Brainup.

IGCSE PHYSICS

0625 / 0972

Syllabus 2024

1-GENERAL PHYSICS

UNITS OF MEASUREMENT

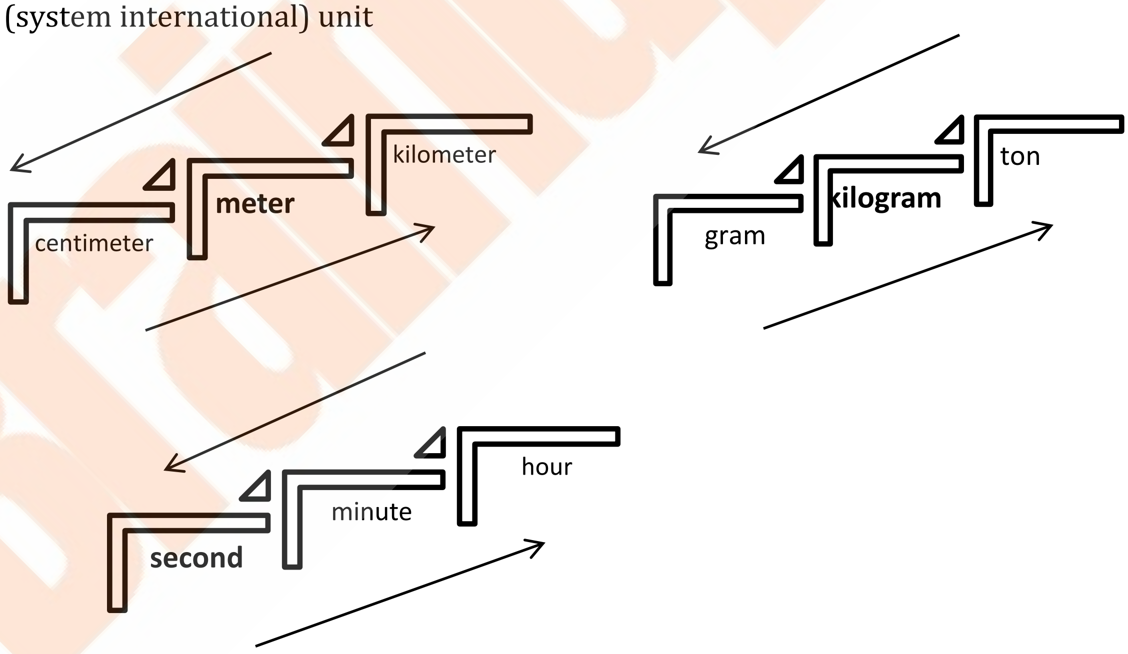
Measurement means comparing any physical quantity with a standard to determine its Relationship to standard this standard is called unit all measurable quantity expressed in

a) Some **number** or magnitude and
b) Some **unit**

For example if the **distance** is **200km**, 200 is the **number** or magnitude and km (kilometer) is the **unit**

Standard International Unit

M.K.S. system: **m**eters – **k**ilogram – **s**econd system used internationally. This system is also called **SI** (system international) unit



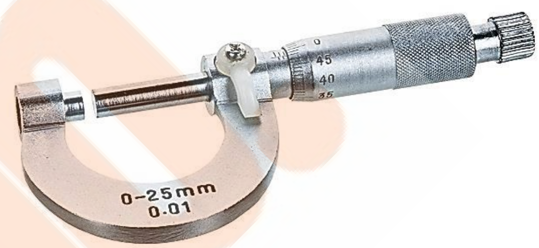
Powers of prefix

Prefixes are used to give multiples and submultiples. The prefix represents a power of ten. The standard multiples and submultiples are ***mostly*** in steps of 10^3

Symbol	Prefix	Value
n	Nano	10^{-9}
µ	Micro	10^{-6}
m	Milli	10^{-3}
C	Centi	10^{-2}
K	Kilo	10^{3}
M	Mega	10^{6}
G	Gega	10^{9}

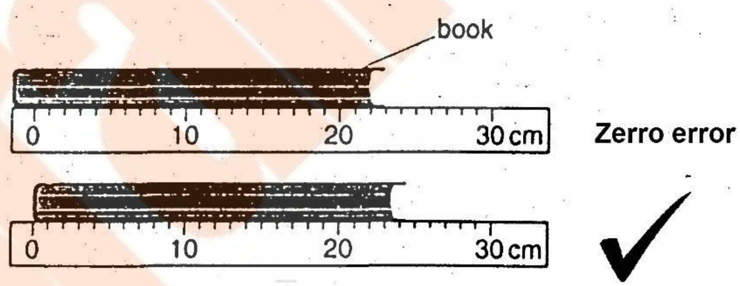
Measuring length and Thickness

Length can be measured with a ruler to the nearest 1 mm. But when very small objects are used; we need to take measurements to the **nearest 0.01 mm the *micrometer screw gauge*** makes this possible.



Zero Error in measurement

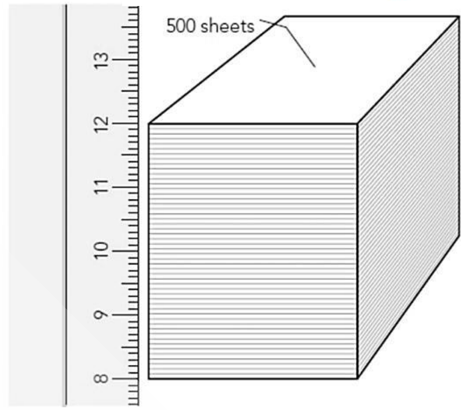
Before taking a measurement, check that the reading is zero in ***measuring length by ruler*** as shown in figure or measuring thickness when the jaws are closed. If reading is not zero, then ***zero error*** must be allowed when the reading is taken.



More measurement technique

If you have to measure a small length, such as the thickness of a wire, it may be better to measure several thicknesses and then calculate the average.

Take a stack of 500 sheets and measure its thickness with a ruler then divide by 500 to find the thickness of one sheet.



Measuring Time

The common devices to measure the time or duration of an event are ***clock and stopwatch***

The precession of time duration of an event can be improved by **measuring the time for number of events and dividing time by total number of events**.

- ✓ For example to measure the time period of a pendulum the time for ten swings should be recorded and dividing the total time by ten to get the time for one swing

Period = ________________

Scalar and Vector Quantities

- **Scalar quantities:** a quantity which has **magnitude** (size) only and is described by its numerical value. (distance, mass, speed, volume, time and temperature)

- **Vector quantities:** a quantity which has both **magnitude** and **direction**, and both should be mentioned to describe it (displacement, weight, velocity and acceleration)

Speed

To calculate speed

$$\textbf{average speed (m/s)} = \frac{\textbf{distance moved (m)}}{\textbf{time taken (s)}}$$

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

Questions

1. The runner completes 400 m is a time of 160 seconds. What is her average speed?

Answer

$$\text{average speed} = \frac{\text{distance moved}}{\text{time taken}} = \frac{400}{160}$$

So the average speed = 2.5 m/s

2. An athlete completes a 4 km mountain race in at an average speed of 3 m/s. How long does the race take?

Answer

$$\text{time taken} = \frac{\text{distance moved}}{\text{average speed}} = \frac{4000}{3}$$

The distance is given **in 'km' and needs to be converted to meters**

4 km = 4000 m.

So the time taken = 1333 seconds.

Acceleration

Is rate of change in velocity

When we speed up - increasing our velocity - we are **accelerating** , When we slow down we are **decelerating**

- ✓ u = the initial, or starting velocity. (m/s)
- ✓ v = the final velocity (m/s)
- ✓ Δv = the change in velocity (m/s)
- ✓ t = the time taken (s)
- ✓ a = acceleration (m/s^2)

$$\textbf{acceleration } (m/s^2) = \frac{\textbf{change in velocity (m/s)}}{\textbf{time taken (s)}}$$

$$a = \frac{v-u}{t} \quad \text{or} \quad a = \frac{\Delta v}{t}$$

- + acceleration (speed up)
- - acceleration (slow down)
- Zero acceleration (constant speed)

Questions

3. The school bus accelerates from rest to a velocity of 16 m/s in a time of 20 seconds. Calculate the acceleration of the bus.

Answer

We know that the change in velocity (v-u, or Δv) is 16 m/s

$$a = \frac{\Delta v}{t} = \frac{16}{20}$$

so the acceleration = 0.8 m/s^2

4. A cheetah is widely believed to be the fastest animal on Earth. It can accelerate at 2.5 m/s^2. If the cheetah starts at a velocity of 3 m/s, how long will it take to reach a velocity of 13 m/s?

Answer

In this question, the change in velocity $\Delta v = 13 - 3 = 10$ m/s.

$$t = \frac{\Delta v}{a} = \frac{10}{2.5}$$

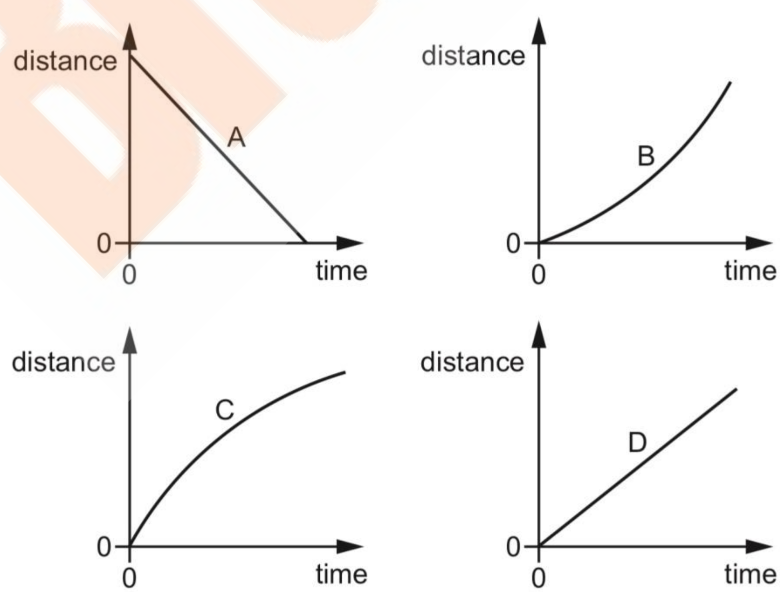
so the time taken = 4 s.

Motion graphs

There are two main types of graph used:

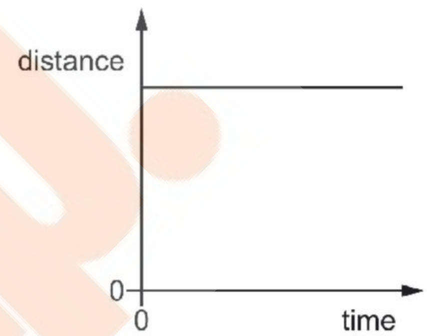
- ✓ Distance - Time graphs
- ✓ Velocity - Time graphs

1- Distance - time graphs



- **Graph (A)** gradient is speed and graph is straight line so it ***constant speed*** opposite direction of (D)
- **Graph (B)**gradient is speed and graph is increasing (stepper up) so ***increase in speed***
- **Graph (C)** gradient is speed and graph is decreasing (stepper down) so ***decrease in speed***
- **Graph (D)** gradient is speed and graph is straight line so ***constant speed***

✓ **Rest or stationary** when graph is horizontal as shown on figure



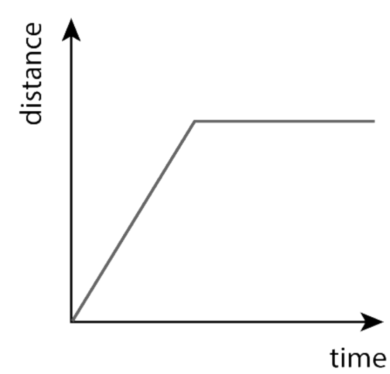
Questions

1. A man is taking his dog for a walk. When he opens the front door, the dog runs off in a straight line at a steady speed. It then stops at a lamp post for some time.

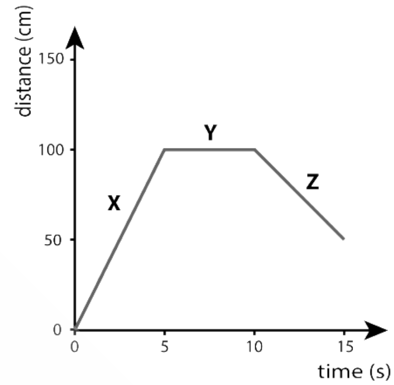
Sketch a distance-time graph for this motion. You do not need to estimate any values for this question.

Answer

✓ The distance should be labeled on the y-axis.
✓ The time should be labeled on the x-axis.
✓ The first section of the line should be a straight line sloping upwards showing "a steady speed".
✓ The next section should be a flat, horizontal line showing the dog remaining in one spot at the lamp post.



2. A student writes a program to make a small robot move across the desk. This graph shows the motion of the robot



- **a). Describe the motion in part 'X' on the graph.**
- **b). Describe the motion in part 'Y' on the graph.**
- **c). Describe the motion in part 'Z' on the graph.**
- **d) Calculate the speed of the robot when it is moving at its fastest.**

Answer

a) Line 'X' shows the robot moving away from the start at **constant velocity**.

b) Line 'Y' shows the robot **stops** / is stationary (100 cm from the start).

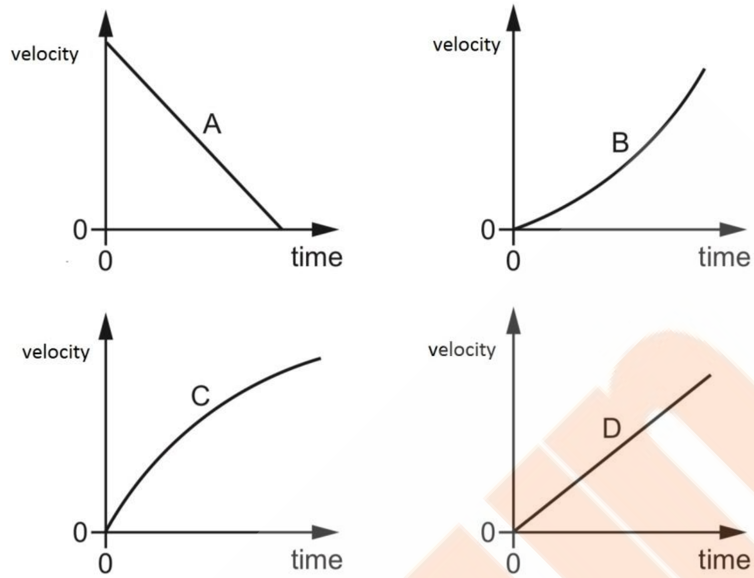
c) Line 'Z' shows the robot moving back towards the start at constant velocity.

d) The fastest speed is where the line is the steepest, (the highest gradient), which is line X. For this section, reading from the graph, the robot covers 100 cm in 5 seconds. As we are using cm, the speed will be given in cm/s.

$$\text{speed} = \frac{\text{distance}}{\text{time}} = \frac{100\text{ cm}}{5\text{ s}}$$

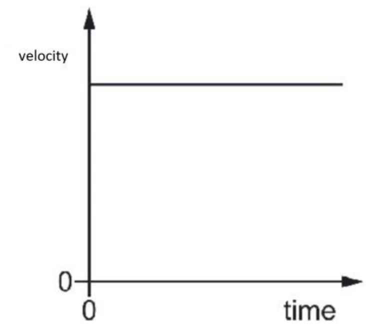
so the speed, or velocity, is = 20 cm /s.

2- Velocity - time graphs



- **Graph (A)** gradient is acceleration and graph is straight line so it ***constant deceleration*** as velocity decrease
- **Graph (B)**gradient is acceleration and graph is increasing (stepper up) so ***increase in acceleration***
- **Graph (C)** gradient is acceleration and graph is decreasing (stepper down) so ***decrease in acceleration***
- **Graph (D)** gradient is acceleration and graph is straight line so ***constant acceleration***

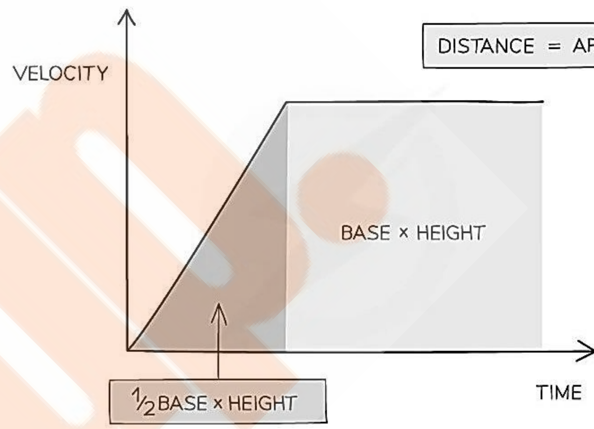
✓ when graph is ***horizontal*** as shown on figure ***zero acceleration*** or constant velocity



Calculations distance using velocity-time graphs

A velocity-time graph is often used to show motion because you can use it to find other information. The two that we will cover here are how to find the **acceleration** and the **distance travelled** from the graph.

- The ***distance*** travelled = the ***area under*** the line.
- The ***acceleration*** = the ***gradient*** of the line.

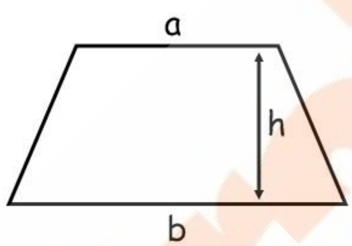


Area under line

Area of triangle = 0.5 x base x height

Area of rectangle = base x height

Area of trapezium = 0.5 x h x (a + b)



Acceleration

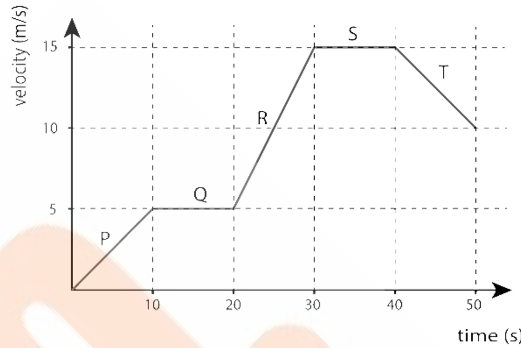
This is the gradient of the line the steeper the line, the higher the acceleration. The 'steepness' of a line is the gradient

$$\text{gradient} = \frac{\text{'rise'}}{\text{'run'}} \quad \text{or} \quad \text{gradient} = \frac{\text{change in y-axis}}{\text{change in x-axis}}$$

Questions

The graph shown in figure gives data on the movement of a city tram moving away from a station.

Which section or sections of the graph shows the tram



a) Moving with constant velocity?

b) Decelerating?

c) Accelerating at the highest rate?

Answer

a) A constant velocity will be shown as a flat, horizontal line on a velocity-time graph.

Therefore the **sections showing this are Q and S.**

b) Deceleration means slowing down, and this is shown by a sloping line with a decreasing velocity.

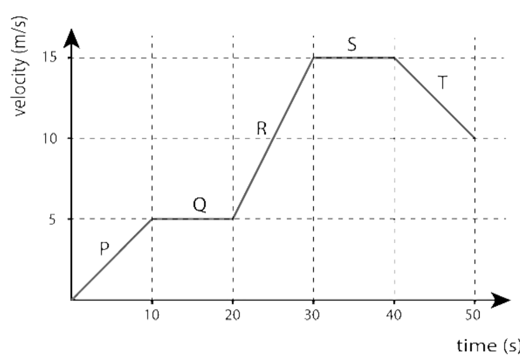
The section showing this is **section T.**

c) A high acceleration is shown by a sloping line with a high gradient (like a very steep hill).

This is shown by **section R.**

(Section P is also showing acceleration, but the tram is not accelerating as much as in section R).

Using the graph shown in figure for the velocity of a tram, calculate:



- **a) The acceleration of the tram in section R.**
- **b) The distance travelled between 30 and 40 seconds.**

- **c) The distance travelled in the first 10 seconds.**

Answer

a) The acceleration is given by:

$$\textbf{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$\text{or by using acceleration} = \textbf{gradient} = \frac{\text{change in y-axis}}{\text{change in x-axis}}$$

$$\textbf{acceleration} = \frac{15 - 5}{10} = \frac{10}{10}$$

So the **acceleration of section R = 1 m/s^2.**

b) The distance travelled between 30 and 40 s is given by:

Distance = area under line = rectangle of height 15 (m/s) and length 10 (s).

Therefore the area = distance = 15 x 10 = 150 m.

c) The distance travelled in the first 10 s is given by:

Distance = area under line = area of triangle = ½ base x height,

So area = ½ x 10 x 5,

Area = distance = 25 m.

Mass

Mass is a measure of the quantity of matter in an object. In simple terms, it relates to the number of atoms present, and how big those atoms are. The international unit for mass is the kilogram (kg).

Weight

Weight is a measure of the pull of gravity on an object. As it is a pull, it is also a force and is therefore measured in newton (N)

Weight = mass x gravitational field strength

W = m x g

[Newton] = [kilograms] x [N/kg]

- ✓ For many of these questions, the **mass** of an object will **remain the same** (assuming it is the same object), but the **weight can change** as it depends on the strength of gravity acting on it.
- ✓ Take the weight of 1.0kg to be 9.8N (***acceleration of free fall = 9.8m/s***^{2})

Questions

1. If we took the 5 kg bag of fruit on a space journey, how much would it weigh in the following locations?

- **a). The Moon.** On the Moon, g = 1.6 N/kg
- **b). Jupiter.** On Jupiter, g = 23 N/kg
- **c). Deep Space.** Deep space, there is no gravity g = zero.

Answer

- a) W= m x g =5 x 1.6 = 8.0 N
- b) W= m x g =5 x 23 = 115 N

- c).In deep space, there is no gravity! g = zero.
  Therefore W = 0 N (The bag is 'weightless').

2. On the Moon mission in 1972, the astronauts picked up a rock to bring back to Earth. The weight of the rock was 32 N on the Moon. Calculate

- **a). The mass of the rock.**
- **b). The weight of the rock when it was returned to Earth.**

Answer

a). We know w = m x g. We also know that g_{moon} = 1.6 N/kg. Therefore

$$m = \frac{W}{g}$$

$$m = \frac{32}{1.6}$$

m = 20 kg.

b) If m = 20 kg, and on the Earth g = 9.8 N/kg,

then W = m x g

W = 20 x 9.8

Therefore W = 196 N

Density

It is defined as the mass per unit volume of a substance. The unit of density is kg/m^3 or g/cm^3.

It is denoted by Greek symbol ρ (rhoo) and is calculated from the formula

Density = ———   ρ = —

Measurement of physical quantities

1. The ***mass*** of an object is the amount of matter contained in this object. The mass is usually measured in kilograms/grams using a balance (beam balance or top pan balance).

2. The ***volume*** of an object is the amount of space occupied by this object. The volume is usually measured in cubic meter (m^3), cubic centimeter (cm^3), or liter (l).

Determining the density of a regularly shaped object

1 .Use a mass balance to measure the ***mass*** m of the object

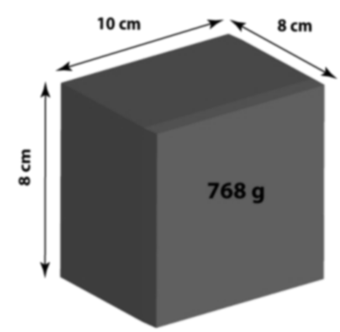
2 .Use a ruler to measure the **dimensions** (length and height and width) of the object and then calculate its volume V = l x h x w

3.Then use the following formula to calculate density

Density = ———

Questions

A block of plastic is shown here.



- **a) State the formula used to calculate density.**
- **b) Using information from the image, calculate the density of the block.**

<u>**Answer**</u>

a) $$\rho = \frac{m}{V}$$

b) The volume of the block is length x height x width,

V = 10 x 8 x 8 = 640 cm^3

$$\rho = \frac{768\ g}{640\ cm^3}$$

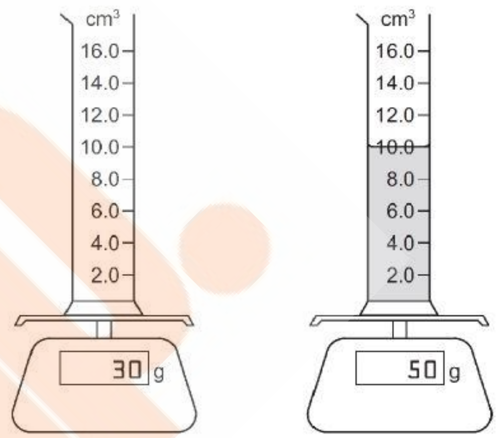
ρ = 1.20 g/cm^3

Determining the density of a liquid

1- The mass m of the liquid can be measured using a mass balance. To find the mass of the liquid we subtract the mass of the empty measuring cylinder from the mass of the liquid and the measuring cylinder.

2- The volume V can be read directly from the measuring cylinder.

3- Then use the following formula to calculate density



Density = ———

Example

Use information in the diagram to calculate density of liquid

Answer

Mass of liquid = 50 – 30 = 20

Volume = 10

So density of liquid Density = — = 2 g/cm^3

Determining the density of an irregularly shaped object

in the procedure below we use the **displacement of water** method to determine the volume V.

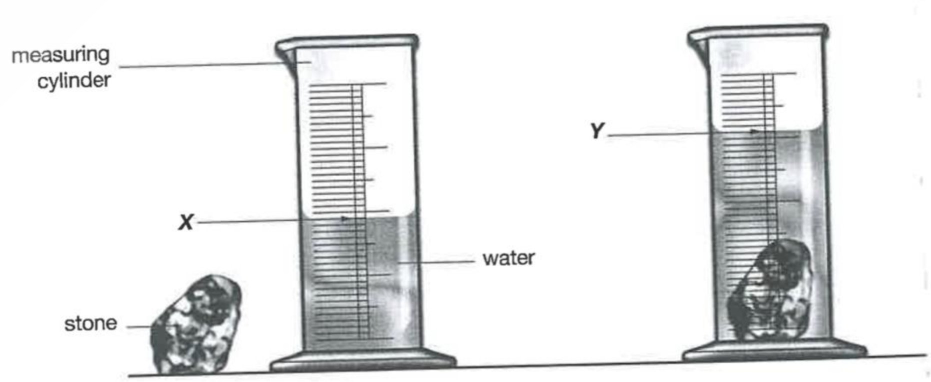
1- Measure the mass m of the irregularly shaped object, in this case a stone, using a mass balance

2- Partially fills a measuring cylinder with a known volume X of water.

3- Immerse the stone into the water.

4- Measure the new volume Y

5- The volume of the stone is Y - X.



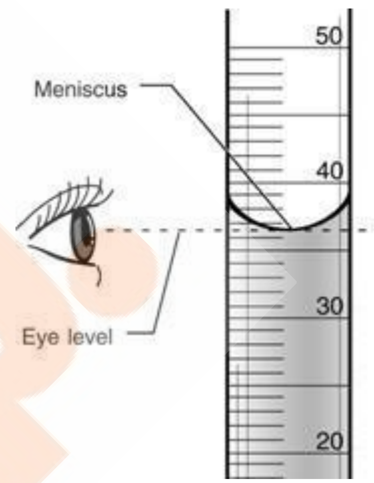
6- Use the following formula to calculate the density

Density = ———

Precautions

1. The measuring cylinder should be placed on a flat horizontal surface.

2. Look perpendicular to the scale of the cylinder (eye level) to avoid **parallax** error.



3. The object must be completely submerged in water. If the object floats in water (less dense than water) therefore a metal sinker is used to submerge it.

4. Tie a string round the object and lower it gently to avoid splashing of water (which will reduce the volume of water & cause an error).

5. Always measure from the **bottom of meniscus** when using measuring cylinder

Questions

A customer orders are large block of aluminum for an art project.

- **a) The block must have a length of 1.2 m, a width of 2.0 m, and a height of 0.8 m. If the density of aluminum is 2700 kg/m³, calculate the mass of this block.**
- **b) The customer suggests supplying the block in two halves of length 0.6 m, to make it easier to transport. What is the density of the aluminum in one of these smaller blocks?**

Answer

a) The volume of this large block will be:

$V = 1.2 \times 2 \times 0.8 = 1.92\ m^3$

The density formula is $\rho = \frac{m}{V}$

So m = ρ x V,

m = 2700 x 1.92 = 5 184 kg

Floating and sinking

The density of pure water is exactly **1.0 g/cm^3**

If you put an object like a piece of wood on the surface of a pure water lake, then

- It will **sink** if the density is **above 1.0 g/cm^3** (the density of water)
- It will **float** if the density is **below 1.0 g/cm^3**.

Forces

A force is basically a push or a pull on something. There are many different things that cause forces, but they are all measured in **newton's (N)**

Here are a few of the most common types of forces found in nature

- **Magnetic** - between magnetic materials. This can be a push (repulsion) or a pull (attraction)
- **Gravitational** - between any mass. This is always a force of attraction.
- **Friction** - this is a force that acts against motion.
- **Electrostatic** - between positive and/or negative charges. This can be attraction or repulsion, depending on the charge.
- **Friction** is a general term for any force produced when an object is in contact with a solid, liquid or gas that pushes against the motion. If a liquid or gas is involved, we often call this force of friction the **'drag'**. If it is an object like a plane moving through the air, we often call this type of friction **air resistance**.

When a force acts on something, many things can happen

- Change the **speed** of a body.
- Change the **direction** of motion (if it is already moving).
- Change the **shape** of a body. (For example, squashing a rubber ball).

Drawing forces

Force is a vector so can be drawn with an arrow. The length of the arrow can be used to show the size of the force, and obviously the direction of the arrow shows the direction of the force.

- ✓ If two or more forces are acting in the **same direction**, we can **add** them together to find the total.
- ✓ if they act in **opposite directions**, we need to **subtract**, as shown here by two forces acting on a ball

Questions

1. A small van is travelling down a road. The forward force provided by the engine is 2 kN . The air resistance acting on the van is 600 N, and the friction between road and tiers is 300 N.

a) What is the resultant force acting on the van?

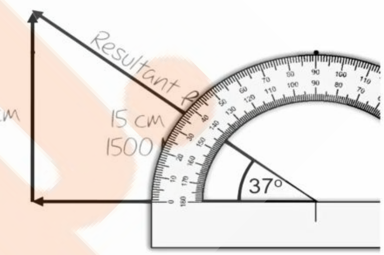
b) Describe the motion of the van at this point.

Answer

- a) The forward force is 2 kN, which equals 2000 N. Air resistance AND friction both act to prevent movement so act backwards, and total 900 N. Therefore there is a **resultant force of 1100 N (1.1kN) acting forwards.**

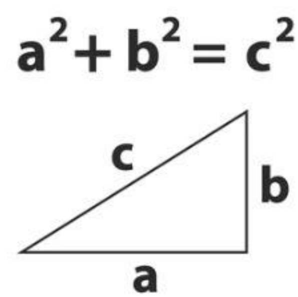
b) As there is a resultant forward force, **the van will accelerate**

Two vectors point in completely different directions



Then the value of the resultant vector can be found graphically triangle method

Draw a triangle to scale, in which two adjacent sides each represent a force. Try to choose a simple scale, for example 1 cm = 1 N



- two lines representing two vectors (draw with scale)
- arrow heads to show the direction in which each vector acts
- complete hypotenuse of triangle
- measure the length of the hypotenuse
- use the same scale to convert this length to the resultant force
- measure the angle (direction) of the resultant to the horizontal

Force and acceleration

If there are unbalanced forces acting on the object, the object will accelerate. The **acceleration depends** on the size of the unbalanced/net **force** and the **mass** of the object

- A force can make an object accelerate. The bigger the force acting on an object, the bigger the acceleration that it gives to the object $\propto F$

(proportional) so, doubling the force acting on an object doubles its acceleration.

- The mass of an object affects how easily it can be accelerated or decelerated. The bigger the mass, the smaller the acceleration given by a particular force $\propto -$ (inversely) so, doubling the mass of the body will halve the acceleration

Force= mass x acceleration

F = m x a

[newtons] = [kilograms] x [m/s^2]

Questions

A mountain bike rider and bike together have a total mass of 80 kg. If the bike is to accelerate at 1.8 m/s, what force needs to be applied?

Answer

F= m x a

Therefore F = 80 x 1.8 = 144 N

A firework rocket of mass 200 g is set alight, and the force produced at the start is 5 N.

- **a). Calculate the initial acceleration of the rocket.**
- **b). the rocket burns and releases fuel, making it lose mass. At what mass will the acceleration be 40 m/s^2, assuming the force produced is still 5 N?**

Answer

a). We know F = m x a and also that 200 g = 0.2 kg (the mass MUST be in kg, not g).

Rearranging the formula gives:

$$a = \frac{5}{0.2} \quad a = \frac{F}{m}$$

$a = 25\ m/s^2$

b) If $a = 40\ m/s^2$ and F = 5 N,
then F = m x a gives:

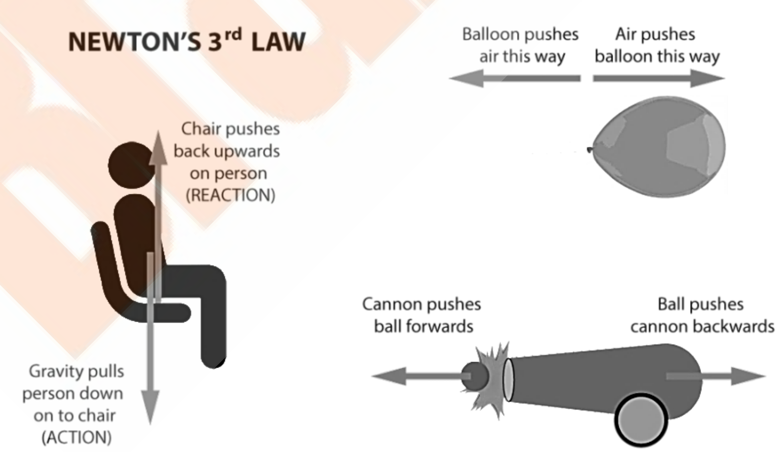
$$m = \frac{5}{40} \quad m = \frac{F}{a}$$

Therefore m = 0.125 kg (or 125 g)

Newton's third law

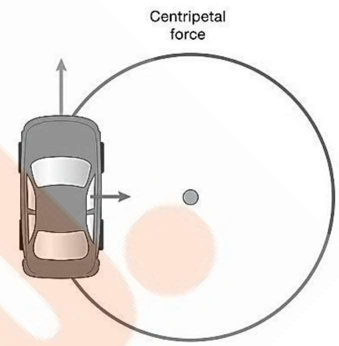
For each **Action** there's **reaction** are **equal** in magnitude and **opposite** direction

- ✓ A common example of this is when you inflate a balloon and then release it without tying the end. The balloon accelerates away. This happens because the balloon pushes the air backwards, so the air pushes back on the balloon (forwards) making the balloon move



The Effect of a Force acting *perpendicular* to the direction of motion

Here, the force is neither driving nor resisting, it acts as a ***centripetal force*** which is the inward force needed to make an object move in a circle As a result Object moves along circular path (or part of a circular path).



- For this car moving round a circular road, what provides the centripetal force? The sideway **friction** exerted by the road on the tires.
- Object can have a steady speed but **a changing velocity** as object moving in a circular path (acceleration change)

Larger centripetal force

1) if the **mass** of the object is **increased**
2) if the **speed** of the object is **increased**
3) If the **radius** of the circle is **reduced**.

Air Resistance and Terminal Velocity of falling object

There are two main forces which affect a falling object at different stages of its fall:

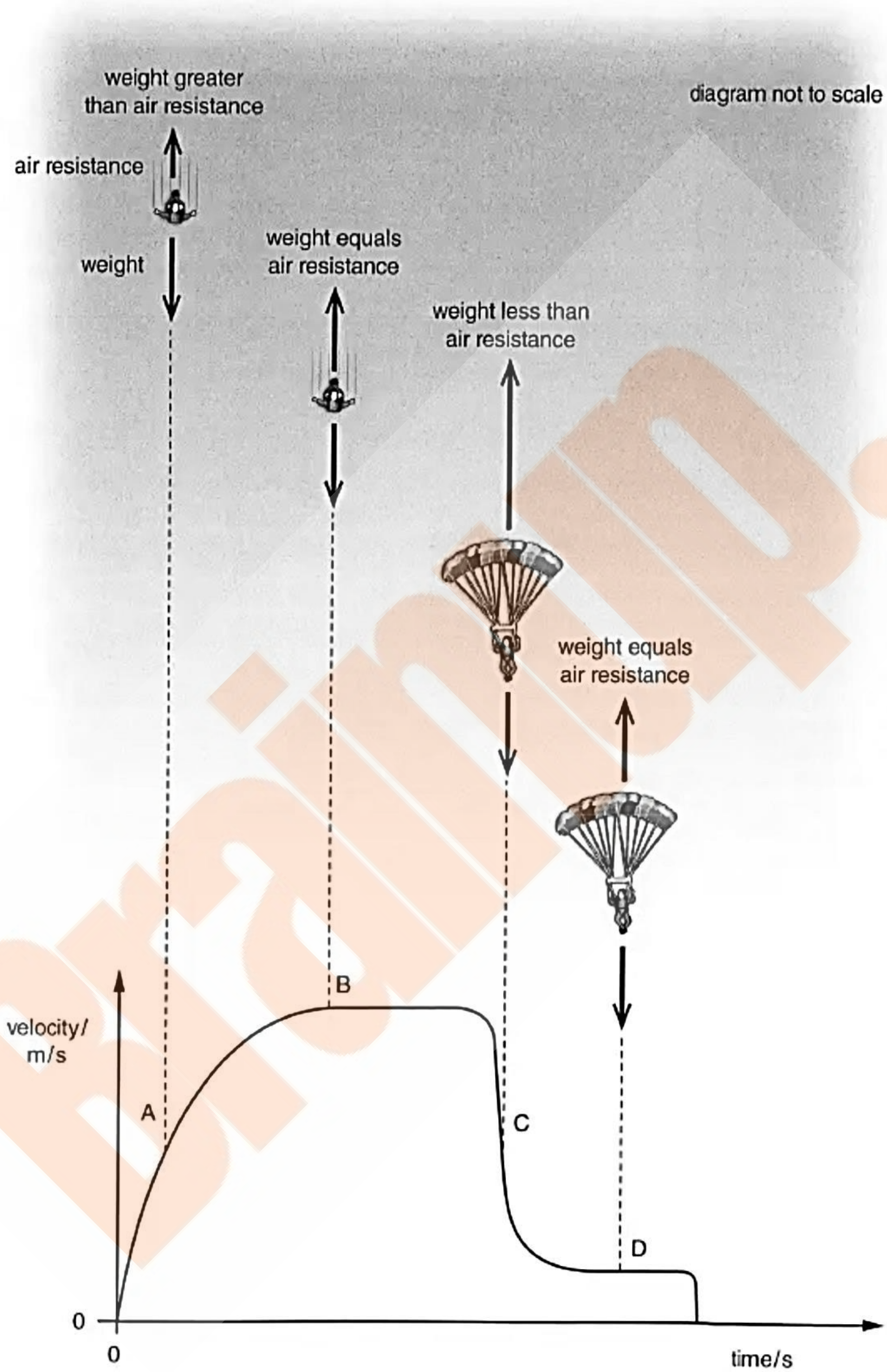
- The **weight of the object** - this is a force acting downwards, caused by the Earth's gravitational field acting on the object's mass.
- **Air resistance** - this is a frictional force acting in the opposite direction to the movement of the object. (Note that in space and other vacuums there is no air resistance.)

