	$F = kx$
work done in stretching = area under a force-extension graph	$W = \frac{1}{2}Fx$
momentum = mass × velocity	$p = mv$
force $= \dfrac{\text{change in momentum}}{\text{time}}$	$F = \dfrac{\Delta p}{t}$
u = initial velocity v = final velocity t = time a = acceleration x = displacement	$v = u + at$ $x = \dfrac{u+v}{2}t$ $x = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2ax$
moment = force × distance	$M = Fd$

SI multipliers

Prefix	Multiplier
p	1×10^{-12}
n	1×10^{-9}
µ	1×10^{-6}
m	1×10^{-3}

Prefix	Multiplier
k	1×10^{3}
M	1×10^{6}
G	1×10^{9}
T	1×10^{12}

Vector and Scalar Quantities

A *Quantity* is just something that can be measured.

The table below gives a list of the quantities you will use in the GCSE Physics course. It's up to you to fill in the blanks, as we go through the course.

Some quantities may have different name, e.g. distance may also be called length and vertical distance is height!

Vector or Scalar?

With ***scalar quantities***, we only need to know their size ***(magnitude)***.
But, with ***vector quantities*** we also need to know which direction they act. A force of 100N pushing right has a completely different effect to a force of 100N pushing left!
Remember*, Up, down, left, right, North, South, etc, are directions.* ***But****, bigger, smaller, higher, lower, etc, are not.*

Quantity	Symbol (H)	SI Unit	Other units	Vector or Scalar
Distance	**d**	metre (m)	light years (l.y.) astronomical unit (AU)	scalar
Displacement	**x**	metre (m)		vector
Time	**t**	second (s)	hour, day, year	scalar
Speed	**S**	m/s		
Velocity Final	**v**	m/s		
Initial	**u**	m/s		
Acceleration	**a**	m/s^2		
Mass	**m**	kg		
Force	**F**	N		
Weight	**W**	N		
Momentum	**p**	kgm/s		
Moment (turning force)	**M**	Nm		
Gravitational field strength	**g**	N/kg		
Energy	**E**	Joules (J)		
Work	**W**	J		
Gravitational Potential Energy	**GPE**	J		
Kinetic Energy	**KE**	J		
Spring constant	**k**	N/kg		
Nucleon number (atomic mass)	**A**	-		
Proton number (atomic number)	**Z**	-		
Count rate/Activity		Becquerel (Bq)		

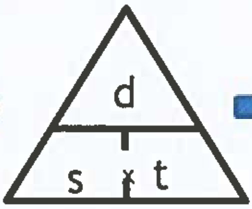
Unit 1 - Motion

Calculating Speed

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

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

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



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

$$d = s \times t$$

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

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

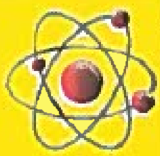
Example 1

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 ?

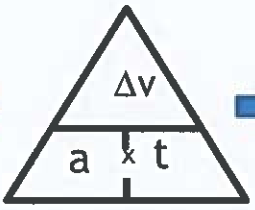
$d = s \times t = 2\,500\,000 \times 60 = 1.5 \times 10^8$ m (Almost 4 times around the Earth !)

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 (Δ) 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^2 (m/s^2)

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^2. How long will the tanker take to come to a complete stop if initially travelling at a speed of 12 m/s ?

$$t = \frac{\Delta v}{a} = \frac{(12)}{0.04} = 300 \text{ s}$$

(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^2, which lasts for 0.45 s. What's the final speed of the ball after this acceleration ?

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

So, final speed $= 12.4 + 21.6 = 34.0$ 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).

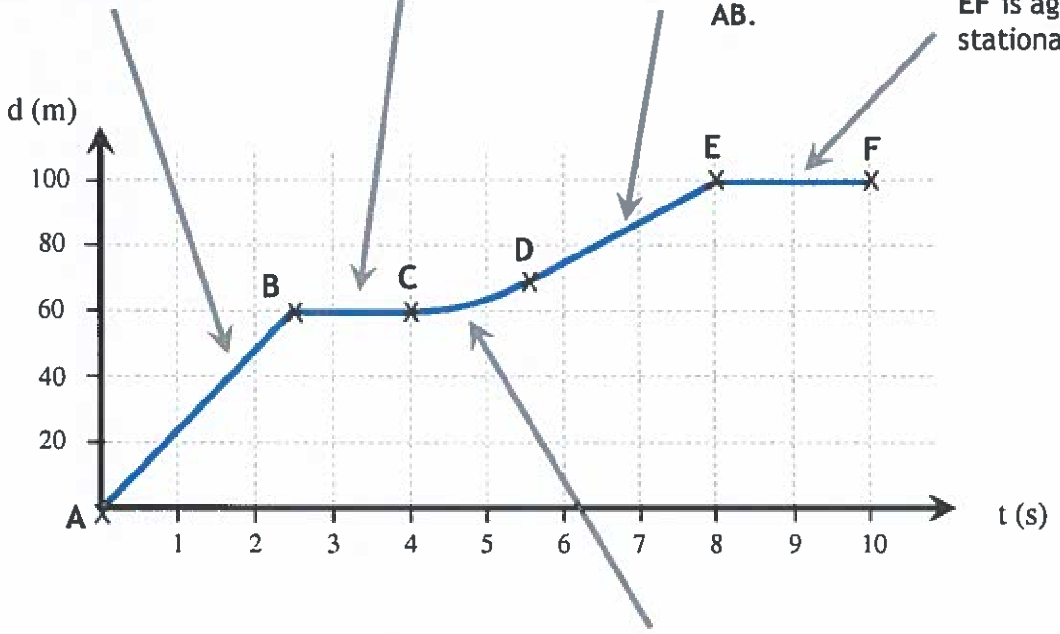
Distance - time graphs

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 1st 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

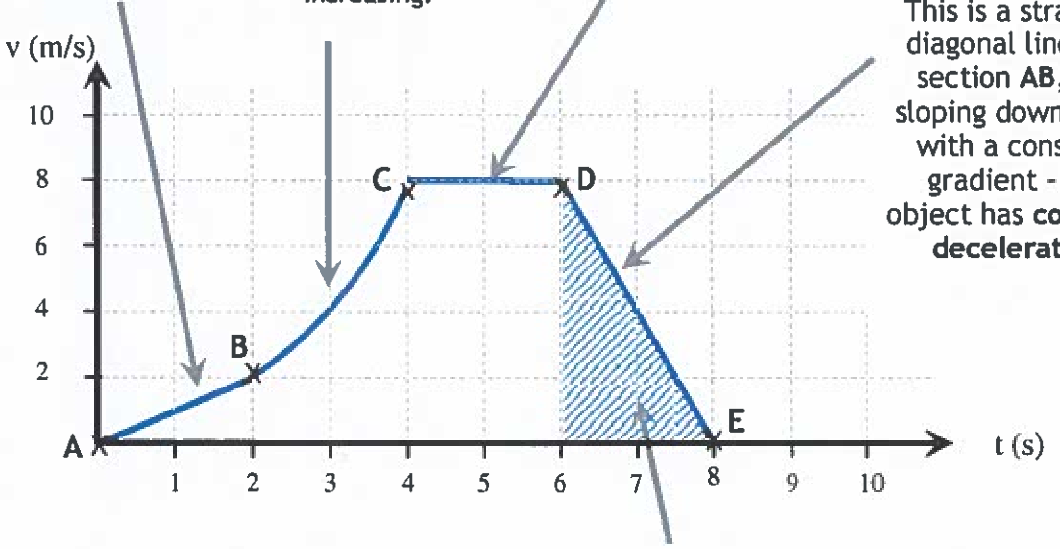
Velocity - time graphs

(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 1st 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 :

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

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

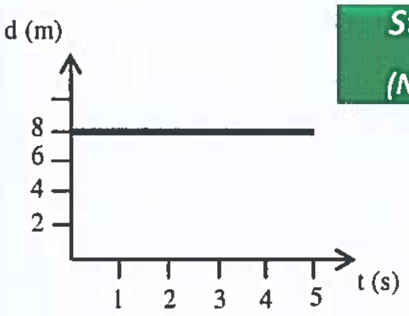
The motion of an object can be shown on one of two types of graphs : distance-time or velocity-time graphs (sometimes called speed-time graphs).

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

Distance - time graphs

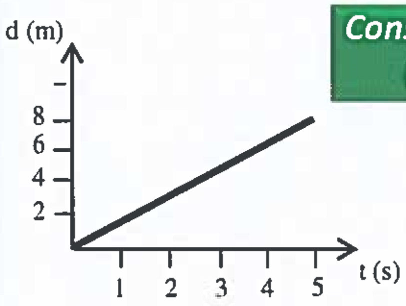
Stationary

(Not moving)



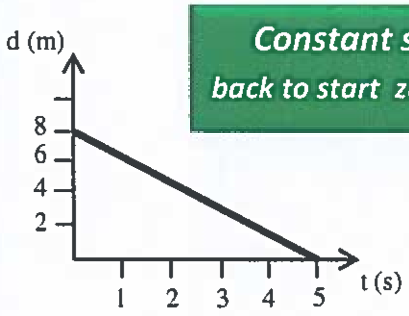
Constant speed

(forwards)



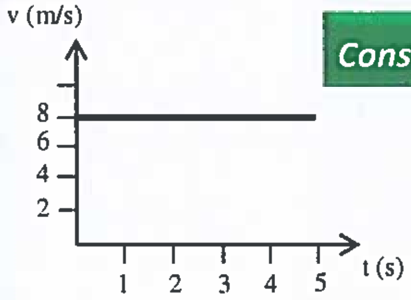
Constant speed –

back to start zero metres)



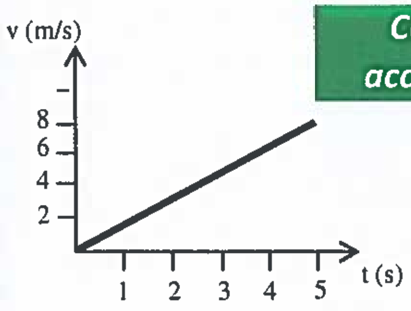
Velocity - time graphs

Constant speed



Constant

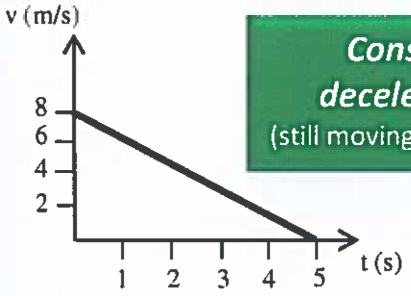
acceleration



Constant

deceleration

(still moving forwards !!)