Stages of falling

When an object is dropped, there are three stages before it hits the ground:

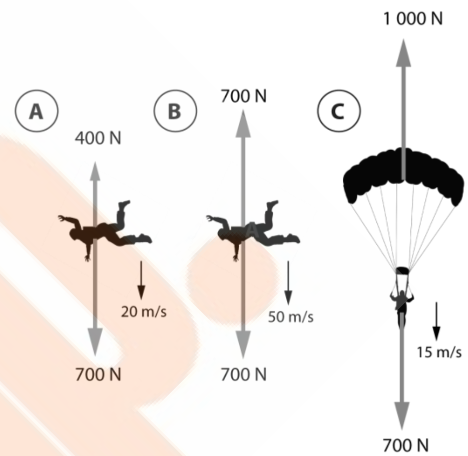
1. At the start, the object **accelerates** downwards because of its weight. There is very little air resistance. There is a **resultant force acting downwards**. The acceleration is constant when the object is close to Earth.
2. As it gains speed, the object's weight stays the same but the **air resistance on it increases**. There is a resultant force acting downwards.
3. Eventually, the object's **weight is balanced by the air resistance**. There is no resultant force and the object reaches a steady speed – this is known as the **terminal velocity**

   ✓ in skydiver as he open parachute the air resistance increase because large surface area of parachute , air resistance is greater than weight so he start to decelerate


weight greater
than air resistance
diagram not to scale
air resistance
weight
weight equals
air resistance
weight less than
air resistance
weight equals
air resistance
velocity/
m/s
A
B
C
D
0
0
time/s

Questions

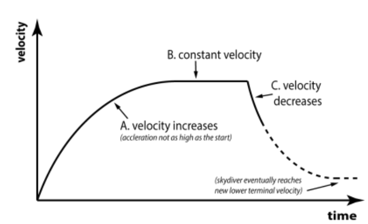
1. The diagrams below figure show forces acting on a skydiver who has jumped out of a plane. There are 3 diagrams, showing different stages of the descent

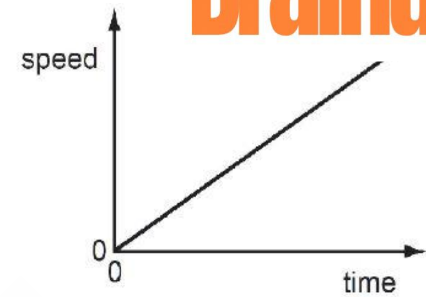


- **a). Describe the acceleration in diagram A.**
- **b). Describe the acceleration in diagram B.**
- **c). Describe the acceleration in diagram C.**
- **d). State the causes of the forces acting downwards and upwards on the skydiver.**
- **e). Complete the velocity time graph shown below to show each of these stages of the skydiver's fall from figure. You do not need to include numbers on the graph. The initial downwards velocity of the skydiver is zero, as shown by the line section given at the start of the graph.**

<u>**Answer**</u>

- a). The downwards force in diagram A is larger (by 300 N) and so the skydiver **accelerates downwards.**
- b). The forces are balanced, so the skydiver stays at a constant velocity. Remember the question asks you to describe acceleration - the **acceleration is zero.**
- c). There is now a resultant force upwards. Be careful - this does NOT make the skydiver go back up to the plane. They are falling downwards, so the unbalanced force just slows them down. The **skydiver decelerates** (or has negative acceleration).
- d) The downwards force is **gravity**, and the upwards force is **air resistance.**
- e) See the example here





Falling object in vacuum (space)

The graph will be straight line due to absence of air resistance as shown in figure

Forces and Deformation

If an object is under the effect of a force, that ***changes its shape***, then this object has experienced deformation. Deformations of objects are either:

1. Elastic deformation

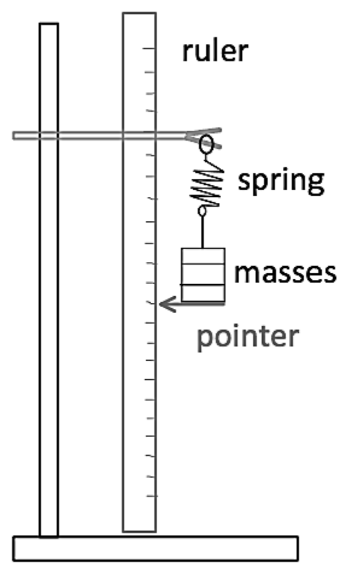
Is when an object (under the effect of a certain force) experiences a change in shape, then ***returns to its original shape when the deforming force is removed***, stretching a rubber band

2. Plastic deformation

Is when an object (under the effect of a certain force) experiences a change in shape, and ***does not return to its original shape when the deforming force is removed***, squeezing a piece of plastic

Most materials are elastic for a certain range for forces "***the Elastic limit***", beyond which they have *plastic* behavior.

Hooks experiment

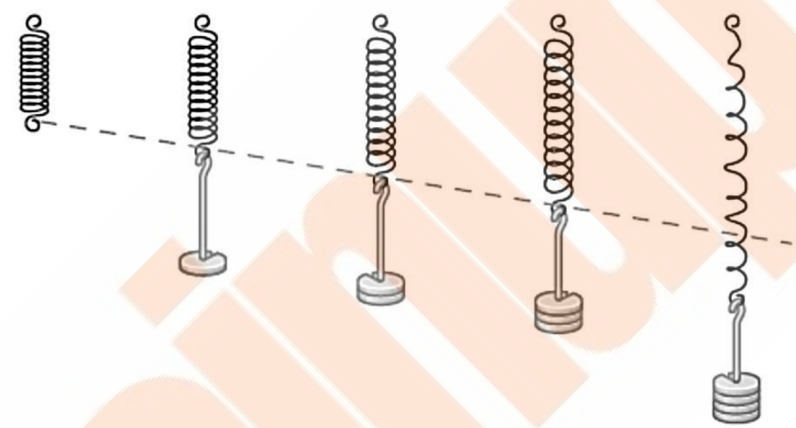


In the opposite figure, a clamp and stands are used to show a stretched spring supporting some weights at rest. When the spring extends (increases in length), therefore the difference between the non-stretched length of the spring and its stretched length (when loaded) is called "***Extension***".

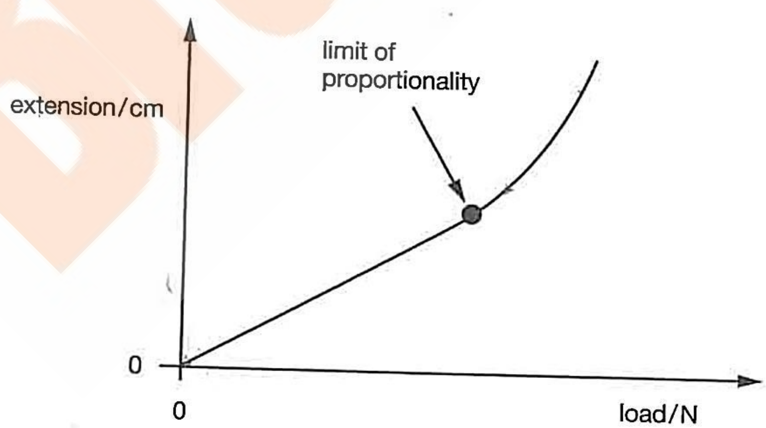
= –

(original length)

- Attach a spring to a clamp or similar support, and measure the upstretched length with a ruler.
- Add a load to the spring. Remember that a mass of 0.1 kg will have a weight of 1 N.
- Measure the new, stretched length.
- Repeat this with additional weights, recording the new length.
- Once finished, work out how much the spring has stretched compared to the original length - this is known as the extension, shown in the diagram as 'x'.



Plot the extension x (cm) against the load (N) applied to see how the spring has behaved under a force



The limit of proportionality

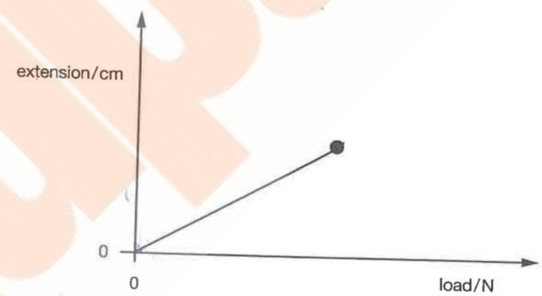
- Is the point beyond which the spring extension will not be proportional to the load Up to this limit the extension increases by a set amount for every newton of force applied Above this limit the increase in extension per newton will be greater.
- The limit of proportionality is an important point.
  If the spring is stretched beyond this point, it will no longer extend proportionally to the load (weight) applied.

Hook's law

Force (F) is Directly Proportional with extension (X) Until Elastic Limit

F = K x X

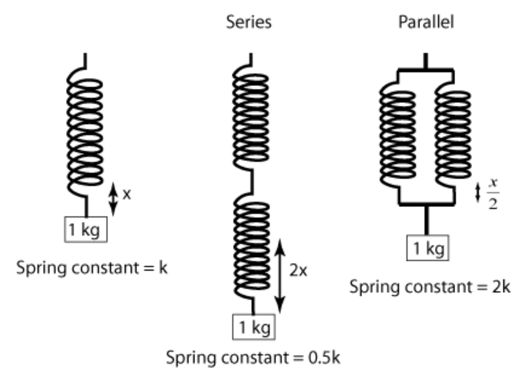
Where k is spring constant



Springs connected in series and in parallel

Springs can be connected in different ways; end to end (in series) or side by side (in parallel).

- When two springs are connected in series, they produce twice the extension because the two extensions add up.
- When two springs are connected in parallel, they produce half the extension because each spring is affected by half the force.



How is Hooke's Law identified on a graph of the load on a spring against the spring's extension?

Answer

Hooke's Law behavior is shown by a **straight line section** on a load-extension graph.

What do we mean by elastic behavior?

Answer

Elastic behavior means that a material will **return to its original shape** after being deformed.

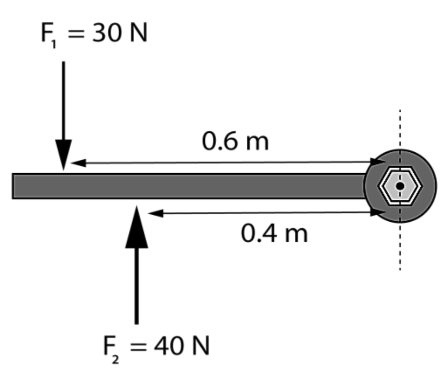
Moment (turning effect)

When a force acts on an object which has a pivot ***a point around which an object can turn or rotate***, it creates a turning effect or moment. When forces are used to open doors, steer and pedal bicycles or turn a tap; they are causing turning effect The moment of a force is defined like this

Moment = force x perpendicular distance (from the pivot)

Moment = F x d

✓ The moment of a force is a ***vector*** quantity that can only have one of **two directions**; either ***clockwise*** or ***anticlockwise***



Combining moments

Questions

In the diagram, there are two forces acting, F_1 and F_2:

- **a) Which of these two forces is trying to rotate the spanner in a clockwise direction?**

- **b) Calculate the clockwise moment on the spanner.**
- **c) Calculate the anticlockwise moment on the spanner.**
- **d) Which way will the spanner turn, if at all?**
- **e) Calculate the total moment acting on the spanner.**

Answer

a) **Force F_2** is pushing upwards on the left hand side, so is trying to turn the spanner in a clockwise direction.

b) The moment of F_2 = force x perpendicular distance to the pivot
So moment = 40 x 0.4 = **16 Nm clockwise**

c) The moment of F_1 = force x perpendicular distance to the pivot
So moment = 30 x 0.6 = **18 Nm anti-clockwise**

d) The anti-clockwise moment is larger (18 Nm compared to 16 Nm) so the spanner will **rotate anti-clockwise.**

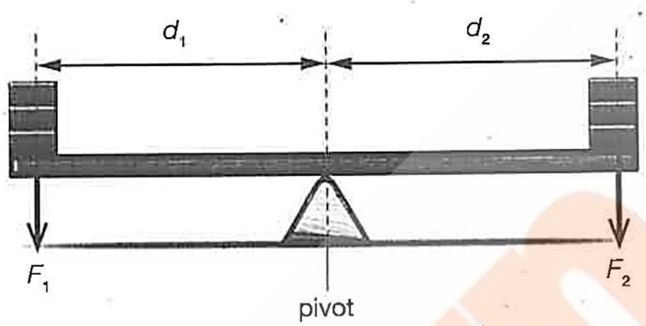
e) The anti-clockwise moment is larger by 2 Nm, so therefore the **total resultant moment is 2 Nm** anti-clockwise.

The principle of moments

A system will not rotate (is in equilibrium) if the sum clockwise moments equal the sum anti-clockwise moments

$$F_1 \, d_1 = F_2 \, d_2$$

or $$m_1 \, d_1 = m_2 \, d_2$$



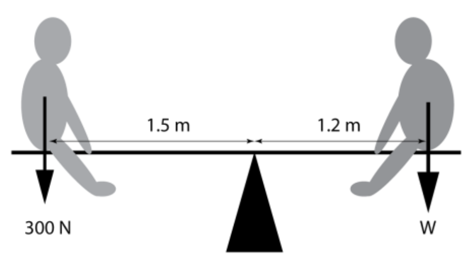
Conditions for equilibrium

1. **The resultant force must be zero**. The sum of the forces in one direction must be equal to the sum of the forces in the opposite direction.

2. There should be **no resultant turning effect** the sum of the clockwise moments equals the sum of the anticlockwise moments about any point (so the object is balanced).

Questions

1. Two children (with unusual body shapes) are on a 'seesaw' in a playground. The seesaw is balanced. What is the weight, W, of the child on the right hand side?



Answer

If the seesaw is balanced, then the anti-clockwise moment = clockwise moment

The child on the left (L) is turning the seesaw anti-clockwise, so we can write:

$F_L \times d_L = F_R \times d_R$

The weight W of the child on the right is called F_R in this formula, so:

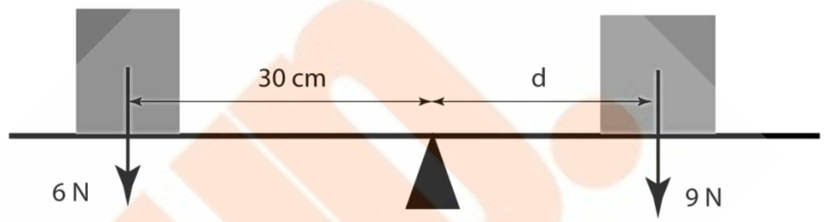
300 x 1.5 = W x 1.2

450 = W x 1.2

$$W = \frac{450}{1.2}$$

W = 375 N

2. Two boxes are balanced on a long beam as shown. What is the missing distance labeled d - the distance of the center of the right hand box from the pivot?



Answer

If the system is balanced, then

the anti-clockwise moment = clockwise moment, So

F_L x d_L = F_R x d_R ,

6 x 30 = 9 x d

180 = 9 x d , so

$$d = \frac{180}{9}$$

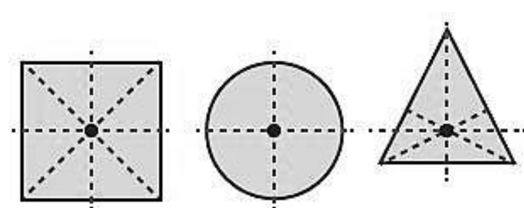
d =20 cm (or d = 0.2 m)

Center of Gravity (center of mass)

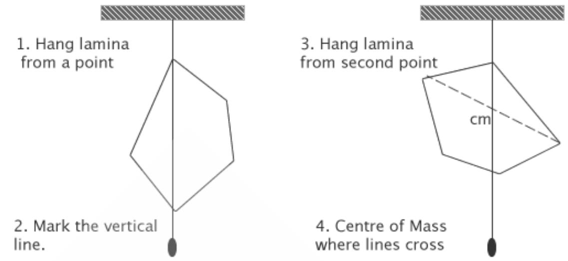
It is a point where the whole weight of a body may be ***considered*** to act.

Center of gravity of a regularly shaped object

It is easy to find the center of gravity/mass for regularly shaped objects as it usually lies at the point you would immediately identify as the ***middle***.



Center of gravity of a irregularly shaped (lamina)



1. Pin the object from one point so that it rotate freely
2. Draw vertical line once the object reaches equilibrium
3. Repeat step 1 & 2
4. The point of intersection is the center of mass

Explanation

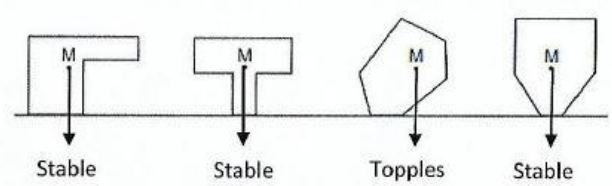
- When the lamina is released, its weight causes a turning effect which makes it swing.
- When the lamina comes to rest, the weight has no turning effect since the line of action of weight passes through the pivot in each case the center of gravity of the lamina lies somewhere along the plumb line, so it has to be at the point where the two lines cross.

Center of Gravity and Stability

The stability of a body is increased by

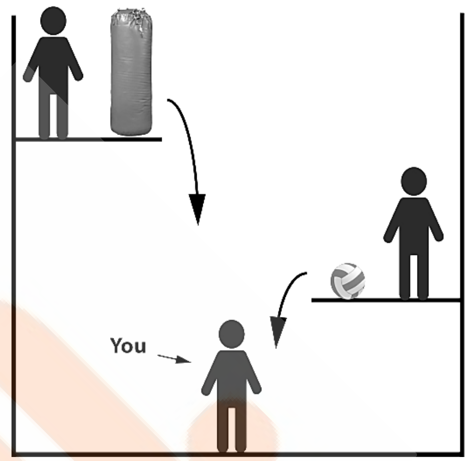
1) Lowering its center or mass

2) Increasing the area of its base (wide)



Momentum

Imagine you work in a sports shop. Some of the equipment is stored on very high storage platforms. Your job is to catch the equipment as it is thrown down to you.



Which would you rather catch - the netball or the large punch bag from the top platform?

This idea of 'how hard it is to stop' is called the **momentum** of an object. A heavy, fast object will have a lot of momentum.
A fast car has more momentum -is harder to stop - than a bicycle because it has more mass and a higher velocity.

The formula for momentum depends on the mass and the velocity of the object

Momentum = mass x velocity

p = m x v

[kg m/s] = [kg] x [m/s]

The units of momentum are simply the units of mass (kg) multiplied by the units for velocity (m/s), and are therefore **kg m/s**

For example, a 2 kg rock rolling down a hill at 3 m/s will have **a momentum of 6 kg m/s.**

Impulse

The impulse of a force is the change in momentum that it causes. Using the concept of impulse, the second law can be written as

= × =

$$\text{force (N)} = \frac{\text{change in momentum (kg m/s)}}{\text{time (s)}}$$

Impulse, like momentum, is measured in Ns or Kg m/s.

Questions

1. 100 g toy car accelerates from rest to 2 m/s in 5 seconds. What force is needed to make the car accelerate?

Answer

$$F = \frac{\Delta p}{t} = \frac{(mv - mu)}{t}$$

- m = 100 g = 0.1 kg (remember to convert units to kg!)
- u = 0 m/s
- v = 2 m/s
- t = 5 s

$$F = \frac{(0.1 \times 2) - (0.1 \times 0)}{5}$$

$$F = \frac{(0.2) - (0)}{5} = \frac{0.2}{5}$$

F = 0.04 N

2. On a roller-coaster ride, passengers are held safely in their seats by seat belts. The belt provides a force that will push backwards on the passengers and slow them down in an emergency.

The maximum force that the seat belts can apply is 2 kN.
If a 100 kg passenger slows down from 15 m/s to rest, calculate:

a) The change in momentum of the passenger.

b) The shortest time in which the passenger can be stopped safely.

Answer

a) The initial velocity here is 'u' and equals 15 m/s. The final velocity v = 0, so:

Change in momentum Δp = mv - mu,

so Δp = (100 x 0) - (100 x15),

Δp = -1500 kg m/s. (or just 1500 kg m/s - the negative sign tells us that the momentum is reducing instead of increasing. however the **change** is momentum is still 1500 kg m/s, so both answers will be marked as correct).

b) We know that

$$F = \frac{\Delta p}{t} \text{ or } F = \frac{(mv - mu)}{t}$$

$$\text{so the maximum force } 2000 = \frac{1500}{t}$$

$$t = \frac{1500}{2000}$$

t = 0.75 seconds at the shortest.

If the time is shorter than this, the force will exceed 2 kN and the seatbelt may break.

Momentum and safety

- The force on our bodies depends on the **change in momentum** and also the **time taken** to do this. If the time is longer, the force needed will be smaller.
- seat belt or air bag or crumble zone is safety features on car as it **increase impact time** , so **reduce force** on passenger for **less injures** since change in momentum is conserved

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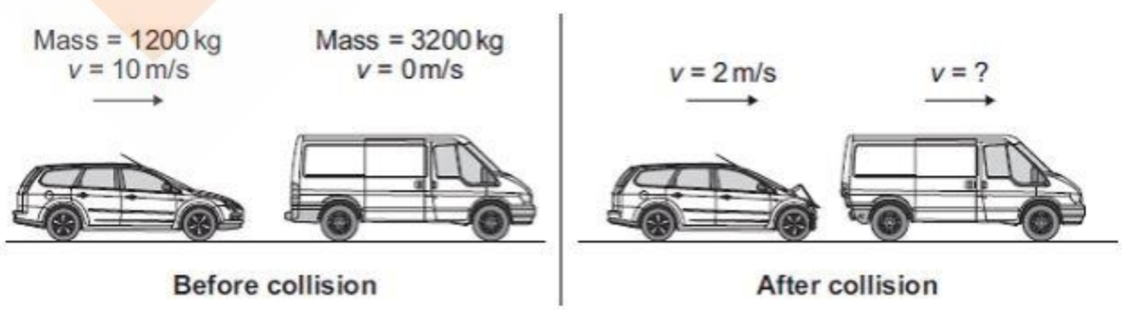
Conservation of momentum

The total momentum before any collision is equal to the total momentum after the collision, as long as no external forces act

Momentum before collision = momentum after collision

✓ **elastic collision (bounce off)**

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$



Questions

Use information in the diagram and calculate velocity of van after collision?

Answers

Momentum before collision = momentum after collision

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$1200 \times 10 + 3200 \times zero = 1200 \times 2 + 3200 \times m2$$

$$12000 = 2400 + 3200 \times V2$$

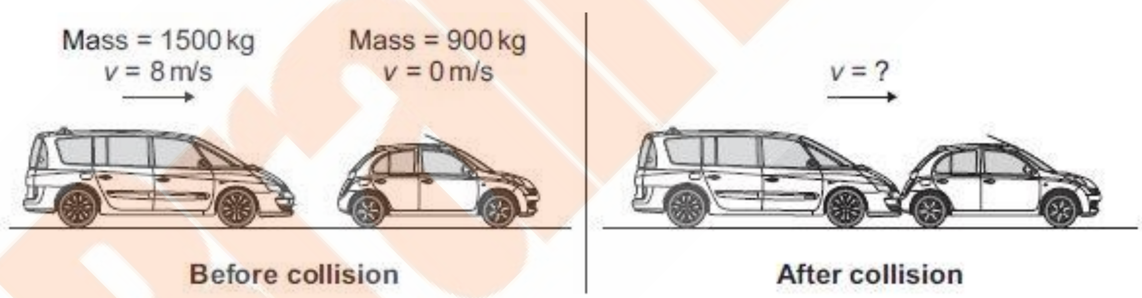
$$12000 - 2400 = 3200 \times V2$$

$$9600 = 3200 \times V2$$

$$V2 = 3 \text{ m/s}$$

✓ **inelastic collision (join together)**

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$



Questions

Use information in the diagram and calculate velocity of van and car after collision?

Answers

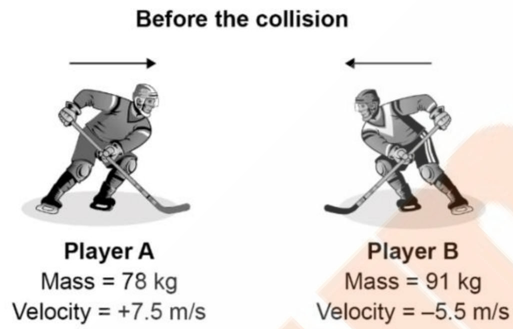
Momentum before collision = momentum after collision

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

$$1500 \times 8 + 900 \times \text{zero} = (1500 + 900)\ V$$

$$12000 = 2400\ V$$

$$V = 5\ m/s$$



Questions

Use information in the diagram and calculate velocity of two player immediately after the collision the two player move together to right ?

<u>Answers</u>

Momentum before collision = momentum after collision

$$m_1u_1 + m_2u_2 = (m_1 + m_2)v$$

$$78 \times 7.5 + 91 \times -5.5 = (78 + 91)\ V$$

$$84.5 = 169\ V$$

$$V = 0.5\ m/s$$

Energy

Physicists say that **"work is done when energy is transferred."** Work and energy are both measured in **joules (J)**.

There are a few different classes of energy

1) Potential Energy

Is the type of energy stored in a body and available to do work

a) Gravitational Potential Energy (GPE)

Is the energy of an object ***due to its position or height*** (about the Earth's surface). The change in GPE of an object depends on the change in its height.

G P E = Mass of Object x Gravity x Height

Questions

A student of mass 60 kg climbs up a long flight of stairs of height 30 m. Calculate the gain in gravitational energy.

Answer

G.P.E. = m g h

G.P.E. = 60 x 9.8 x 30

so the gain in G.P.E. = 17640 J

A farmer has a small hydroelectric scheme that stores water in a large tank high on a hill when needed, the water flows downhill and through a generator, transferring the stored gravitational energy to electrical energy. The tank is 50 m above the nearby river.

What mass of water needs to be stored at this height so that the tank stores 2 MJ of gravitational energy?

Answer

G.P.E. must be 2 MJ (2 million joules)

G.P.E. = m g h

2 000 000 = m x 9.8 x 50

2 000 000 = m x 490

rearranging the equation gives

$$m = \frac{2\,000\,000}{490}$$

So m = 4081 kg

b) Chemical Potential energy

Stored form of energy released by chemical reactions.

- Chemical energy in **fuels** released by burning them
- Chemical energy in **batteries**, when in use, it is transferred to electrical energy.
- Chemical energy of **food** is released by chemical reactions in our body (respiration).

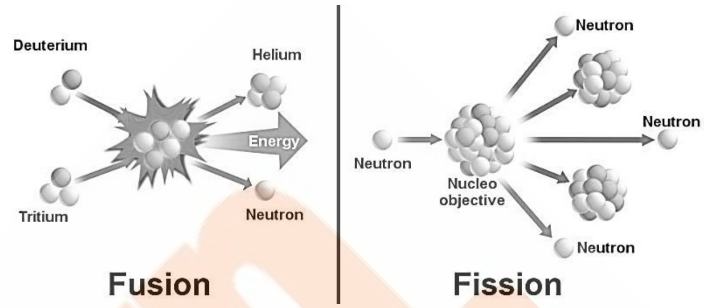
c) Elastic Potential Energy (Strain Energy)

This is the **energy stored in a body when it stretch or bend** this type of stored energy is used in rubber band , or spring

d) Nuclear Potential Energy

Energy ***stored in the nucleus of an atom***. This nuclear energy can be released from the nuclei of certain elements (radioactive elements) by either

- Nuclear **Fission** ***splitting*** of a heavy nucleus into lighter nuclei
- Nuclear **Fusion** The ***join of light nuclei*** to form heavier ones, energy is released by nuclear fusion in the sun.



2) Kinetic Energy

Is the ***energy of an object due to its motion*** the faster the object moves, the more KE it has.

$$= - \qquad 2$$

Where, KE = Kinetic Energy, in Joules

m = mass of object, in kg

v = speed of object, in m/s

Questions

2 kg cat is running across a room at 4 m/s. What is the kinetic energy of the cat?

Answer

K.E. = ½ m v^2

K.E. = ½ x 2 x 4^2

So K.E. = ½ x 2 x 16

so the cat has a K.E. = 16 J

A dog is chasing the cat from question 1. It has mass of 14 kg and a kinetic energy of 63 J

<u>Answer</u>

K.E. = $\frac{1}{2} m v^2$

Substituting in the values from the question gives

$63 = \frac{1}{2} \times 14 \times v^2$

$63 = 7 \times v^2$

rearranging the equation

$$v^2 = \frac{63}{7}$$

$v^2 = 9$ square route of answers giving $v = 3$ m/s

Conservation of Energy

The Law of conservation of Energy states that

" ,
"

Some examples of energy conversion

- A light bulb converts electrical energy to light energy;
- A moving car converts chemical energy from petrol to kinetic and heat energy;
- A drill machine converts electrical energy to kinetic energy.
- A mountain climber changes chemical energy from his muscles to potential energy.

Questions

A ball rolls down a hill. State the energy store at the top and at the bottom of the hill.

Answer

At the top of the hill the ball will have stored **gravitational energy**. At the bottom, the ball will have accelerated and have **kinetic energy**.

A catapult is used to fire a small stone, using a strong elastic band.

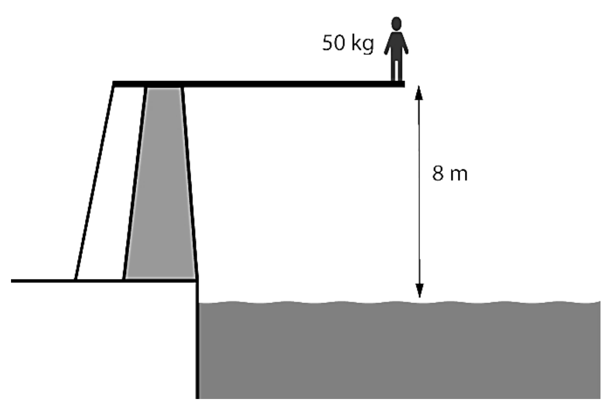
i) State the energy store in the catapult just before, and after firing.

Answer

i) Before firing, there is a store of **elastic energy**. Afterwards, the stone has a store of **kinetic energy**.

Kinetic energy to gravitational potential energy and vice versa

At the top of the board, the diver has gravitational potential energy. When the diver jumps, this G.P.E. will convert to K.E. However,



G.P.E. of the diver = mgh.
Substituting in the values gives
G.P.E. = 50 x 9.8 x 8
So the **G.P.E. = 3920 J**

This will convert into kinetic energy.
K.E. = ½ m v^2
Substituting in the values from the question gives

$3920 = \frac{1}{2} \times 50 \times v^2$

$3920 = 25 \times v^2$

rearranging the equation gives

$$v^2 = \frac{3920}{25}$$

$v^2 = 156.8$

so $v = \sqrt{156.8}$ giving $v = 12.5$ m/s

Questions

A 100 g tennis ball is thrown upwards at 20 m/s. If we ignore air resistance, how high will it go?

Answer

The mass of the ball is 0.1 kg (don't forget to convert 100g to kg)

If the velocity is 20 m/s we can calculate the K.E. of the ball

K.E. = $\frac{1}{2} m v^2$, therefore

K.E. = $\frac{1}{2} \times 0.1 \times (20)^2$

K.E. = 20 J

This is converted to G.P.E., so G.P.E. = 20 J

G.P.E. = m g h

$20 = 0.1 \times 9.8 \times h$

so h = 20.4 m

Efficiency

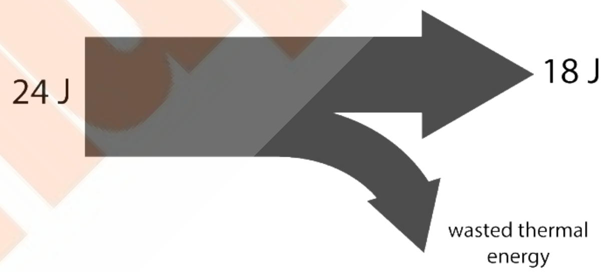
The efficiency of any process that does work by transferring energy

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{energy input}} \times 100\%$$

Questions

1. A small toy car uses a spring inside to drive the car. The spring can be wound up using a key, and then the car released.

This sankey diagram shows the energy transfers that take place. Some labels are missing from the diagram.



a) What form of energy is stored in the spring at the start?

b) What form of energy store does the car have once it is released?

c) How much energy is dissipated as heat into the surroundings?

d) State the formula for efficiency.

e) Calculate the efficiency of the toy car.

Answer

a) The spring stores **elastic energy**.

b) Once the car is released, the energy stored into the spring as elastic energy is transferred to **kinetic energy**.

c) The energy lost as wasted thermal energy is dissipated into the surrounds. The missing value is 24 J - 18 J = 6 j

d)

$$\textbf{efficiency} = \frac{\textbf{useful energy output}}{\textbf{energy input}} \textbf{ x 100\%}$$

e)

$$\text{efficiency} = \frac{18}{24} \text{ x } 100\%$$

Efficiency = 75 %

Work

Is the product of the force (F) and the distance (d) in the direction of the force

Work done = force × distance moved in the direction of force

$$Work = F \times d$$

✓ The unit of work (and energy) is the joule

Example

- Work is ***done when you push a car to start it moving***: you force transfers energy to the car; the car's KE increases (you lose energy while the car gains)
- Work is ***not done when you push a car but it doesn't move***; no energy is transferred because your force does not move the car. The car's KE does not change.

Questions

A dolphin swims for 1 km in water, producing a forward force of 800 N to overcome the resistance from the water. Calculate the work done by the dolphin.

Answer

We know W = F x d, and 1 km is equal to 1000 m

W = 800 N x 1000 m

W= 800 000 J

A small toy boat contains a battery storing 2 kJ of energy. When moving at top speed, the resistance from the water is 12 N Assuming the boat motor is 100 % efficient, how far could the boat travel before the batteries run out?

Answer

We know that W = F x d, and the work done will be 2 000 J assuming all the battery energy is transferred. So:

2 000 = 12 x d

$d = \frac{2000}{12}$ d = 167 m

An 8 kg drone is moving upwards at a constant speed to take pictures of a new building from above. It travels 600 m upwards.

a) What is the weight of the drone?

b) What work has been done getting to this height?

Answer

a) The weight of the drone is given by = m g

so weight = 8 x 9.8

Weight = 78.4 N

b) Work done = F d

so Work = 78.4 x 600

Work done = 47040

Power

Is the **rate** at which energy is transformed from one form to another or the work done per unit **time**

Power = ————————————

✓ Unit of power 1 Watt = 1 joule/second

Power can be defined in two ways

- ✓ Power is the ***rate*** of transfer of ***energy***
- ✓ Power is the ***rate*** of doing ***work***

Questions

A phone battery needs 28 kJ of electrical energy to be transferred to fully charge the phone. If the charger supplies 4 W of electrical power, how long will it take to charge the phone?

Answer

$p = \frac{W}{t}$ $4 = \frac{28\,000}{t}$

rearranging this equation gives

$$t = \frac{28\ 000}{4}$$

t = 7 000 seconds

Amy is timed running up some stairs. She weighs 550 N, and takes 12.5 seconds to complete the climb. The stairs have a vertical height of 9 m.

Calculate

a) The work done by Amy climbing the stairs.

b) Amy's average power output during this climb.

Answer

a) Amy's weight is the downward force of gravity (F) on her. The work done is given by

W = F d So W = 550 x 9 = 4 950 J

b) Her power output is given by

$$p = \frac{W}{t} \text{ and therefore:- } P = \frac{4\ 950}{12.5}$$

Her power output is P = 396 W

ENERGY SOURCES

Renewable energy source

Renewable energy source is the one that is generated from natural resources such as sunlight,

Wind, **waves**, **tides** and **geothermal** and **hydroelectric** heat which means it can be received from nature forever

Non-renewable energy source:

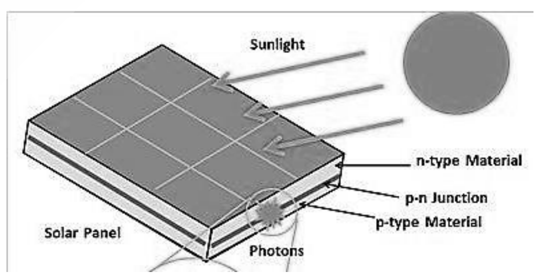
Non-renewable energy sources are those energy sources that are used up and cannot be replaced.

One day they are going to be finished. These are fossil fuels like **coal**, **oil** and **natural gas** and **Nuclear** fuel like uranium,

- The Sun is the source of energy for all our energy resources except **geothermal**, **nuclear** and **tidal**.

1) Solar energy

Solar heating systems consist of water-filled black panels. Heat from the Sun warms the panels, and the hot water can be used directly, for central heating systems or for hot water at home.



Solar panels work in a different way. They convert sunlight directly into electricity using silicon crystals. These panels contain smaller **photovoltaic cells** which generate a current.

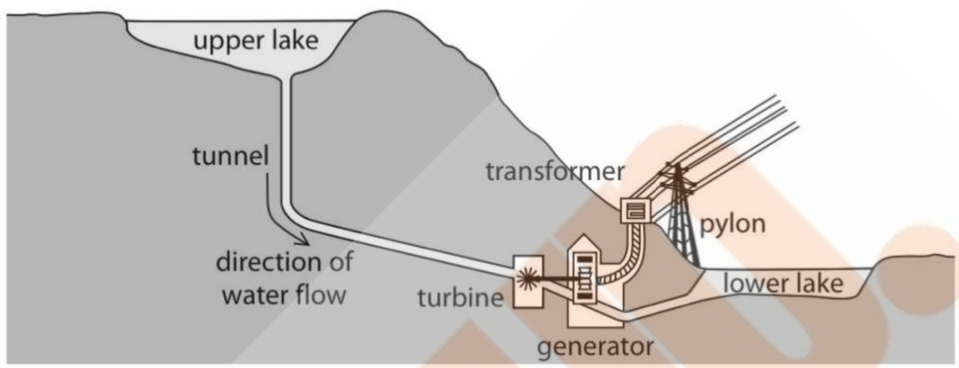
2) Wind Power

Wind energy turns the turbine blades in a wind turbine. The turbines rotate the generator. The kinetic energy of the wind is converted into electrical energy by the generator.

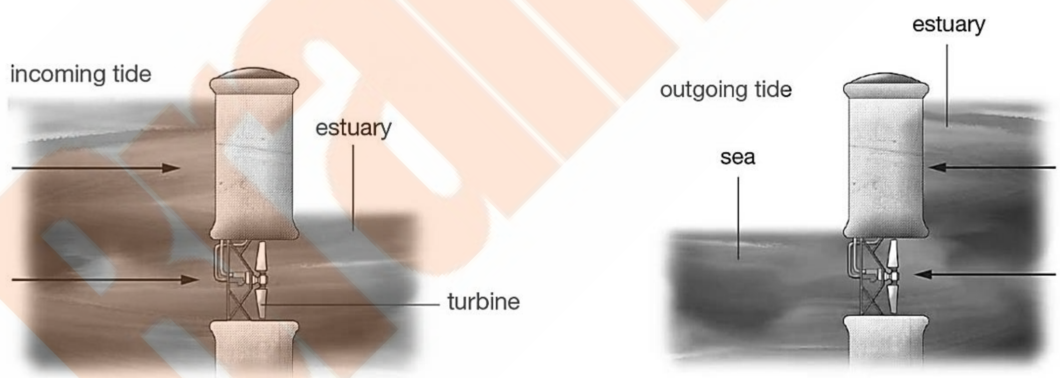
3) Water

✓ **hydroelectric power station**

Energy stored as G.P.E. transfers to kinetic energy as it flows down through pipes to turbines and a generator, which convert this to electrical energy.



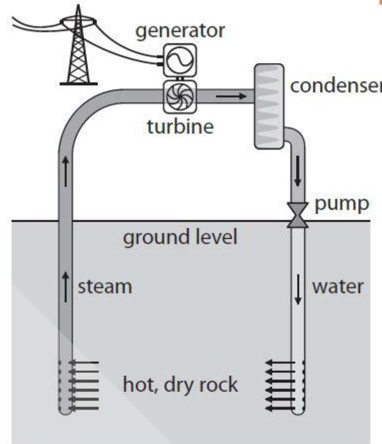
✓ **A tidal power station** uses the rising and falling of water in the sea to generate electricity. The tides are produced by the gravitational pull of the Moon and Sun on the seas



✓ **Waves**

Generators are driven by the transverse (up and down) motion of the wave. The kinetic energy of the wave motion causes water to rise and fall in the air chamber. The air above the water causes the turbine to turn and electricity is produced by the generator.

4) Geothermal



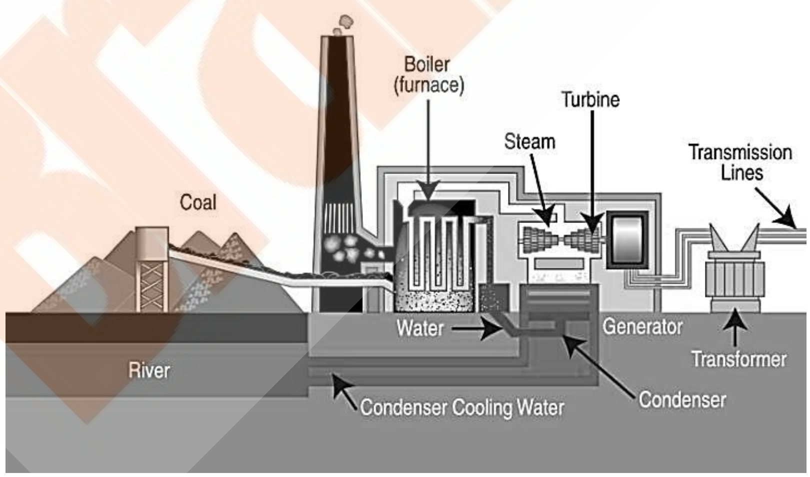
Geothermal power stations use heat from underground where hot rocks lie near to the surface. Water is pumped in pipes down to hot rocks and returns as steam to turbine and a generator produce electricity.

5) Biofuel

biofuel are produce from natural product , as waste material from farm crops PowerStation burn waste material to generate electricity , its renewable source as crops can be regrown to replace resource

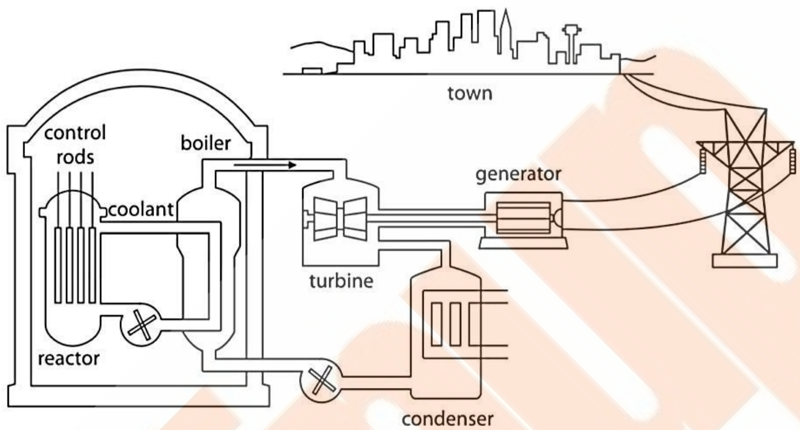
6) Fossil fuels

Fossil fuel power stations can produce a large power output, 24 hours a day. For this reason, the majority of the World's electrical energy is still produced in this way. Fuel (coal, oil, gas) energy stored as chemical energy by burning fuel it converted as thermal energy which supply in water in boiler water turn into steam kinetic energy of steam turn turbine and generator produce electricity



7) Nuclear power

Nuclear power stations have a huge power output and are also reliable, working 24 hours a day. Nuclear energy stored in nucleus (uranium atom) by fission it release huge energy thermal energy released which supply in water in boiler water turn into steam kinetic energy of steam turn turbine and generator produce electricity



Advantages of non-renewable sources	Disadvantages of non-renewable sources
These fuels are far more energy dense than renewable sources and thus, in many countries, they allow production of **larger amounts of energy** in comparison to renewable sources. They are also relatively **easy to transport** and can be **stored** ready for use.	Fossil fuels are becoming increasingly **expensive** to mine (coal) and drill for (oil), as reserves are running out (being depleted). They cause **global warming** due to high carbon dioxide (CO.) emissions when they are burnt. Some also produce sulfur dioxide (SO,), which causes **acid rain.** Nuclear power stations are **expensive** to build and any radiation **leak** or explosion may have a devastating effect on the immediate population and **environment**

Advantages of renewable sources	Disadvantages of renewable sources
They are all regarded as **clean** (producing little or no pollution) and will **not run out**. The fuel itself is cheap or **free**.	Generally all renewable energy sources have high **installation costs**

Solar energy

- When the sun doesn't shine (at night) no electricity is produced.
- Dirty solar panels are inefficient.
- To install panels is an expensive process.
- The panels take up large areas.

Wind energy

- When the wind doesn't blow no electricity is produced.
- Wind farms can destroy the natural beauty of a landscape and are noisy.
- Offshore wind farms are expensive to build and need to be avoided by shipping.

Wave energy

- Waves vary in size and therefore will produce varying quantities (amounts) of energy. When the sea is calm, no electricity is produced
- Installation is expensive and challenging.
- Boats would have to be careful and be aware of the location of the turbines to prevent accidents.

Tidal energy

- Many countries do not have suitable locations.

- Might affect local marine life and destroy habitats.

Geothermal energy

- There are few locations that are suitable.
- It is often necessary to drill very deep and this makes the energy very expensive to obtain.

Hydroelectric energy

- The local environment may be destroyed because water needs to be stored behind a dam, the land behind it flooding.
- Dams are expensive to build.

Pressure

1) Pressure under Solids

Pressure indicates how the force is shared out over the area it acts on, pressure ***is defined as the normal force acting per unit area.***

$$\text{Pressure} = \overline{\qquad\qquad}$$

- Where, force is measured in Newton (N), area is measured in square meters (m^2) and the unit for pressure is ***Pascal*** (Pa).
- 1 Pa = 1 N/m^2

Questions

1. A syringe is used to squeeze a liquid down a tube. A force of 5N is applied to an area of 0.8 cm^2. Calculate the pressure on the liquid

answer

$$P = \frac{F}{A} \qquad P = \frac{5}{0.8}$$

Therefore P = 6.25 N/cm^2

2. A classroom stool has a weight of 160 N. Each of the 4 stool legs produces a pressure of 8.0 N/cm^2 on the floor.
Calculate the area of each stool leg that is in contact with the floor.

Answer

Each stool takes ¼ of the weight. This means the force on each leg is ¼ of 160 N, or 40 N each.
We know that:

$$P = \frac{F}{A} \qquad A = \frac{F}{P} \text{ and therefore } A = \frac{40}{8}$$

A = 5.0 cm^2 (The pressure was given in N/cm^2 so the answer must be in cm^2, not m^2).

2) Pressure in fluids (liquids & gases)

A liquid held in a container exerts pressure on the inner walls of the container as well as on any object that is inside the liquid. Following are the properties applied to any object in a liquid.

1. Pressure of liquid on an object acts ***equally in all direction***,
2. Pressure of liquid increase with the ***increase of depth***,
3. Pressure ***depends*** upon the **density** of the liquid,
4. Pressure ***does not depend upon the shape*** of the container.

The pressure due to liquid of density ρ and height h can be expressed by

$$\text{Pressure} = \text{Density} \times \text{Gravity} \times \text{Height}$$

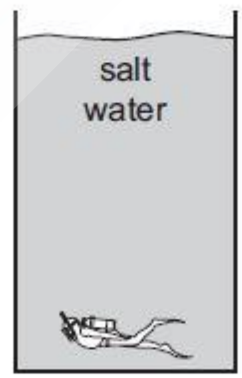
$$P = \rho \times g \times h$$

Where

- P is the **pressure difference** between two points in a liquid or a gas.
- *h* is the depth ***beneath*** the surface of the liquid (measured in ***meters***). The greater the depth, the greater the pressure.
- ρ is the **density** of the liquid (kg/m3). The greater the density, the greater the pressure at any depth.
- *g* is the gravitational field strength (N/kg)

The atmosphere

The Earth's atmosphere is a thick layer of a mixture of gases. This produces a pressure just like a deep pool of water



When diving in a swimming pool, we are under atmospheric pressure at the surface and under an additional pressure due to the water as we swim downwards.

Total pressure = atmosphere pressure + water pressure

Questions

A whale is diving for food in sea water of density 1050 kg/m^3.

- **a) Calculate the water pressure on the whale at a depth of 500 m.**
- **b) The whale's eye has an area of 0.0015 m^2. Calculate the inward force acting on the eye at this pressure.**

Answer

a) We know that P = ρ x g x h.

The value of 'g' on earth can be taken as 10 N/kg.

P = 1050 x 10 x 500

P = 5 250 000 Pa

b) F = P x A,

F = 5 250 000 x 0.0015

F = 7 875 N

The maximum pressure increase for safe recreational diving in water is given as 400 kPa. In a fresh water lake of density 1000 kg/m^3, how deep can a diver go so that this limit is not exceeded?

Answer

P = ρ x g x h.

So 400 000 = 1000 x 10 x h

400 000 = 10 000 x h

$$h = \frac{400\ 000}{10\ 000}$$

h= 40 m

2-Thermal PHYSICS

Thermal Physics

The branch of physics that study the temperature, heat energy and their relation to the matter

Molecular Model

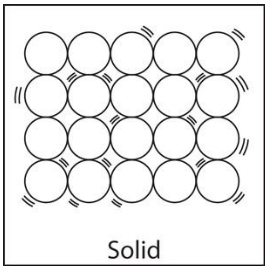
Matter is made up of atoms and molecules, which may only be seen by electronic microscope

States of Matter

- All matter is made up of tiny particles (molecules) that are moving. The idea that molecules have a certain kind of motion is called the ***Kinetic* Theory**. The way that the particles are arranged and the way that they move determine the properties of a material, such as its state at room temperature or it density. Therefore, the kinetic theory can explain the existence of **solid, liquid and gas** states.

- All substances can exist in any of the three states **solid, liquid or gas.** The increase in particle separation during a change of state from solid to liquid is small, whereas particle separation during change of state from liquid to gas is large. This particle separation is responsible for the main physical properties that we observe for any of the three states

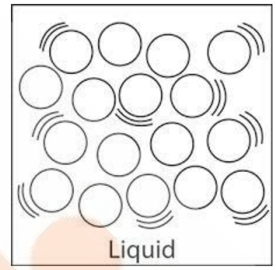
Solid



- ✓ are **tightly packed** (*dense*)
- ✓ Are held in a **fixed pattern** or crystal
- ✓ Structure by ***strong* forces** between them (have a fixed shape).
- ✓ Have **fixed volume** and are incompressible.
- ✓ **Vibrate** around their **fixed positions** within the close-packed regular structure.

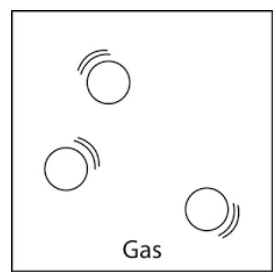
- ✓ As we **heat a solid**, the particles **vibrate** more **quickly.** The increase in the kinetic energy of the particles is noticed as an increase in the temperature of the substance.

Liquid



- ✓ Are **tightly packed** (but have **slightly smaller** densities than solids).
- ✓ Are **not held in fixed positions** but are still bound together by strong forces between them. Thus, they have a **fixed volume but not a fixed shape.**
- ✓ Take up the shape of their container (occupy the lowest part) and are almost **incompressible.**
- ✓ **Move** at **random** with close packed irregular structure.
- ✓ As we **heat** a **liquid**, the **movement** of the particles **becomes more energetic**.

Gas



- ✓ Are **very spread out** (have much smaller densities than solids and liquids)
- ✓ Have **no fixed positions** and the **forces between them are very weak.** Thus,
- ✓ Have **neither a fixed shape nor a fixed volume.**
- ✓ Can fill up all the **space** available to them and are **compressible.**
- ✓ Move with a rapid, **random** motion.
- ✓ Bump into anything in the gas or into the walls of the container, and forces caused by these **collisions are responsible for the pressure the gas exerts.**

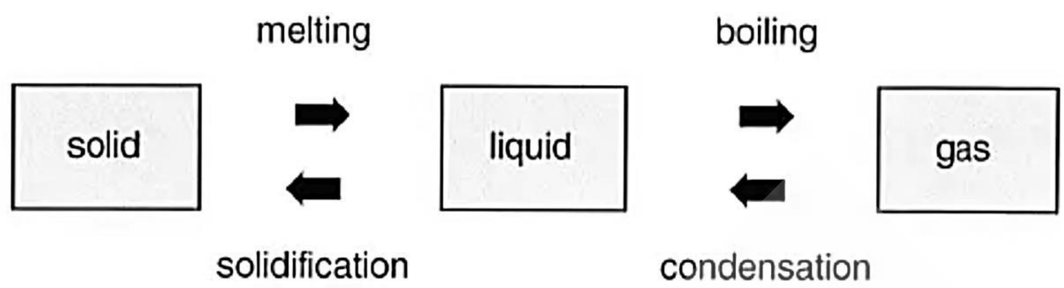
Summary of the properties of solids, liquids and gases

Property	*Solids*	*Liquids*	*Gases*
Attractive forces between molecules	Very strong attractive forces	strong attractive forces	Negligible attractive forces
Spacing between molecules	molecules are closely packed	molecules are loosely packed	Molecules are far apart
Motion of molecules	Vibrate about a fixed position	Move around while sliding past each other	Move with rapid, random motion
shape	Fixed	Not fixed, take up the shape of the container	Not fixed
Can be easily compressed	no	no	yes

Heating and change of state

When substances gain or lose energy, one of two things happens to the substance: its temperature changes ***OR*** its state changes. Putting heat energy into a solid does not necessarily increase its temperature. It may make the solid change into a liquid and similarly heat may make the liquid change into a gas.

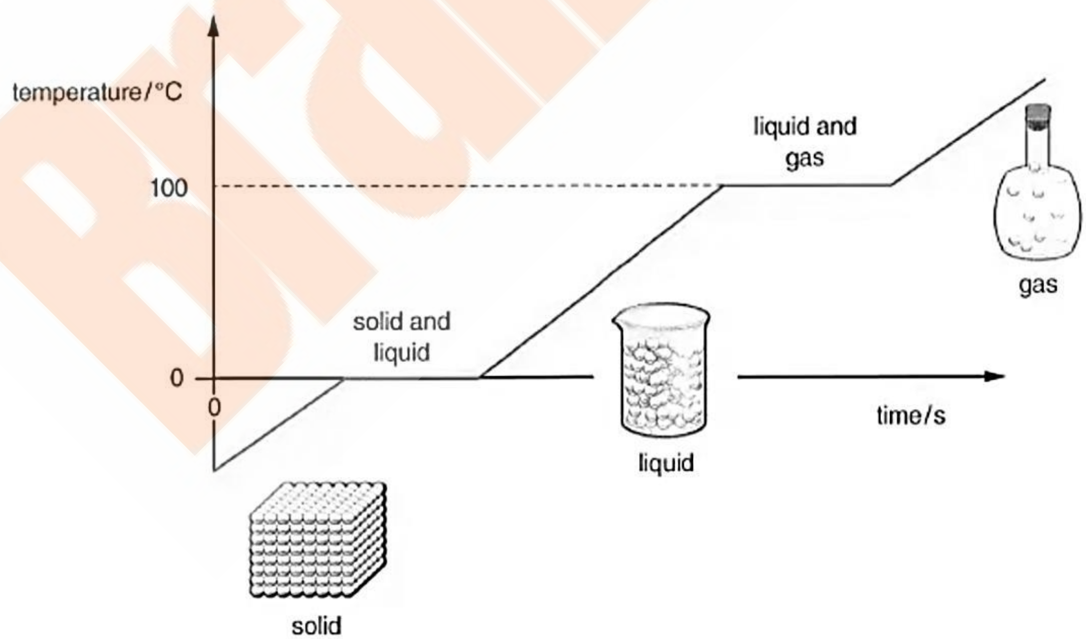
- ***Melting*** is the change of state from a solid to a liquid. The ***melting point*** of a substance is *the temperature* at which the substance changes from a solid to a liquid. Most substances have a unique melting point that can be used to identify them.
- ***Freezing*** is the reverse process of melting. It is the change of state from a liquid to a solid (sometimes called **solidification**). During freezing, some bonds are formed between the molecules and energy is released to do this.
- ***Condensation*** is the change of state from gas to liquid, during which energy is also released and bonds are formed.



Heating curve

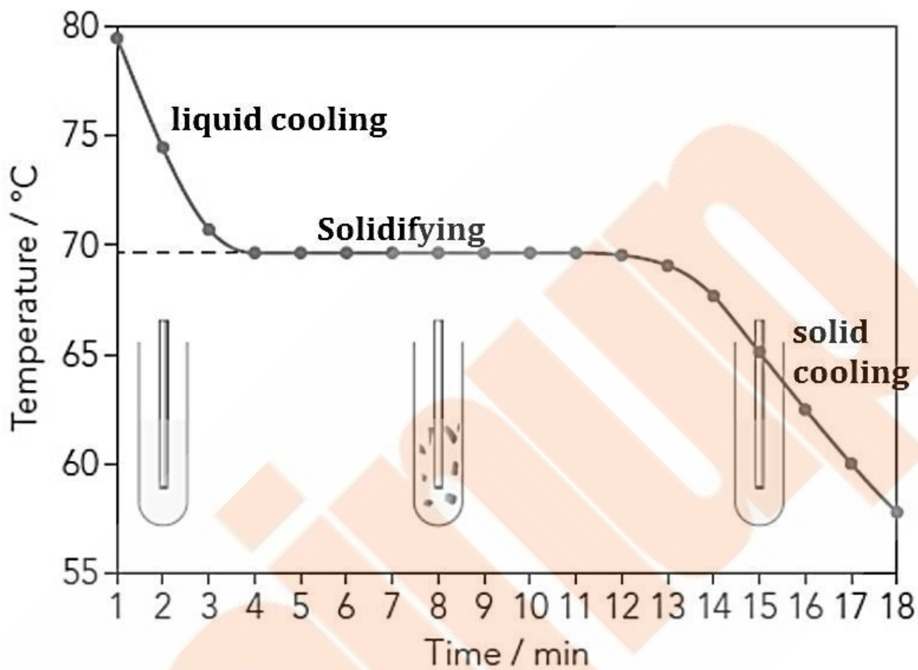
If we take an ice cube as an example, and we start heating it, the following curve is obtained (by plotting temperature against time).

- The graph is **horizontal** at two places. These are where energy is being used to **break the bonds** (against attractive force) between the particles to change the state, rather than increase the speed of the particles (and so to increase the temperature).
- The **longer the horizontal** line, the more energy has been used to cause the change of state (**boiling)**



Cooling curve

- during condensing and freezing, **internal energy decreases** as the motion of particles decreases and **new bonds** are formed **Horizontal** line Freezing (**Solidifying**)
- The more **stepper** Graph the more **rate** of **cooling**



Questions

1. Liquid oxygen can be stored in containers for transporting.

- **a) Describe the arrangement of oxygen molecules in a liquid.**
- **b) Describe two changes to this arrangement as the oxygen is released from the container as a gas**.

Answer

a) The molecules are close together, moving past each other, taking the shape of the (bottom of the) container, moving randomly, have weak forces between them holding them near to each other

b) The molecules move far apart, move faster, have no forces keeping them together, fill the container they go into or spread through the atmosphere.

2. Some ice cubes are left outside on a sunny day.

- **a) Describe the changes that take place to the molecular arrangement in the ice as it melts.**
- **b) Explain what is meant by a change of state.**
- **c) Explain why the temperature of the ice remains constant during this change of state.**

Answer

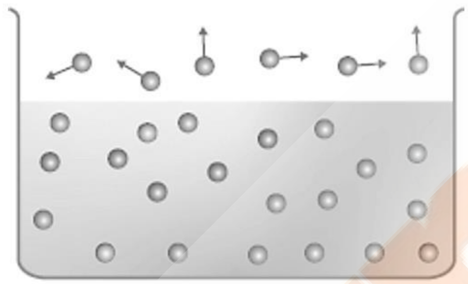
a) Ice is a solid, so to begin with the molecules are arranged in a fixed pattern and are held in place by strong forces between them. They vibrate around a fixed point, and are close together. As the ice melts, heat energy is used to break/weaken the bonds between the molecules, allowing them to move more freely with only weak forces between them. They stay close together, moving randomly.

b) A change of state occur when a substance changes between a solid, liquid or gas state. For example, the ice cube changes state from solid to liquid as it melts.

c) Normally, heating a substance increases the temperature as the K.E. of the molecules increases. During a change of state, the heat energy supplied is used to break or weaken the bonds between the molecules with no increase in K.E., and therefore no change in temperature.

Evaporation

Is the escape of **more energetic molecule** from the **surface** of liquid, these molecule will be able to overcome the intermolecular force with neighbor molecule and escape so **reaming molecule** of liquid has **less** kinetic **energy** and **cool**



Evaporation	Boiling
Surface molecule only	Whole the liquid
Any Temperature	Specific Temperature
No Bubbles	Bubbles

Factors affecting Evaporation

1. Temperature (Heat) as it increases, the rate of evaporation increases. This is because the molecules move faster, so more of them have enough energy to escape from the liquid within the same time.

2. Surface area as it increases, the rate of evaporation increases. As this gives the faster molecules a greater chance of escaping

3. Air currents over the surface of the liquid as it increases

(Increase **draught**) the rate of evaporation increases. When air moves across a liquid surface, it carries away molecules escaping from the liquid and reduces their chances of returning to it.

4. Humidity as it increases, the rate of evaporation decreases. Otherwise, Molecules escaping from a liquid have lower chances of returning to it if the humidity is low.

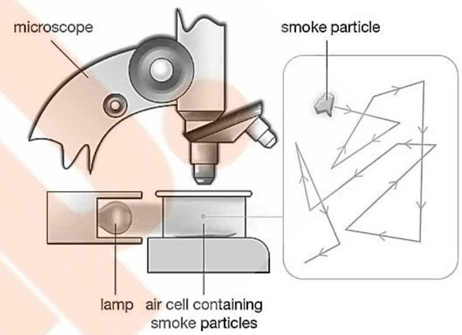
- ✓ During evaporation, the liquid loses its most energetic molecules, leaving behind the less energetic ones. Therefore, the average kinetic energy of the remaining molecules decreases, accordingly, the liquid's temperature decreases. This explains the cooling of a body in contact with an evaporating liquid. This is known as ***cooling effect due to evaporation.***

Brownian motion

Is an evidence for the continual motion of particles in a ***liquid*** or a ***gas***

It shows that massive particles may be moved by light, fast moving particles

Procedure



1. Fill the smoke cell (or glass cell) with smoke.
2. Replace the lid on the cell and set it on the microscope platform.
3. Switch on the lamp; focus the light on the smoke.

Observation

Finding bright specks of light **moving** about in a **random**

Conclusion

The air molecules are: **very tiny**, **moving randomly** about and their motion is **much faster** than that of the smoke particles.

Explanation

The smoke particle in air is being **hit** by air particle from **all direction** (as air has kinetic energy) so smoke particle move in **random** straight line

✓ The same experiment can be carried out by **sprinkling some pollen grains in water** and observing the motion of the pollen grains.

Pressure by Gas

- All moving particles have kinetic energy and momentum Gas molecules have large energies (because they are moving very fast).

- The average **kinetic energy** is related to the **temperature** of the gas. Increasing the temperature of a gas increases the average kinetic energy of particles within that gas and they move **faster**.

- The gas particles **exert a force on the walls** of a container when they collide with it. The pressure exerted by the gas particles is the **force per unit area**. The **total pressure** of the gas is the effect of the **sum** of all the collisions with the wall.

- When the molecules collide with the walls of the container they **change direction** and **bounce back**. This means that the **velocity** (a vector quantity) has **changed**. If the velocity changes**, the momentum changes**.

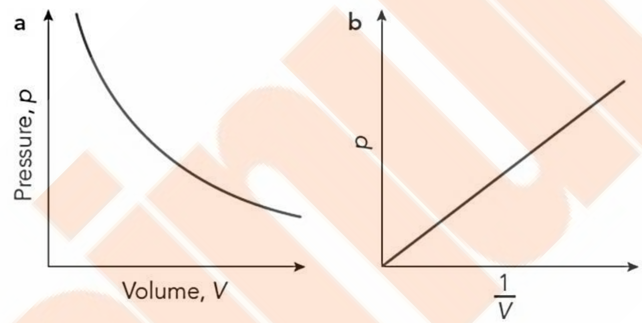
- **The force is larger** if the particles are **moving faster** (because the change in momentum is greater) or if there are more particles colliding with the walls per second.

- A **higher temperature** gases **more collisions** in a given time and causes the collisions to be **harder** because the particles are moving faster. Consequently, a higher temperature causes a **larger pressure**.

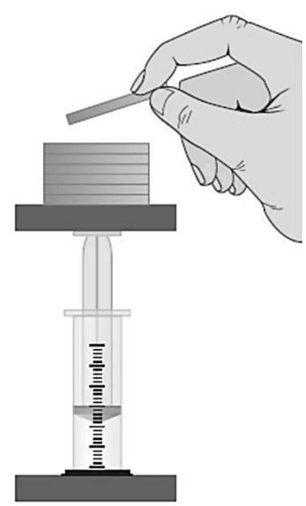
Boyles's Law

Boyle's Law states that

- For a fixed mass of gas at constant temperature, the **pressure is inversely proportional to the volume.**
- This means that for a fixed mass of gas at **constant temperature**, the pressure multiplied by the volume is constant $p \times V =$ constant
- When the pressure increases, the volume decreases and vice versa, as shown in the graph below.



- By add mass on piston the **pressure increases** because the gas molecules are squeezed into a smaller space **volume decrease** Therefore there are **more collisions** per second between the molecules and the container walls. The **more frequent collisions** cause a **larger force** on the walls and hence a larger pressure.



- pressure and volume are related by equation

  $p_1 v_1 = p_2 v_2$

Questions

1. An aerosol can contain a fluid under pressure. Explain why it is dangerous to expose the can to high temperatures.

Answer

If you increase the temperature, the **pressure inside the can increases** further. This could cause the can to break open or even explode in high temperatures.

2. A diver is deep under the sea. When divers breathe out, they release bubbles of gas which rises to the surface. Explain what happens to:

- **a) The pressure in the water surrounding a bubble as it rises to the surface.**
- **b) The volume of a bubble as it rises to the surface.**

Answer

a) The pressure in water depends on the height (h) of water above that point due to the formula $P = \rho g h$.
Therefore as a bubble rises, h decreases, and so the **pressure decreases**.

b) If the pressure of the water decreases as a bubble rises, then the pressure on the gas bubble also decreases. If the pressure decreases, the **volume increases.**

3. A syringe contains 10 cm^3 of air at a pressure of 100 kPa.

- **a) Calculate the new pressure in the syringe when the gas is compressed to a volume of 4 cm^3.**
- **b) State one condition required for the calculation above to be true.**

Answer

a) $P_1 \times V_1 = P_2 \times V_2$

Substituting in values for the initial volume (10 cm^3) and pressure (100 000 Pa), and the final volume (4 cm^3) gives:

$100\,000 \times 10 = P_2 \times 4$

$$P_2 = \frac{1\,000\,000}{4}$$

So the final pressure **P_2 = 250 000 Pa**

b) This formula only applies if the temperature or mass of gas remains constant.

4. A diver descends to a depth of 40 m, breathing air that is at a pressure of 500 kPa. The diver's lungs have a total volume of 0.006 m^3.

a) Calculate the volume the air in the diver's lungs would occupy at the surface, where the pressure is only 100 kPa.

b) Suggest why it is dangerous for divers to hold their breath whilst swimming upwards to the surface.

Answer

a) $P_1 \times V_1 = P_2 \times V_2$

Then substituting in values for the initial and final values gives

$500\ 000 \times 0.006 = 100\ 000 \times V_2$

$$V_2 = \frac{500\ 000 \times 0.006}{100\ 000}$$

So the final volume of air at the surface will be $\mathbf{V_2 = 0.03\ m^3}$.

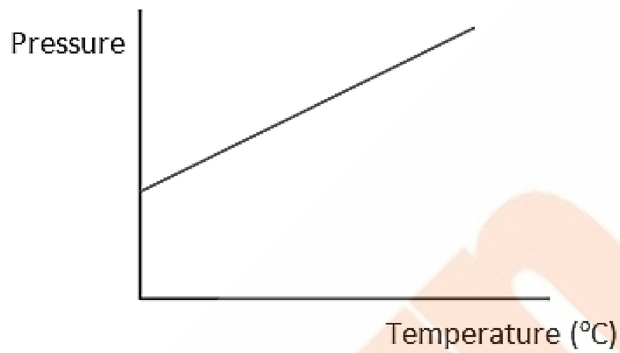
b) This volume is 5 times larger than the volume of the lungs. The diver is in danger of causing **damage to his /her lungs** or even rupturing them, as the air expands outwards.

Temperature and pressure

- The pressure of a fixed volume of gas is related to its temperature. As the **temperature increases**, so does the pressure. When the temperature of a gas is **increased the internal energy** of its molecules increases. The molecules **move faster** because the average kinetic energy of the molecules increases.

- The pressure of the gas is determined by the **force of the particles** colliding with the walls of the container and by the **rate of collision.** As the temperature increases, the force increases and so the **pressure** of a gas **increases** with temperature.

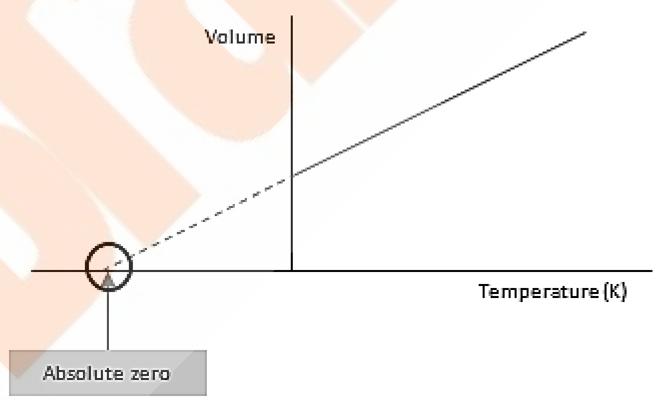
- As the volume of the container is kept constant, there will also be more **molecules hitting the walls** of the container every second and so the **pressure is increased**



Decreasing temperature and pressure

When the **temperature** of a gas is **decreased** the average kinetic energy of the particles decreases. The temperature at which **particles** can be considered to be **stationary** is **called absolute zero** this corresponds to a temperature of **-273°**

The **zero** of the **Kelvin** scale is **absolute zero**, the lowest possible temperature



= °C+273

Questions

1. Scientists are studying the conditions found on the planet Mars.

- **a) One block of frozen CO_2 is at a temperature of 150 K. What is this temperature in degrees Celsius?**
- **b) Surface rocks can get as warm as 20 ^{0}C in the day time. What is this temperature in Kelvin?**

Answer

a) The temperature will be 150 K - 273 = **-123 ^{0}C**

b) The temperature will be 20 ^{0}C +273 = **293 K**

Thermal Expansion

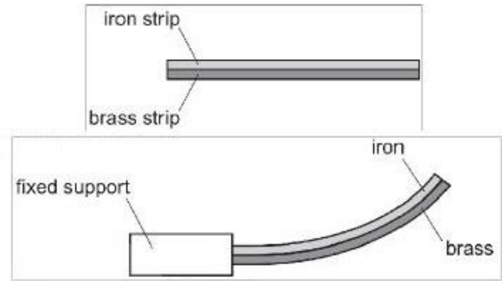
When matter is **heated**, it **expands** (**volume increases**). When it is **cooled, it contracts**. Higher temperatures of a substance mean **greater speed** of molecules and **bigger vibrations**. Accordingly, spacing between molecules increases causing ***expansion***.

a) Expansion in solids

When a **solid** is heated, its atoms vibrate faster about their fixed points. The relative increase in the size

- For **railway tracks** Gaps are left between lengths of rail to allow for expansion in summer.
- For **cables**: provide sagging between telephone poles to allow for contraction of cables.

- **Bimetallic strips**: Strips of iron and copper or brass , brass expands more than the Iron. It is mostly used in fire alarm and thermostat (metal).



b) Expansion in Liquid

Liquids expand for the same reason, but because the **bonds between separate molecules** are usually less tight they **expand more than solids**. This is the principle behind liquid-in-glass thermometers. An increase in temperature results in the expansion of the liquid which means it rises up the glass

c) Expansion in gas

Molecules within **gases** are further apart and weakly attracted to each other. Heat causes the molecules to move faster,

"Expansion of a gas more than the volume of liquid and, liquid is more than solid "

Specific heat capacity

By increasing **temperature** the **internal energy** of substance increase, as temperature increase **kinetic energy of molecule** increase

Specific heat capacity (c)

It is the amount of energy needed to raise the temperature of *1 kg* of a substance by 1 ºC It is measured in ***J/kgºC***

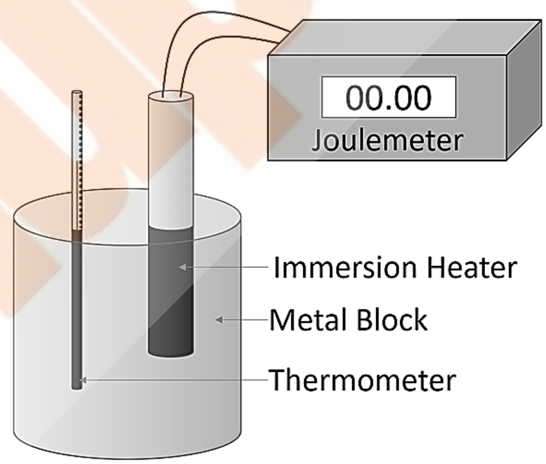
When there is ***no change of state,*** the heat lost or gained by an object can be calculated

$$= \quad \Delta$$

Where

- ✓ ***E*** is the quantity of heat energy, measured in J. note that heat energy supplied by an electric heater is given by: = ×
- ✓ m is the mass of the object in g or kg
- ✓ ***c*** is the specific heat capacity of the material in J/kgºC or J/kgK.
- ✓ ***ΔT*** is the change in temperature in ºC or K since as the change in temperature of 1 ºC equals the change in temperature of 1 K and is always expressed as (Tf - Ti).

Finding specific heat capacities (solid)



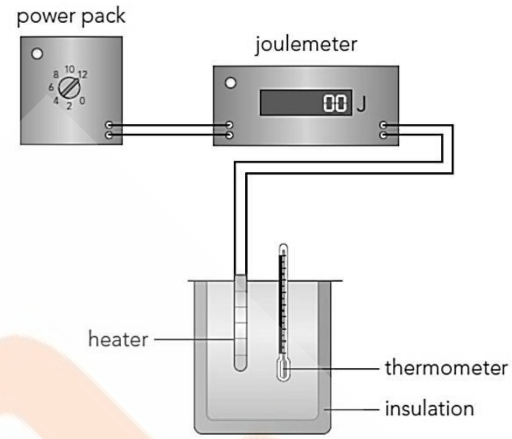
1. Record the power of the electric heater.
2. Find the mass (m) of the aluminum block (1kg)
3. Using a thermometer, measure and record the initial temperature of water (Ti) before switching on the heater.
4. Start the stop watch as you switch on the heater.
5. After a certain time, switch off the heater, record the time (t) on the stop watch and record the final temperature (Tf).
   - ✓ ***if the temperature rise is too large then too much heat will be lost.***
6. Calculate the temperature rise Δ = − and the quantity of energy supplied as heat
7. The specific heat capacity can be calculated using the following formula

c = ———

Improvement

- ✓ put ***insulating*** material around the aluminum block (to ***reduce heat lost***)
- ✓ put ***oil in the gap*** of the aluminum block (to ***ensure thermal conduct*** between aluminum and thermometer)

Finding specific heat capacities (liquid)



1. put 0.25 kg of water into beaker
2. setup the experiments as shown in figure
3. measure and record the initial temperature(Ti) of the block
4. turn on power supply and leave until the temperature change by about 50 C°
5. turn off power supply record final temperature (Tf)
6. calculate the change in temperature Δ = −
7. record joule meter reading and calculate specific heat capacity by equation

$$c = \frac{\quad}{\quad}$$

Questions

1. A kettle is filled with 2.5 kg of water of S.H.C. 4180 J/kg ^{0}C. Calculate the energy needed to heat the water from a room temperature of 25 ^{0}C to the boiling point at 100 ^{0}C .

<u>Answer</u>

ΔQ = m x c x ΔT

ΔQ = 2.5 x 4180 x (100-25)

ΔQ = 784 000 J (784 kJ)

2. An investigation is carried out to find the S.H.C. of a 1 kg copper block. The block increases from 22 ^{0}C to 61 ^{0}C with 16 400 J of heat energy transferred.

- **a) Show that the S.H.C. of copper is about 400 J/kg ^{0}C**

- **b) The heating element has a power output of 48 W. Calculate the time it takes to heat the copper to 61 ^{0}C.**

Answer

a) ΔT is 61-22 = 39 ^{0}C. Rearranging the formula for S.H.C. gives

$$c = \frac{\Delta Q}{m \times \Delta T} \qquad c = \frac{16\ 400}{1 \times 39}$$

c= 421 J/kg ^{0}C

b) we know that power and energy /work are related by the formula

$$t = \frac{W}{P} \qquad t = \frac{16\ 400}{48} \qquad t = 341 \text{ seconds}$$

3. Ice cubes of mass 60 g are placed into a glass of 300 g of water. The ice is initially at -18 ^{0}C and warms up to -1 ^{0}C over a period of 4 minutes. Ice has a S.H.C. of 2110 J/kg ^{0}C.