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 :

Stopping distance = Thinking distance + 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 applies (car is slowing down)

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

Thinking distance = speed x reaction time (d = s x 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,

@ 20 m/s Thinking distance = 20 x 0.4 = 8m

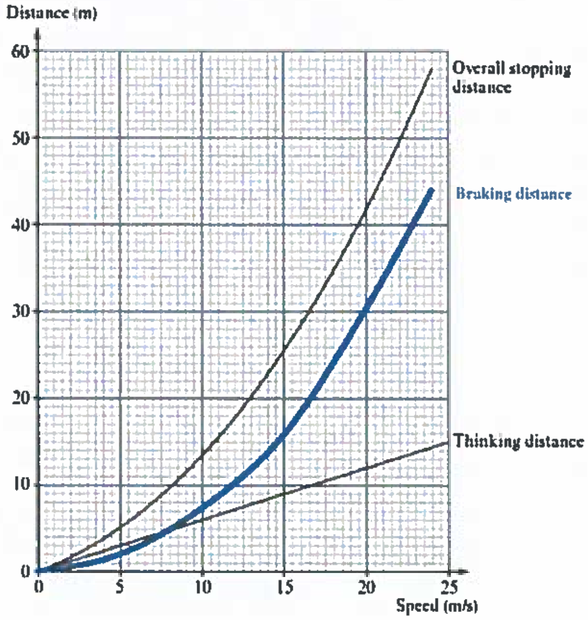
@ 40 m/s Thinking distance = 40 x 0.4 = 16m

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 ➔).

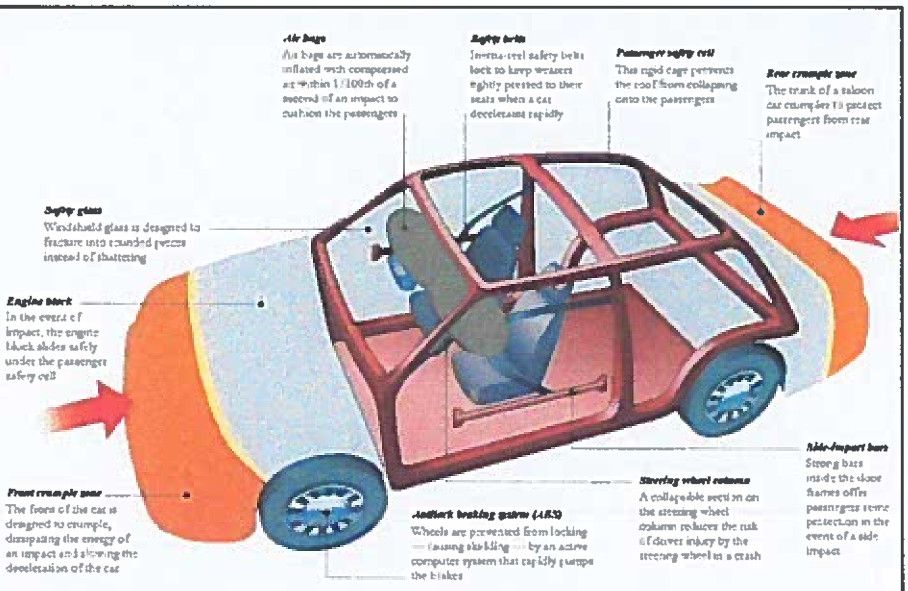
(In fact, doubling the vehicle's speed quadruples the braking distance, since the speed is squared in the KE equation).

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



Stopping distance & Car Safety

There are many safety fe
in modern cars/vehicles –
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.

Force = mass x acceleration

Since your mass is fairly constant, the only way to reduce the force is to reduce the **acceleration (or deceleration)**. There are two ways of reducing the deceleration :

1. If the vehicle's speed is less, then less deceleration is needed to stop it !
2. The deceleration is less if the change in speed happens over **more** time.

The safety devices mentioned work by ensuring that you take **more time** to slow down. Remember the following reasoning :

Change the speed over more time. → Less deceleration → Less force

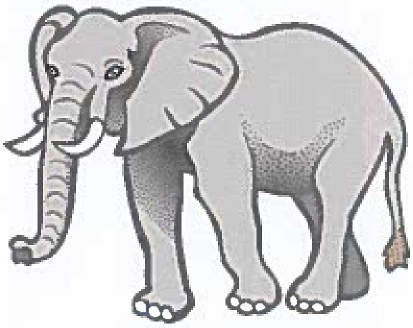
P6.2 (a) ~ Inertia:

Inertia: An object's resistance to any change in its motion.

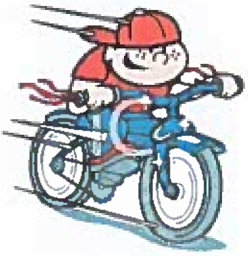
This just means that the heavier something is (***more massive)*** the more effort is needed to speed it up, slow it down or change its direction.

A. mouse

B. Jupiter



D. elephant.



B. bicyle and rider

Put these 4 objects in order of their ***inertia*** (least inertia first). *The pictures are **not** to scale.*

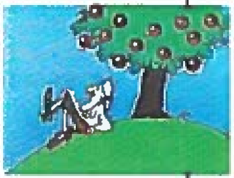
Unit 2 - Forces

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 in newtons, or N.**

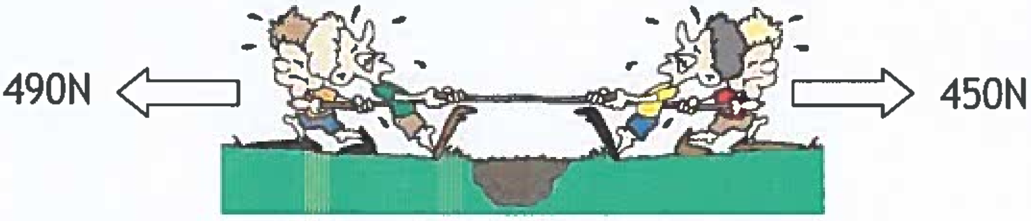
Sir Isaac Newton came up with three laws of motion, all of which describe the effect that forces have on things.

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



Resultant force

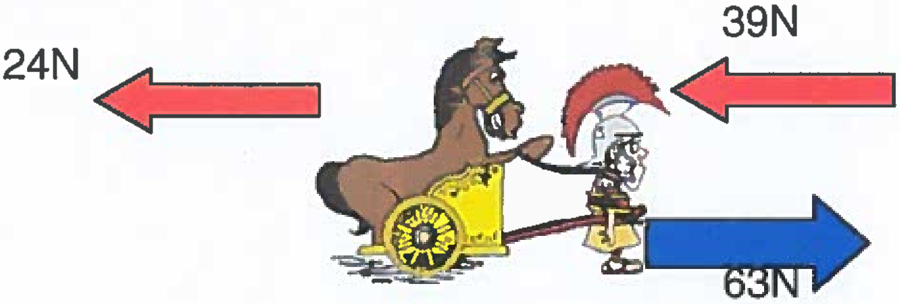
Usually, more than one force is acting on an object, like in the 'tug-of-war' below. In order to work out the effect of these forces on the object, we need to calculate what's known as '**resultant force**'.



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

In the above example, the **resultant force** , RF = 490 – 450 = **40N** ←

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



Answer : RF = 0 (zero) N, 39N ← + 24N ← = 63N ← (then 63−63 = 0)

Newton's laws

Newton's 1st 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').

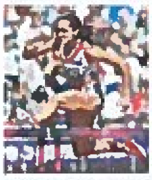
Momentum

Newton's 2^{nd} law (see the next page) is defined using a quantity called "momentum".

Momentum is a difficult thing to explain - simply, it is how much 'motion' an object has. However, it is quite easy to calculate the momentum, p, of an object if you know the object's mass, m, and velocity, v, (velocity is like 'speed'). This is the equation for calculating momentum :

momentum = mass x velocity **p = m x v**

p = m x v = 3 000 x 10
= 30 000 kgm/s



p = m x v = 70 x 5
= 350 kgm/s

Docked !

p = m x v = 50 000 000 x 0
= 0 (zero !) kgm/s

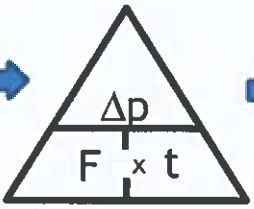
Newton's 2nd law

The rate of change of momentum is proportional to the (resultant) force applied, and takes place in the direction of the (resultant) force.

It is the **resultant** force on an object that causes a change in the speed or direction of the object. This is how it is written in equation form :

$$\text{Force} = \frac{\text{change in momentum}}{\text{time}}$$

$$\boxed{F = \frac{\Delta p}{t}}$$



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

$$\boxed{t = \frac{\Delta p}{F}} \qquad \boxed{\Delta p = F \times t}$$

Force is measured in newtons, N,
time in seconds, s,
'Δp' (change in momentum) is measured in kg m/s (or Ns)

In an examination, you will typically be asked to calculate the change in momentum before using the value in the above equation. There's a worked example below .

A small rocket is launched. At a certain point in the flight, the rocket's mass is 82kg, and is travelling at a velocity of 30m/s. 10 seconds later, the mass of the rocket has reduced to 72kg, and its velocity has increased to 65 m/s. Calculate the (average) resultant force on the rocket during this 10 seconds.

Step 1 : Calculate the change in momentum, **Δp.**

Momentum at the start of the 10 s, $p_s = m \times v = 82 \times 30 = 2460$ kg m/s

Momentum at the end, $p_e = m \times v = 72 \times 65 = 4680$ kg m/s

So, change in momentum , $\Delta p = p_e - p_s = 2220$ kg m/s

Step 2 : Use Newton's 2nd law to find 'F'.

$$F = \frac{\Delta p}{t} = \frac{2220}{10} = 222 \text{ N}$$

Newton's laws

Newton's 2^{nd} law

In situations where the mass is constant, Newton's 2^{nd} law can be simplified :

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

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 !

$$\boxed{W = m \times 10}$$

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.

Weight of rocket , W = m x g = 2.5 x 10 = 25 N

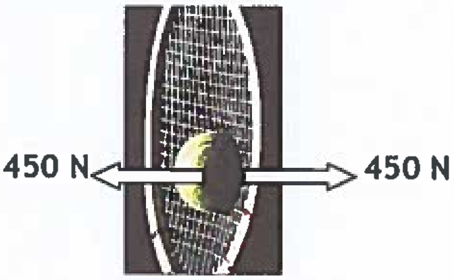
So, resultant force on the rocket = 75 – 25 = 50N (↑)

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

Newton's 3rd 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 !

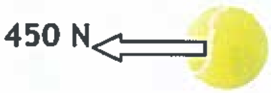


The racquet pushes the ball **forwards** with a force of 450N. Therefore, by Newton's 3rd law, the ball pushes the racquet **backwards** with an equal force.

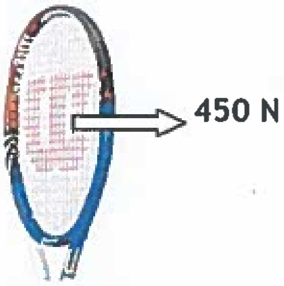
Note : one force is on the racquet, the other on the ball, so they don't 'cancel'.

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 :

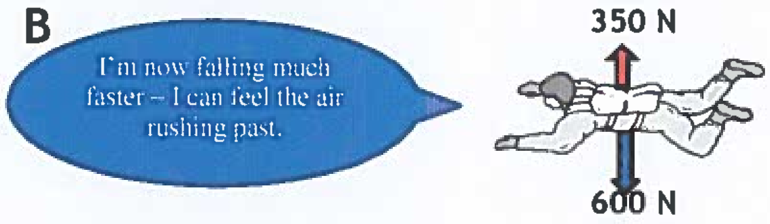


Note : Other forces like gravity and air-resistance have not been shown on these diagrams !

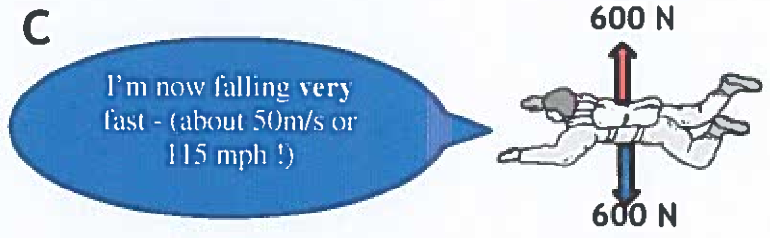
Applying Newton's laws

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 2nd law is used) but later become balanced (➔ Newton's 1st law).

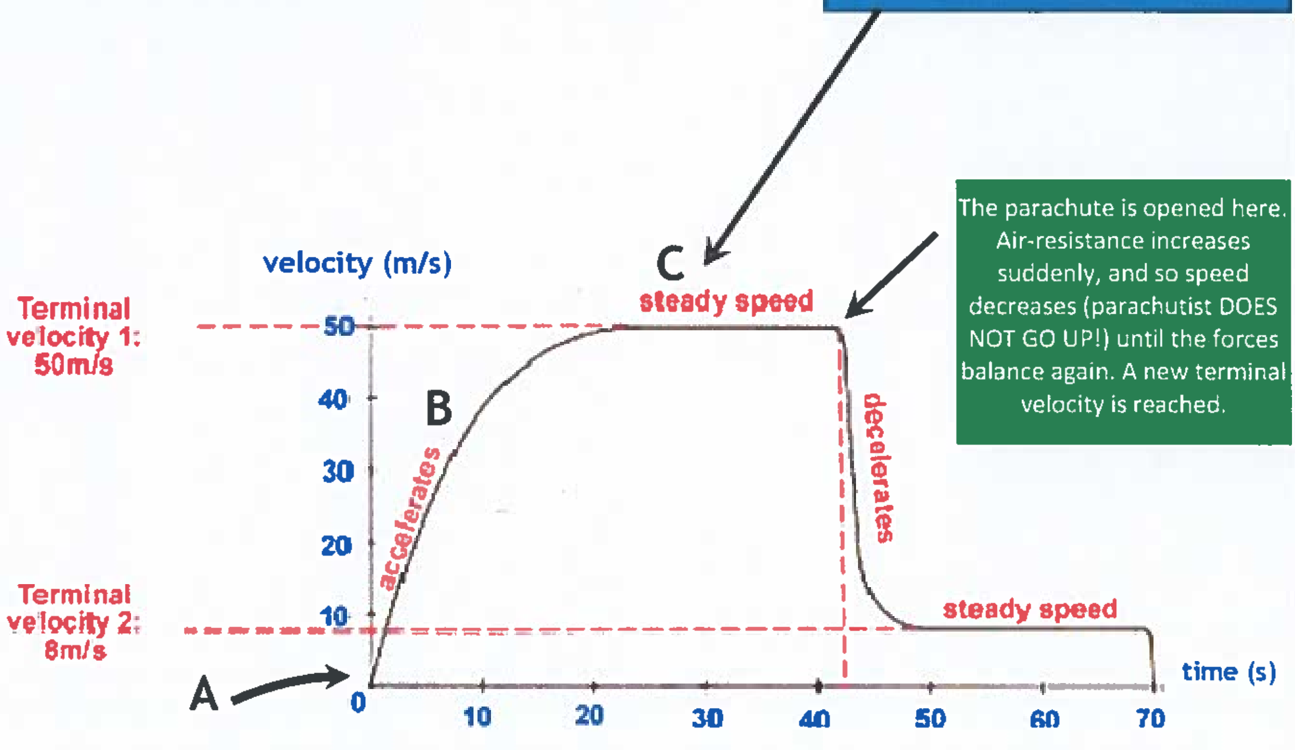
Air-resistance is zero, and so Newton's 2nd law states that the skydiver will **accelerate** downwards.



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



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 1st law) - **terminal velocity**

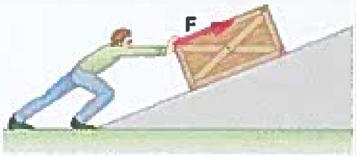


The parachute is opened here. Air-resistance increases suddenly, and so speed decreases (parachutist DOES NOT GO UP!) until the forces balance again. A new terminal velocity is reached.

Unit 3 - Work done & Energy

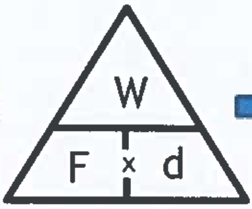
Work Done

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

$$\boxed{W = F \times d}$$



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

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

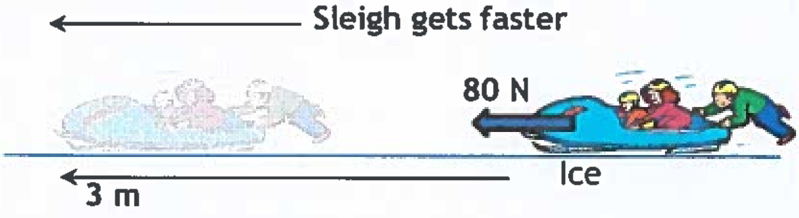
Work, W, (or energy transferred) is measured in	**joules (J)**
Force, F, is measured in	**newtons (N)**
Distance, d, is measured in	**metres, (m)**

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).

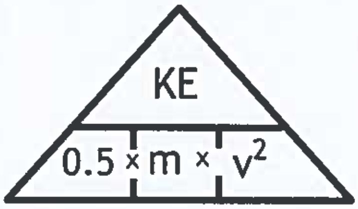
Work Done & Energy transfers

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 :

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



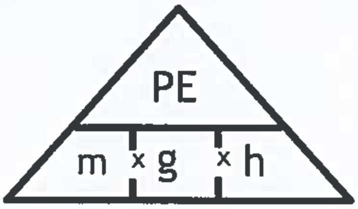
In order to find the speed of an object of known mass and KE, the above equation is re-arranged like this :

$$v = \sqrt{\frac{2\ KE}{m}} \quad \text{or} \quad \underbrace{v = \sqrt{\frac{KE}{0.5\ m}}}_{\text{Using the triangle}}$$

(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 :

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

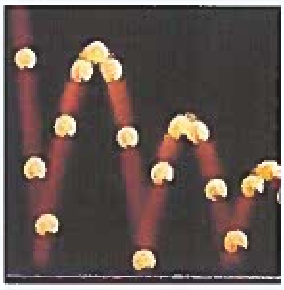


PE	is measured in	joules, J
m	is measured in	kilograms, kg
g	is measured in	N/kg (or m/s^2)
h	is measured in	metres, (m)

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

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

For objects thrown upwards

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

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 :

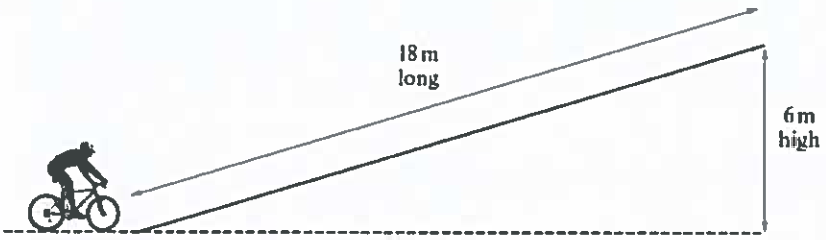
Work = Force x distance

$$W = F \times d$$

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.



HINTS !!

(a) By using the equations

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

where $g = 10$ 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]

Simply add the KE_{top} and the PE.

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]

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.

Frictional force = ... N

Answers

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

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

(b) **Expected method**

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

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

(b) **Alternative method**

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

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

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

Work Done & Energy transfers

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

A cruise ship's engines produce a constant thrust of 1.6×10^6 N. It has a mass of 1.2×10^8 kg.

(a) Use the equation

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

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

Acceleration = ... m/s²

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

Work done = ... J

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

K.E. increase = ... J

(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]

Mean work done = ... J

Mean drag force = ... N

HINTS !!

'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'.

Look up the equation for 'work done'.

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

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

Answers

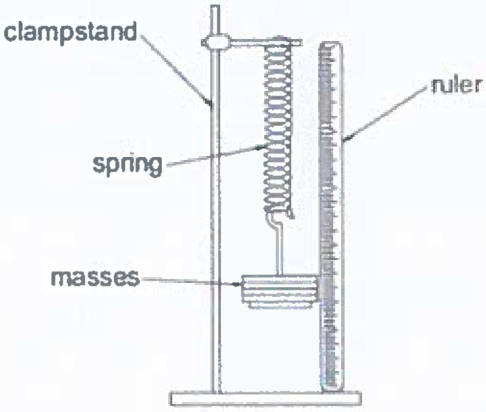
(a) $a = 0.013\ \text{m/s}^2$

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

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

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

Stretching Things: Hooke's Law

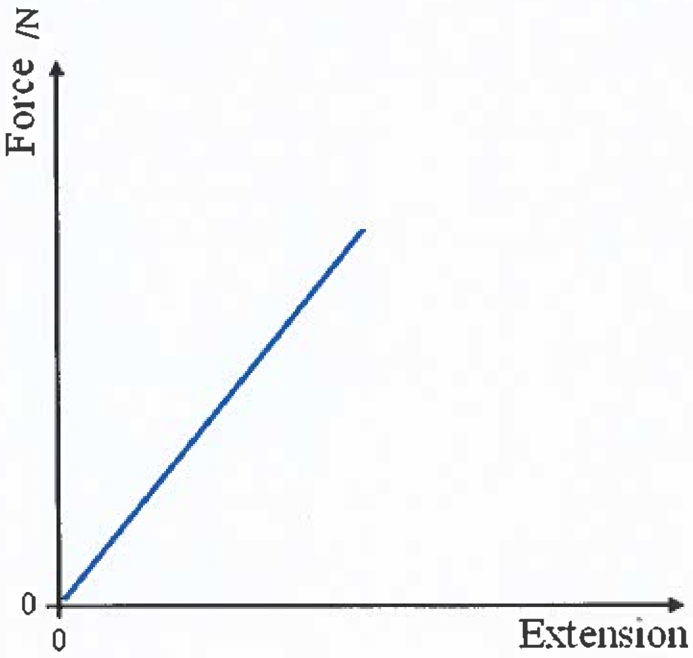


When a material stretches, but then goes back to its original length and shape, we say it is ***elastic.***

Almost all materials are at least a little ***elastic***, even glass! You'll know this if you've ever walked into a glass door by accident.