- **a) Calculate the heat energy gained by the ice during this time.**
- **b) Calculate the temperature drop of the water as heat energy is transferred to the ice. The S.H.C. of water is 4180 J/kg ^{0}C.**
- **C) Suggest one reason why the answer in (b) may be unrealistic and incorrect.**

Answer

a) ΔQ = m x c x ΔT, and m= 60 g = 0.06 kg

Therefore for the ice,

ΔQ = 0.06 x 2110 x 17= 2150 J

b) The heat energy to warm the ice comes from the surrounding water. Therefore the water cools, losing the same quantity of heat energy.
As $\Delta Q = m \times c \times \Delta T$, then using m = 0.3 kg gives

$$\Delta T = \frac{\Delta Q}{m \times c} \qquad \Delta T = \frac{2150}{0.3 \times 4180}$$

$\Delta T = 1.71\ ^0c$

c) The water may not cool by 1.71 ^{0}C due to any of the following:
Glass cools down as well / heat gain or loss due to surroundings / some ice may melt / ice may not cool by the same temperature drop across the cubes

Heat / Thermal Energy Transfer

Thermal or heat energy is a form of energy possessed by **hot** matter. Hot***, Thermal energy travels from a body/place that is hotter (at a higher temperature) to a body/place that is colder (at a lower temperature).*** Thus, the cold object warms up by receiving heat energy and the hot object cools down by losing heat energy till ***thermal equilibrium*** takes place.
The transfer of thermal energy between bodies/places that have different temperatures can occur in three ways ***conduction, convection and radiation.***

Conduction

Thermal conduction is the transfer of thermal (heat) energy through a substance ***without the substance itself moving.***

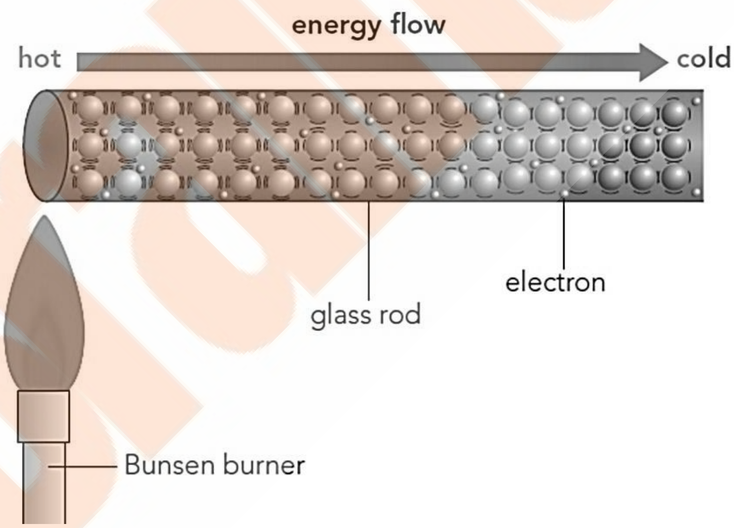
*There are **2 methods** by which **conduction** can take place*

1) Collisions between neighboring particles

When heat is applied to a substance, the kinetic energy of its atoms increases so their vibrations get bigger. **The vibrating atoms bump into neighboring atoms and pass on their kinetic energy**. These atoms then pass on their kinetic energy to atoms close to them and so on. In such way, the heat energy moves through the substance. Conduction takes place in solids, liquids and gases, but it works best in solids as their molecules are closer together.

2) Flow of free electrons (for heat conductors only)

Metals are the best solids for conducting heat since they have **free moving electrons**. When a metal is heated these free electrons gain kinetic energy and move towards the other cooler parts of the metal, accordingly, spreading the energy to these cooler parts. This process is fast and that's why all **metals are good conductors** of heat.

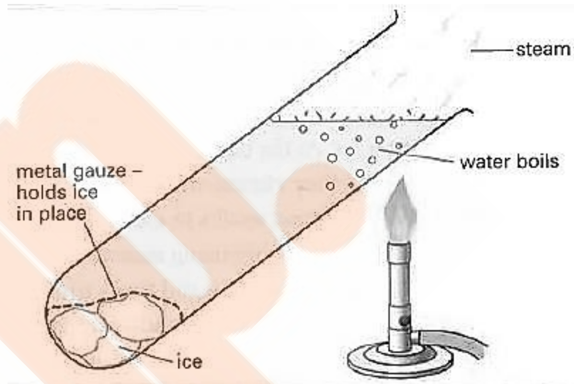


- ✓ Conduction in **solids** is better than in liquids than in gases.
- ✓ Liquids (water) and gases (air) are **poor conductors** as the spacing between their molecules is much greater than in solids.
- ✓ All **Metals** are good conductors of heat due to presence of **free electron**
- ✓ **Vacuum** does not conduct heat, as there are no molecules in vacuum to pass the kinetic energy on.

✓ During heat transfer by conduction, the **molecules do not change their positions** within the substance.

Poor Conductors

- They **do not possess free moving electrons**. When such substances are heated, the kinetic energy of the molecules increases and they move faster and bump into their neighboring molecules giving them part of their kinetic energy. Here, **this is a much slower process**, that's why these substances are **called poor conductors or insulators of heat.**

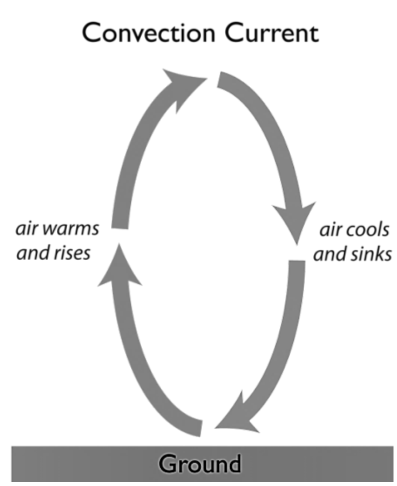


- Generally, **most non-metal solids, almost all liquids** (except mercury) and gases are **poor conductors of heat.**
  ✓ This figure shows that water is a poor conductor of heat.

Convection

Convection is the transfer of heat through fluids (**liquids** and **gases**) by the upward movement of warmer, less dense regions of fluid.

- When a mass of liquid (or gas) is heated, the ***heated liquid expands and become less dense*** than the colder surrounding liquid so it ***floats up to the top of the container***. ***Colder liquid sinks*** to take its place, and is then heated too. At the top, the warm liquid starts to cool, becomes denser again and will begin to sink, so a circulating current is set up in the liquid. This is called ***convection current***



- ✓ Convection **cannot** occur in **solids** as the molecules are not free to move about within the solid structure.
- ✓ Convection **cannot** occur in **vacuum** as there are no molecules to transfer heat by convection.
- ✓ Convection **cannot** occur if the **fluid** is heated at the top rather than at the bottom. The warmer, less dense fluid simply stays at the top.

Why heat transfer by convection is possible in liquids and gases?

Because the molecules of **liquids** or **gases** are free to **move around** so they can transfer the heat through **convection currents**.

Radiation

Thermal radiation is the transfer of energy by **infra-red (IR)** waves unlike conduction and convection (both need matter to occur), radiation can occur in **vacuum**. In radiation, heat energy is transferred by infra-red waves – one of the **electromagnetic spectrum**. Radiation is emitted by all objects in all directions, at the speed of light (3×10^8 m/s). The amount of radiation emitted depends on the

1. **Surface temperature**
2. **Surface area of the body**

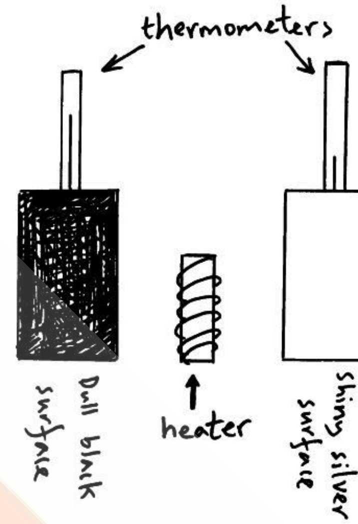
- ✓ Highly polished **silvered** shiny **light colored** surfaces are good reflectors of thermal radiation

(Are poor emitters and poor absorbers)

- ✓ **Dull matt black** and **dark** surfaces are poor reflectors of heat radiation

(Are good emitters and good absorbers)

Experiment *Good and bad absorbers of radiation*



1. Two flasks are used, one covered with dull (matt) black paint and the other with shiny white paint.

2. Both flasks contain the same amount of water, at the same Temperature and are placed at equal distances from a radiant heater.

Results

The temperature of the water in the flask with the dull black surface is found to rise significantly more than the flask with the light shiny surface.

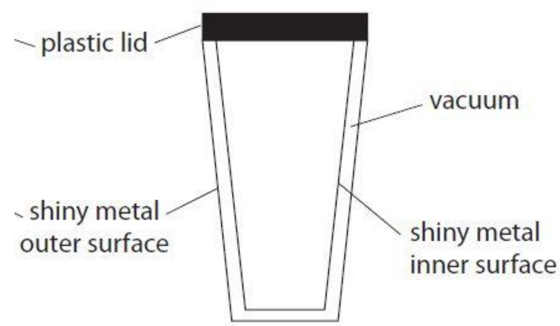
Conclusion

Dull dark matt surfaces are the best absorbers; shiny mirror-like surfaces are the poorest.

Applications on Heat Transfer

1) Vacuum flask

A vacuum flask has several features to reduce flow of thermal energy, and will keep liquids hot (or cold) for several hours.



- Transfer by **conduction** is minimized by making the flask **double-walled glass vessel with vacuum** between the walls.
- Heat loss by **convection** and evaporation is reduced by using a **stopper**.
- **Radiation** is reduced by **silvering** both walls on the **vacuum** side.

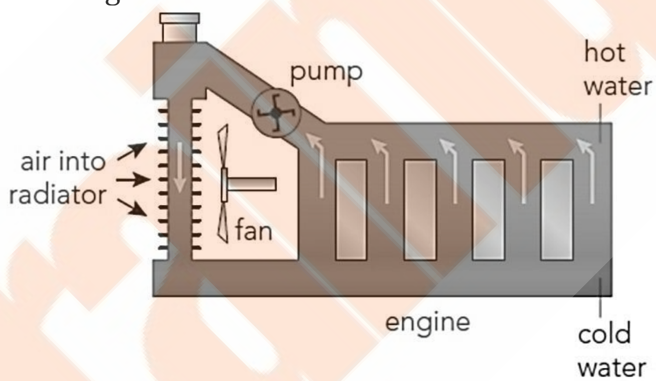
2) Windows are double or triple glazed

Two or three layers of glass with **vacuum** in between or with a moderate layer of air trapped in-between this reduces heat loss by conduction, convection and not radiation

3) Car radiator cools the engine

In a car radiator, the **coolant liquid** flows through the tubes inside combustion engine and absorb the engine's heat and in-turn gets heated itself

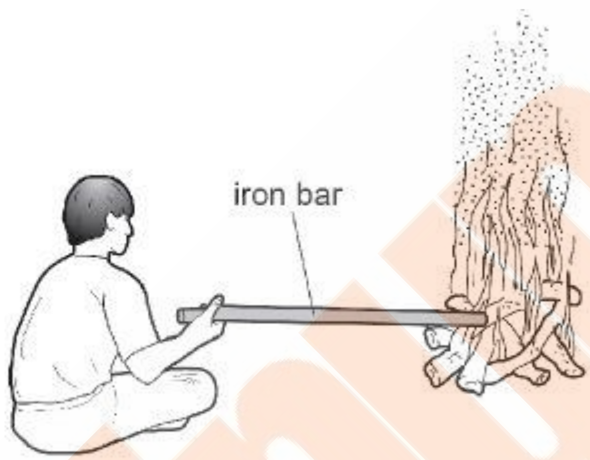
The heated fluid then makes its way through a rubber hose to the radiator in the front of the car. As it flows through the thin tubes in the radiator, the hot liquid is cooled by the air stream entering the engine compartment from the grill in front of the car. Once the fluid is cooled, it returns to the engine to absorb more heat.



The air picks up heat from the coolant by **convection** process, heated air is blown away by the fan, and colder air replaces it.

4) A fire burning wood or coal

When coal or wood is **burnt** the chemical combustion releases **infra-red radiation**, in addition the air close to fire heat and rises so thermal energy transfer to surrounding by **convection**, energy transfer by **conduction** to object in contact with burning fuel



3-Waves

Waves

Waves are a means of transferring ***energy*** from one place to another through ***vibrations*** without transferring matter

Types of waves

1) Mechanical waves

These are waves that require a ***medium*** to travel through; they ***cannot travel through vacuum***.

Sound waves ripple waves and slinky spring waves. These waves are either: transverse or longitudinal.

2) Electromagnetic waves

These are waves that do not require a medium to travel through and ***can travel through vacuum***.

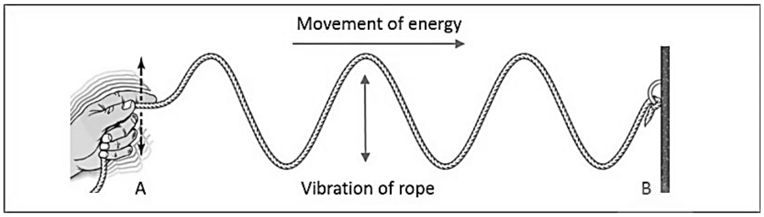
Radio waves, X-rays, infrared waves… ***All electromagnetic waves are transverse.***

- ✓ Waves can be classified according to how the particles vibrate relative to the direction of wave propagation into two categories ***transverse or longitudinal***

1) Transverse waves

A transverse wave is one that vibrates or ***oscillates*** at ***right angles (perpendicular)*** to the direction in which the energy or wave is moving light waves and waves travelling on the surface of water.

- ✓ This can be shown by a slinky spring: give one end a quick wiggle at right angles to the spring the coils of the slinky are vibrating up and down "across" the direction

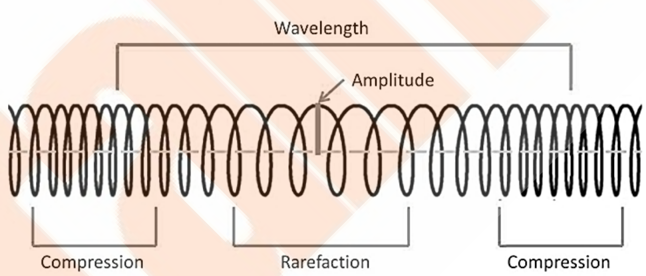


2) Longitudinal waves

A longitudinal wave is one in which the vibrations or ***oscillations*** are ***along (parallel to)*** the direction in which the energy or wave is moving, sound waves.

Longitudinal waves are recognized by their ***compressions*** and ***rarefactions***.

✓ This can be shown by a slinky spring: push and pull the end of a slinky in a direction parallel to its axis the coils of the slinky are vibrating in the directions that are along its length.



Questions

1. A wave produced on a long rope is a transverse wave.

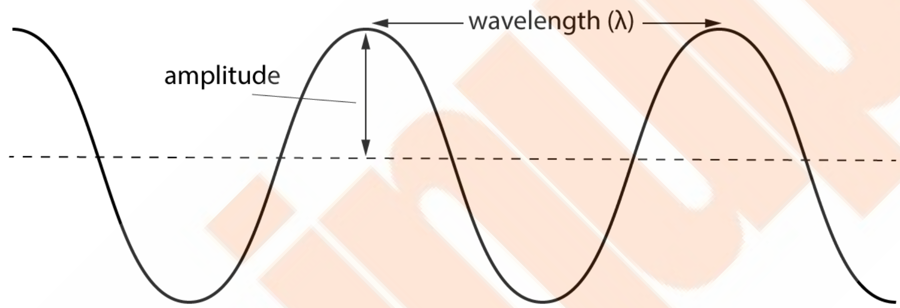
- **a) Explain what is meant by a transverse wave.**
- **b) Give one other example of a transverse wave.**
- **c) Give one example of a longitudinal wave.**

Answer

a) A transverse wave is where the particles/disturbance moves at 90^0 - perpendicularly - to the wave motion.

b) Water (surface) waves, Light (or any electromagnetic wave) are all transverse waves.

c) Sound is the most common example of a longitudinal wave.



Wave properties

Amplitude (A)

The amplitude '*A*' is the maximum height of wave from rest position

Wavelength (λ)

The wavelength of a wave, represented by the Greek letter λ (lambda), is the distance between the two successive points (crests or troughs).

Frequency (f)

The frequency *f* is the number of complete waves generated per second. The unit of frequency is 'cycle per second' or hertz (Hz). Where 1 Hz = 1 wave/second

Time period (T)

It is the time taken for a wave to complete one cycle or one wave.

The frequency and the period are related by the following equation

$$= -$$

Questions

1. Ocean waves hit a wall in a harbor at a rate of 12 waves per minute. What is the frequency of these waves?

Answer

If there are 12 waves per minute, then we have 12 waves per 60 seconds.
The frequency is defined as the number of waves per second, so we need to divide 12 by 60

$$\text{frequency} = \frac{12}{60}$$

Frequency = 0.2 Hz (hertz)

2. A guitar string produces a sound of frequency 1.2 kHz. What is the time period of this wave?

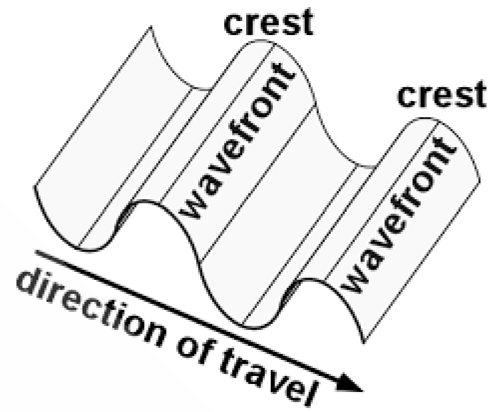
Answer

1.2 kHz is equal to 1200 Hz. using the formula above, the time period is therefore:

$$\text{time period} = \frac{1}{1200}$$

Time period = 0.000833 s

Wave fronts



The wave front can generally be thought of as continuous line, perpendicular to direction of propagation, like view sea waves from top of cliff (Straight lines and can be thought as the crests or troughs of the waves)

Wave equation

The higher the frequency (*f*) of a wave the smaller its wavelength (λ) It is true for all types of waves and the relation between them is called wave equation which is

Speed of wave = wave length x frequency

$$v = f \times \lambda$$

Questions

1. Sound waves have a velocity of 340 m/s in air. A car horn in a stationary car makes a sound of frequency 500 Hz.

- **a) Calculate the wavelength of the sound produced.**
- **b) Describe how the frequency of the sound changes if the car moves quickly away from the observer.**

<u>**Answer**</u>

a) We know that $v = f \times \lambda$, so the wavelength λ is

$$\lambda = \frac{v}{f} \qquad \lambda = \frac{340}{500}$$

λ = 0.68 m

b) As the car moves away from the observer, **the frequency decreases** (because the pitch we hear is lower).

Behavior of waves

1) Reflection

Change in direction of wave when it meets a hard boundary (mirror)

Law of reflection

"The angle of incidence is equal to the angle of reflection"

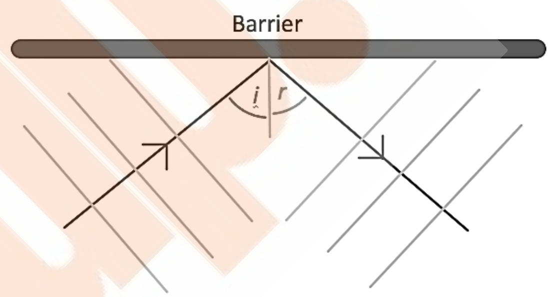
$$i = r$$

Where

The angle of incidence (i) is the angle between the incident ray and the normal.

The angle of reflection (r) is the angle between the reflected ray and the normal.

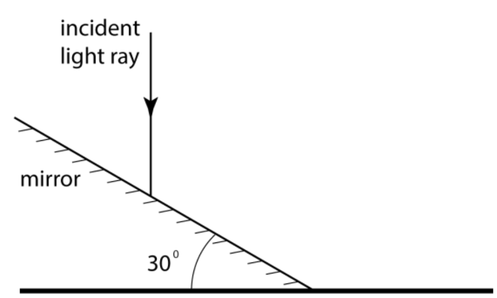
The normal is a line drawn at right angles to the surface.



✓ When a wave is reflected, it is still in the same medium so its speed doesn't change. Accordingly, its wavelength doesn't change.

Questions

1. The diagram below shows a mirror angled at 30^0 to a flat table. A ray of light is directed vertically down onto the mirror as shown here:



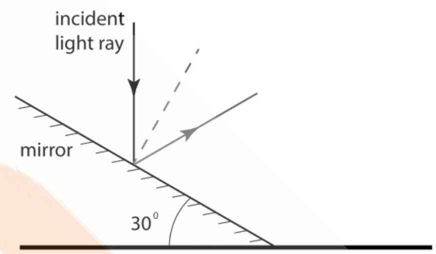
On the diagram shown above

- **a) Draw a normal line to the mirror at the point where ray hits the mirror.**
- **b) Draw the reflected ray.**

- **c) Measure or calculate the angle between the incident and reflected ray.**

Answer

a) The normal line should be (approximately) perpendicular to the mirror.



b) The reflected ray should be above the horizontal. It should be drawn so that the normal line is (approximately) in the center of incident and reflected ray.

c) The angle between the incident and reflected rays should be 60^0. This can be measured, or you could calculate it by extending the normal line

Reflection of light

When light reflects from a plane mirror, the angle of incidence ***(i)*** is equal to the angle of reflection ***(r)***; the law of reflection is applied.
This figure shows how an image is formed behind a plane mirror. Two rays from any point on the object are sufficient to establish the position of the image of that point.

Properties of the formed image

1. The image is ***virtual*** it is formed by the extension of the real (reflected) rays.

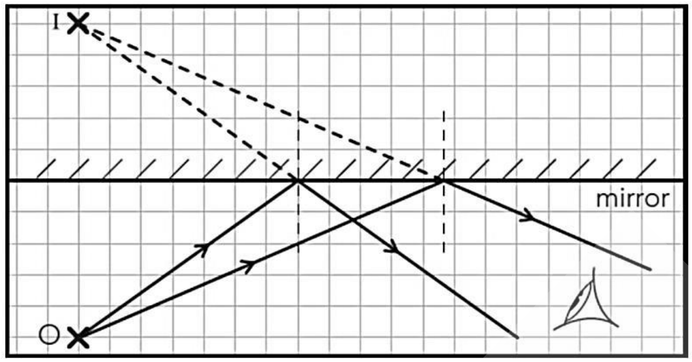
✓ ***Solid lines*** represent ***real*** rays whereas ***dashed lines*** represent ***virtual*** rays.

2. The formed image has the ***same size*** as the object.

3. The image is **as far behind the mirror as the object** is in front (same distance)

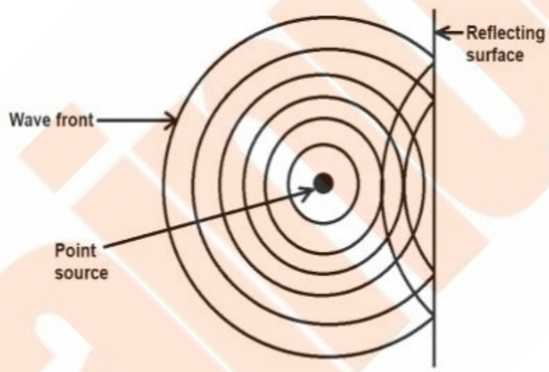
4. It is ***laterally inverted***.

5. It is ***upright***.



Circular waves (reflection)

The reflected waves are also circular and appear to come from a corresponding image point at the same distance behind the reflector as the point source is in front of it.



2) Refraction

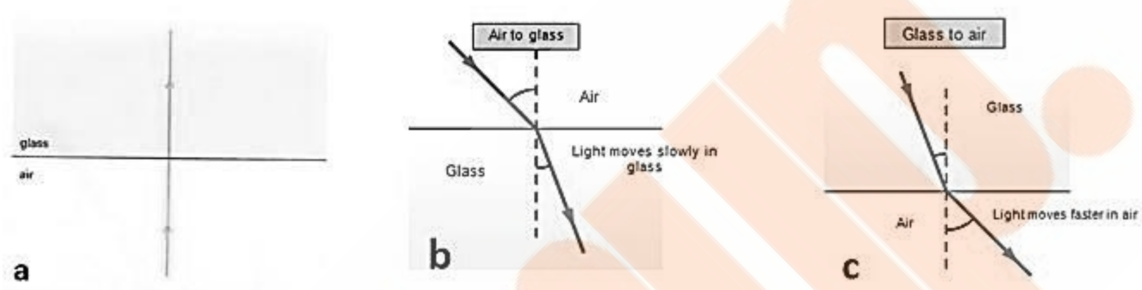
is the ***change*** in both speed and wavelength of a wave as it ***travels from one medium to another*** or the bending of a wave due to change in its speed as it moves from one medium to another.

Remember this

a) If the ***incident ray is lying along the normal*** (the ray is perpendicular to the boundary or the angle of incidence = zero), then ***no bending occurs***.

b) If the wave comes from a ***less dense medium to a more dense medium***, then its ***speed decreases*** and it ***bends towards the normal*** (i>r).

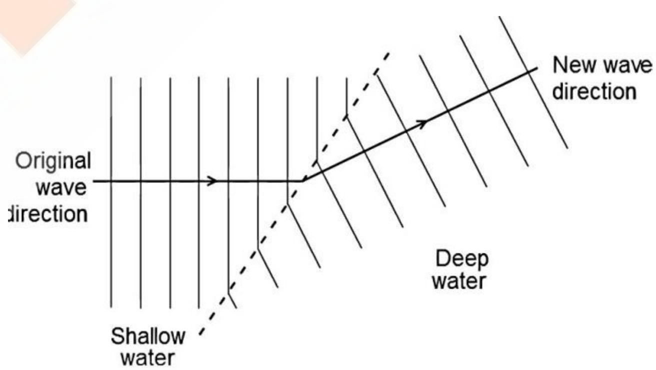
c) If the wave comes from a ***more dense medium to a less dense medium***, then its ***speed increases*** and it ***bends away from the normal*** (i<r).



Where,

i is the ***angle of incidence*** (the angle between the ray incident to the boundary and the normal) and ***r*** is the ***angle of refraction*** (the angle between the refracted ray and the normal).

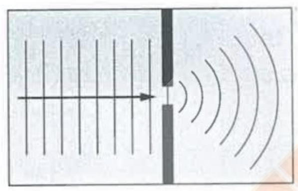
- ✓ When water waves pass across a boundary, from ***deep water (less density)*** to ***shallow water (more Density)*** they move slower in the shallow water



3) Diffraction

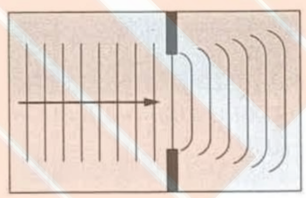
Is the ***spreading out*** of waves as they travel through a ***gap*** or round a corner

- If the waves pass through ***a narrow gap*** which is ***equal*** to or ***smaller*** than the wavelength of the wave, then there are waves to the left and right of the gap ***"complete diffraction"***.



small gap

- If waves pass through ***a large gap***, the majority of the waves passing through the gap continue in straight line ***"small/partial diffraction"***.



large gap

✓ The ***narrower the gap***, the more the waves spread out ***" more diffraction"***

✓ In all diffraction cases, ***the wavelength and frequency do not change***. Accordingly, the speed does not change.

Summary

	reflection	refraction	diffraction
speed	Stays the same	Increase/ decrease	Stays the same
wavelength	Stays the same	Increase/ decrease	Stays the same
Frequency	Stays the same	Stays the same	Stays the same

Refractive index

- ✓ It is a ratio that has no unit

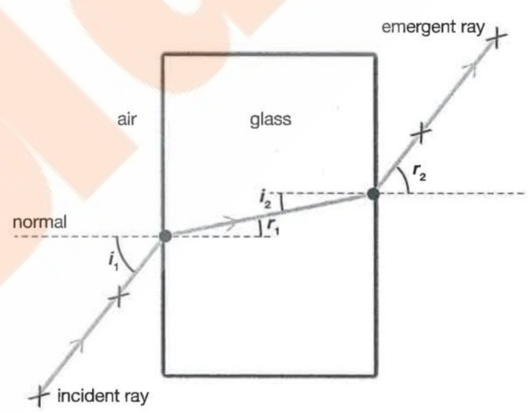
Refractive index = ——

= ————————

= ——————————————

- ✓ Speed of light (3×10^8 m/s).

Experiment to show refraction of light



1-Place a transparent block in the middle of a plain sheet of paper; trace around the block in pencil.

2-Position a ray box so that the light from it strikes the glass block at an angle.

3-Mark the positions where the light meets the glass boundary and where it leaves the glass boundary with dots

4-Mark two crosses (or place optical pins) on the paper along the incident ray and the emergent ray approximately 5cm apart.

5-Remove the glass block and switch off the ray box.

6-Using a ruler, complete the lines between the dots and the crosses.

7-Draw in the normal at 90° to where the light strikes the glass boundary.

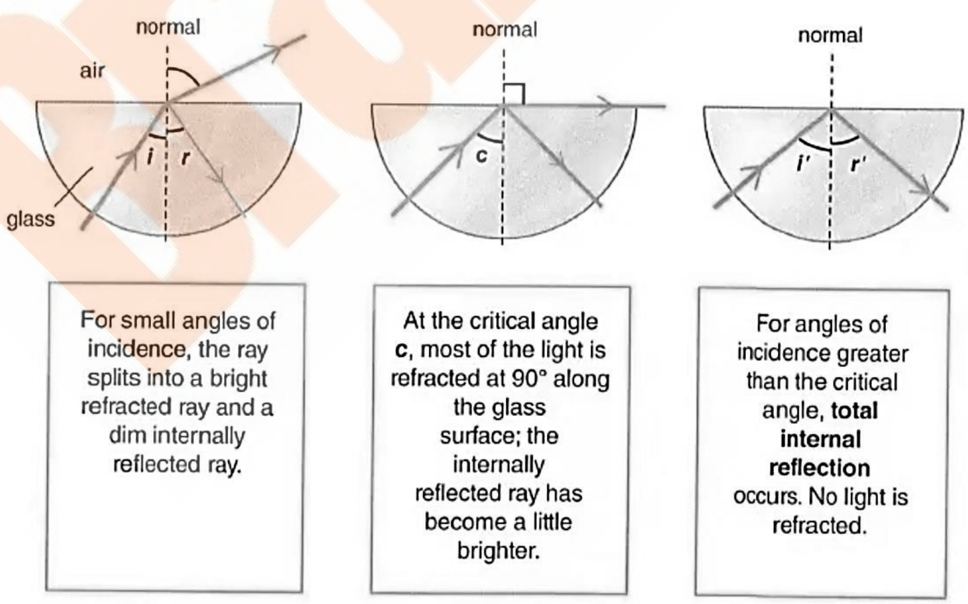
8-Draw the second normal where the light leaves the glass boundary, again at 90°.

9- Using a protractor, measure the angles of incidence and refraction as shown on the diagram above.

Critical angle

Waves going from a ***dense medium to a less dense medium*** speed up at the boundary between them. This causes light rays to bend when they pass from glass to air at an angle other than 90°. This is refraction.

Beyond a ***certain angle***, called the ***critical angle***, all the waves **reflect back** into the glass. We say that they are ***totally internally reflected***

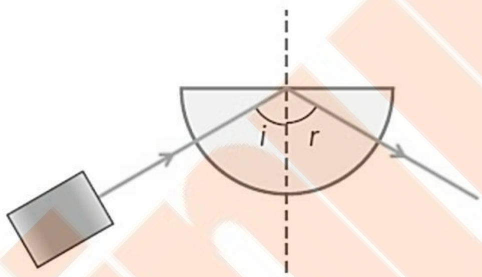


- ✓ **critical angle** (I = c) is the incident angle when the refracted ray at the top of the prism

$$n = \underline{\qquad}$$

Total internal reflection

If the angle of incidence " **I** " is more than critical angle ***"c"*** (i>c) all the light is ***reflected*** back at the boundary and no light is refracted. The ray experiences ***"total internal reflection"***, this takes place only in the denser medium.



Uses

1-communcation

Mobile phones and internet transmit information digitally (0,1) in form of light pulses by total internal reflection

2-medical

Endoscope is a device used to view inside stomach of a patient

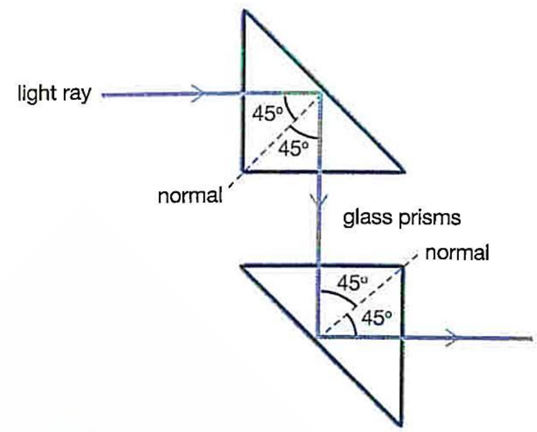
Consist of two fibers:

fibre 1 transfer light from outside of the body to the inside

fibre 2 transfer image from inside to the outside

3-periscope

The inside of glass prism can be used as mirror, total internal reflection take place on the longest face of prism as shown in figure



Questions

1. A light ray is incident on the surface of a glass of water with an angle of incidence of 25^0. If the refractive index of water is 1.33, calculate the angle of refraction of the light ray.

Answer

We know that n = 1.33, and $i = 25^0$. Using Snell's Law we get

$$\frac{\sin 25^0}{\sin r} = 1.33$$

rearranging this and finding

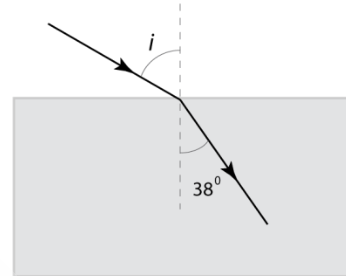
$$\sin r = \frac{0.423}{1.33}$$

So $\sin r = 0.318$,

$r = \sin^{-1}(0.318)$

$r = 18.5^0$, or 19^0

2. The diagram below shows a Perspex block with a refractive index of 1.5.



Calculate the angle of incidence *i* that produces this refracted ray with an angle of refraction of 38^0.

Answer

We know that n = 1.5, and *r* = 38^0. Using Snell's Law we get:

$$\frac{\sin i}{\sin 38^0} = 1.5$$

$\sin i = 1.5 \times \sin 38^0$

$\sin i = 0.93$

$i = \sin^{-1} 0.93$

$\boldsymbol{i = 67^0}$

3. Water has a refractive index of 1.33.

- **a). Calculate the critical angle of water.**
- **b). Describe and explain what will happen to a ray of light travelling upwards through water, hitting the surface with an angle of incidence of 50^0.**

Answer

a) Using the formula above, and n= 1.33 gives

$$\sin C = \frac{1}{1.33}$$

sin C = 0.75

$C = \sin^{-1}(0.75)$

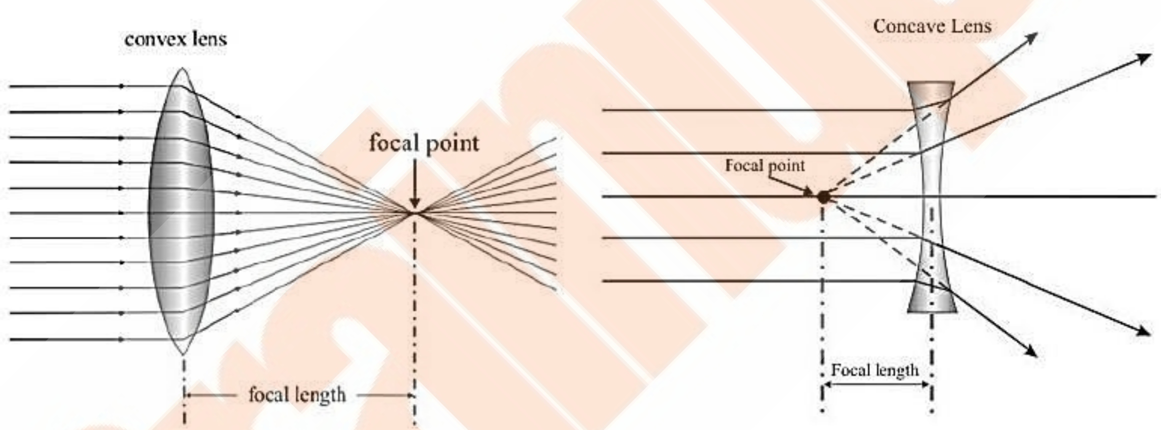
$\boldsymbol{C = 48.6^0}$

b) At an angle of incidence of 50^0, the ray will be **reflected,** because this angle is **greater than the critical angle** calculated in part (a).

LENSES

They are divided into two types

1. Convex or ***converging*** lens is thicker at the middle than the edges.
2. Concave or ***diverging*** lens thicker at the edge than at the center.



Principal axis

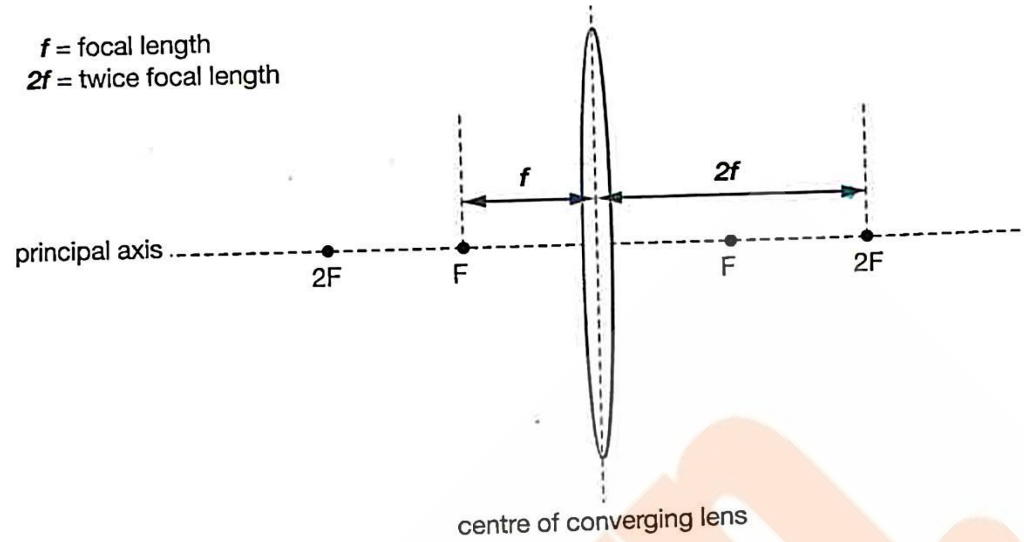
The straight line passing through the center of the lens is called principal axis.