Some materials are much more ***elastic*** than others, they stretch (or ***deform***) a lot and still go back to their original size and shape.

Hooke's Law applies if the ***extension*** of an object e.g. a spring) is ***directly proportional*** to the force applied.



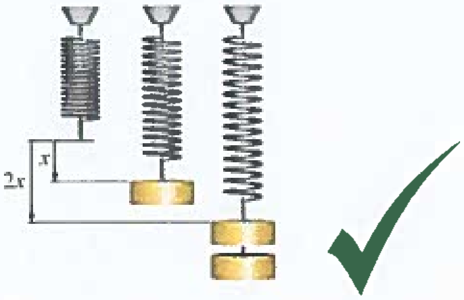
This graph is ***directly proportional*** because it is a straight line going through the origin.

Any material that gives this shape of graph is said to ***obey Hooke's Law.***

Doubling Force will double extension.

Hooke's Law, the equation: See next page.

The Spring Constant.



The ***spring constant*** has got nothing to do with lambs gambolling!

It tells us how much a spring of a particular type will extend by for every 1N of force that's applied to it.
Every spring of the same type will have the same ***spring constant***.
But springs of a different type have different ***spring constant***.
The ***spring constant*** depends on the material the spring is made from, the thickness of the metal, etc.

The *spring constant* is often just written as *k*.

('Cause it's an awful lot easier!)

Hooke's Law
as an equation

Using the spring constant (*k*):

Force* = *spring constant* x *extension

Newtons (N) *Newtons per metre (N/m)* *metres (m)*

$$F = kx$$

Tasks:

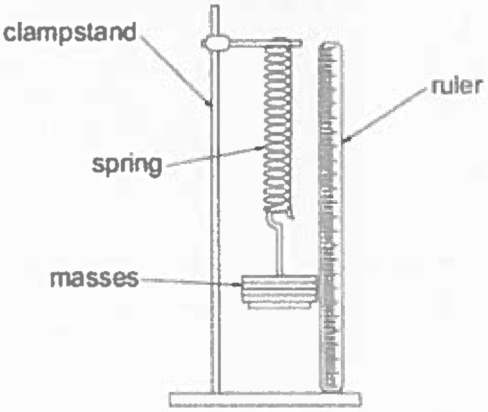
1. A spring has a spring constant of 5N/m. What force is needed to stretch it by 0.02m?

2. An ***open wound*** spring can be compressed or stretched.
a). ***Calculate*** it's extension when a force of 120N is applied, if it has a spring constant of 480N/m.
b). ***Describe*** what would happen if the direction of the force was reversed. *(you must give a magnitude as part of your answer).* No calculations are necessary.

3. During an experiment a large spring is found to extend 7.5cm when a force of 30kN is applied.
a). ***Calculate*** the spring constant for this particular type of spring.
b). How much would the spring extend by is a force of 90 000N was applied? Justify your answer.

Stretching Things: Hooke's Law (Tasks)

1. Stretching Springs:



Task A: The table below gives results from an experiment to find out how much a spring extends by, when different forces are applied to it.

Force/N	Total Length of Spring/cm				Mean Extension/cm
	Test 1	Test 2	Test 3	Mean	
0	4.0	4.1	3.9		
1	6.5	66.0	6.5		
2	9.2	9.0	9.2		
3	11.4	11.2	11.5		
4	14.0	13.8	11.2		
5	16.2	16.5	16.6		

1. Look for any anomalous results. Circle them and leave them out of any calculations.
2. Work out the mean total length of the spring for each force.
3. Complete the column for mean extension. (The extension is how much it has stretched by from its original length.)
4. Draw a graph to show these results. Extension goes on the x-axis, force on the y-axis. (This is back to front from what you should expect, don't worry, it's for this graph only!)

Task B: The next two tables show results from another two experiments. Two springs are used in each experiment. The way they are arranged is shown next to each table.

<u>Two springs in series</u>

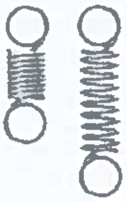
Force/N	Extension/cm
0	4.0
1	9.1
2	13.9
3	19.0
4	24.2
5	29.3

<u>Two springs in parallel</u>

Force/N	Extension/cm
0	4.0
1	5.2
2	6.5
3	7.8
4	9.0
5	10.3

5. Draw ***one*** graph to show ***both*** sets of results.
6. Write a conclusion to compare how much springs in series stretch compared to springs in parallel.

Elastic Energy



When a force is applied to any ***elastic object*** (e.g. a spring, or a rubber band), the object ***deforms*** (stretches or changes shape). When the force is removed, the object goes back to its original size and shape.

When we use a force to stretch an ***elastic object***, ***elastic energy*** is stored.

How much elastic energy?

1. **Calculation:** This is based on the fact that work is done when something is stretched. (Don't worry about the ½, it's ***got*** to be there in this calculation, but you don't need to explain why).

Work = ½ x Force applied x extension

Joules (J) *Newtons (N)* *metres (m)*

$$W = Fx.$$

a). A spring is stretched from 6.0 cm to 15.0 cm. A maximum force of 25N is needed.
(i) ***Calculate*** the work done in stretching the spring (remember to calculate *extension* first, and change cm to m). [4]

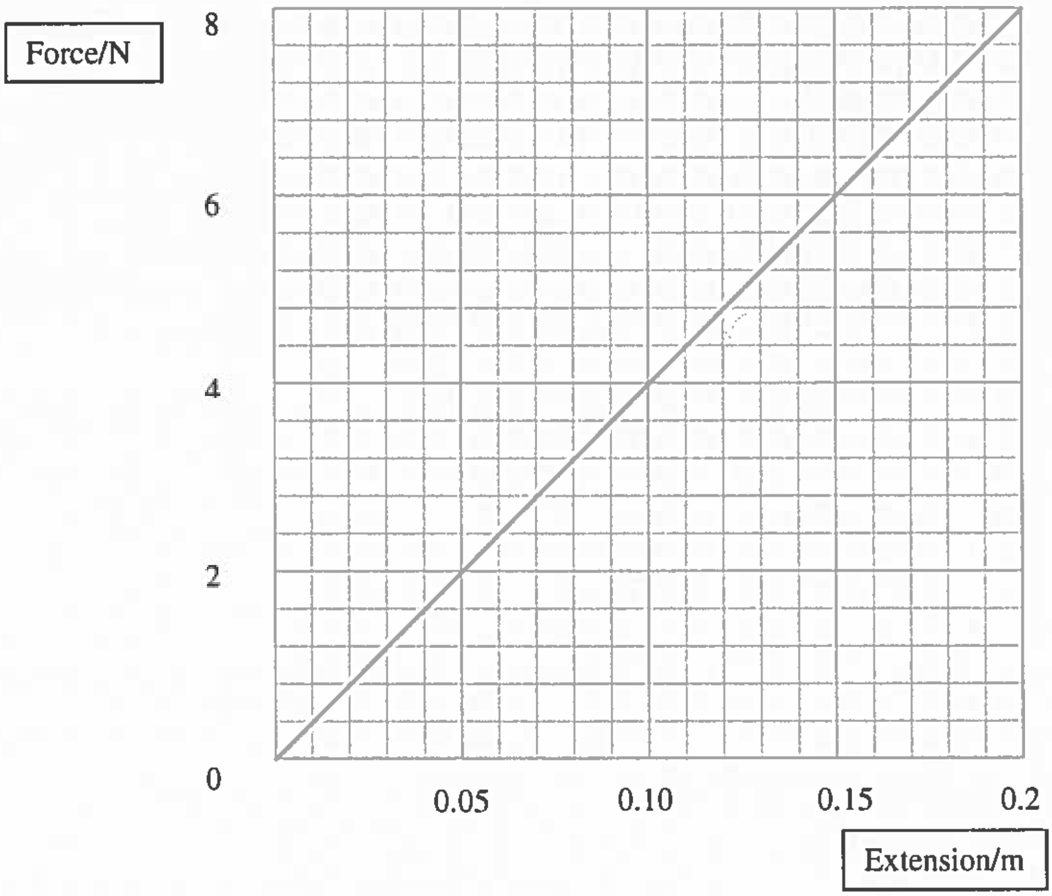
(ii) ***State*** the elastic energy that is now stored in the spring. [1]

b). A rubber ball is compressed 1.5cm when a 7N force is applied.

(i) ***Calculate*** the work done compressing the ball.

(ii) ***State*** the elastic energy that will be released by the ball when it goes back to its original shape.

2. **Graphs:** The elastic energy stored when an object is deformed (and, therefore, the ***work done*** in deforming it) can be worked out from the ***area under the force/extension (F/x) graph***).



a). The graph above is a Force/extension (F/x) graph for a metal spring.

(i). Find the area under the graph for an extension of 15cm. You ***must*** show how you do this on the graph.
(ii). ***State*** the elastic energy stored in the spring.
(iii). ***State*** the work done stretching the spring by 15cm.
(iv). Use W = ½Fx to check your answer.

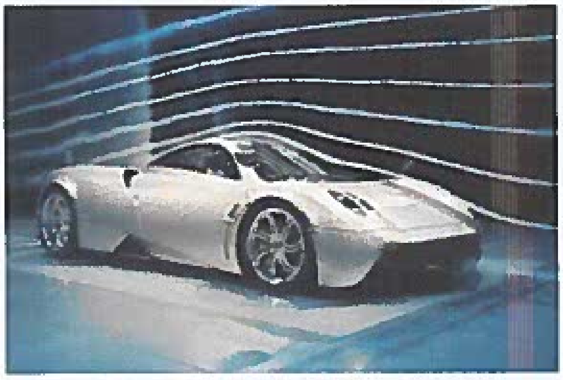
Energy Efficiency ~ Vehicle Design (1)

Tyre pressure: Road bikes, including those used by Chris Froome in the Tour de France, have really high tyre pressures so the tyres are really, really hard and don't deform much as they are being ridden. Tyre pressures are often measured in ***Bars***. A road bike tyre may be blown up to nearly 9.0 bar. A car tyre, however, may only be inflated to less than 3.0 bar. This means that the car tyre deforms much more. The friction between the rubber molecules in the tyre wastes lots of heat energy. Try touching the tyres of a car after it's been on a long journey *(wait till it's stopped first).*

Inertial Energy losses: The greater any objects inertia is, the more force (and energy) that's needed to change its motion (speed up, slow down, change direction). The more mass any object has, the greater its inertia. That's why it's harder to push a bus out of the way than a tennis ball! Racing cars are designed to be as light as possible (low mass) so that their inertia is as low as possible.

All sorts of cutting edge technology is used to achieve this. Body panels are made from very low density composite materials. Engines are made from expensive metal alloys that are strong, resistant to high temperatures, but very light.

Streamlining: Vehicles that are designed to travel fast are ***streamlined.*** This is also known as being ***aerodynamic***. Aerodynamic vehicles have a very low ***air resistance***. This means less of the engine's ***thrust force*** is used overcoming ***drag/air resistance***. This picture shows how air particles pass easily over an aerodynamic shape. Very few particles strike the car. Since less force is needed to overcome drag, less energy is wasted.



Stop – start systems: When an electric car stops at traffic lights, or in a traffic jam, the electric motor doesn't turn and so it doesn't use up any energy. Petrol, diesel and gas powered cars are not like this. If the engine is running, it's using energy. To help avoid this, some modern cars are fitted with automated ***start-stop systems***. These use sensors to detect when the car has stopped moving and the car's on-board computer switches off the engine. When the driver is ready to move off, all the need to do is press the accelerator – the car does the rest. A running engine ***transfers*** the ***chemical energy*** stored in its fuel into ***thermal*** and ***sound energy***, as well as the ***kinetic energy*** we really want.

Energy Efficiency ~ Vehicle Design (2)

TASK: Each of the three examples shown below have at least one design feature that will either save energy, or waste it.
For each vehicle say; **a)** what the feature is,
b) use sheet 1 to help you ***explain*** how energy is saved, or wasted.

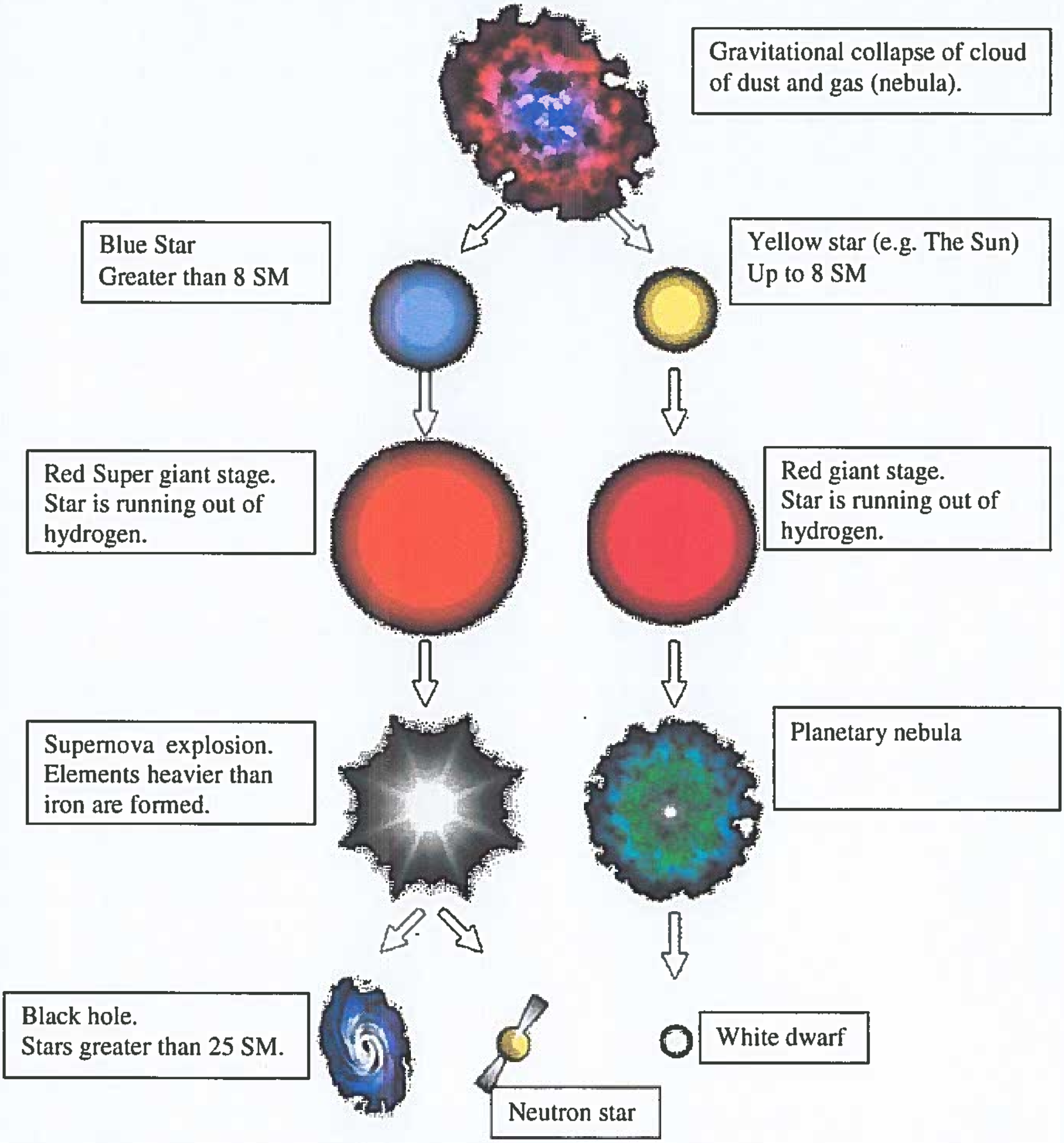
1. An Argocat is designed to cross very difficult, very soft ground. To achieve this it has very, very soft tyres. Each of its eight tyres are blown up to only 0.2 Bar (At the very most). A normal car tyre will be inflated to about 2.8 Bar (14 times higher). If an argocat ran over your foot, you probably wouldn't notice it. A car doing the same would probably put you in hospital!

2. Modern lorries: The articulated lorry (artic) on the left is modern. The one shown on the right was common about 40 years ago.

3. Bicycle frames: Over the years, bicycle designers have made use of new materials which are lighter ***(lower density)*** and ***stronger*** than the steel from which older bikes were made. This means that a modern bike may be less than half the weight of a bike from the 1950's.

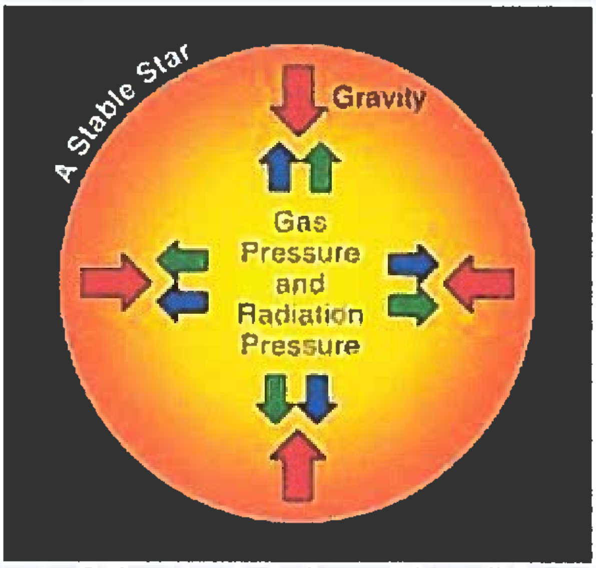
Life cycle of the stars.

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 long lifetimes. They are main sequence stars.



There are 2 forces at acting inside a star.

1. Inward force of gravity

2. Outward: combination of gas and radiation pressure.

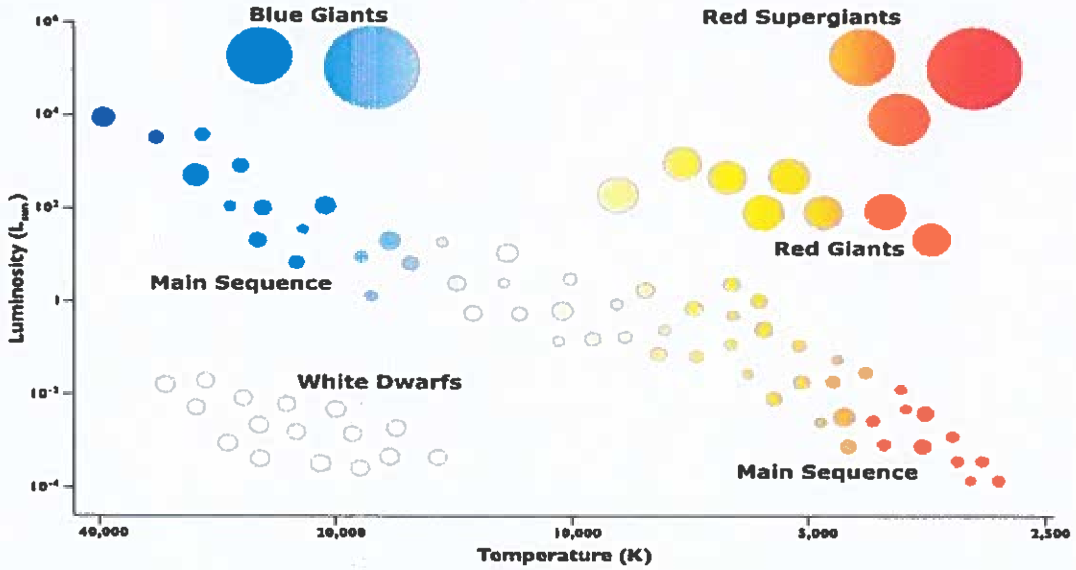
Gas pressure: caused by rapid random motion of particles in the sun.
Radiation pressure: caused by light hitting the particles.

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.

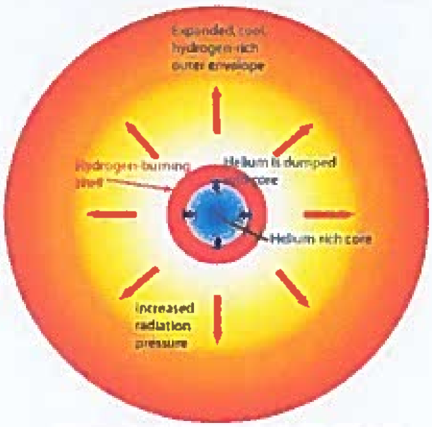
If the pressure in the middle ***falls***, this will cause a star to ***shrink*** - this will cause the pressure to rise once more until a new equilibrium is established with the star smaller. If the pressure increases, the star will ***expand***.