Focal point or Focus

A point at which incident rays parallel to the principal axis of a lens converges

Focal length

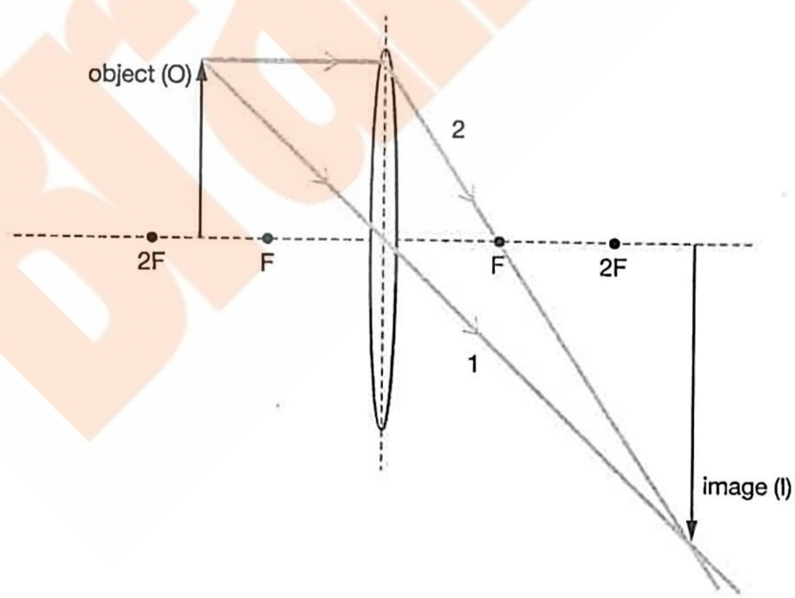
The distance from the optical center to the focus



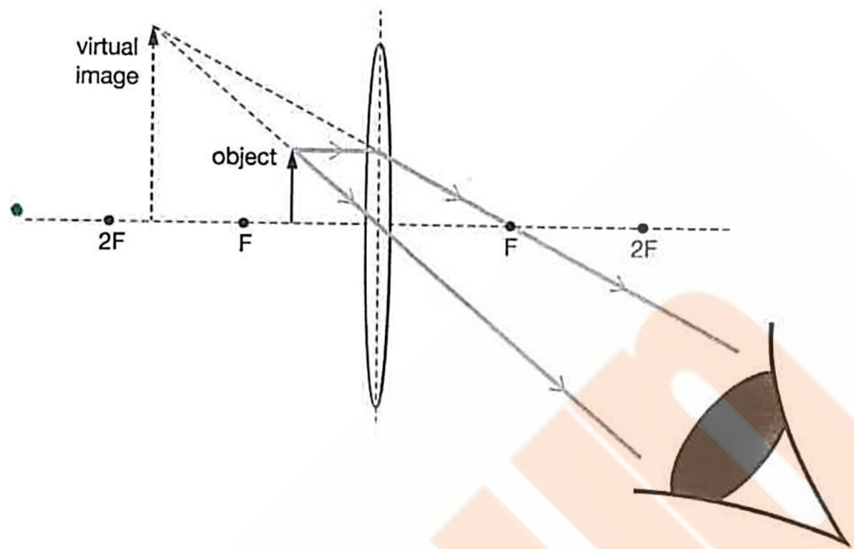
Drawing ray diagrams

1-Draw a ray from the top of the object through the Centre of the lens, which does not change direction

2-Draw a ray from the top of the object parallel to the principal axis until it reaches the central plane of the lens. The ray then passes straight through the principal focus on the other side of the lens. An image is formed where the rays meet



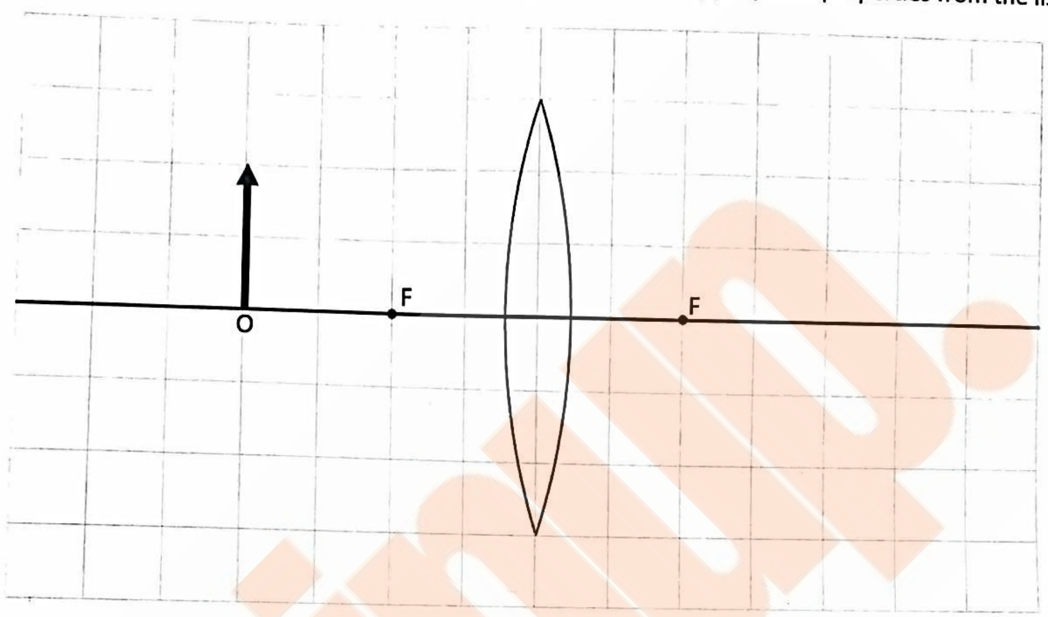
A converging lens can be used as a magnifying glass when an object is placed between F and the lens , image describe as (upright , virtual , enlarged)



- ✓ **real** image it can be formed on screen
- ✓ **virtual** image can't be formed on screen

Optics Work Sheet 1

Draw three rays to find the location of the image and tick the appropriate properties from the list.

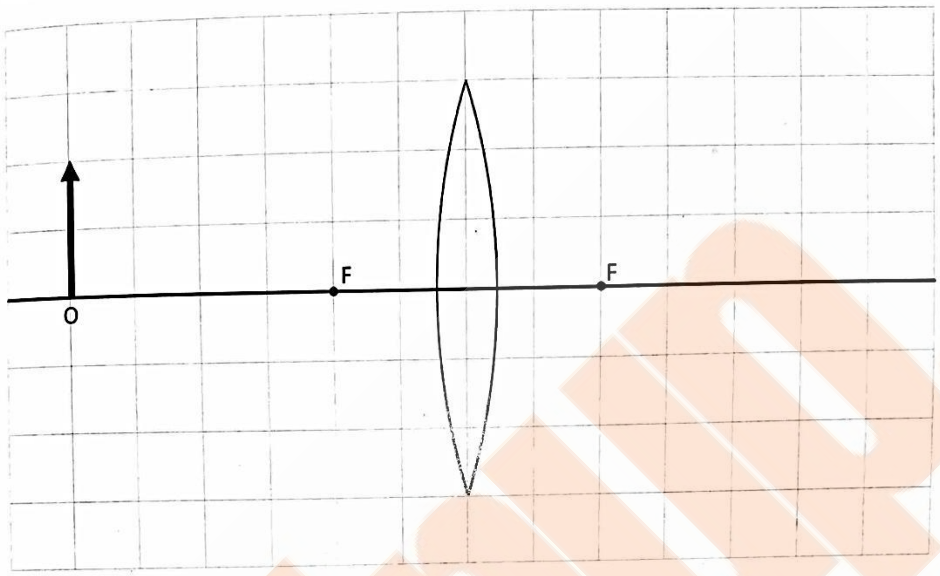


Tick the possible properties that the image has:

- ☐ Real
- ☐ Virtual
- ☐ Larger Than
- ☐ Smaller Than
- ☐ Same Size
- ☐ Inverted
- ☐ Upright
- ☐ Closer to the Lens
- ☐ Farther away from the Lens
- ☐ Same distance from the Lens
- ☐ No image

Optics Work Sheet 2

Draw three rays to find the location of the image and tick the appropriate properties from the list.

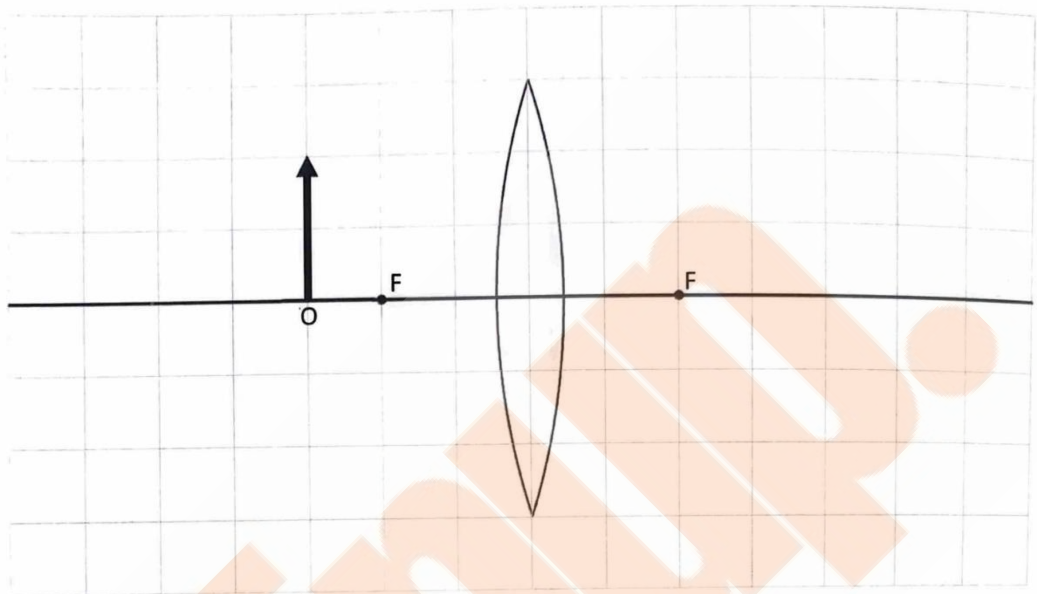


Tick the possible properties that the image has:

- ☐ Real
- ☐ Virtual
- ☐ Larger Than
- ☐ Smaller Than
- ☐ Same Size
- ☐ Inverted
- ☐ Upright
- ☐ Closer to the Lens
- ☐ Farther away from the Lens
- ☐ Same distance from the Lens
- ☐ No image

Optics Work Sheet 3

Draw three rays to find the location of the image and tick the appropriate properties from the list.

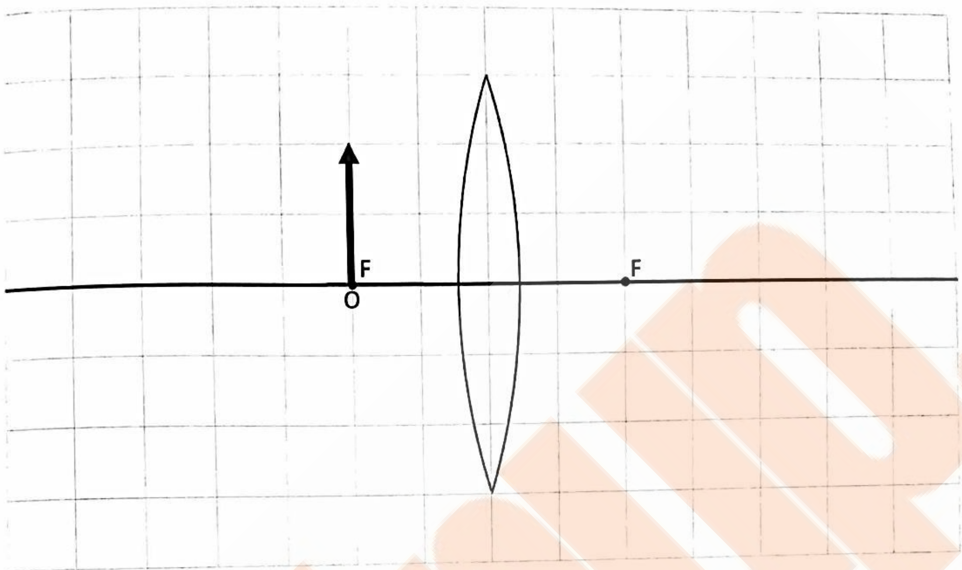


Tick the possible properties that the image has:

- ☐ Real
- ☐ Virtual
- ☐ Larger Than
- ☐ Smaller Than
- ☐ Same Size
- ☐ Inverted
- ☐ Upright
- ☐ Closer to the Lens
- ☐ Farther away from the Lens
- ☐ Same distance from the Lens
- ☐ No image

Optics Work Sheet 4

Draw three rays to find the location of the image and tick the appropriate properties from the list.

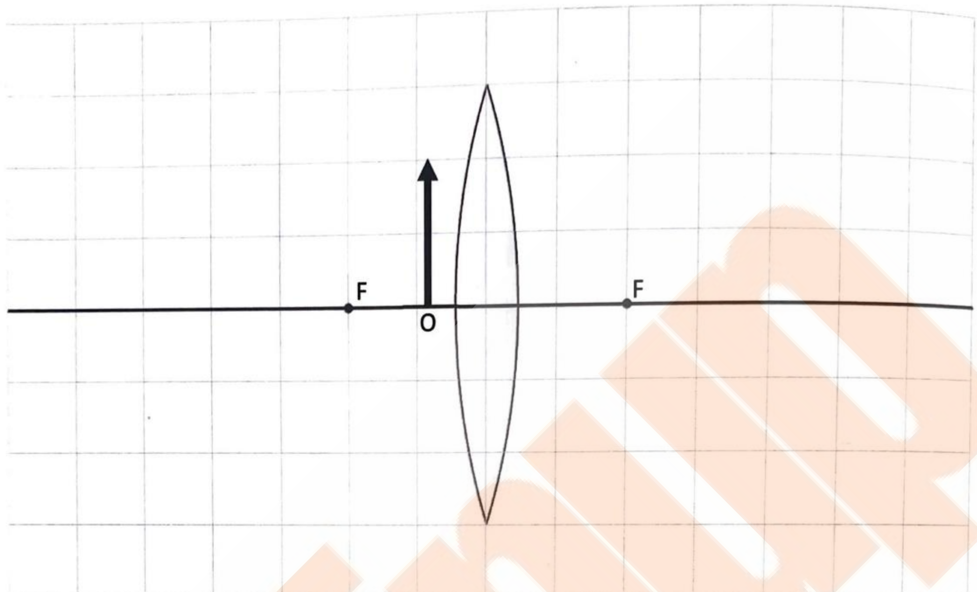


Tick the possible properties that the image has:

- ☐ Real
- ☐ Virtual
- ☐ Larger Than
- ☐ Smaller Than
- ☐ Same Size
- ☐ Inverted
- ☐ Upright
- ☐ Closer to the Lens
- ☐ Farther away from the Lens
- ☐ Same distance from the Lens
- ☐ No image

Optics Work Sheet 5

Draw three rays to find the location of the image and tick the appropriate properties from the list.



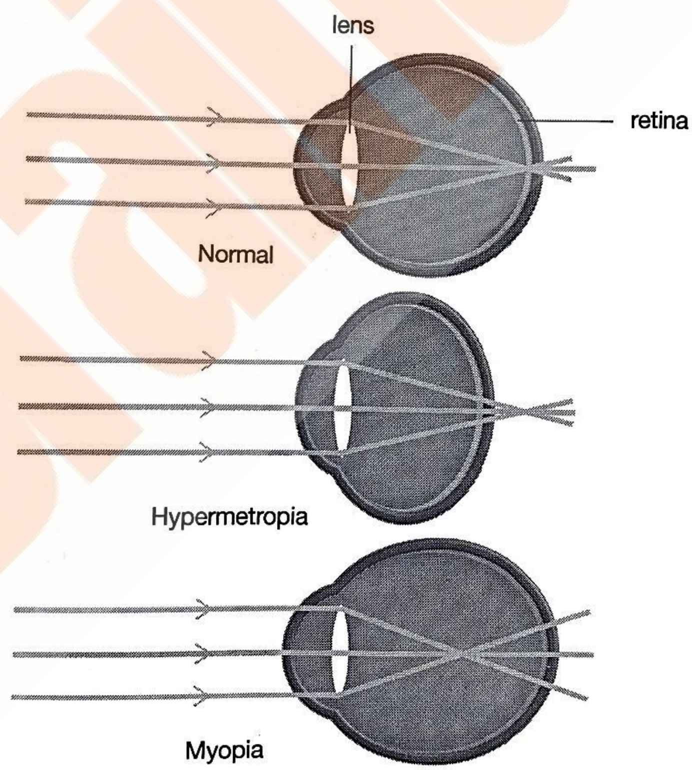
Tick the possible properties that the image has:

- ☐ Real
- ☐ Virtual
- ☐ Larger Than
- ☐ Smaller Than
- ☐ Same Size
- ☐ Inverted
- ☐ Upright
- ☐ Closer to the Lens
- ☐ Farther away from the Lens
- ☐ Same distance from the Lens
- ☐ No image

Eye

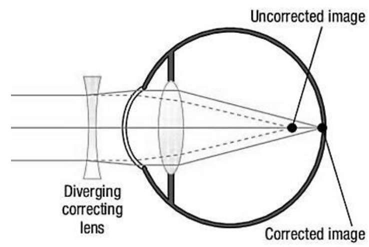
The normal human eye has a lens that converges light to form an image on the light-sensitive membrane at the back of the eyeball called the retina. The image is converted to an electrical signal, which is relayed to the brain via the optic nerve to translate the image into something meaningful. The focal length of the eye lens is very short - less than 20 mm - the distance from the lens to the back of the eyeball.

- ✓ If a person has **normal sight** the image is formed on the retina.
- ✓ If a person has **short-sight (myopia)** the image is formed in front of the retina
- ✓ if a person has **long-sight (hypermetropia)** the image is formed behind the retina.
- ✓ If the image is not formed on the retina the brain cannot translate the image into something meaningful and the person sees a blurred image.



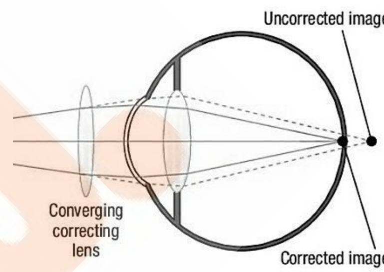
- ## short sighted

  Can see close object but object faraway are blurred, to **correct** short sighted **diverging lenses** can be placed in front of eyes



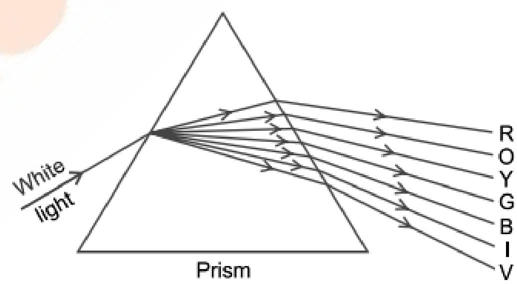
- ## long sighted

  Can see object a long way away but object close by are blurred, to **correct** long sighted **converging lenses** can be placed in front of the eyes

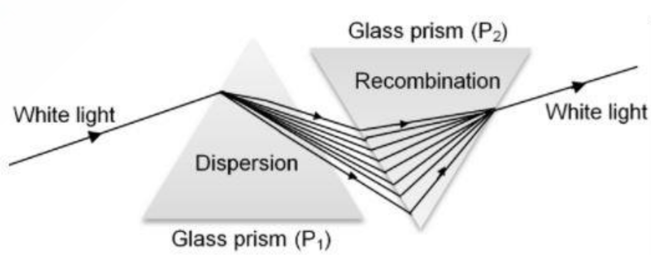


Dispersion of white light

When white light falls on triangular glass prism a band of colour called ***spectrum*** is obtained. The effect is called ***dispersion***. It arises because white light is mixture of ***seven colours*** which the prism separates because the refractive index of glass is different for each color

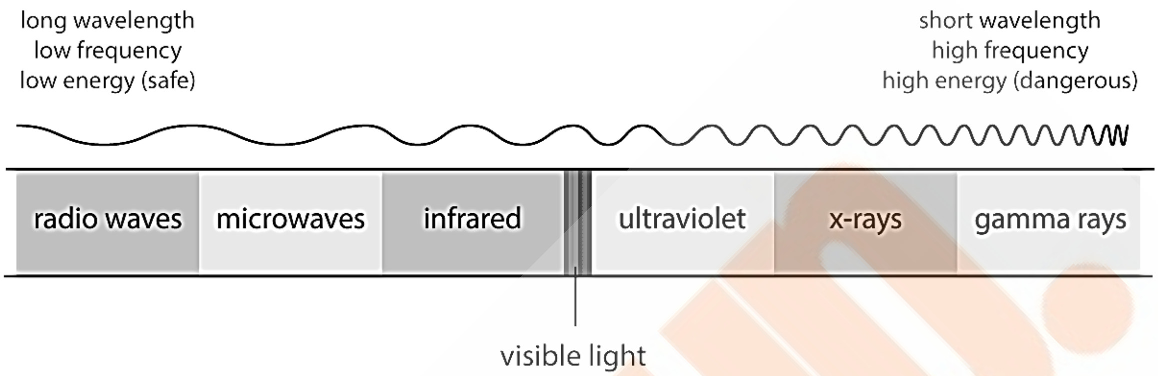


- ✓ ***red*** colour is the ***lowest frequency*** , ***violet*** is the **highest frequency**
- ✓ ***monochromatic*** means single colour , single frequency
- ✓ The spectrum of colors can be recombined through the following arrangement



Electromagnetic spectrum

A spectrum of different wavelengths this spectrum includes visible light, X-rays and radio waves. Electromagnetic radiation can be useful as well as hazardous



Properties of E.M. waves

All of these waves have some key identical properties

- They all travel at the same speed (the speed of light) in a vacuum.
- They are all transverse waves.
- They are all electromagnetic waves.

They can all be reflected and refracted

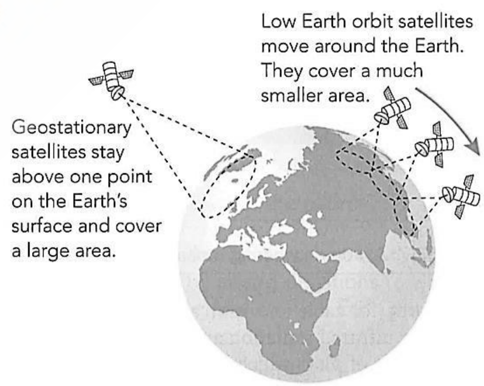
Region of E.M. spectrum	Uses	Dangers
radio	broadcasting, communication	-
microwaves	cooking, satellite communication	internal heating of body tissue
infrared	heating, night vision , remote control	skin burns
visible	photography, fiber-optic communication	skin burns

ultraviolet	fluorescent lamps and inks	blindness, damage to surface cells
x-rays	observing internal structures, for medicine and materials	damage to internal cells and organs
gamma rays	sterilizing food and medical equipment	mutation of cells, cancer

Communication

- Communication with **artificial satellites** usually uses microwaves because they can pass straight through the atmosphere. An artificial satellite is a human-made satellite that orbits the Earth. Some satellite phones and television broadcast systems use **microwaves** to communicate with **low level** artificial satellites.

- Most communications satellites occupy a **geostationary** orbit, they remain above the same point on Earth as they orbit. This means that a signal can be pointed at the artificial satellite and that a link can be established between that point on Earth and the satellite so that information can be passed between them.



- **mobile phones** (cell phones) and wireless internet use **microwaves** because microwaves can penetrate some walls and only require a **short aerial** for transmission and reception

- **Bluetooth** uses **radio waves** because radio waves pass through walls but the **signal is weakened** on doing so
- **optical fibres** (visible light or infrared) are used for cable television and high-speed broadband because glass is transparent to visible light and some infrared; visible light and short wavelength infrared can carry high rates of **data**

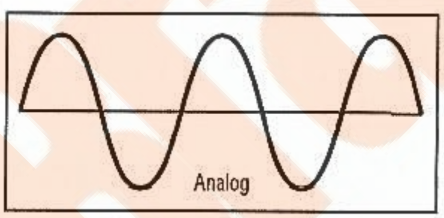
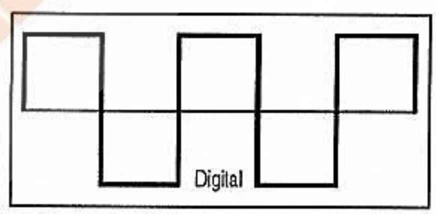
Analogue and digital signals

a) Analogue signals

A signal whose properties change continuously with time and can have any value, thermometers, speedometers and old-fashioned watches

b) Digital signals

A signal that consists of a voltage that can have one of only two values "High and low" or "On and Off" or "0 and 1" , digital clocks and digital meters

Analogue	Digital
*Is a signal which can take any value within a specific range **(continuous change)***	*Is a signal which can take discrete **(specific)** values (0,1).*
	
e.g.: Cassette, Human voice	***e.g.: CD, Mobile phones***

Advantages of using digital signals

1. ***high quality*** of video and video file
2. ***cheaper*** and more available electronics
3. ***higher security*** due to encryption of data
4. ***extra added bits*** for error checking

Sound

✓ Sounds are produced by objects that are ***vibrating***.

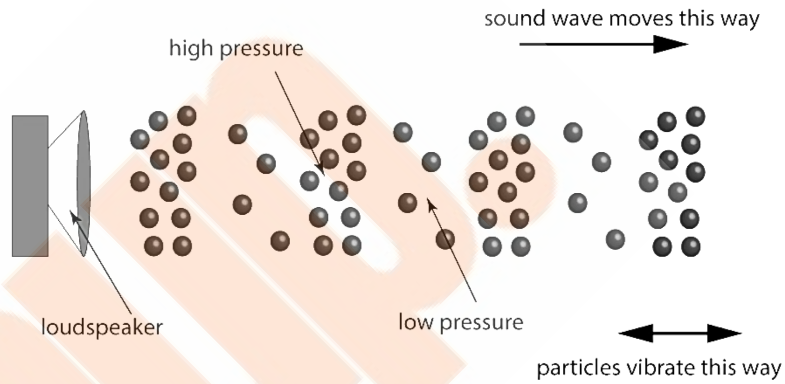
✓ Sound is a form of kinetic energy which travels in the form of ***waves.***

- Sound waves is **longitudinal**

  consist of a series of :

  ✓ ***compressions*** (air molecules pushed closer together at a slightly higher pressure)

  ✓ ***Rarefactions*** (air molecules are farther apart at a slightly lower pressure).

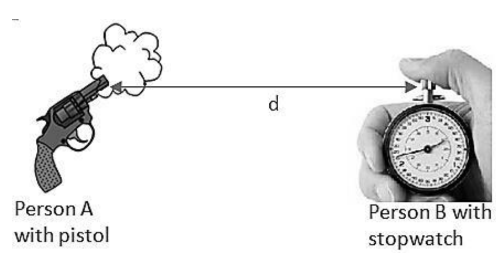


Measuring the speed of sound

The speed of sound in ***air*** is approximately ***340 m/s***. In ***liquids 1500 m/s*** and ***solids 5000 m/s*** the particles are much closer together. This means that they are able to transfer sound energy more quickly. So ***sound travels faster in solids more than liquids more than gases***

Speed of sound	
gas	***340 m/s***
liquid	***1500 m/s***
solid	***5000 m/s***

- two people (person A and person B) are placed a distance apart, 100 meters by measuring tape
- person A fires a starter's pistol



- person B times the difference between **seeing** the flash of the gun and **hearing** the sound - this is measured in seconds

Where,

= ________

Human Hearing

Humans can hear a wide range of frequencies. The **lowest sounds** that we can detect are about **20 Hz**. The **highest sounds** for a healthy young adult are about **20 000 Hz** or **20 kHz.**

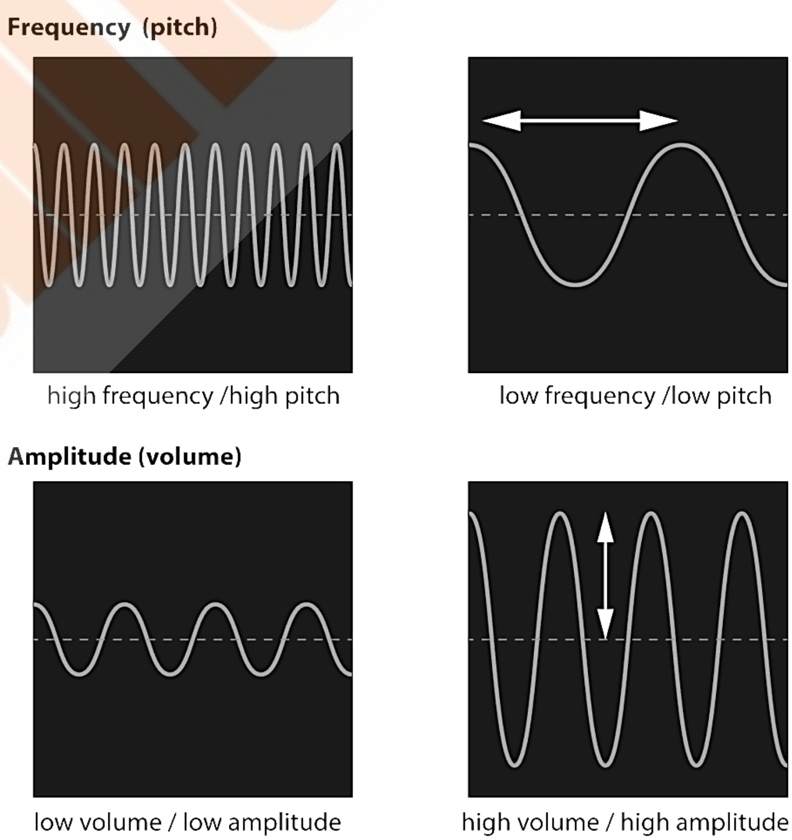
- ✓ less 20 Hz is **infrasound**
- ✓ more 20000 Hz **ultrasound**

Loudness and amplitude

The amplitude of a wave gives us some idea of the energy it is transferring. For a sound wave, its ***amplitude*** is a measure of its ***loudness***.

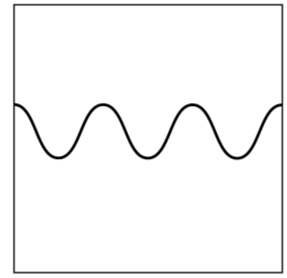
Pitch and frequency

The frequency of a source is the number of complete vibrations it makes each second and is measured in ***Hertz (Hz)***. Objects vibrate quickly and produce sound waves with a ***high frequency***. The sounds are heard as high ***pitch.***

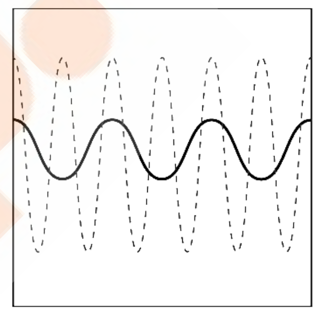


Questions

1. The diagram here shows a wave displayed on an oscilloscope screen. Add a second wave on the diagram to show a wave with a higher pitch and louder than the original sound.



Answer



- **Taller than the original**, showing a higher amplitude and therefore higher volume,
- **Closer together than the original** (more than 4 peaks in the box), showing a higher frequency and therefore a higher pitch.

Echo

An echo is a reflection of the sound from the wall).

$$\text{Speed (echo)} = \frac{2 \text{ distance}}{\text{time}}$$

Questions

A wall is 80 m away from some observers. A loud bang is produced by a drum, and an echo is heard 0.48 s later.
Using this data, calculate the speed of sound.

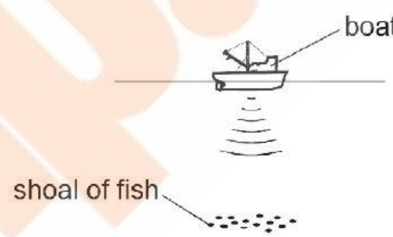
Answer

The sound wave travels there and back, so the distance is 160 m. The time taken is 0.48 s, so

$$\text{speed} = \frac{\text{distance}}{\text{time}} \qquad \text{speed} = \frac{160}{0.48}$$

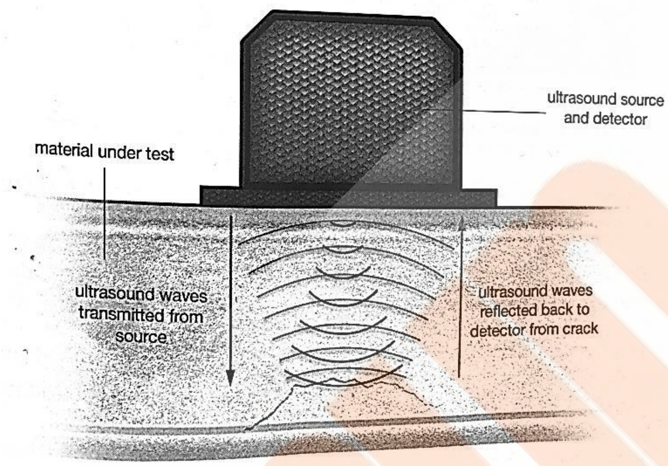
speed of sound = 330 m/s

- Boats use a **SONAR** (Sound Navigation and Ranging) system to locate objects such as shipwrecks and shoals of fish beneath the surface of the sea, and to measure the **depth** of the ocean. An ultrasound pulse is sent from the boat to the object and the time taken for the pulse to reach the object and return to the ship, together with the speed of sound in seawater, enables the distance to be calculated.



- **Ultrasound** scanning can also be used to **diagnose** problems with various organs **in the body**, such as the heart, liver and kidneys. It is a non-invasive technique, i.e. doctors do not have to operate on patients to be able to 'see' what is inside them, and it does not have the same risks as X-rays.

- **Ultrasound** scanning can also be used to search for **defects in metals**, pipes and other materials. If **an ultrasonic pulse is aimed through a sheet of metal** it would be expected to send an **echo** back from the far side, but if there is a **crack** within the metal an echo is sent back **sooner** than expected as shown below.



4-Electricity and Magnetism

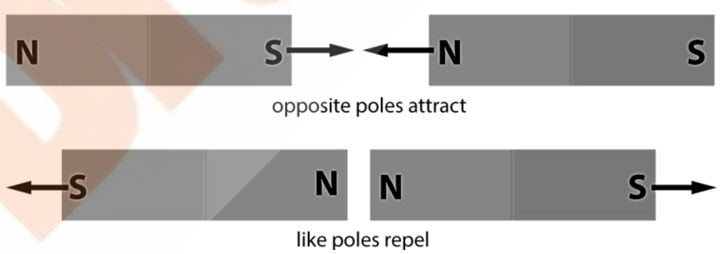
Magnetism

Properties of Magnets

- Objects made from ***magnetic materials*** called ***ferrous materials*** or ***ferromagnetic*** (such as iron, steel, nickel and cobalt) can be magnetized or attracted by a magnet.
- Objects made from ***non-magnetic materials*** called ***non-ferrous materials*** (such as plastic, wood, paper or rubber) cannot be magnetized or attracted to magnets.
- The parts of a magnet where the ***magnetic force*** is the strongest are called its ***poles*** (as we move Away from the poles, the magnetic force strength decreases).
- ***The poles*** of a bar magnet are near its ends and occur in pairs of equal strength ***(a north pole and a south pole)***.
- When a magnet is suspended freely***, its north pole will point towards the north of the Earth*** and ***its south pole will point towards the south of the Earth***

Magnetic forces

"Similar poles repel and opposite poles attract"



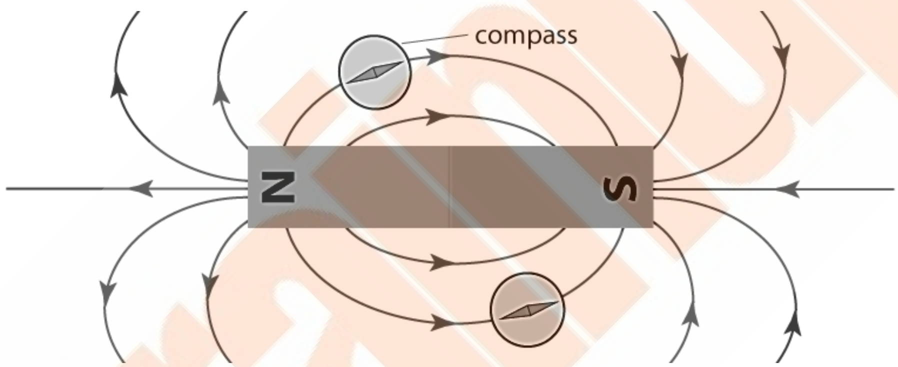
Magnetic Fields

The ***magnetic field*** is the region around a magnet where magnetic force can be detected. This region contains the ***magnetic flux*** which is represented using ***lines of force*** or ***flux lines.***

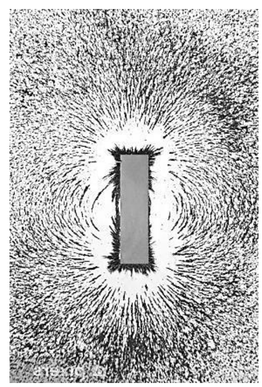
Magnetic flux is a vector quantity, so ***flux lines*** should represent both magnitude and direction,

Accordingly they

1. Show the ***shape*** of the magnetic field.
2. Show the ***direction*** of the magnetic field (field lines travel from north to South Pole).
3. Show the ***strength*** of the magnetic field (the closer the lines the stronger the field).



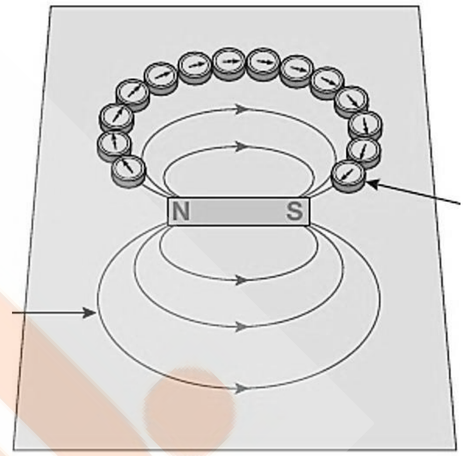
To investigate the magnetic field of a bar magnet



1. Place a sheet of paper on top of a bar magnet.
2. Sprinkle iron filings on the paper and tap the paper gently to allow for redistribution.
   - ✓ The iron filings align themselves according to the shape of the magnetic field

To investigate Direction of magnetic field of a bar magnet

1. place the plotting compass near the magnet on a piece of paper
2. mark the direction the compass needle points
3. move the plotting compass to many different positions in the magnetic field, marking the needle direction each time
4. join the points to show the field lines



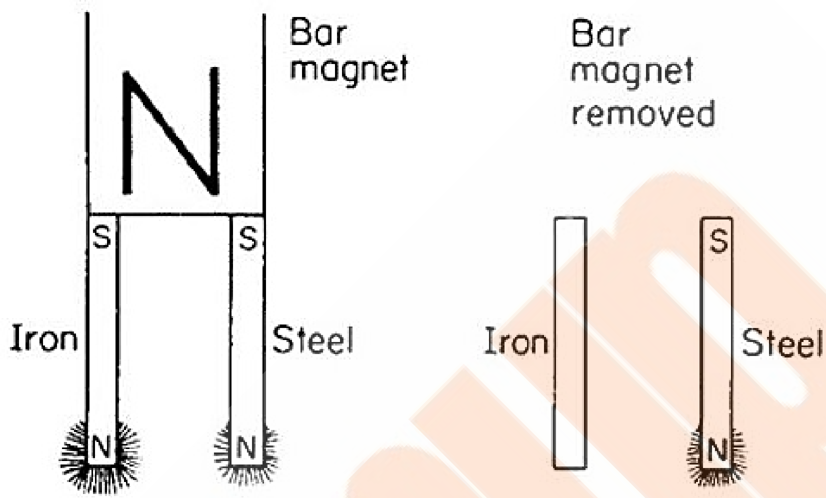
The magnet could be either one of two types

Hard Magnet (Steel)	Soft Magnet (Iron)
Hard to be magnetised and hard to be demagnetised	Easily magnetised and easily demagnetised
Use: *Permanent Magnet*	***Use:*** *Core of an Electromagnet*

Induced Magnetism

A magnet is placed near a magnetic substance so that the magnetic substance attracted to the magnet and act as magnet, both iron and steel are magnetized by induction but there are some differences:

- ✓ More iron filings cling to iron than to steel so induced magnetism in iron is stronger than in steel. Therefore, iron is easier to magnetize than steel.
- ✓ When the magnet is removed, iron loses its magnetism easily but steel retains its magnetism.