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.



End of main sequence stage.



Hydrogen Shell Burning on the Red Giant Branch

Once a star has exhausted (run out) of its supply of hydrogen it will swell up into a red giant. The temperature of the star 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 has begun and the temperature increases once again resulting in an increase in gas and radiation pressure.

In 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/starlife_main.html

Nuclear fusion

All **main sequence stars** generate their energy by the fusion of hydrogen to helium, according to the equation (remember):

$$4\ {}_{1} \longrightarrow {}^{4}_{2}He + 2\ {}^{0}_{1}e$$

Hydrogen Helium Positron

A and Z numbers on left and right hand side are balanced.

Left: total A = 4 x 1 = 4
total Z = 4 x 1 = 4

Right: total A= 4 + (2 x 0) = 4
total Z = 2 + (2 x 1) = 4

A positron is the antiparticle of an electron. When a particle and its corresponding particle meet they annihilate one another releasing a large amount of energy. Therefore when a positron is created during fusion it meets an electron and is annihilated.

Nuclear fusion

Other fusion reactions occur in stars.

$$^{3}_{2}He \quad ^{3}_{2}He \longrightarrow ^{4}_{2}He + 2\,^{A}_{Z}X$$

A=1 Z=1

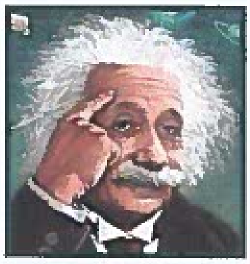
+

Determine the value of A and Z. $\longrightarrow$

A=3 Z=2

$$^{2}_{1}H + ^{1}_{1}H \qquad ^{A}_{Z}X + \gamma \text{ (gamma ray)}$$

Determine the value of A and Z.

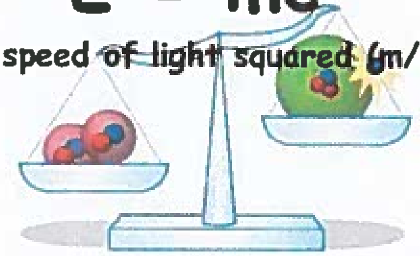


Why is energy released during fusion?

Look at the last equation showing the fusion of hydrogen and deuterium. The total mass of the helium formed is less than the mass of the 2 hydrogen isotopes and **that mass is converted into energy**. A famous scientist (Albert Einstein) predicted this to be true and gave one of the most famous of equations:

$$E = mc^2$$

Energy (J) = mass (kg) x speed of light squared (m/s) (300,000,000 m/s or 3×10^8)



Question 1. When 1kg of coal is burnt 3×10^7J of energy is released. Calculate the mass lost.

$$E = mc^2 \quad \text{rearrange formula} \quad m = \frac{E}{c^2} \qquad m = \frac{3\times10^7}{(3\times10^8)^2} = 3.33\times10^{-10}\text{ kg}$$

As you can see this is a very small mass so it is ***negligible/insignificant***.

Question 2. Calculate the mass loss per second from the Sun given that its energy output is 4×10^{26} W and the speed of light is 3×10^8 m/s.

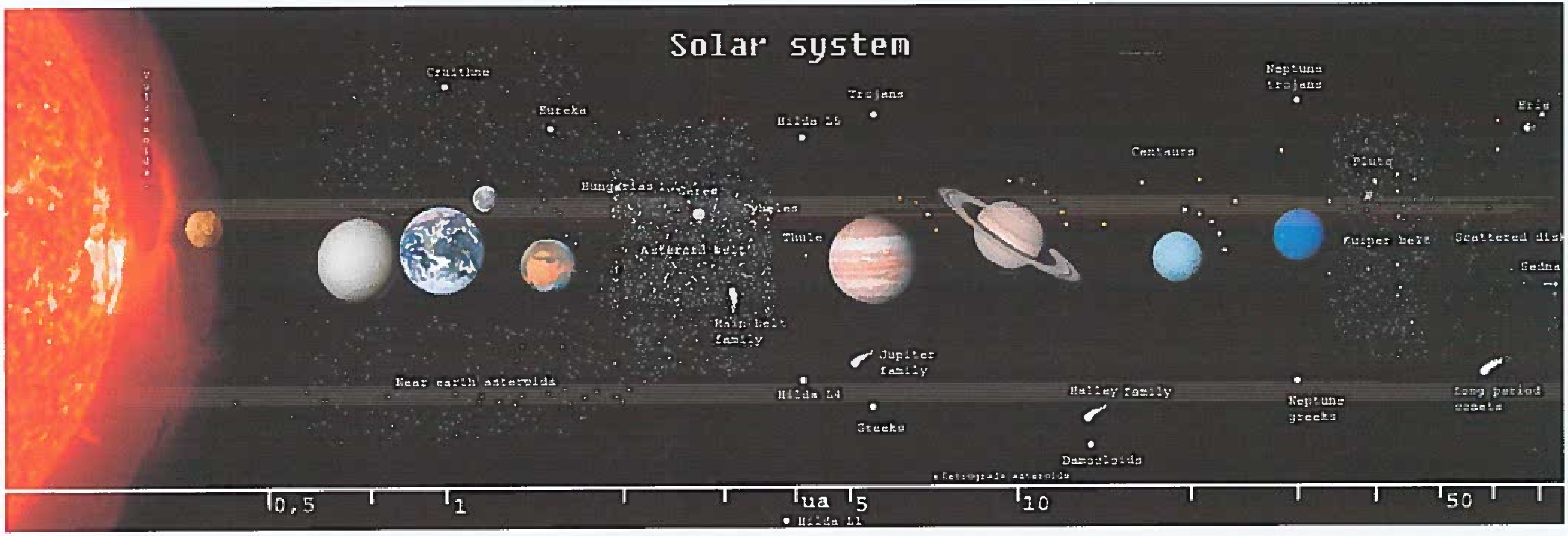
The first step is to realise that power is energy transferred per second. So the energy transferred from mass into energy per second is 4×10^{26} J. Now we must calculate how much mass this is equivalent to.

$$E = mc^2 \quad \text{rearrange formula} \quad m = \frac{E}{c^2} \qquad m = \frac{4\times10^{26}}{(3\times10^8)^2} = 4.44\times10^9\text{ kg}$$

Nuclear fusion

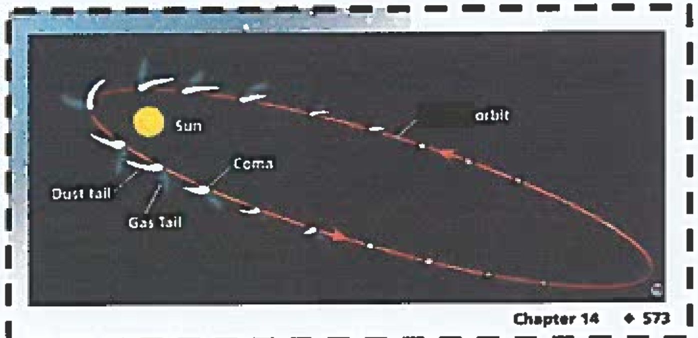
This means that the sun is losing ***4.4 million tonnes a second***!!!!!!!!!!!!

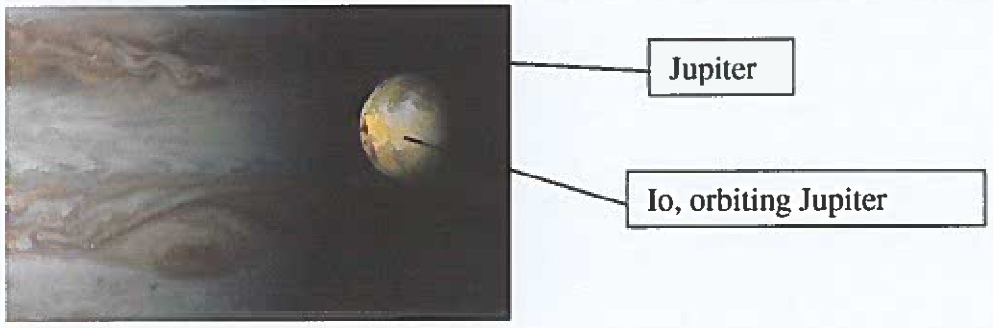
P6.4 (a) ~ Our Solar System:

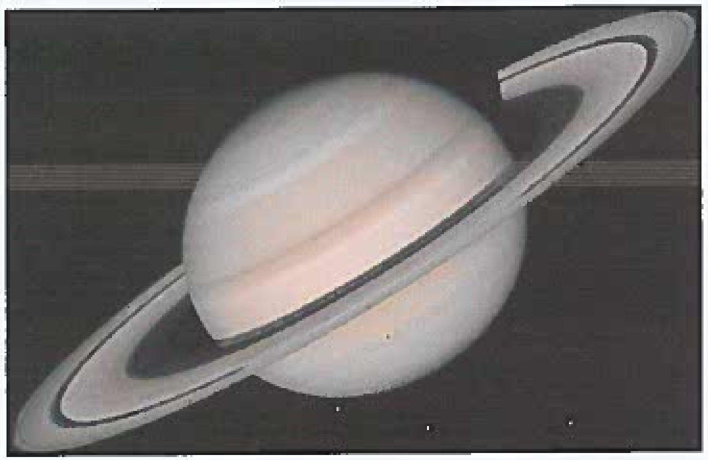


- Our solar system is made up of ***a star*** (the Sun) and many, many much smaller objects which ***orbit*** it.
- The ***inner planets,*** Mercury, Venus, Earth and Mars have solid, rocky surfaces. They are called ***terrestrial planets.***
- The ***outer planets,*** Jupiter, Saturn, Neptune and Uranus are ***Gas Giants.***
- Pluto is no longer classed as a planet. It is now grouped with lots of other smaller ***dwarf planets.***
- Some planets, like the Earth and Jupiter have ***moons***, much smaller, rocky spheres, which orbit them. ***Moons orbit a planet,*** They don't orbit the Sun.
- Between Mars and Jupiter lies the ***asteroid belt***, a ring of rocky fragments from dust sized right up to hundreds of kilometres across. These are thought to be the remains of two planets which collided when the Solar System was first being formed.
- ***Comets*** balls of rock and ice with *fiery tails,* which also orbit the Sun. The have a very ***elliptical*** (squashed) orbit. They fly in very close to the Sun before disappearing off out into the furthest reaches of the Solar System. Their orbits can take hundreds of years.

P6.4 (a) ~ Our Solar System (b):







Cut out each of the pictures and labels.

Match them up and stick them in your book.

Under each one, write at least one fact about it.

A moon

A terrestrial planet

A comet

A Gas Giant

An asteroid

A dwarf planet

P2.6.4(b) ~ Distances in Space

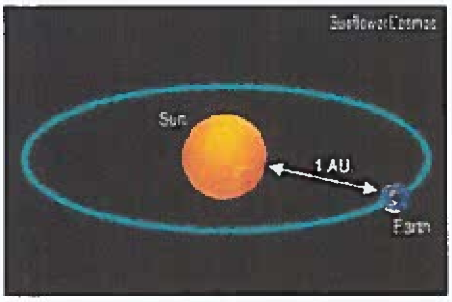
We measure distances on Earth using metres (m) and kilometres (km).

But space is ***Huge!*** Metres and kilometres are just too small to be useful.

You need to know about different units we use to measure distances in space.

Astronomical Units (A.U.).

The astronomical unit (A.U.) is dead simple, **1 A.U. is the *mean* distance from the Earth to the Sun.**

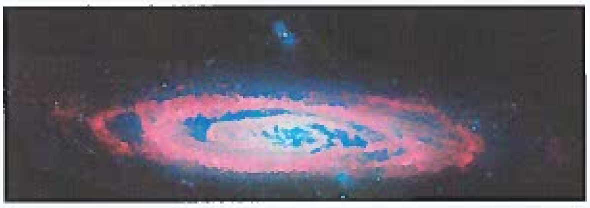


So 10 A.U. is just 10 times the distance from the Earth to the Sun.

But the Earth isn't always the same distance from the Sun – that's why we use the ***mean*** (average) distance.

1 A.U. is about 1.5 x 10^{11}m. So It's pretty big. *(You don't need to remember this).*

Light Years (l.y.).



The light year is also simple. **1 light year is the distance light can travel in one year.**

Light travels at 300 000 000 m/s (3.0 x 10^{8} m/s), so a light year is ***really*** big! The Milky Way galaxy is so big it takes 100 000 years for light to cross it.

We can also use ***light minutes*** or ***light seconds***. The Sun is 8.3 light minutes from the Earth.

Task:

1. What is an Astronomical Unit?

2. What is a light year?

3. What are **(a)** light minutes and **(b)** light seconds?

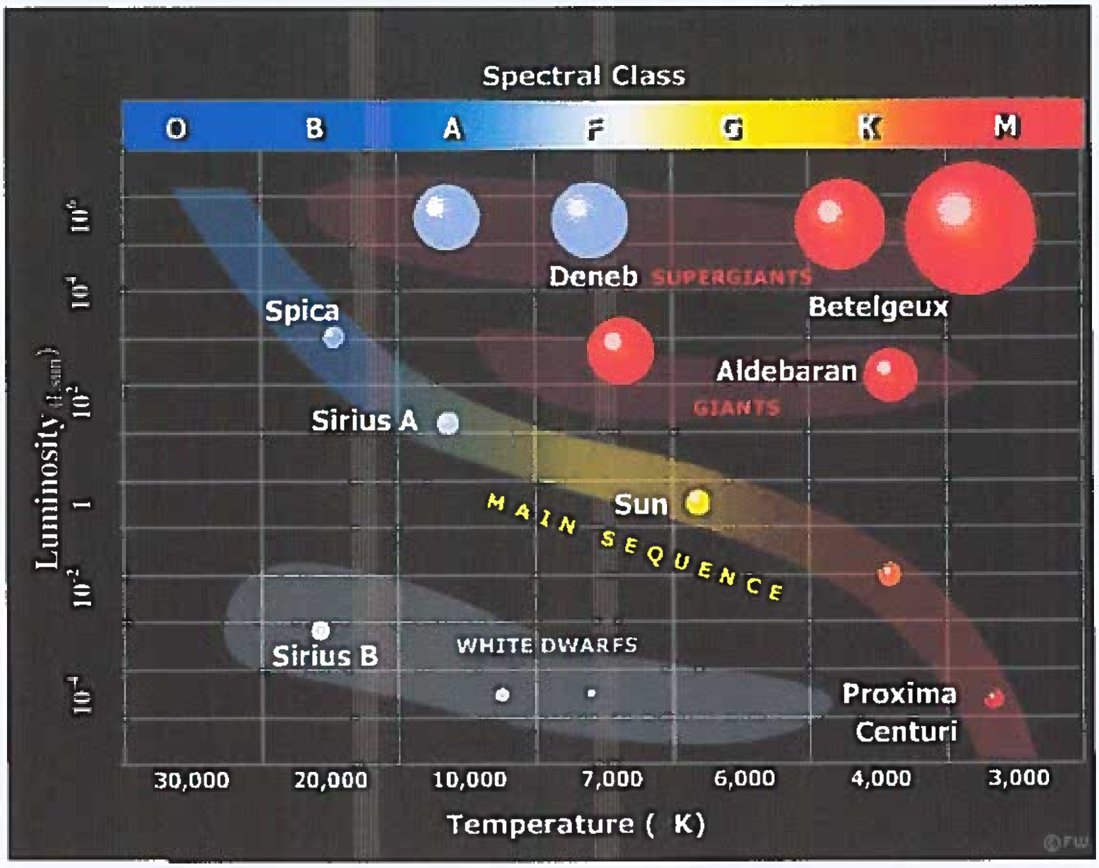
4. How many light minutes is 1 A.U. ? You don't have to do any calculations, the answers in the information above.

5. How many metres are in **(a)** 1 light second, **(b)** 1 light minute and **(c)** 1 light year?

(1 minute = 60s, 1hour = 60min, 1 day = 24h, 1 year = 365.25 days)

6. Using information from above, ***calculate*** **(a)** the distance across the Milky Way and **(b)** the size of 1 A.U. ***Give your answers in m.***

P2.6.4(g) Hertzprung-Russell Diagram (Higher)



<u>Don't</u> try to memorize this diagram!!!!

This diagram looks fiendishly complicated, at first glance. But, with a bit of thought, it's dead easy!

Follow these simple steps:

1. Find the different ***classes of stars*** on the diagram (Red Super Giants, Blue Super Giants, Main Sequence, etc). You should find 5 on this diagram.

2. Look for names of specific stars (e.g., Sun, Sirius B). These are just there as examples.

3. Look at the scales on each axis. (Luminosity is another name for brightness). These are not ***linear scales,*** equal divisions are not worth the same. *N.B. the temperature scale on the x axis is going <u>down</u> as you look left to right.*

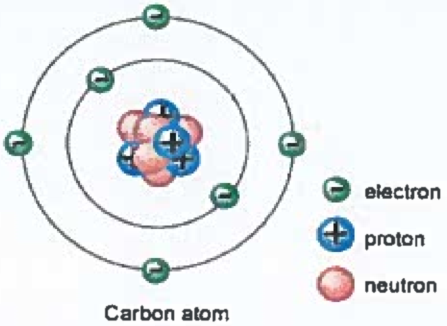
Now answer these questions:

a) *Name 2 main sequence stars that are (i) brighter and (ii) dimmer than the Sun*
b) *What other factor can be applied to the stars you names in **a**)?*
c) *Which star is given a luminosity value of 1?*
d) *How many times brighter than the Sun is Betelgeux (Beetle-juice)?*
e) *Which category of stars, in general, have a lower luminosity than main sequence stars?*
f) *Which main sequence star is an exception to this rule?*
g) *Are blue stars hotter or colder than red stars?*
h) *Where do you think yellow stars, like the Sun, go in this temperature sequence?*

Unit 5 - Nuclear Physics

Nuclear physics.

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



The atom consists of:

6 protons

6 neutrons

6 electrons

where X is the symbol for the element

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.

$$\boxed{N = A - Z}$$

Example: $^{7}_{3}\text{Li}$

Number of protons = 3

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

Try the following examples.

Element	Proton (Z) number	Nucleon (A) number	Number of protons	Number of neutrons, N
Hydrogen	1	1		
Iron	26	56		
Uranium	92	235		

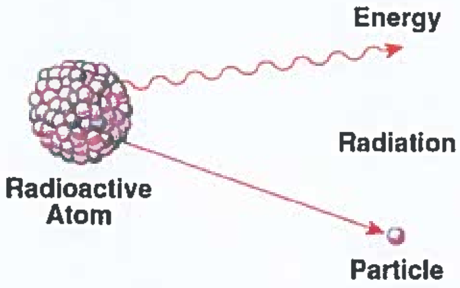
Isotopes: These are atoms of the same element which have the same number of protons but a different number of neutrons. They have the same proton number and differing nucleon number.

Example. Iodine-123 and iodine-131 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).

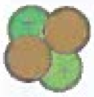


The nucleus tries to become stable by breaking up into stable fragments: **RADIOACTIVE DECAY**. Carbon has three common isotopes ^{12}C, ^{13}C a ^{14}C. Carbon-14 is radioactive because it has an ***imbalance of protons and neutrons.***

$$\longrightarrow \qquad +$$

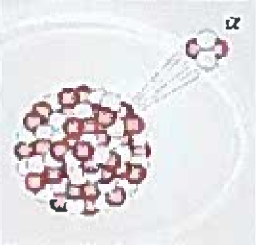
Carbon will **emit radiation** to try and make itself stable, a nitrogen nucleus is formed in the process. This process is called **RADIOACTIVE DECAY**.

There are 3 types of radiation emitted from the nucleus.

Information	**Alpha (α)**	**Beta (β)**	**Gamma (γ)**
Symbol			γ
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



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:

$$\boxed{\quad \longrightarrow \quad + \quad}$$

$$\longrightarrow \quad +$$

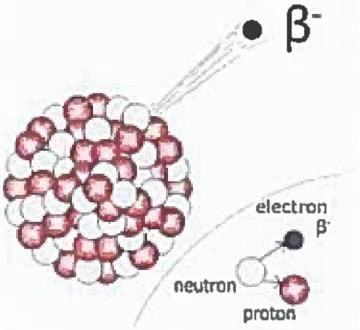
Balance the following nuclear equations by calculating the value of a, b, c and d.

1. $\longrightarrow \quad +$

2. $\longrightarrow \quad +$

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

General equation:

$$\boxed{\quad \longrightarrow \quad + \quad}$$

$$\longrightarrow \quad +$$

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

1. $\longrightarrow \quad +$

2. $\longrightarrow \quad +$

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

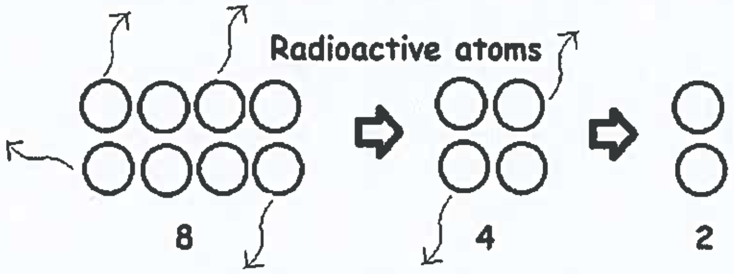
Half life.