Questions

1. The south pole of a magnet is used to test a range of materials. Explain what will happen when the South Pole is placed near to:

- **a) Another south pole.**
- **b) A copper wire.**
- **c) A steel paper clip.**

Answer

a) Like poles repel, so the other South Pole will repel.

b) Copper is a non-magnetic material, so it will not be attracted or repelled.

c) Steel is a magnetic material so will always be attracted to any magnetic pole.

2. A loudspeaker contains a magnetically soft iron core.

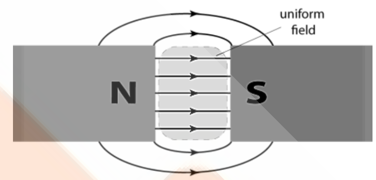
Explain what is meant by a soft magnetic material.

Answer

A soft magnetic material can be magnetized easily but quickly loses a magnetic field / is a temporary magnet.

3. Describe how to produce a uniform magnetic field between two permanent magnets. You may add a diagram if needed.

Answer



To produce a uniform field you need two magnets, with opposite poles facing/next to each other. The uniform region will be between the two poles.

4. A student tries to demonstrate the magnetic field lines around a permanent magnet by sprinkling salt crystals on a table mat placed over a strong permanent magnet.

- **a) Explain why no magnetic field pattern is seen.**
- **b) Suggest an improvement to this investigation, so that field lines can be seen.**

Answer

a) Salt is not a magnetic material. The crystals will not be affected by the magnetic field.

b) Iron filings should be used instead, and sprinkled slowly on the region around the magnet.

Electric charge

According to the ability of a substance to allow electric charges to flow through it, substances have been classified into

- ✓ **Electrical conductor** *these* are substances that allow charges (electricity) to flow through

Them easily this is because they have **free charge** carriers, all metals are good conductors as they have **free electrons.**

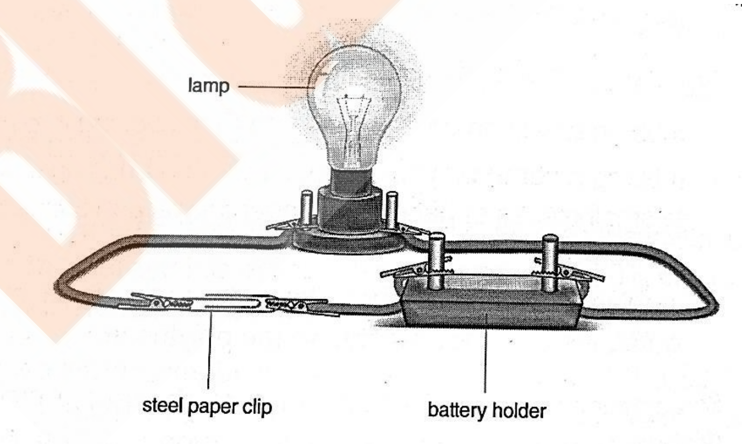
- ✓ **Electrical insulators** these are substances that do not allow electric charges to flow easily through them. This is because they **do not have free charge carriers**, most non-metals plastic, rubber, glass and wood. (except graphite and silicon)

Determine whether material is conductor or an insulator

1- Set up the circuit as shown to connect a dry cell to lamp via steel paper clip attached with crocodile clips

2- Observe that the lamp is lit, and conclude that the steel paper clips allow the flow of charge (current)

3- Replace the steel paper clip with various other materials and observe the appearance of lamp

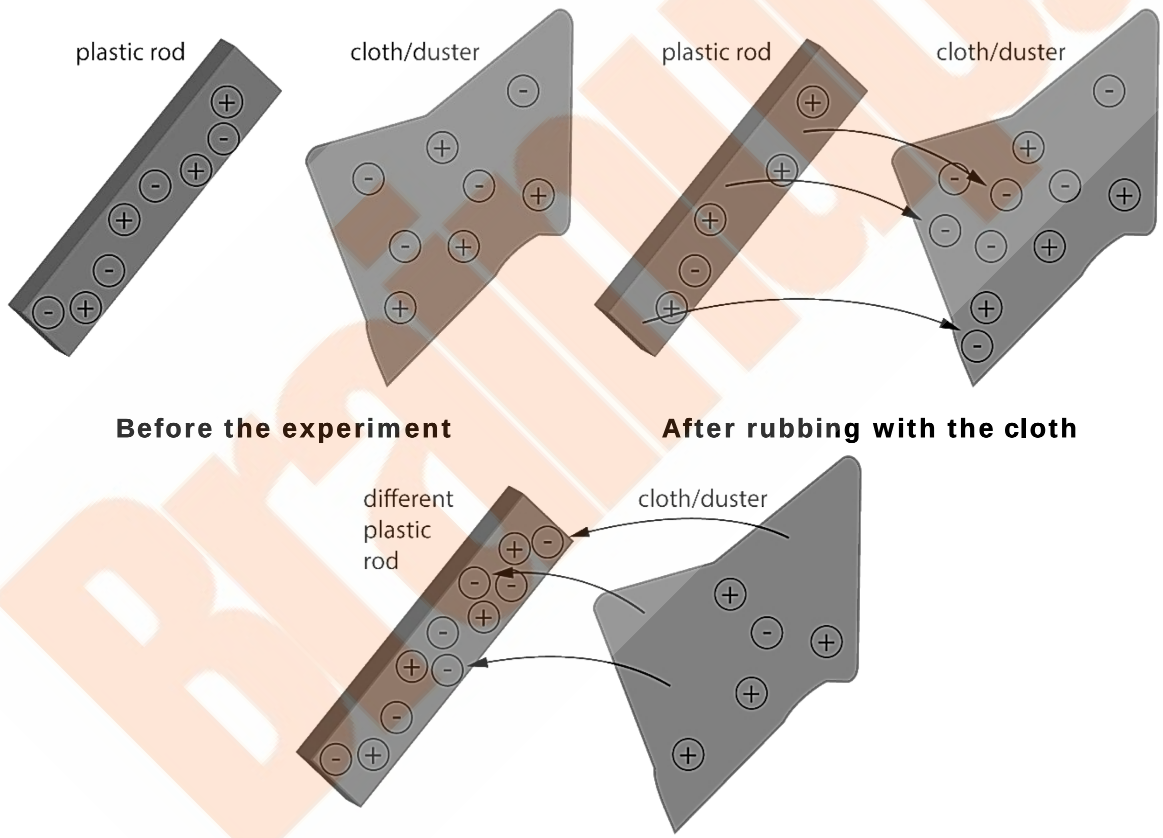


- There are **two methods** to obtain static electricity, either by **friction of an insulator** or By **induction of conductor**

1. Charging an insulator by friction (rubbing)

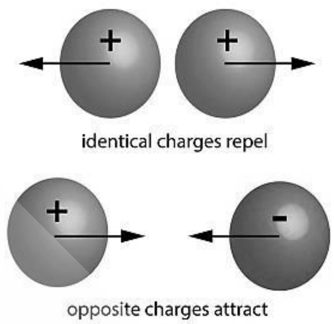
When the uncharged plastic rod is rubbed with an uncharged dry piece of cloth, electrons from the atoms of the rod may move onto the cloth. Now the charges on each object are imbalanced. The rod becomes positively charged and the cloth becomes negatively charged (has excess electrons).

✓ ***Only negative electrons can move / the positive protons remain fixed.***



Electric forces between charges and electric fields

a) Electric forces



Charged objects can exert forces on other charged objects without being in contact with them.

The closer the charges, the greater the force

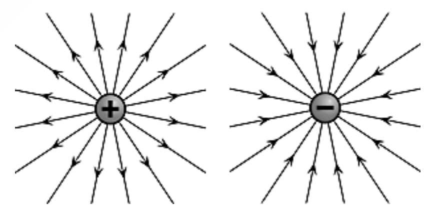
"Like charges repel and unlike charges attract"

- ✓ Attraction exists between charged and

Uncharged (neutral) objects therefore, a neutral object can be attracted to a positively charged rod and also to a negatively charged rod. Accordingly, attraction is not considered to be a proof that an object carries a charge but repulsion is considered to be. Because for repulsion to occur, both objects should have the same type of charge

"Only repulsion can confirm that an object is charged"

b) Electric fields

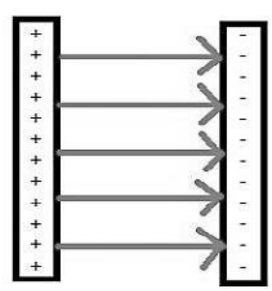


An electric field is ***a region where an object experiences a force due to its charge***,

It is the region around a charge where the force of ***attraction*** or ***repulsion*** can be observed by another test charge.

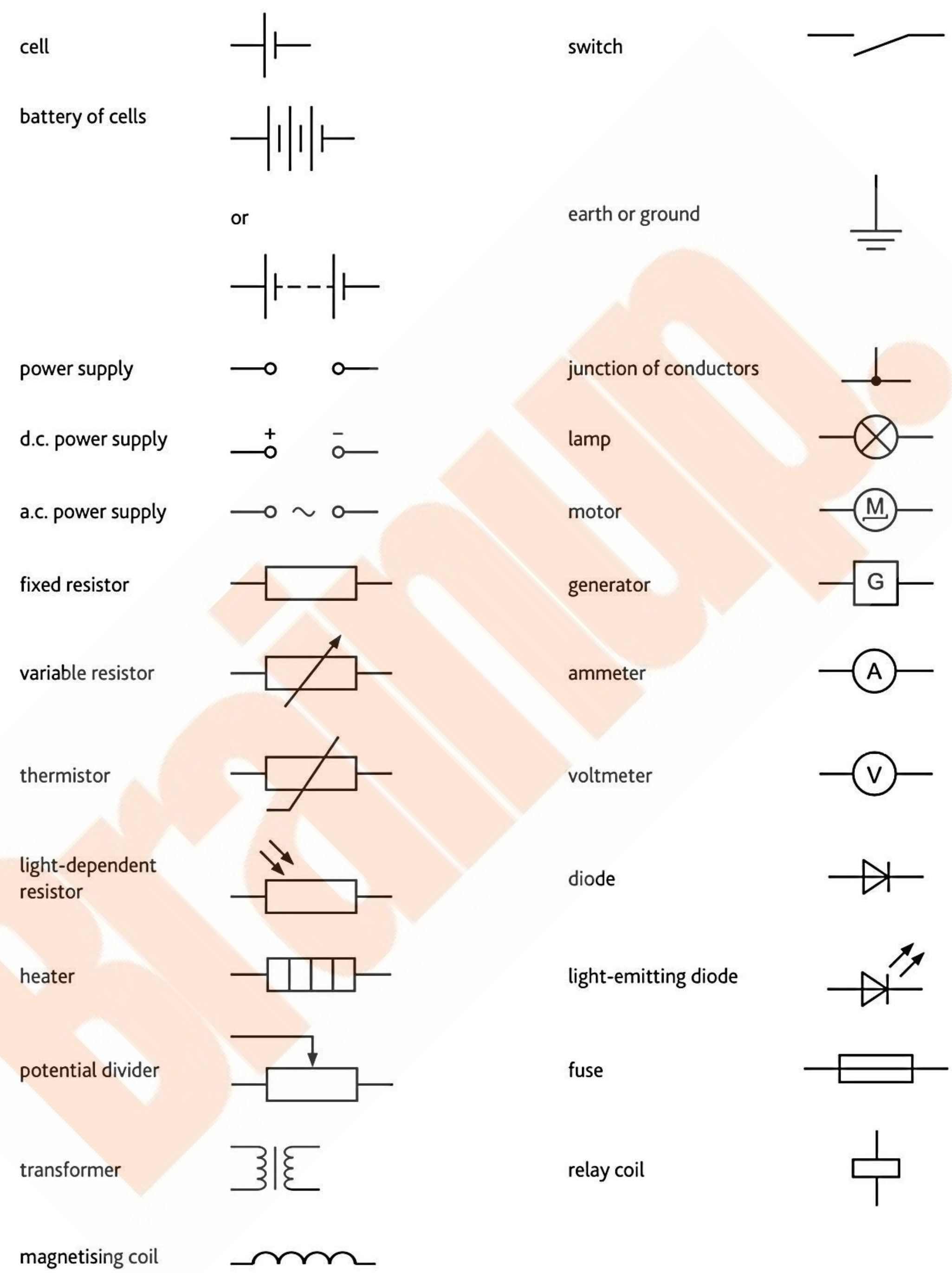
Electric fields are represented by ***imaginary lines*** showing the ***direction*** of the ***force*** (away from a

positive charge and towards a negative charge). The spacing of the lines shows the ***strength*** of the field. The more closely packed field lines, the stronger the field



- ✓ The field lines caused by the parallel plates are parallel are parallel to each other and equally spaced. The field is ***uniform***. .
- ✓ The field of a point charge is called a radial field and is ***non-uniform***

Electrical symbols



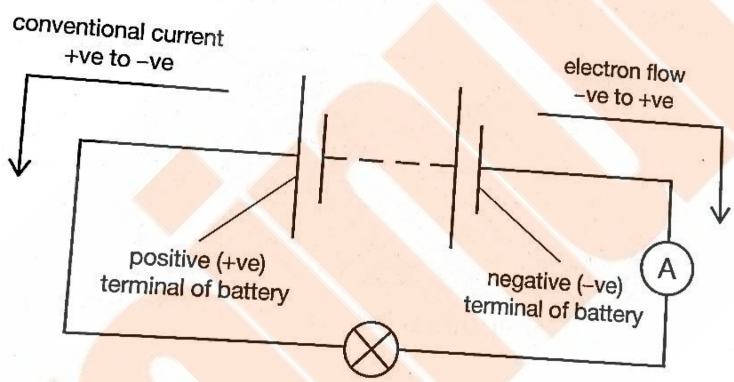
Electric current

Electron flow and conventional current

Electric current is the flow of charge (carried by electrons)

- If a cell or battery is connected across the conductor (in a closed circuit), ***the electrons flow in the direction away from the negative terminal and towards the positive terminal***. This flow of charge is an electric current.
- The free electrons flow from the negative terminal to the positive terminal of the battery "Direction of electron flow".

Whereas the "direction of conventional current" is from the positive terminal to the negative terminal of the battery



Measuring Electric current

Electric current is the rate of flow of charges.

Electric charge (Q) is measured in coulombs (C). One coulomb of charge is the equivalent of the

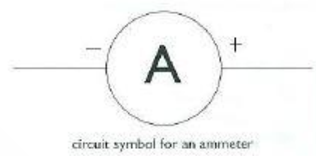
charge carried by electrons.

Electric current is measured in amperes where 1 C/s = 1 A

$$(\;) = \frac{\qquad}{\qquad}$$

- ✓ The size of the current flowing in a circuit is measured using an ***ammeter*** which is connected in ***Series*** with the component of the circuit being investigated

- ✓ Ammeters have ***low resistance*** so that they measure the size of the current flowing in the circuit without affecting its value.



Questions

1. A 0.3 amp household lamp is left on for 5 minutes. Calculate the charge flowing through the lamp in this time.

<u>Answer</u>

In 5 minutes, the time in seconds is 5 x 60 = 300 s,

We know that Q = I x t

Therefore Q = 0.3 x 300

Q = 90 coulombs

2. A 30 mA L.E.D. is left on for some time. During this interval, 6 C of charge flows through it. How long was the L.E.D. on for?

<u>Answer</u>

30 mA = 0.03 A, or if you are using standard form, 30×10^{-3} A (= 3×10^{-2} A).

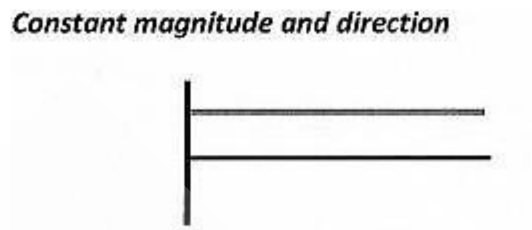
If Q = I x t

$$t = \frac{Q}{I} \qquad t = \frac{6}{3 \times 10^{-2}}$$

t = 200 s

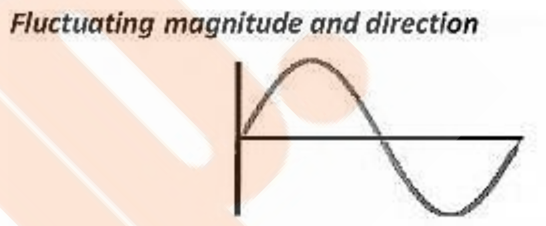
Electrical sources

1. Direct Current D.C



it is the supply which has an e.m.f. of constant polarity and the ***current is always in the same direction***. *Cells and batteries* provide direct current, which may change in value but remains in the same direction.

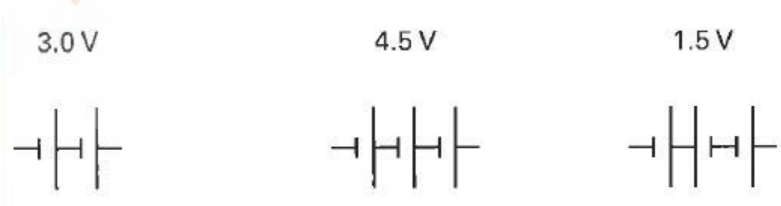
2. Alternating Current A.C



It is the supply which has an e.m.f. of varying magnitude and alternating polarity. This means that the voltage is continuously ***changing in magnitude and the direction of the current*** is reversed continuously.

Electricity ***generators*** provide alternating current

- ✓ ***A cell is a single component power supply*** has a value 1.5v or 2.0v
- ✓ ***A battery*** however is ***a group of cell connected together*** to increase voltage or power supply
- ✓ When battery is a group of cell in ***series*** the voltage increase , but the positive terminal has to be followed by a negative terminal and vice versa so that the ***current would flow in the same direction***
- ✓ if the cells are connected so that like ***terminals face each other's*** the current opposite direction so decrease the current and may cancel current in the circuit



Switches

A switch is used to control the flow of current in a circuit. Current flows in a circuit when the Switch is closed or on… and does not flow when the switch is open or off.

1. Normal switch: opens and closes a circuit
2. Parallel switch: A circuit can be switched on and off using either of the two switches.

Voltage (potential difference)

- Cells or batteries transfer energy to the charges as they move them around circuits. If a 1.5V cell is connected into a circuit, it means that 1.5 Joules of energy is given to each coulomb of charge that passes through the cell.
- So the ***potential difference (voltage)*** between two points in a circuit is ***the work done to drive one coulomb of charge between these two points***. It is the energy transferred per unit charge which is measured in Volt (V). 1 Volt = 1 J/C.

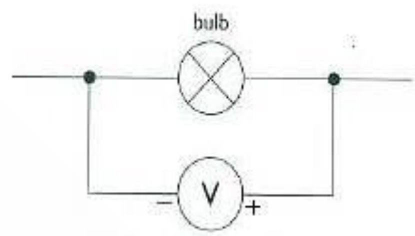
$$(V) = \underline{\hspace{8cm}}$$

- ***The electromotive force (e.m.f.)*** of an electrical source is the work done (energy supplied) by the source to drive 1 coulomb of charge round a closed circuit (***energy gained by each coulomb***).

- The ***potential difference (voltage drop)*** across a component (or between two points in a circuit) is the drop in electric potential energy experienced by each coulomb of charge due to resistance between these two points (difference in electrical energy)

Measuring the voltage

- ✓ To measure the voltage across a component in a circuit we use a ***voltmeter*** which is connected in ***parallel*** with this component.
- ✓ Voltmeters have a ***very high resistance*** (very little current flows through it) so that they measure the potential difference across a component without affecting the value of the current passing through this component.



Questions

3. A kettle needs 20 kJ to boil the water inside. If the kettle voltage is 240 V, calculate the total charge flowing through the kettle.

<u>Answer</u>

20 kJ is equal to 20 000 J.

We know E = Q x V,

$$Q = \frac{E}{V} \qquad Q = \frac{20\ 000}{240}$$

Q = 83.333 coulombs

4. A small cell is used to run a camping lamp. The cell stores 180 J of energy, and is rated as 1.5 V.

- **a) What is the total charge that can be delivered by the cell before it runs out? (Assume when running, the cell voltage remains constant and the cell is 100% efficient).**

- **b) The lamp needs 20 mA to operate. Using this information and your answer from part (a), calculate the time for which the lamp can remain lit.**

Answer

a) If E = Q x V

$$Q = \frac{E}{V} \qquad Q = \frac{180}{1.5}$$

Q = 120 C

b) If I = 20 mA (0.02 A) and Q = 120 C,

then using Q = I x t

$$t = \frac{Q}{I} \qquad t = \frac{120}{0.02}$$

t = 6000 s

Ohm's law and Resistance of a conductor

The resistance of a component is what causes a voltage drop *"potential difference"* across this component. The resistance of a conductor is ***"the ratio of the p.d. applied across it, to the current passing through it".***

Resistance can be calculated by

(R) = ______________________________

- ✓ Where R is measured in Ohms (Ω), V in volts and I in amperes. Thus, 1 Ohm= 1 Volt/Ampere

Type of resistor

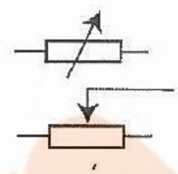
1-fixed resistor

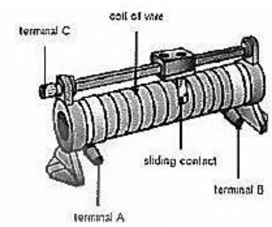
A resistor which have constant value all the time (obey ohm's law)

2-variable resistor (rheostat)

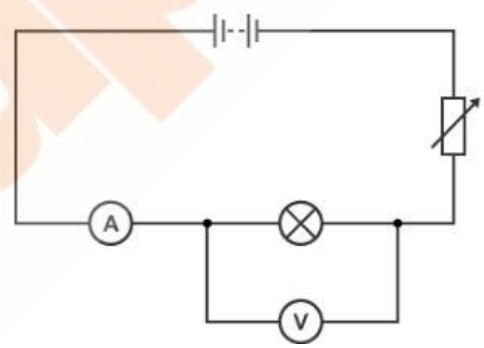
A resistor which has range of value which could be change manually

function: vary the current in the circuit by varying resistance





Measuring the resistance of a resistor



Set up the following experiment

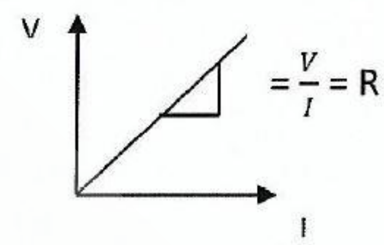
- The voltmeter measures the voltage drop across the resistor.
- The ammeter measures the current through the resistor.
- The variable resistor allows you to change the size of the current

Accordingly note the readings of the ammeter and voltmeter.
Then move the variable resistor and take more readings.

Finally, plot a graph of voltage against current using your readings:
The slope of V against I graph gives the resistance of the wire
(R= V/I)

Ohm's law

The current that flows through a metallic conductor is directly Proportional to the potential difference across its ends, provided its temperature remains constant



Questions

1. A 20 Ω resistor is connected to a 6 V battery. What current flows through it?

<u>Answer</u>

We know that V= I x R, So

$I = \frac{V}{R}$ $I = \frac{6}{20}$

I= 0.3 A

2. A 4 kΩ resistor has a current of 2 mA flowing through it. What is the p.d. across the resistor?

<u>Answer</u>

As 1 kΩ = 1000 Ω, then 4 kΩ = 4000 Ω

There are 1000 mA in an amp. So 2 mA = 0.002 A (2 ÷ 1000)

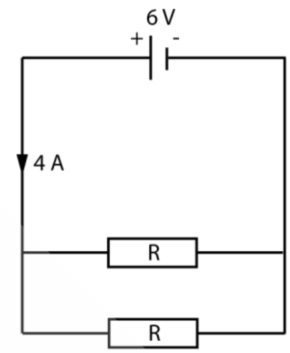
p.d. means potential difference - the voltage across the component.

Therefore as V = I x R;

V= 0.002 x 4000

V = 8 V

3. Two identical resistors R are connected to a 6 V cell as shown. The current flowing from the cell is 4 A. What is the value of the resistor R?



Answer

In a parallel circuit, the current splits, and here both branches of the circuit are identical. Therefore 2 amps flows down each branch.

Also for a parallel circuit, the voltage across all branches is the same as the cell, so each resistor has a p.d. of 6V.

$$R = \frac{V}{I}$$

$$R = \frac{6}{2}$$

R = 3 Ω

Four factors affecting resistance

1. As the length increases, the resistance increases so

$$R \propto l$$

2. As cross-sectional area increases, the resistance decreases.

$$R \propto 1/A$$

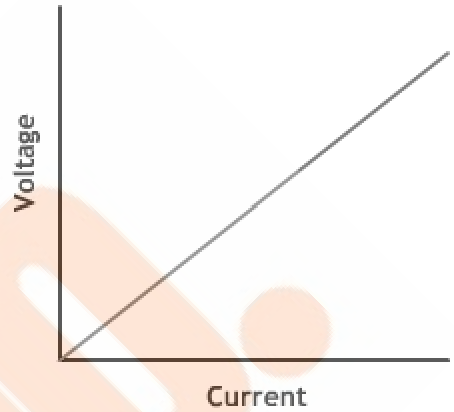
3. The resistivity (ρ) of the material

Copper is a good conductor "low resistivity" so used for connecting wires, while nichelcrom has more resistance, so used in the heating elements of electric fires.

4. Temperature

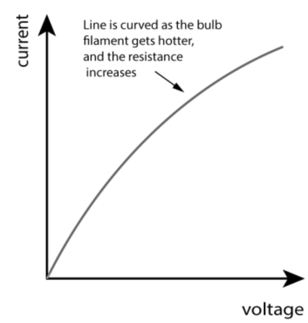
a) I-V characteristics of Ohmic conductors

- The graph is a straight line passing through the origin , the current flowing through the wire is directly proportional to the voltage applied across its ends. This is ***Ohm's law***.
- The steeper the graph, the lower the resistance and vice versa.
- Copper wire and all other metals ***"metallic resistors"*** give this shape of graph, unless they change temperature.
- The -V & -I show what happens when the battery connections are reversed so current flows in the opposite direction. Accordingly, values of V & I are negative.
- The graph shows that the conductor has a constant resistance (constant slope) which is the same for both current directions.



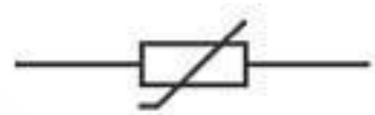
b) I-V characteristics of a filament lamp:

- The graph is not a straight line, so the lamp is a non-ohmic
- Conductor. ***As more current flows, the metal filament gets hotter*** and **electron** in the wire **collide** with the particle inside the wire the electron transfer energy to the particle therefore **internal energy** of wire increase



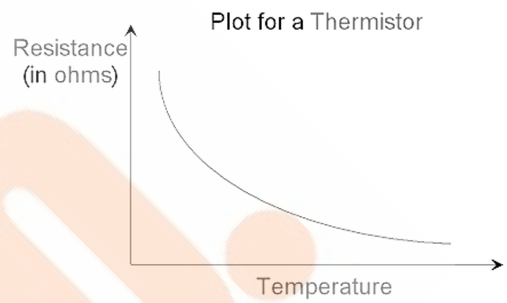
Other circuit components

Thermistor

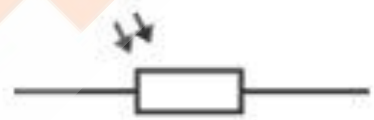


Thermistors are used as temperature sensors, for example, in fire alarms. In the most common type of thermistor, the resistance decreases as the temperature increases

- at low temperatures, the resistance of a thermistor is high and little current can flow through them
- at high temperatures, the resistance of a thermistor is low and more current can flow through them

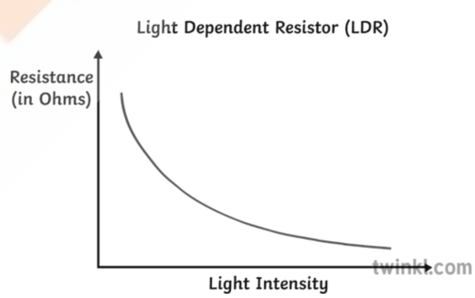


LDRs (light-dependent resistors)



LDRs (light-dependent resistors) are used to detect light levels, for example, in automatic security lights. Their resistance decreases as the light intensity increases

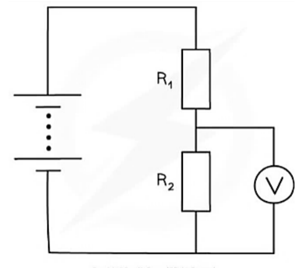
- in the dark and at low light levels, the resistance of an LDR is high and little current can flow through it
- in bright light, the resistance of an LDR is low and more current can flow through it



Potential divider

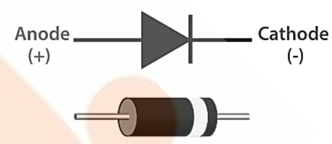
splits the potential difference of a power source between two components

– = –



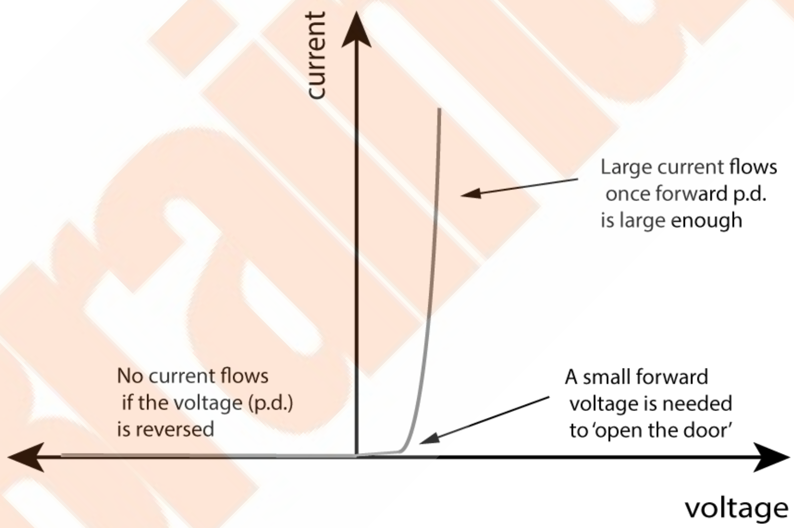
Diode

It allow the current to flow in one direction only



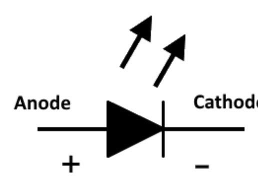
A diode has a very high resistance in one direction. This means that current can only flow in the other direction.

This is the graph of current against potential difference for a diode



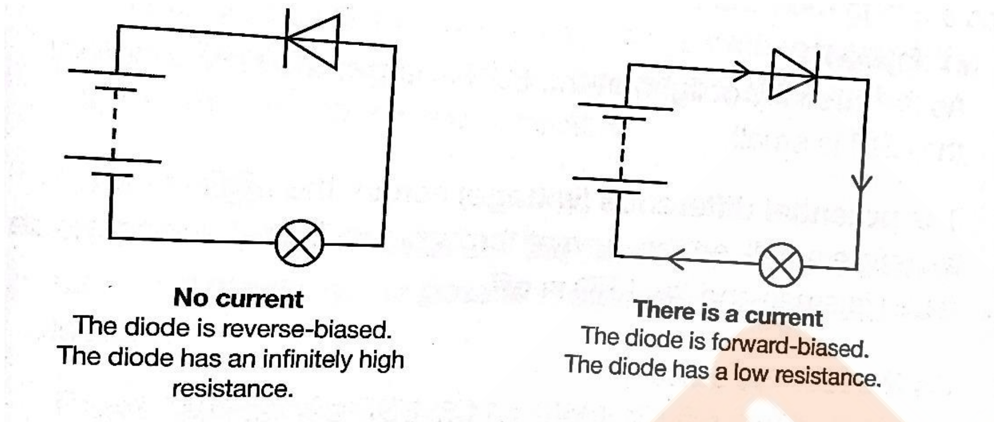
Light-emitting diodes (LEDs)

Produce light when a current flows through them in the forward direction.



LEDs and lamps are often used for indicator lights in electrical equipment, such as computers and television sets

- ✓ diode have to be forward biased for current to pass



Advantages of parallel circuits over series circuits

In series circuit:

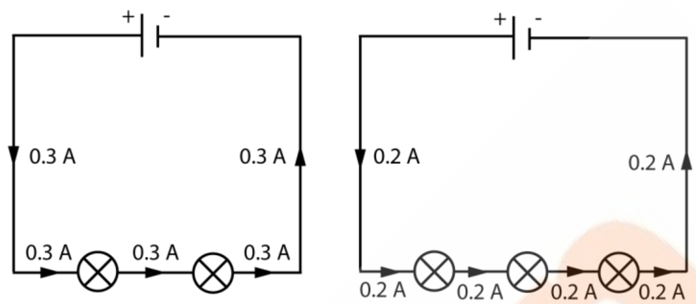
- ✓ if one component fails to work or blows, then all other components will not work.

In parallel:

- ✓ if one component fails to work, all the other components still work.
- ✓ When components are connected in parallel to a power supply, they receive more power than when connected in series
- ✓ also in parallel components can control separately by switch

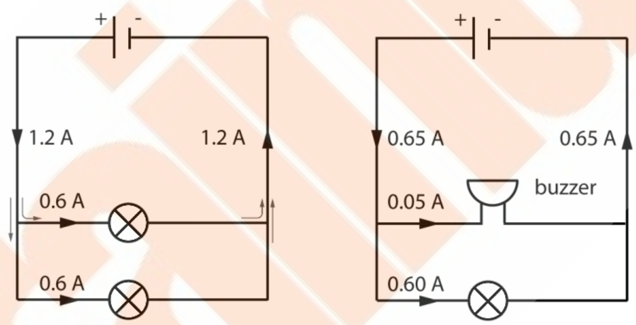
Current in series and parallel circuits

Current in series



- ✓ The current at all points around a series circuit is always the same

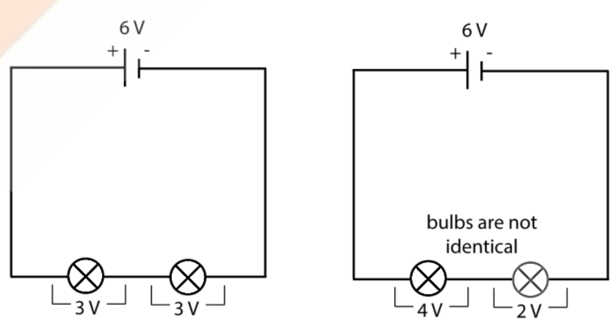
Current in parallel



- ✓ The current in a parallel circuit splits between the branches of the circuit.

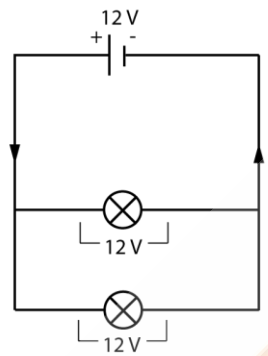
Voltage in series and parallel circuits

Voltage in series



✓ The voltage in a series circuit is split (or shared) between the components

Voltage in parallel



✓ The voltage (p.d) across all components in a parallel circuit is the same

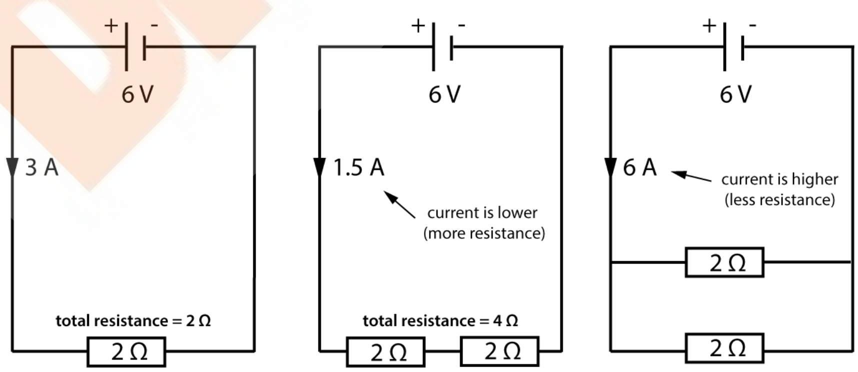
Resistors in series and parallel

Series

If we connect two resistors in series, it makes it harder for current to flow **- the total resistance has increased**. In fact, we can just **add the value of the resistors together** to find the total resistance.

Parallel

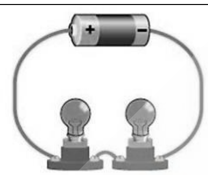
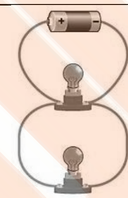
If we connect two resistors in parallel, there are now two paths for the current, and it makes it easier for current to flow round the circuit. **The total resistance is lower and the current is higher**.



Series

Parallel

Summary

Series connection	Parallel connection
▪ $I_T = I_1 = I_2$	▪ $I_T = I_1 + I_2$
▪ $V_T = v_1 + v_2$	▪ $V_T = v_1 = v_2$
▪ $R_T = R_1 + R_2$	▪ — = — + —
	

Calculating Electrical power & Electrical energy

Cost of electricity

- We can calculate the amount of energy transferred electrically in joules (J).
- but it is much more convenient to use kWh.
- This is because 1 kW = 1000 W and 1 h = 3600 s,
- so 1 kWh = 1000 W x 3600s = 3.6 × 106 J
- 1 kWh is sometimes called a unit of electricity.

question

ali switches on a water heater for two hours. The power of the heater is 3.5 kW. How much energy is transferred in kWh (units)?

answer

- power = 3.5 kW
- time = 2 hours

• energy transferred (kWh) = ?

• energy transferred (kWh) = power (kW) × time (hours)

the answer , energy transferred (kWh) = 3.5 kWx 2hours = 7kWh

question

andrew checks her electricity bill for a three month period. The meter reading at the start was 2531 kWh and at the end it was 2647 kWh. Electricity costs 16p per unit. What is her bill for electricity?

aeswer

- metre reading at start = 2531 kWh
- meter reading at end = 2647 kWh
- cost per unit = 16p
- units used =?
- total cost of electricity =?

Work out how many units were used.