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.

<u>**The half life.**</u> Each half life the number of 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.

Actvity. The activity is a measure of number of radioactive decays per second. It is measured in **becquerel, Bq.** So an activity of 1 bequerel 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?

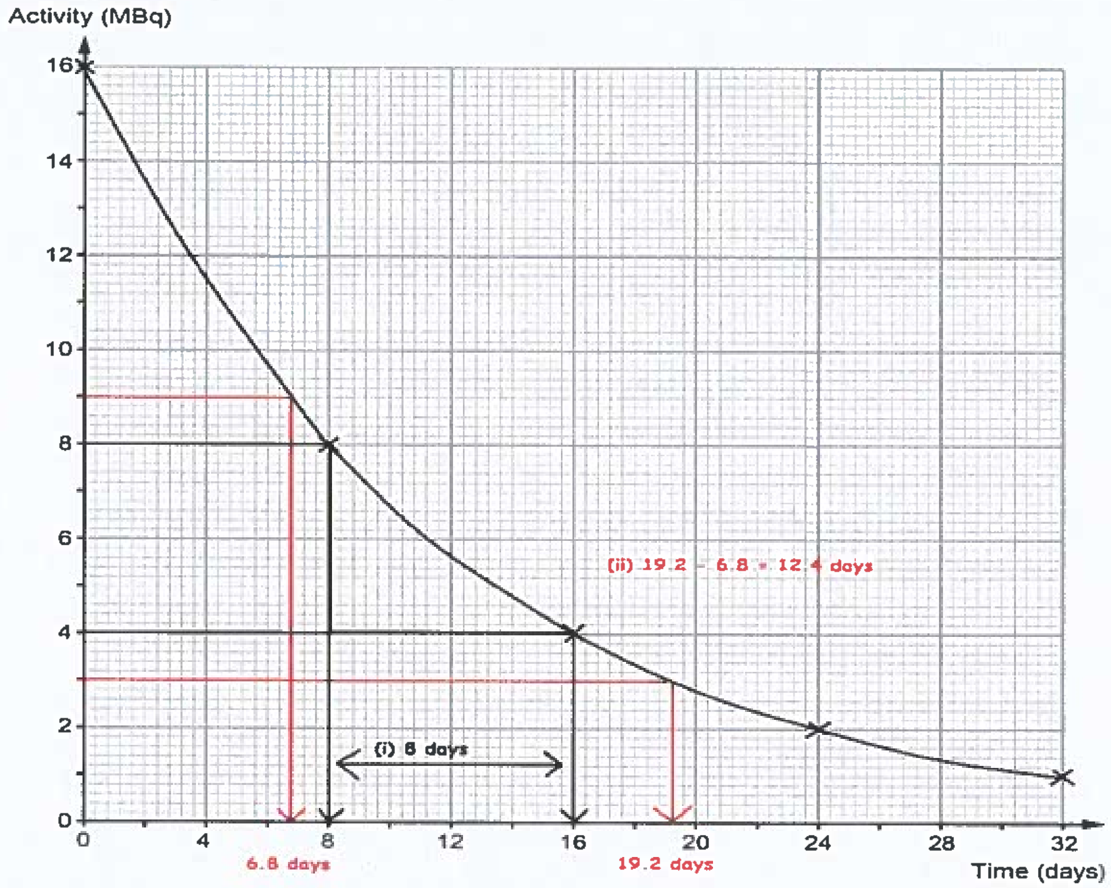
$$6400\text{Bq} \xrightarrow[\textbf{8 hours}]{1} 3200\text{Bq} \xrightarrow[\textbf{8 hours}]{2} 1600\text{ Bq} \xrightarrow[\textbf{8 hours}]{3} 800\text{ Bq} \xrightarrow[\textbf{8 hours}]{4} 400\text{ Bq}$$

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 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 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 in we can calculate how long this took. 19.2 - 6.8 = **12.4 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.

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

Total time = 8 + 8 = 16 days

Uses of radioactive materials.

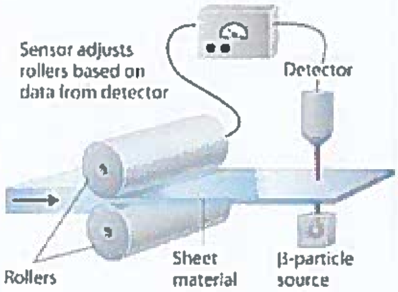
There are many uses of radioactive materials; carbon dating, sterilising medical equipment, killing cancer cells, smoke alarms and controlling the thickness of aluminium foil.

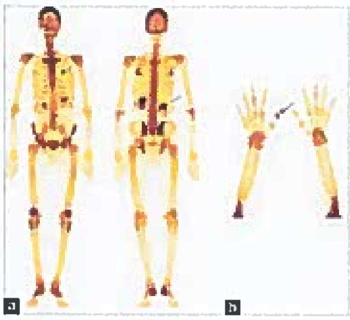
What is required is that you can select from a given list and explain which isotope is suitable for use in a specific case. Consider the ***type of radiation*** emitted and the ***half life.***

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 – γ	**Beta**	**Alpha**
Technetium-99 (6.01hrs) Cobalt-60 (5.27 yrs)	Iridium-192 (74 days) Strontium-90 (28.5 yrs) Carbon-14 (5730yrs)	Polonium-210 (138days) Americium-241 (432 yrs) Plutonium-238 (87.7 yrs)

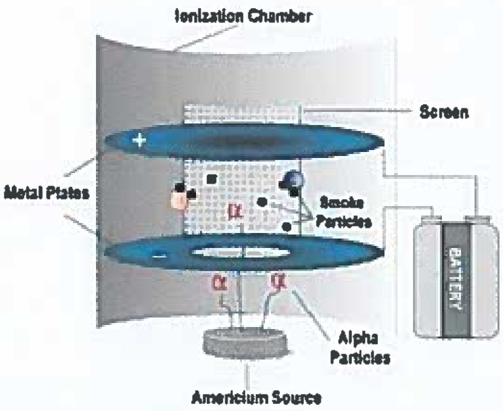
(a) Monitoring the thickness of aluminium sheet in a factory.
Isotope: Strontium – 90 (beta emitter).
Reason: because **fewer** beta particles will pass through when the thickness of aluminium increases. The half life is fairly long so the source will last a reasonable amount of time.



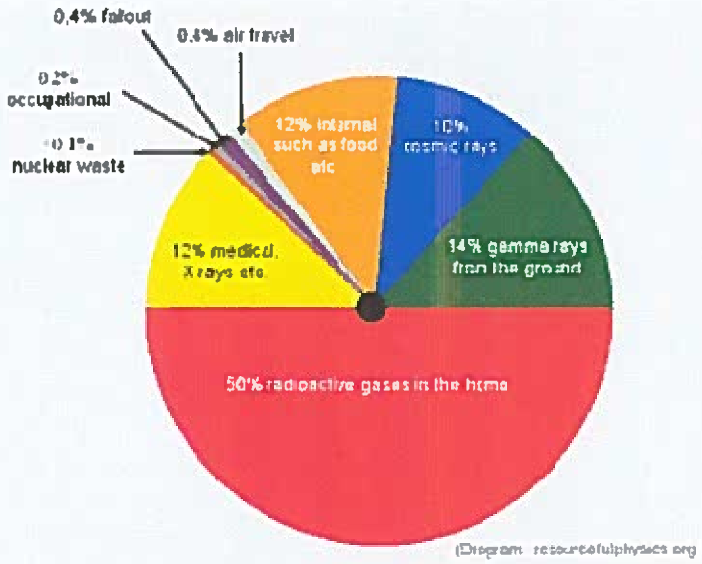


(b) Medical tracer in monitoring internal organs by using a camera outside the body.
Isotope: Technetium-99 (γ – emitter)
Reason: because it's a gamma emitter, it passes out of the body easily. The half life is short so it will not remain in the body for a long time.

(c) A smoke detector.
Isotope: 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



Background Radiation



(Diagram: resourcefulphysics.org

Background radiation is radiation that comes from, mainly. Natural sources. *Fallout (from nuclear bombs) Occupational (uses in industry), Nuclear Waste (from Power Stations) and Medical* are not natural.

Background radiation is perfectly normal and surrounds us all the time. Because ***radioactive decay*** is a ***random*** thing, background radiation changes all the time. Lots of different readings need to be taken to allow us to work out the ***mean value.***

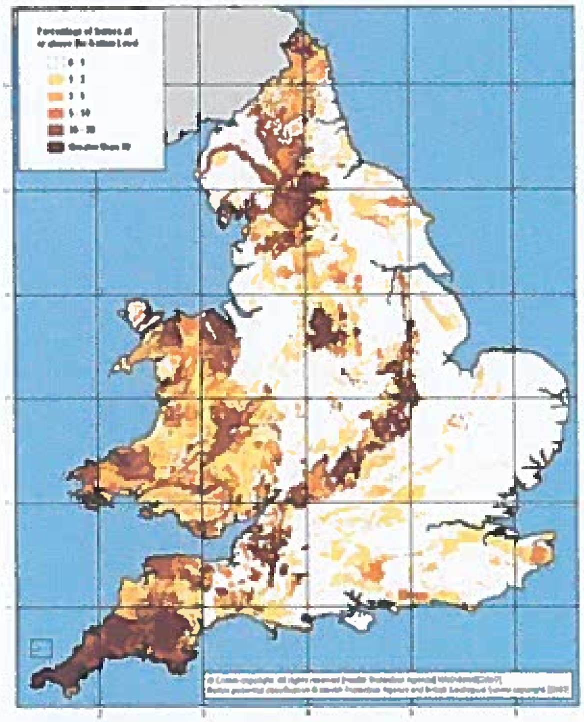
A ***Geiger-Muller (GM)*** counter can be used to measure background radiation.

Radon Gas:

The single main source of background radiation is ***Radon Gas.*** Radon is formed when ***unstable isotopes of uranium*** *decay in the Earth's crust.* This happens mainly in ***igneous rocks.*** So, Radon is far more common in some parts of the country than others.

The darker areas on this map are where most radon is found.

What do you thing will happen to background count rate in these places?



Nuclear Waste:

Some background radiation comes from ***Nuclear Waste.***

This waste can come from Nuclear Power Stations or from Hospitals.

Radiation from Nuclear Waste is only a tiny part of overall background radiation, but the safe storage of this waste is a major problem.

There are two reasons for this.

1. Some of the waste (***High Level Waste***) is very, very dangerous.

2. Some of the waste has a very long ***half life***. This means it will be dangerous for hundreds of thousands (100 000's) of years.