• Units used = 2647 kWh - 2531 kWh = 116kWh

• total cost of electricity = number of units x cost per unit

• total cost of electricity = 116kWhx 16p = €18.56

Calculating Electrical power & Electrical energy

To calculate the power used up by any electrical component

= & =

Using this rule and Ohm's law, 2 other formulae can be obtained

$$= \ ^2 \quad \& \quad = \ ^2$$

$$p = — \quad \& \quad E = \ —t$$

✓ energy (E) is measured in joules (J) , power (P) is measured in watts (W)

Questions

1. A 240 V toaster uses a current of 2A.

- **a) Calculate the power used by the toaster whilst in operation.**
- **b) When the toast pops up after 1 minute, the toaster turns off. Calculate the total energy transferred by the toaster.**

Answer

a) We know that P = I x V, so:

P = 2 x 240

P = 480 W

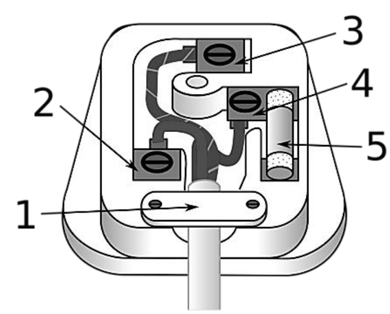
b) Firstly, remember to use 60 seconds, not 1 minute.

For this part of the question we can use E = I x V x t

E = 2 x 240 x 60

E = 28 800 J

Mains electrical plugs



1 = cable grip

2 = **neutral** pin and wire

3 = **earth** pin and wire

4 = **live** pin and wire

5 = fuse

- ✓ **The live wire** - this is the wire that is effectively connected to the power station, pushing and pulling current around the circuit. If you touch the live wire, you will receive a shock!
- ✓ **The neutral wire** - this is the 'return wire' completing the circuit back to the power station.
- ✓ **The earth wire** - this is the third wire that is frequently missing in some plugs, along with the third pin.
- ✓ **The cable grip** - this simply locks the cable in place, preventing someone pulling on the connections, and possibly disconnecting part of the plug. Sparks inside the plug can cause fires.
- ✓ **Fuse** - this is another safety feature like the earth wire,

Hazards of electricity

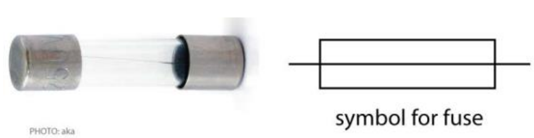
- **Damaged insulation** ‘ electric shock ‘
- **Damaged plug** ‘ short circuit ‘
- **Damage conditions near socket** ‘ short circuit ‘
- **Long and tangled cables** ‘ injuries

Protection

1. Fuse

It consists of a **thin** metal **wire**, mounted inside a short cylinder the fuse is designed to **melt** when a specific current passes through it

When the fuse melts, it breaks the circuit and turns the appliance off **preventing** a **fire** or other hazard. The appliance no longer works, so the fault is investigated, fixed, and the fuse replaced



Choosing the fuse

The fuse used must be chosen carefully to match the appliance. This is because the fuse should always be rated **as just above the current needed for the appliance**

✓ This is because the fuse should always be rated as just above the current needed for the appliance.

Questions:

1. A 2kW hairdryer is connected to the mains supply of 240 V.

- **a) Calculate the current used by the hairdryer when in operation.**
- **b) Fuses of 1 A, 5 A, 8A and 13 A are available. Which of these fuses should be fitted to the mains plug?**

Answer

a) We know that P = I x V, so

$$I = \frac{P}{V}$$

$$I = \frac{2000}{240}$$

I= 8.33 A

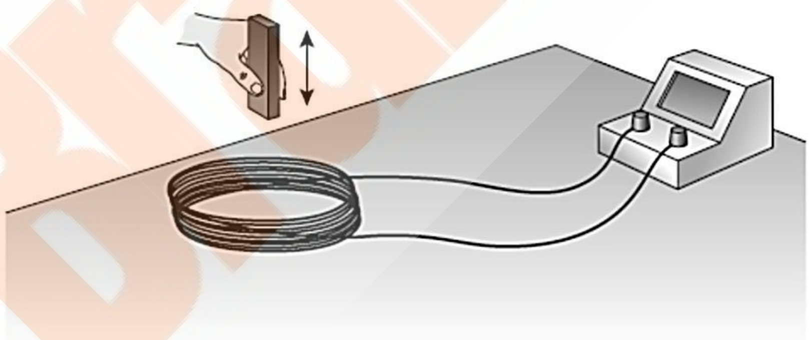
b) If the hairdryer uses 8.33 A, then an 8 A fuse will blow, as will anything rated lower than 8 A. The next one available above 8.33 A is the 13 A fuse.

2. Circuit breakers

A circuit breaker is basically a more modern adaptation to the fuse. They work using ***electromagnets***, which ***open a switch*** if the current gets too high, and this breaks the circuit. Many different current ratings are available.
Although the large circuit breaker box used in many homes is expensive, the ***advantage*** is that the switches ***can be easily reset***.

Electromagnetic induction

If a wire is moved across a magnetic field at right angles (***to cut across lines of flux***), ***voltage is induced*** or generated in the wire this is called ***electromagnetic induction.***



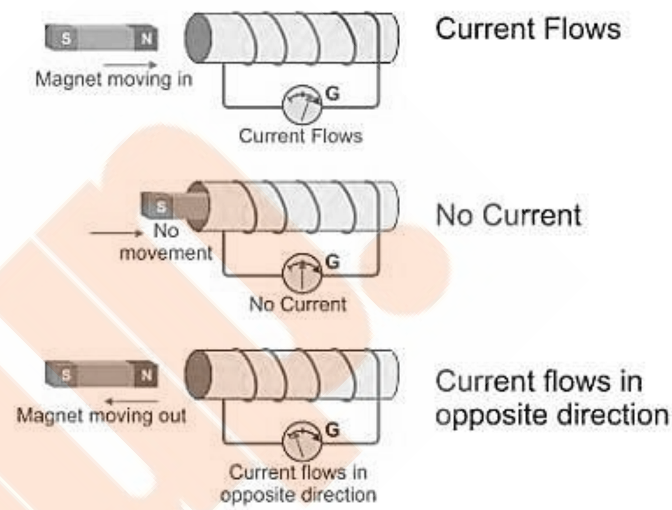
This can be demonstrated using the following experiment

a) When the magnet is **moved into the coil**, the galvanometer deflects in one direction. If the magnet is pulled away from the coil, the galvanometer deflects in the opposite direction showing that the induced current flows in the opposite direction.

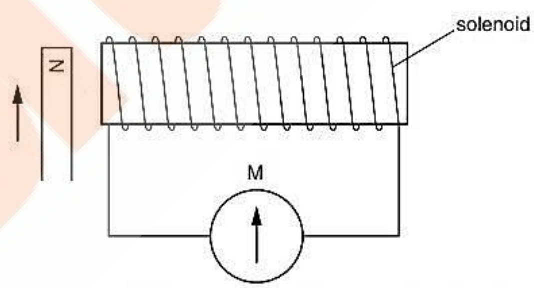
b) If the magnet is **stationary**, the galvanometer **point** is at **zero** and there's no current induced in the circuit.

c) If you move the magnet **slowly**, then small deflection if you move it quickly, then large deflection.

d) If you move a weak magnet, **then small deflection** if you move a strong magnet, then large deflection.



- ✓ ***cut off*** or ***interference*** between two magnetic field (magnetic field magnet and magnetic field of coil) so ***change in magnetic field line so induced voltage*** or induced current
- ✓ if it move ***parallel*** to magnetic field (no cut off) ***no current is induced***



move ***parallel*** to magnetic field ***no current is induced***

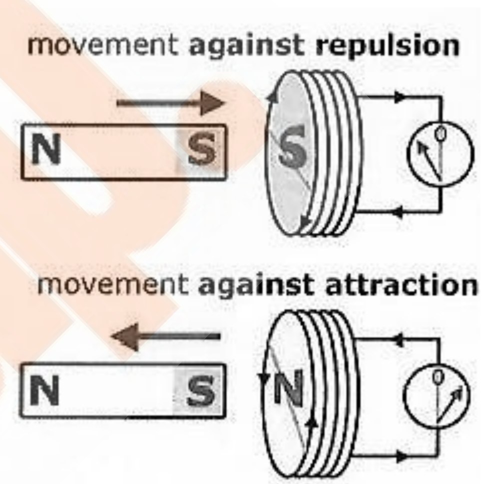
To increase induced current

1. Using coil with ***more turns*** (increases the peak value not the frequency).
2. Using a ***stronger magnet*** or a powerful electromagnet or winding the coil round a soft-iron core so that the field is stronger (increases the peak value not the frequency).
3. **Rotating** the coil ***faster*** (increases both the peak value and the frequency).

Direction of deflection

Used to determine the direction of the induced current

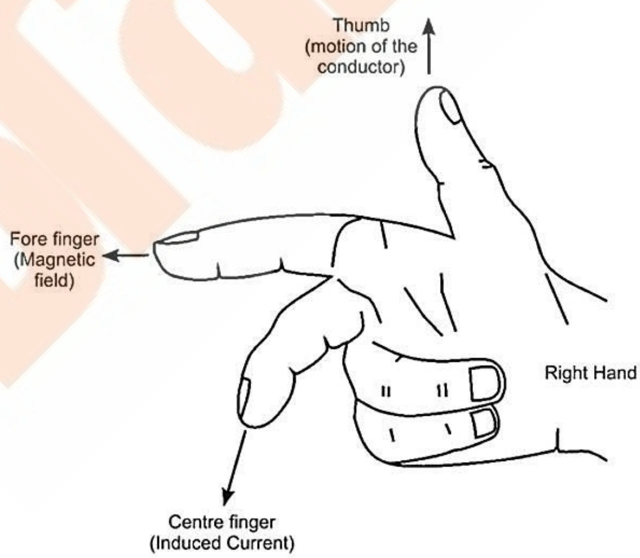
The ***direction of induced current is opposite to the change causing it***

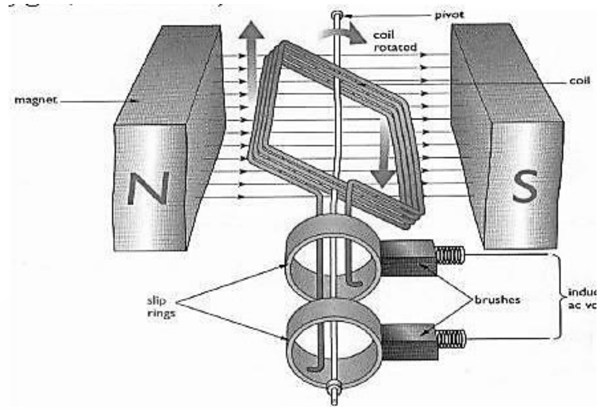


✓ if the south pole is approaching the coil it should be repelled so a south pole close to the south pole of the magnet will be induced and vice versa

Fleming right hand rule

This rule is used to indicate the direction of current caused by induced E.M.F





A.C. Generator

- *The a.c. generator converts kinetic energy into electrical energy.*
- The induced e.m.f. in an a.c. generator varies with time (alternating) because the rate of **change in magnetic flux** around the sides of the coil varies as the coil rotates within the **magnetic field.**

To increase induced current

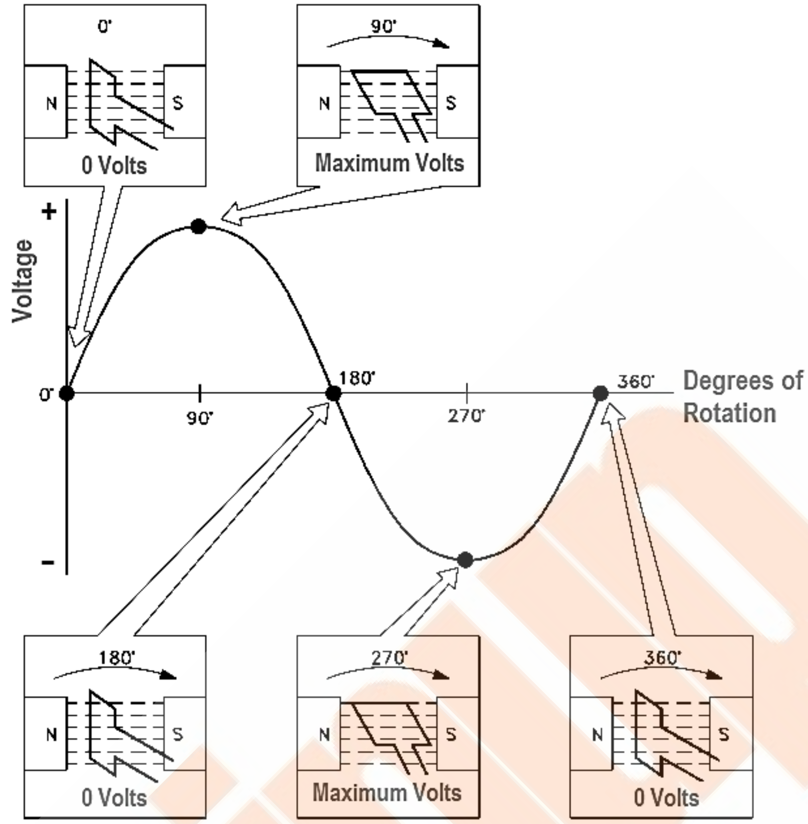
1- Using coil with ***more turns*** (increases the peak value not the frequency).

2- Using a ***stronger magnet*** or a powerful electromagnet or winding the coil round a soft-iron core so that the field is stronger (increases the peak value not the frequency).

3- Rotating the coil ***faster*** (increases both the peak value and the frequency).

The diagram shows how the varying voltage corresponds to the different positions of the coil:

- The ***voltage is largest*** when the coil is ***horizontal*** (cutting through the field is maximum as the coil is perpendicular to the field).
- The ***voltage is zero*** when the coil is ***vertical*** (no cutting through magnetic field lines as the coil is parallel to the field).
- The ***direction of the induced current is reversed every half a rotation***. This is because the sides of the coil reverse their direction of motion across the field every half a rotation.



Questions

1. Describe the conditions necessary for induction to occur.

Answer

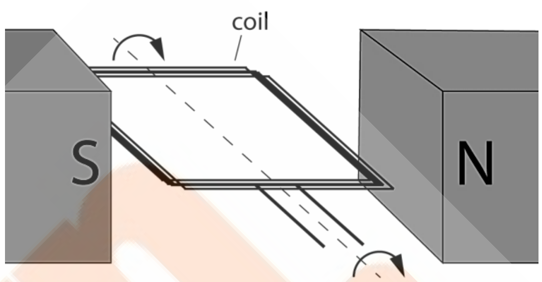
- Movement
- Of a wire / coil / conductor..
- Through a magnetic field /cutting through field lines / perpendicular to a magnetic field.

2. An a.c. generator consists of a rotating coil in a magnetic field as shown in figure

- **a) State one way the output voltage from the generator can be increased.**

- **b) Explain why an alternating voltage is produced.**
- **c) Explain why there is a point in the rotation where no voltage is produced.**

Answer



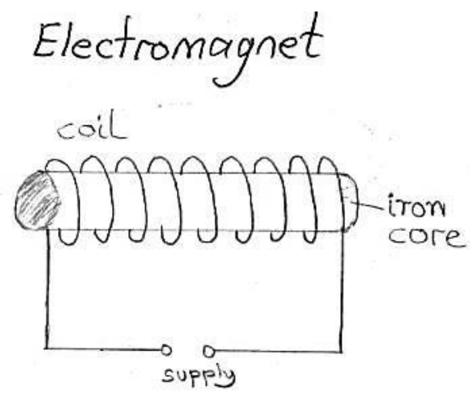
a) To make the voltage higher, you can either increase the strength of the magnets / magnetic field, rotate the coil faster, or use more turns on the coil.

b) An a.c. voltage is produced because any one side of the coil moves up then down through the field as it rotates, making the direction of the induced voltage change constantly.

c) At one point of the rotation, the sides of the coil are moving parallel to the field, so no field lines are cut. Therefore, no voltage is induced

Magnetic Effect of a Current (electromagnetism)

When a current flows through a wire a ***magnetic field is created*** around the wire. This is called ***Electromagnetism.***



To make a powerful electromagnet, you need three things

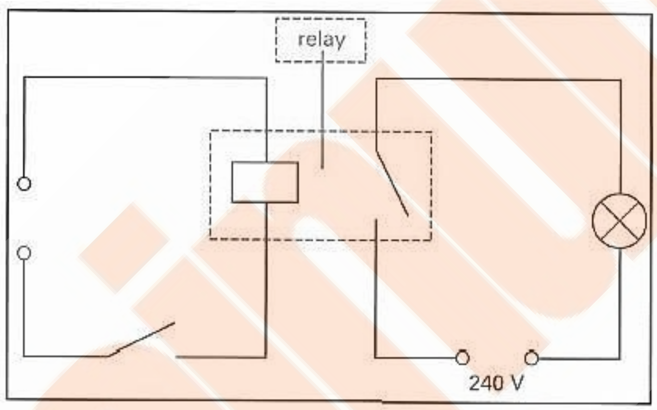
- A **coil,** like the solenoid, that will produce a concentrated field inside.
- A **current** flowing through the coil.
- A soft magnetic material **core** inside the coil that will be magnetized when the current is turned on, and quickly lose its magnetism when switched off.

To make a powerful electromagnet, you need a large number of turns in the coil, a high current, and a highly magnetic material like a soft iron core, notice the 3 'C's Remember **C**oil, **C**urrent, **C**ore.

Relay switch

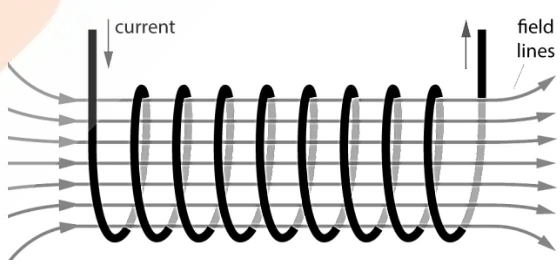
allow a small current to ***switch on or off a large current***

- ✓ when small current , usually supplied with a low voltage passes through the coil (***electromagnet***) it is magnetized and attracts the spring metal to close the second circuit which has separate power supply (high current)



Solenoid

Is basically a long coil of wire When a current passes through it, a strong magnetic field is produced in the center of the coil as shown in figure Outside the coil, the field is much weaker.



Properties of the magnetic field around a solenoid

1. The magnetic field around a solenoid is the same as that around a bar magnet. One end of the coil is a north pole and the other is a south pole.

2. The magnetic field inside a solenoid consists of close, equally spaced and parallel flux lines *"it is a strong uniform field"*.

3. If the direction of the current flowing through the solenoid is reversed, so too are the positions of the poles.

The strength of the magnetic field around a solenoid can be increased by

1. ***Increasing*** the ***current*** flowing through the solenoid.

2. **Increasing** the ***number of turns*** on the solenoid – this does not mean making the coil longer but packing more turns into the same space to ***concentrate the field***.

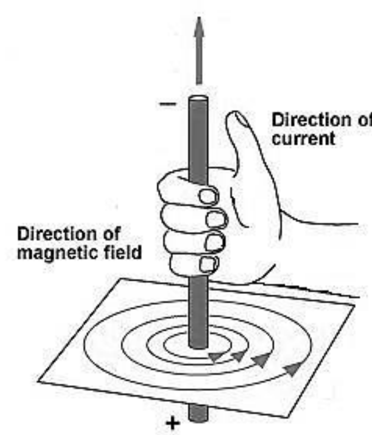
3. Wrapping the solenoid around a magnetically ***soft core such as iron***. Iron is easily magnetized when current flows and is easily demagnetized when no current flows in the solenoid

✓ **reversing** the direction of the **current** reverse the direction of the **magnetic field**

The right hand grip rule

Hold out your right hand with your thumbs tucked in and your thumb pointing upwards:

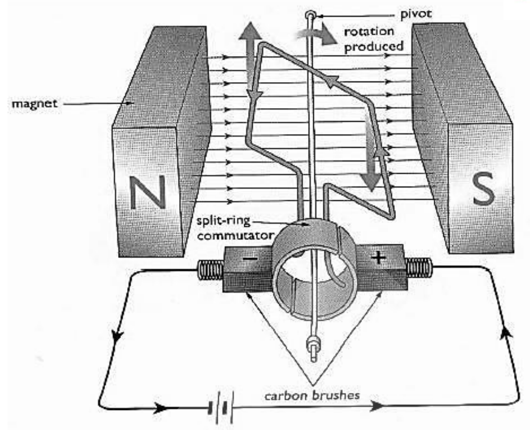
- the **thumb** is equal to the direction of **current**
- the **fingers** are equal to the **magnetic field direction**



DC electric motor

Motor consists of

1. a rectangular coil
2. N-S poles of a permanent magnet,
3. split ring commutators
4. Carbon brushes.



- As ***current*** passing to coil by two carbon brushes ***magnetic field is created around the coil***
- ***Repulsion Force*** between magnetic field of coil and magnetic field of permanent magnet , the ***coil turn 180 ^{0} half turn***
- split ring commutator ***reverse direction of current every half turn*** , to reverse magnetic field of coil to complete rotation of coil (complete turn)

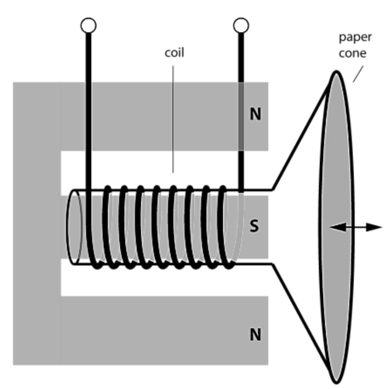
To increase the rate of motor (the speed of rotation)

1. ***Increase*** the ***number of turns*** or loops of wire
2. ***Increase*** the ***strength of the magnetic field*** (use a stronger magnet).
3. ***Increase*** the ***current*** flowing through the loop of wire.

✓ If the direction of the current, or the poles of the magnet are ***reversed***, rotation will proceed in the ***Opposite*** direction.

Loudspeaker

The interact of the magnetic field generated by the coil and magnetic field of permanent magnet apply force on the cone so that it moves in certain frequency which produce sound



Questions

1. A loudspeaker is connected to an a.c. electrical supply and produces a sound wave. Suggest one way the speaker or supply could be modified or changed to produce:

- **a) A louder sound.**
- **b) A higher frequency sound.**

Answer

a) To make the sound louder, you can increase the current (or voltage) from the supply, increase the strength of the magnet / field used in the speaker, or use more turns on the coil.

b) To produce a higher frequency sound, the frequency of the a.c. supply must also be increase

2. A simple motor rotates due to the 'motor effect' forces acting on the coil. Suggest two ways of increasing the force on the coil, and hence the speed of rotation.

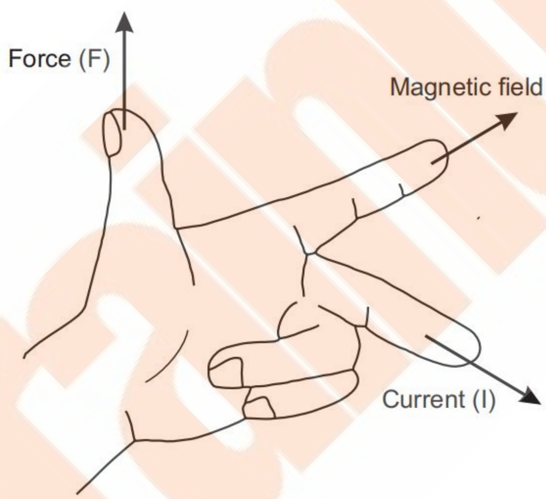
Answer

- Increase the current (or supply voltage).
- Increase the magnetic field strength produced by the magnets.
- Increase the length of the wire in the field, by having more turns on the coil.

Fleming's left-hand rule

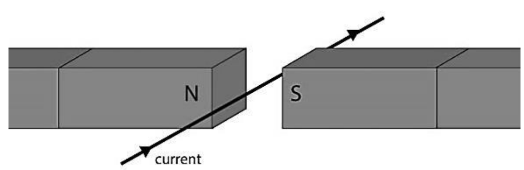
- The **Thumb** indicates **the thrust (a force)** on the current carrying conductor.
- The **First** finger indicates the magnetic **field** (remember field lines go from north to south).
- The **second** finger indicates the **current.**
- The magnetic field is always directed from **north to south**.

✓ Note that all three fingers in the left-hand rule are **perpendicular** to each other. If there is a situation where the current is parallel to the magnetic field, then there is no force.



Questions

1. A metal wire has a current flowing through it, and is placed between two permanent magnets as shown here:

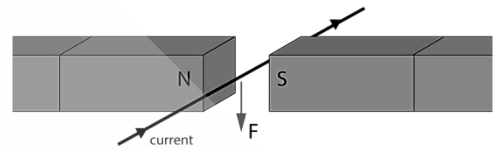


- **a) Use the left-hand rule to predict the force on the wire. Draw an arrow on the diagram to show the direction of this force. Label the arrow 'F'.**

- **b) Describe a method of increasing the size of the force F without replacing the magnets.**

Answer

a) Your first finger on your left hand should point right, from N to S. Your second finger should point into the 'page'. This leaves your thumb pointing downwards. Your thumb indicates the motion and hence the force. Draw an arrow downwards as shown here



b) You can increase the force by increasing the current. Alternatively, wrapping the wire into a loop or coil with only one edge inside the field will effectively increase the length of the wire. (Note that the magnets cannot be replaced in the question, so you cannot increase the field strength).

Summary

	D.C. Motor	A.C. Generator
Inputs → outputs	I + magnetic field → Force	Force +magnetic field → I
Energy transformations	Electrical → K.E	K.E. → Electrical
Hand Rule	Fleming's Left	Fleming's Right
Main Application	D.C. Motor	A.C. Generator
Electricity	Input is D.C.	Output is A.C.
Brushes connection	Split ring commutator	Slip rings
How to Increase	Increase I, magnetic field or turns	Increase speed of rotation, magnetic field or turns
Another application	Loudspeaker	Transformer

Transformers

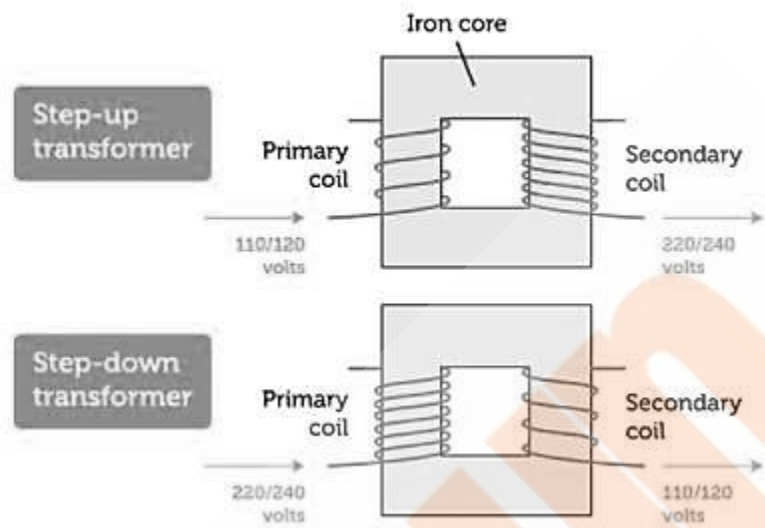
A transformer is a device that can ***change*** the ***potential difference*** or ***voltage*** of an ***alternating current*** AC

- a ***step-up*** transformer ***increases*** the ***voltage***

In a step-up transformer,($V_s > V_p$) &($N_s > N_p$)

- a ***step-down*** transformer ***reduces*** the ***voltage***

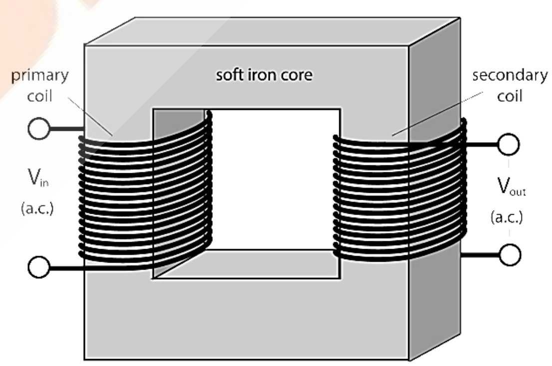
In a step-Down transformer $(V_s < V_p)$ & $(N_s < N_p)$



Structure of a transformer

A basic transformer is made from ***two coils of wire***, a ***primary coil*** from the ***alternating current*** (ac) input and a ***secondary coil*** leading to the ac output. The coils are not electrically connected. Instead, they are wound around an iron core. This is easily magnetized and can carry magnetic fields from the primary coil to the secondary coil

- ✓ **The alternating voltage causes an alternating magnetic field to be set up inside the iron core. This in turn induces an alternating voltage in a secondary coil**



$$\frac{\text{input (primary) voltage [V]}}{\text{output (secondary) voltage [V]}} = \frac{\text{number of primary turns}}{\text{number of secondary turns}}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

Questions

1. A phone charger uses a transformer with 5 000 turns on the primary coil and 250 turns on the secondary. It is plugged into the mains supply with an input voltage of 240 V.

- **a) Explain if this is a step-up or step-down transformer.**
- **b) Calculate the output voltage of the transformer.**

Answer

a) There are **fewer** turns on the secondary coil than the primary, so this is a step-down transformer.

b)

$$\frac{V_{in}}{V_{out}} = \frac{n_p}{n_s}$$

$$\frac{240}{V_{out}} = \frac{5000}{250}$$

$$\frac{240 \times 250}{5000} = \frac{V_{out}}{1}$$

So $V_{out} = 12$ V

2. A very high voltage is required for 'spark' plugs that ignite the petrol in any car engine. The transformer used to do this has an input voltage of 12 V and an output voltage of 4800 V. The primary coil has only 10 turns.

Calculate the number of secondary turns required to produce 4800 V.

Answer

$$\frac{V_p}{V_s} = \frac{n_p}{n_s} \qquad \frac{12}{4800} = \frac{10}{n_s}$$

$$\frac{n_s}{1} = \frac{4800 \times 10}{12}$$

So $n_s = 4000$

Transformers and efficiency

The formula for electrical power is P = I x V as We also know that energy cannot be created **Assuming the transformer is 100% efficient** and no power is lost, then the output power must match the input power.

Input power = output power

$$V_p \times I_p = V_s \times I_s$$

Questions

3. A school power supply is used to run a heating element for an experiment. The heating element runs on 12 V, and has a power output of 60 W.

The transformer used in the power supply has 240 V input and 800 turns on the primary coil.

Calculate:

- **a) The number of turns on the secondary coil of the transformer.**
- **b) The current output to the heating element.**
- **c) The current input to the transformer.**

Answer

$$\frac{V_p}{V_s} = \frac{n_p}{n_s} \qquad \frac{240}{12} = \frac{800}{n_s}$$

and rearranging this gives

$$n_s = \frac{12 \times 800}{240}$$

So $\mathbf{n_s = 40}$

b) P = I x V,

so 60 = I x 12 Therefore **I = 5 A**

c) Using the second transformer equation $V_p \times I_p = V_s \times I_s$ gives:

$V_p \times I_p = V_s \times I_s$

$240 \times I_p = 12 \times 5$ (from part b)

Therefore:

$$I_p = \frac{12 \times 5}{240}$$

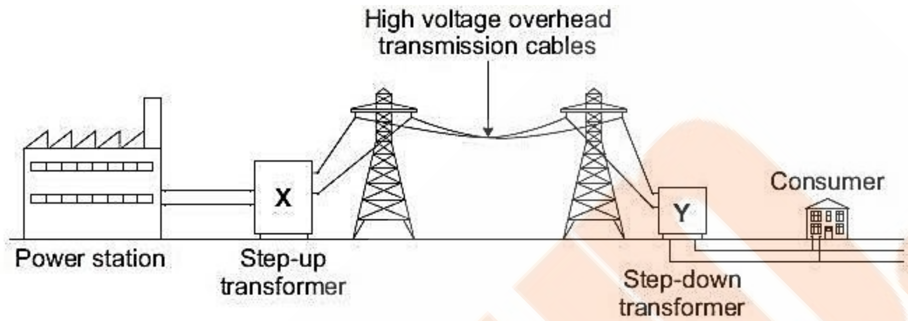
$\mathbf{I_p = 0.25\ A}$

The national Grid system

- It is a network of wires and cables that carries electrical energy from power stations to consumers such as factories and homes. To transfer the energy from the power station to your home we use ***A high voltage and a low current.***
- Because if the ***current*** flowing through the wire is kept to a ***minimum***, the ***heat losses are also reduced*** This is done with transformers at each end of the Grid

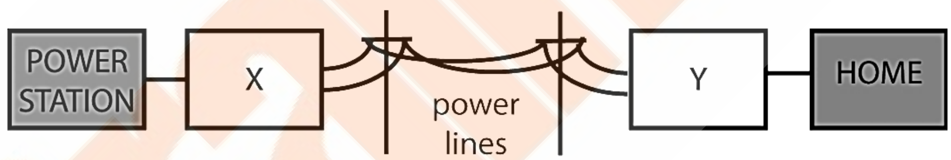
system to step-up the voltage and keep the current very low. This is the main reason for ***using a.c.*** in the Grid (transformers do not work with d.c.).

- The step down transformer at the end of the transmission line reduces the voltage back to safe usable levels at the consumer end



Questions

4. The diagram below shows the main stages in a local power distribution system:



a) State the name of the type of transformer used at X and Y.

b) Explain why these transformers are required.

Answer

a) X is a step-up transformer, Y is a step-down transformer.

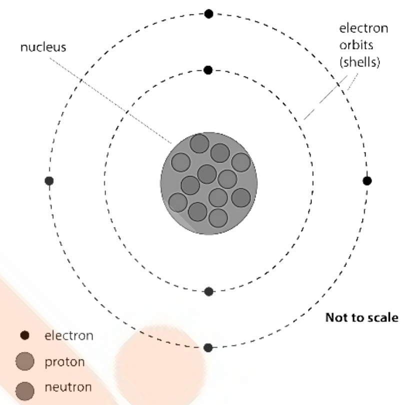
b) A step-up transformer increases the voltage and decreases the current. A lower current leads to less power loss in the cables. (The high voltage and low current makes the transmission more efficient).

The step-down transformer is required to reduce this high voltage back down to safe levels for domestic use.

5-Atomic Physics

Atom

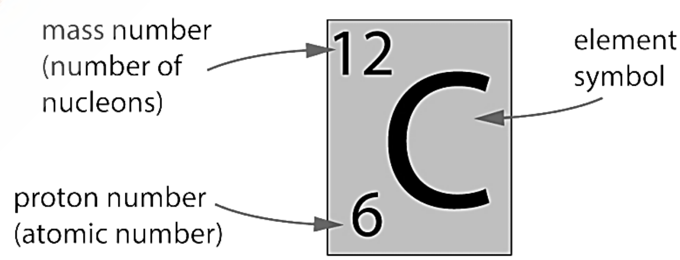
All atoms are made of three sub-atomic particles



- **Protons** - these have a positive charge (of +1) they are found in the nucleus.
- **Neutrons** - these have no charge (are neutral) they are also found in the nucleus.
- **Electrons** - these have a negative charge (of -1), they orbit the nucleus.

Subatomic particle	Mass	Charge	Location
Proton	1	+1	Nucleus
Neutron	1	Neutral	Nucleus
Electron	1/2000	-1	Outer shell

- You will need to learn the terms atomic (or proton) number, mass (or nucleon) number, and what they mean:
- The bottom number is always the **atomic number**, and is the **number of protons in the nucleus.**



- The top number is always the **mass number**, and is equal to the **mass of the nucleus**. It equals the **total number of particles in the nucleus**, known as nucleons.

Example

an atom of oxygen is represented by O_8^{16}

- ✓ is the chemical symbol for oxygen
- ✓ The atomic number is 8 (the nucleus contains 8 protons)
- ✓ The mass number is 16 (so it must have 8 neutrons).

Questions

1. The element sodium (Na) is written in notation as: $^{23}_{11}\mathbf{Na}$

State the number of protons and neutrons in this atom of sodium.

Answer

The bottom number represents the proton number, so there are 11 protons.
The top number of 23 gives the total number of protons and neutrons, so there are 23 - 11 = 12 neutrons.

2. Lead is a metal with the symbol Pb. A common atom of lead has 82 protons and 125 neutrons. Using standard notation (as shown in question 1), give the notation for this atom of lead.

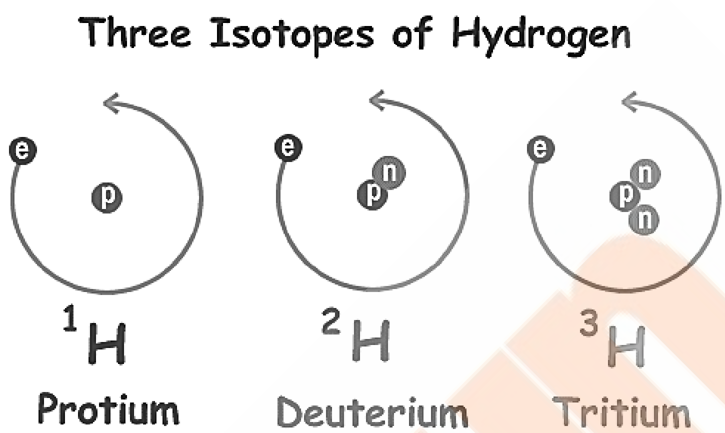
Answer

If the atom has 82 protons and 125 neutrons, the total mass is 82 + 125 = 207.
Therefore the notation will be:

$^{207}_{82}\mathbf{Pb}$

Isotopes

Isotopes have the **same number of protons, but different numbers of neutrons.**



Questions

3. The list below shows the notation for some atoms found in a sample of sea water. It includes 2 isotopes:

$^{1}_{1}\mathbf{H}$ $^{4}_{2}\mathbf{He}$ $^{5}_{3}\mathbf{Li}$ $^{2}_{1}\mathbf{H}$ $^{9}_{5}\mathbf{B}$ $^{9}_{4}\mathbf{Be}$

- **a) Define the term 'isotopes'.**
- **b) Identify the two isotopes in the list.**

Answer

a) isotopes have the same number of protons but different numbers of neutrons.

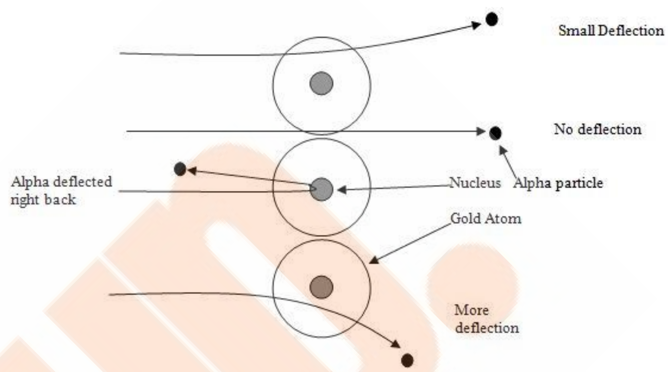
b) We are looking for 2 atoms with the same proton number (the bottom number) and hence the same symbol.

The two isotopes are: $^{1}_{1}\mathbf{H}$ and $^{2}_{1}\mathbf{H}$

Alpha scattering experiment

In this experiment, a beam of alpha particles was aimed at a thin sheet of gold foil. The experiment must be carried out in a vacuum tube to prevent alpha particles from being stopped by air particles.

Results



1. ***Most*** of alpha particles ***pass straight through the gold foil***, because they do not pass close to the nucleus

2. ***Some*** particles suffer ***some deflection***. The closer the particles are to the nucleus, the more they are deflected.

3. ***Few*** particles ***closely approach a gold nucleus*** so they ***deflect backwards***

Conclusions

- ✓ From 1, the volume of the ***nucleus is small*** as compared to the volume of the atom; ***the atom is mostly empty space.***
- ✓ From 2, the atom has a ***positively charged nucleus***.
- ✓ From 3, the atom has a ***dense, relatively heavy nucleus***; the nucleus carries most of the atom's mass.

Radioactivity

1) Stability & radioactivity

Some elements have atoms with ***unstable nuclei***. These unstable nuclei emit high-energy particles and rays called ***radiations***.

Radioactive decay

Is the ***spontaneous random*** emission of alpha (α), beta (β) particles or gamma (γ) rays from the nuclei of unstable atoms to become more stable

Random

Means we cannot predict which particular nucleus will decay next, all nuclei have a constant probability of decay.

Spontaneous

Means that the decay process is unaffected by environmental conditions such as temperature, pressure,

2) Types of nuclear radiation

Nuclear radiations are sometimes called ***ionizing radiations***. This is because these radiations interact with neutral atoms of air, which makes ***atoms gain or lose electrons***, forming ions.

The three types are

- ✓ Alpha (α) particle
- ✓ Beta (β) particles
- ✓ Gamma (γ) radiation

a) Alpha particles (α)

It is identical to the nucleus of a ***helium atom*** (a helium atom without its orbiting electrons, it's not a helium atom). Alpha particles make frequent collisions with gas molecules along their paths, causing intense ionization. Accordingly, they have ***strong ionizing***

Here's its nuclear equation

$$^{A}_{Z}X \rightarrow \, ^{A-4}_{Z-2}Y + \, ^{4}_{2}He$$

Note that

- ✓ The mass number reduced by 4 and the atomic number reduced by 2

For example

$$^{222}_{88}Ra \rightarrow ^{218}_{86}Rn + ^{4}_{2}He$$

b) Beta particles (β)

A beta particle is a ***very fast moving electron*** that is ejected by a decaying nucleus, This means that ***the atomic number increases by 1, while the mass number stays the same***. Beta particles are smaller & carry less charge so they interact less frequently with matter in their paths. This is why they have ***weak ionizing***

Here's its nuclear equation

$$^{A}_{Z}X \rightarrow {}_{Z+1}^{A}Y + {}_{-1}^{0}e$$

For example

$$^{14}_{6}C \rightarrow ^{14}_{7}N + {}_{-1}^{0}e$$

Note that

- ✓ the mass number stay the same while the atomic number increase by 1

C) Gamma rays (γ)

Gamma rays is electromagnetic radiation emitted from the nucleus of an unstable atom so they have a ***very weak ionizing***

Neutron decay

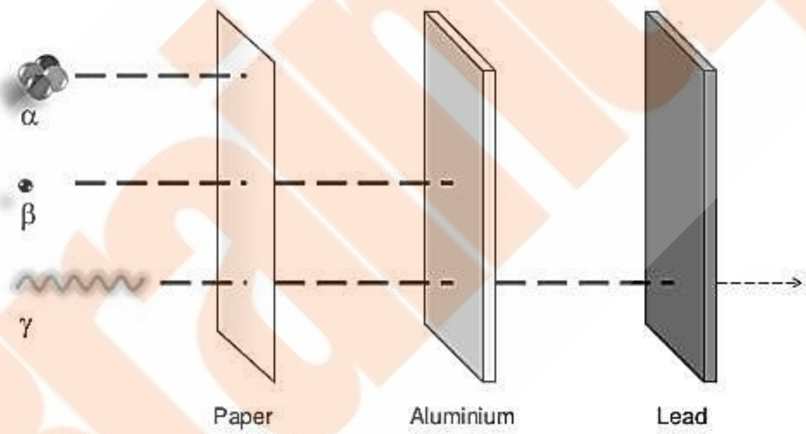
Some isotopes lose neutrons when they decay , A neutron has a mass of 1 and no charge, it is therefore written as: $^{1}_{0}\mathbf{n}$

Again, the decay of an isotope is then quite easy to work out. For example, if Beryllium-13 decays by emitting a neutron:

$$^{13}_{4}\textbf{Be} \rightarrow\ ^{1}_{0}\textbf{n} +\ ^{12}_{4}\textbf{Be}$$

Penetrating power

The **penetrating power** of alpha rays, beta rays, and gamma rays varies greatly. ***Alpha*** particles can be blocked by a few pieces of ***paper***. ***Beta*** particles pass through paper but are ***stopped by aluminum*** foil. ***Gamma*** rays are the most difficult to stop and require ***concrete, lead***, or other heavy shielding to block them



Types of radiation	Composition	Mass	Charge	Symbol	Ionizing Power	Penetration Power
Alpha Particle	2 Proton& 2 neutrons (Helium nucleus)	4	+2	$^{4}_{2}\alpha$	Very Strong (highest p)	Completely absorbed by a paper or by skin **In air:** 5-10 cm
Beta Particle	1 high energy electron (Range of speeds)	Almost zero (1/2000)	-1	$_{-1}^{0}\beta$	Weak	Completely absorbed by a thin sheet of aluminium. **In air:** 5-10 m
Gamma rays	Electromagnetic waves	zero	zero	γ	Very Weak	A sheet of several cm of lead or concrete wall will absorb most of gamma rays but **In air:** 5-10 Km

Questions

1. A student is researching the nature of alpha, beta and gamma radiation. Which of these three:

- **a) Has the largest mass?**
- **b) Has no charge?**
- **c) Will only pass a few centimeters through air?**

Answer

a) Alpha particles have the largest mass.

b) Gamma radiation has no charge.

c) Alpha can only pass through a few cm of air.

2. A radioactive isotope is thought to be a beta emitter, with no alpha or gamma being emitted. Describe an experiment to prove this result.

Answer

You need a Geiger counter to use as a detector.

First, place paper / tissue in front of the source. If alpha radiation is present, the detected count rate will drop significantly. If there is no drop, the radiation is beta or gamma.

Second, place **a** thin aluminum sheet or two in front of the source. If the count rate drops, the source is a beta emitter. Gamma rays will not be significantly affected by the aluminum barrier.

3. An alpha particle is given the letter α

- **a) State the mass number and atomic number of an alpha particle.**
- **b) Complete the missing numbers in the alpha decay equation below, for the isotope plutonium 239:**

$$^{239}_{94}\mathbf{Pu} \rightarrow {}^{\_}_{\_}\mathbf{U} + {}^{\_}_{\_}\boldsymbol{\alpha}$$

<u>Answer</u>

a) Alpha particles have a mass of 4 and an atomic number of 2.

b) The missing numbers are shown here

$$^{239}_{94}\mathbf{Pu} \rightarrow {}^{\mathbf{235}}_{\mathbf{92}}\mathbf{U} + {}^{\mathbf{4}}_{\mathbf{2}}\boldsymbol{\alpha}$$

4**. During beta decay, the mass of the nucleus remains constant, whilst the atomic number increases by 1.**

- **a) Explain the change in the nucleus that causes this result.**
- **b) Stronium-90 (Sr) is a radioactive isotope ('radioisotope') that decays by emitting a beta particle. The resulting nucleus is an isotope of yttrium (Y). Complete the missing numbers in the beta decay equation shown below:**

$$^{90}_{38}\mathbf{Sr} \rightarrow {}^{\_}_{\_}\boldsymbol{\beta} + {}^{\_}_{\_}\mathbf{Y}$$

Answer

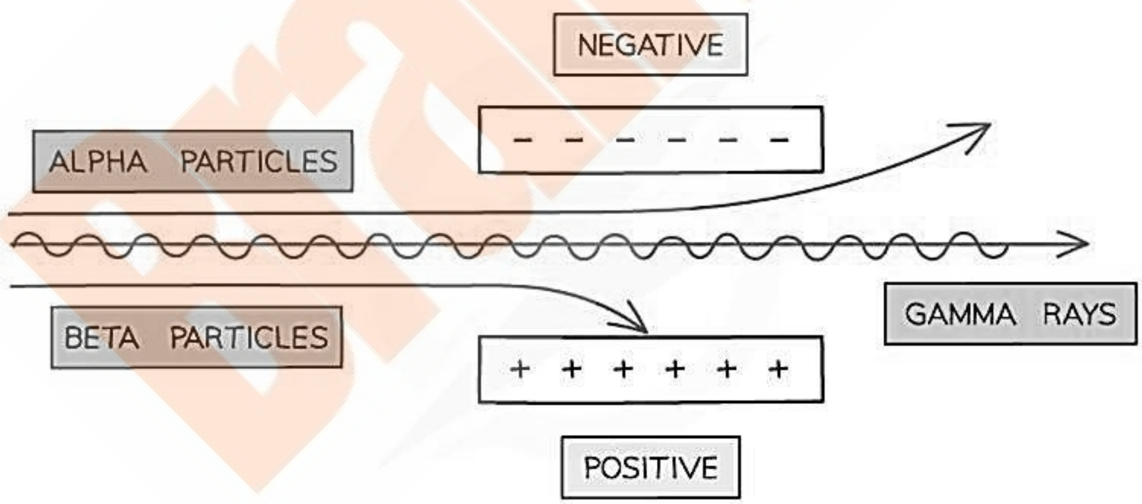
a) During beta decay, a neutron changes into a proton and an electron, causing an increase in the nuclear proton number of +1 but no change in mass. (The electron is ejected from the nucleus).

b) The missing numbers - shown i

$$^{90}_{38}Sr \rightarrow \, ^{0}_{-1}\beta + \, ^{90}_{39}Y$$

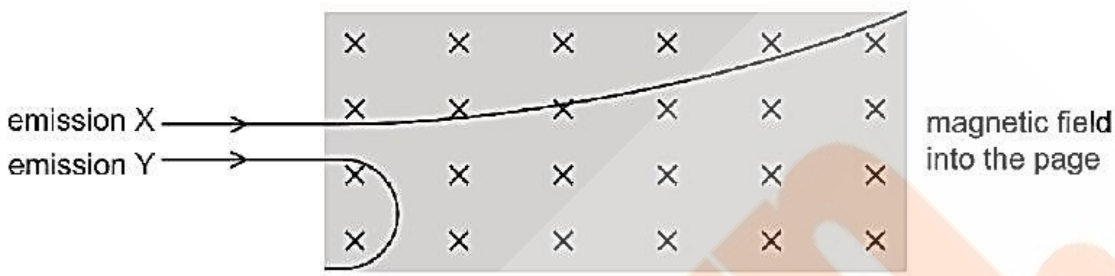
a) Deflection in electric fields

Electric field lines represent the direction of an electric field which is from the ***positive*** plate to the ***negative*** plate. The ***positively*** charged ***alpha particles are attracted to the negative plate*** while the ***negatively*** charged ***beta particles are attracted to the positive plate***.



b) Deflection in magnetic fields

Alpha & beta particles are deflected in directions given ***by Fleming's left hand rule***. Keep in mind that negative charges traveling to the right counts as a conventional current to the left



Radiation and half-life

The half-life time of a radioactive sample is the time taken for half the nuclei present in this sample to decay

(**The *time taken for the activity of a radioactive sample to decrease to its half***)

- The half-life is unaffected by temperature or pressure but each radioactive element has its own definite half-life.

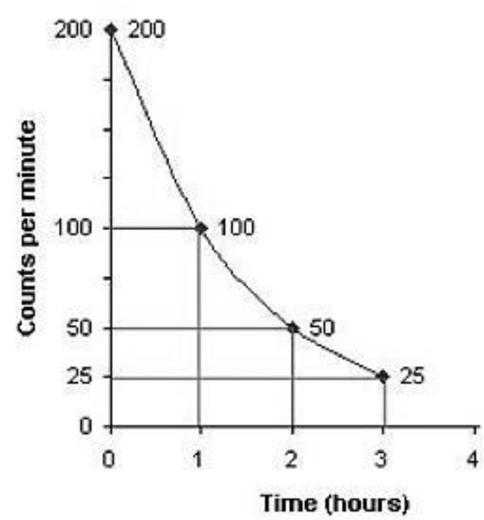
The decay curve

The activity of a sample is the average number of ***decaying*** atoms per unit time. If the activity of a sample is measured at different times, a decay curve against time can be plotted.

The decay curve of a sample starting with an activity of 200 radiations per hour is shown.

The curve shows that the activity falls by the same fraction in successive equal intervals of time.

The half-life time of this sample is 1 hr.



Questions

1. Radioactive radon gas can be found in caves in high concentrations. The isotope has a half-life of 3.8 days.

- **a) Explain the term 'half-life'.**
- **b) If the total mass of radon gas found in a cave is found to be 4 grams, calculate the quantity that should remain after 7.6 days. (Assume no more radon gas enters the cave).**

Answer

a) The half-life of a substance is defined as the time it takes for...

- half the nuclei to decay, or
- the count rate / activity to fall to half the original value

b) After 3.8 days, the mass will have halved, from 4 g to 2 g.
After 7.6 days (a further 3.8 days), it will have halved again down to 1 gram.

2. An isotope used in engineering has a half-life of approximately 10 years and an activity of 800 kBq.

If the dangerous isotope is buried for 30 years, what will be the activity after this period?

Answer

For this we will use a table of results to show our working out, halving the activity each half-life:

number of half-lifes	0	1	2	3
Time (yrs)	0	10	20	30
Activity (kBq)	800	400	200	100

From this table we can see that after 30 years, the activity is 100 kBq.

3. A medical sample of technetium-99m has an activity of 20 000 Bq. It has a half-life of 6.0 hours. What will the activity of the sample be after 24 hours?

Answer

Using a table again gives these results

number of half-lifes	0	1	2	3	4
Time (hours)	0	6	12	18	24
Activity (Bq)	20 000	10 000	5 000	2 500	1 250

From the table we can see that after 24 hrs, the activity is 1250 Bq

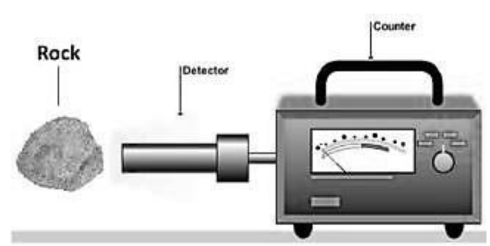
Detection of Radiation By

1-photographic film

Become blacked when subject to radioactivity, the darker the film the greater the radiation dose

2-Geiger-Muller (GM) tube

The main detector used now which is connected to a count rate meter giving reading in counts per unit time (minute or second)



Background radiation

A GM tube will record some count rate even in the absence of a source. This count rate is due to the ionizing radiation which is always present from the surroundings. It is called ***background radiation*** and ***should be subtracted from the counts recorded*** when a source is present to give the true count rate due to the source.

Sources of background radiation

1. ***Radon gases*** in the air
2. Some ***rocks in the Earth's crust*** or in building material
3. Radioisotopes used in certain ***medical*** procedures.
4. ***Cosmic rays*** from outer space.
5. Emissions from ***nuclear power stations***.

Used of radioactivity

1. ***Gamma rays*** are used to ***kill bacteria*** specially in ***sterilizing medical equipment*** and in ***preserving food***.
2. ***Alpha particles*** are used in **smoke alarm** for smoke detection. Alpha particles have high ionization effect and therefore they ionize the air molecules in between the two metal plates allowing the current to pass through. When smoke enters between the plates, some of the alpha particles are absorbed causing less ionization to take place. This means a smaller than normal current flows so the alarm switches on.
3. ***Beta particles*** are used to ***monitor the thickness of the paper or metal sheets*** in manufacturing factory. Some of the radioactivity is absorbed by the foil and some passes through to the detector. The thicker the foil, the fewer radio activities passes through it to the detector. The amount of radioactivity arriving at the detector is monitored by the computer. The thickness of the foil is controlled by the gap between the rollers.
4. ***Carbon-14*** is used to find the ***age of living organism or plants***. This method is called radioactive carbon dating. There's a small amount of radioactive carbon-14 in

all living organisms. When they die no new carbon 14 is taken in by the dead organism. The carbon-14 it contained at the time of death decays over a long period of time. By measuring the amount of carbon-14 left in dead organic material the approximate time since it died can be worked out

5. ***Uranium -238*** which eventually ***decays*** into lead is used to ***find the age of igneous rock***

6. In ***radiotherapy*** the ***high doses of gamma radiation are used to kill the cancer cells***

7. Find ***leaks*** or blockages in underground **pipes**.

Safety precautions

1. Always use the ***radioactive symbol*** where there is a radioactive substance stored
2. Always be ***stored in a lead-lined container***;
3. Be ***handled*** only with ***tongs***
4. ***Never*** be pointed at ***anyone***
5. **Never** be put in ***pockets***
6. Only ***checked*** by ***looking*** at them in a ***mirror***.

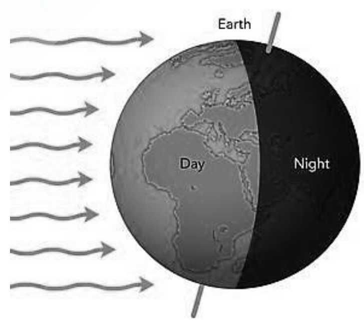
6- SPACE PHYSICS

The Earth

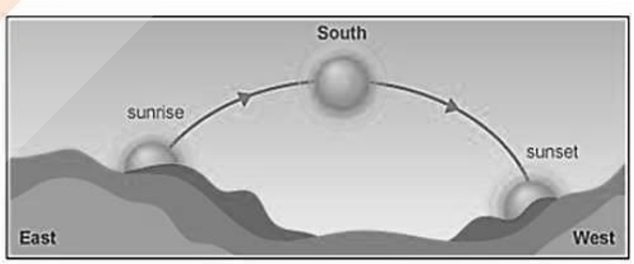
- The Earth is a **planet**, and it **orbits** the **Sun**.
- The Earth takes just over **365 days** to complete **one** orbit.
- The Earth also **spins** on its **axis** and it takes about **24 hours** to rotate once.
- The Earth's axis (an imaginary line through the Earth from the North pole to the South pole) is tilted at an angle of about 23.5 degrees
- The Earth is about 150 million kilometers from the Sun, and the Moon is about 384 thousand kilometers from the Earth

Day and night

- Because the **Earth spins** on its axis, sometimes you are facing the Sun and sometimes you are facing away from the Sun. The Sun only shines on the half of the Earth that is facing it.
- When you are **facing the Sun**, you are experiencing **day-time**.
- When you **face away from the Sun**, you are experiencing **night-time.**

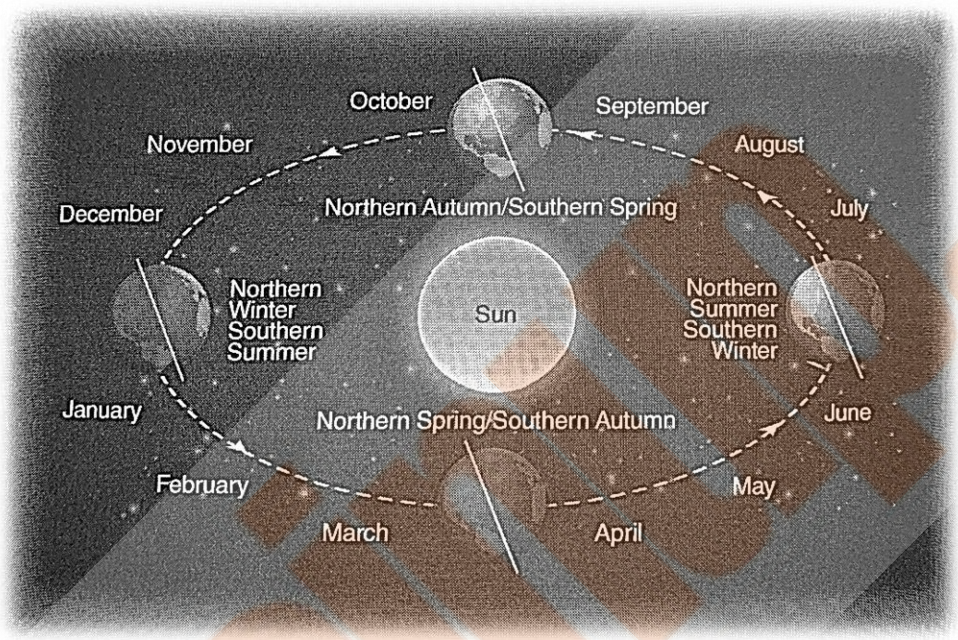


- The **Earth spins towards the East**. That is why the Sun appears to **rise in the East** and set in the West. At midday in the Northern Hemisphere it appears to be in the South.
- the earth that is rotating not the sun is moving

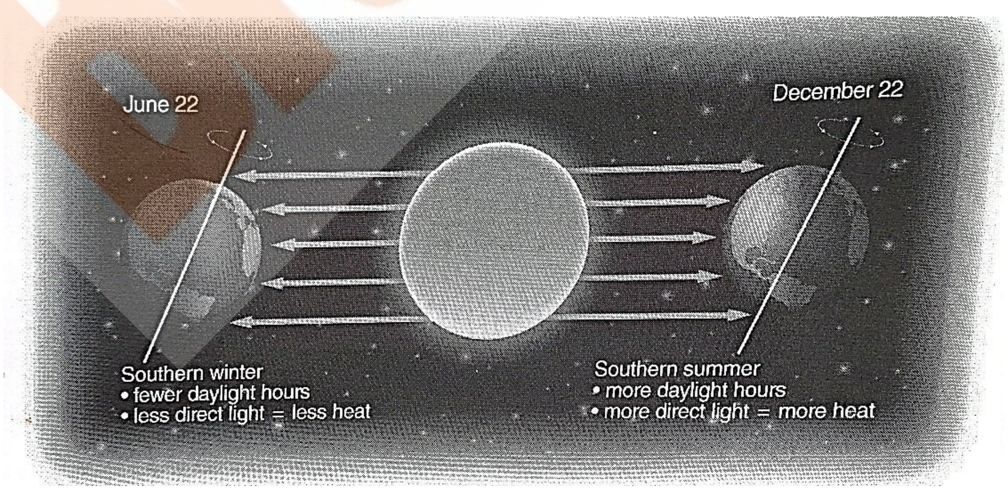


The Seasons

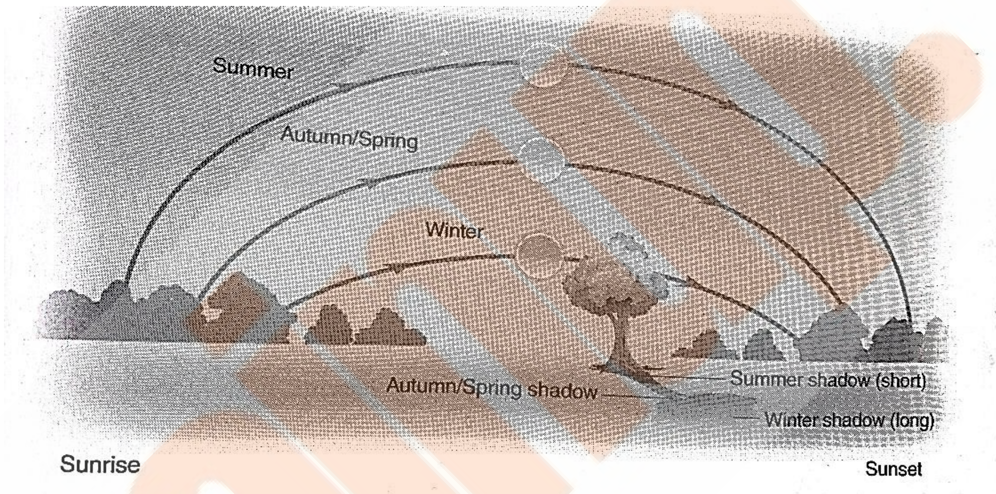
- The **Earth moves round the Sun** once in approximately 365 days , We experience different seasons due to the **amount of direct sunlight we receive**



- In December the **Northern Hemisphere** is tilted away from the Sun and in June it is tilted towards the Sun. In June the Northern Hemisphere receives more direct sunlight and so it is **summer**. At the same time, the Southern Hemisphere is tilted away from the Sun and it is **winter**.

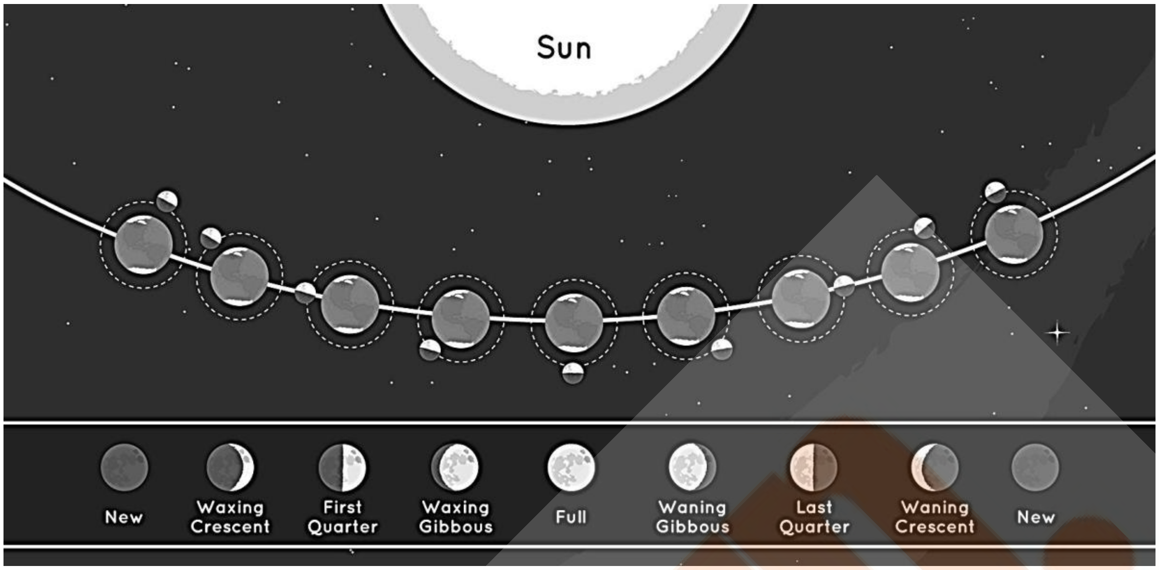


- At the **equator** the seasons do not vary as much because there is direct sunlight all year round.
- At the **poles** during winter there are days when the Sun never rises, and days during summer when the Sun never sets.
- The **maximum height** of the Sun in the sky varies according to the seasons. In summer it is high and casts short shadows. In winter it is low and casts long shadows. The variation is more pronounced nearer the poles. The diagram below shows how shadows vary in the Northern Hemisphere.



Phases of moon

- It takes about a **month** for the Moon **to orbit the Earth**. It orbits with the same side of the Moon facing the Earth all the time.
- We can only see the Moon because it is illuminated by (**reflects light from the Sun)**, which shines on it. It does not produce its own light.
- As the **Moon orbits** the Earth it reflects different amounts of light towards Earth. When the Moon is between the Sun and the Earth it does not reflect any light towards the Earth. We call this a New Moon. As it continues to orbit we see more and more of the Moon, and we say it is **waxing**, towards a Full Moon, and then it wanes again



Orbital speed

This formula to give us the speed around a circular orbit:

$$\text{orbital speed} = \frac{2 \times \pi \times \text{orbital radius}}{\text{time period}}$$

$$v = \frac{2 \times \pi \times r}{T}$$

- If a question gives the radius in kilometers (km) and the time in hours (h), then the speed will be in units of km/h.

Questions

1. The moon orbits the Earth in approximately 708 hours, with a radius of orbit of 385 000 km. Using the formula given above, calculate the orbital velocity of the Moon.

Answer

$$v = \frac{2 \times \pi \times r}{T} \qquad v = \frac{2 \times \pi \times 385\,000}{708}$$

Therefore v = 3 420 km/h (to 3 sig figs) or 0.949 km/s.

2. The Hubble Space Telescope (HST) orbits the earth at a speed of 7.6 km/s and has an orbital time period of 5700 seconds.

- **a) Using the formula given above, calculate the radius of the HST's orbit from the center of the Earth.**
- **b) The Earth has a radius of 6400 km. Calculate the distance from the HST to the Earth's surface.**

Answer

a) Both time period and speed include seconds, so we can substitute the numbers directly into the formula

$$v = \frac{2 \times \pi \times r}{T} \qquad 7.6 = \frac{2 \times \pi \times r}{5700}$$

$$r = \frac{7.6 \times 5700}{2 \times \pi}$$

Therefore r = 6900 km (to 3 sig figs) .

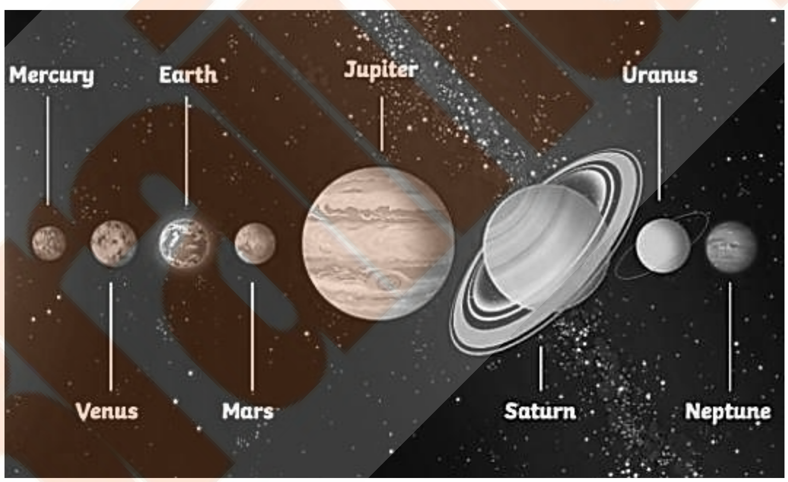
b) The Earth's radius is 6400 km, so the HST's height above the Earth's surface is 6900 - 6400;

so the distance = 500 km

Space

1. The solar system: Our solar system consists of the Sun at the center, with 8 planets in orbit around it. There are also comets orbiting the Sun, and moons orbiting the planets. There are similar solar systems around other stars.

- To remember the planets in order " **M**y **V**ery **E**ducated **M**other **J**ust **S**erved **U**s **N**oodles"
- the four planets **nearest** to sun are **rocky and small** and the four planet **further** from the sun are **gaseous** and **large**



2. Galaxies: There are **billions of stars** in most **galaxies.** Our Sun is in a huge galaxy called the **Milky Way**. It has about 100 billion stars in it. Many probably have planets. The galaxy nearest to us is called the Andromeda galaxy both of these galaxies are spiral galaxies, with the outer stars orbiting around a very heavy central mass of stars.

3. The universe: The observable universe is believed to consist of **billions of galaxies**

Gravity

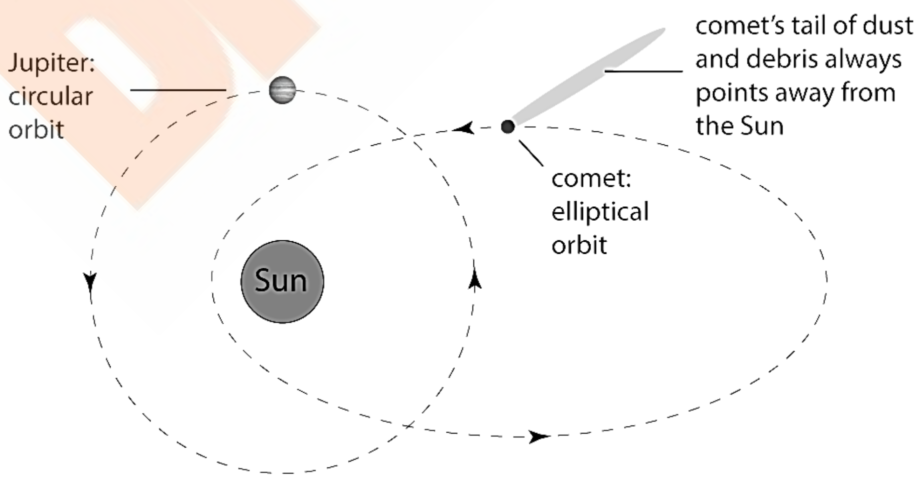
The motion of galaxies, stars and planets are all ruled by the force of gravity. This force between any 2 objects depends on the **masses** of the objects and also the **distance** between them. The pull of gravity makes:

- moons orbit planets
- artificial satellites (like the international space station) orbit the Earth
- the Planets orbit the Sun
- Comets orbit the Sun.

Orbits

Moons generally travel around planets in a circular orbit. This means that they keep approximately the same distance from the planet at all times. This is also true of planets as they orbit the Sun. The Earth stays at approximately the same distance from the Sun all year as it travels around in its orbit.

However, **comets** are very different. The distance from the Sun and the speed of a comet varies dramatically, as shown in figure



The correct mathematical name for this orbit shape is an **ellipse**. All comets have an elliptical orbit, and as they approach the Sun, the pull of gravity makes them travel faster and faster. The comet is fastest at its closest approach to the Sun

- as the distance from the sun increase the time to complete an orbit for a planet increase for planet increase because
  -the orbital distance increase
  -the speed of a planet in its orbit decrease as gravitational field strength decrease
- in **elliptical** orbit the distance from the sun change and gravitational potential energy change because of the **conservation of energy**

$$\textbf{Total energy} = E_k + E_p$$

- when the planet is **closer** to the sun its E_p is smaller and its E_k is greater and it move faster

Asteroids

- Are made up of **metal** and **rock** and are much smaller than planets usually with irregular shapes
- most of them are found **between** the planets **mars** and **Jupiter** the dwarf planet ceres is found there

Comets

- comets are lumps of **ice** and **dust** which orbit around the sun , many comets have **elliptical** orbit

Satellites

A satellite is anything that **orbits** a celestial body (star, planet, moon). Both natural and artificial satellites exist.

Natural satellites

The **Moon** is the Earth's natural satellite. Scientists believe that it was formed when a Mars-sized planet collided with the early Earth, throwing some of the crust into orbit. However the Moon was formed, it is locked into the Earth's gravitation field and circles our planet once every 27.5 days. Many other moons are the natural satellites for other planets in our solar system and beyond.

Artificial satellites

These have been placed into **orbit by man**. Among other jobs, artificial satellites orbiting the Earth are used for:

- telecommunications (transmitting information between distant parts of the Earth)
- satellite navigation systems
- spying on other countries
- weather forecasts
    - Communications satellites occupy a **geostationary** orbit. They are in orbit above the equator at just the right distance so that it takes them one day to complete an orbit. As a result, they always appear in the same position when seen from the ground. This is why satellite television dishes can be bolted into position and do not need to move.

Questions

3. A rocket launched from the Earth's surface has to escape from the Earth's gravitational pull.
Explain why it might be easier to launch a rocket from the surface of Mars.

Answer

Mars has a lower mass than the Earth, and therefore lower gravitational field strength (g). This means it takes less energy to launch the rocket into space.

4. Explain the difference between the orbit of a comet and of a planet.

Answer

Both comets and planets orbit the Sun. However, planets have an approximately circular orbit, whereas comets have a highly elliptical orbit

Stars

Stars have many **different colors**, ranging here from red and orange, to white and blue. This is because the stars all have a **different temperature** at the **surface**.

The **color** of the star indicates the temperature. Red stars are not as hot as orange stars. Then comes yellow/white, white, and finally blue stars that are extremely hot at the surface.

Surface temperatures in °C	Colour of the star	
30000 – 60000	Blue	
10000 – 30000	Blue white	
7500 – 10000	White	
6000 – 7500	Yellow white	
5000 – 6000	Yellow	
3500 – 5000	Orange	
< 3500	Red	

The evolution of stars

Nebula

All stars begin from a humble cloud of gas and dust, called a **nebula**. If the mass of a region of the nebula is large enough, gravity begins to pull the nebula together and compress it form a hot ball of gas known as **protostar**

- ✓ protostar becomes a **stable** star when the **inward force of gravitional** attraction is **balanced** by an **outward force** due to the high temperature in the centre of the star

Main sequence stars

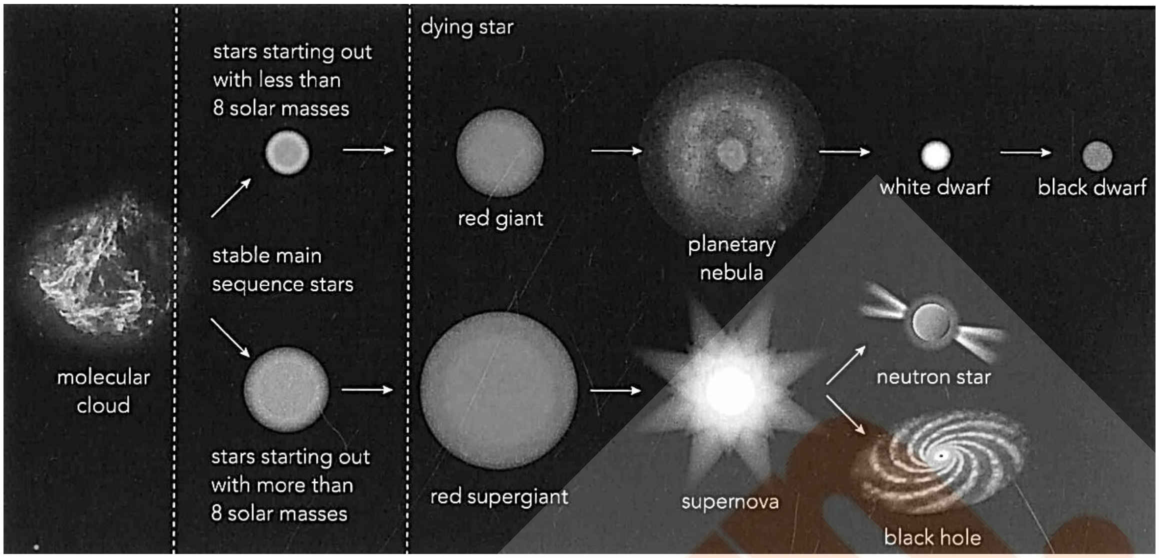
The gas has been compressed so much that the temperature reaches millions of degrees Celsius, enough for a fusion reaction to begin. A star is born! The fusion reaction lasts for a long time - billions of years for a star like the Sun

Red giant

When stars begin to run out of hydrogen, more complicated fusion reactions can start. The star begins to swell outwards and cool a little at the surface, producing **red giant stars**.

White dwarf

When the last of the fusion reactions stops, the star shrinks. As it does this, the compressed gases heat up making the star white hot at the surface, but very small



Very large stars (Supergiant)

Stars with a mass much higher than the sun will be extremely bright and will convert hydrogen at a vast rate through fusion reactions when the hydrogen runs out, they also swell up to make **red supergiant stars**

Supernova

Once a red supergiant runs out of fuel to sustain the complicated fusion reactions that occur, the star collapses very rapidly. As it rushes inwards, The star explodes in a flash releasing so much energy it can out-shine an entire galaxy This explosion is called a **supernova**.

Neutron star

The remaining core collapses into a tiny, extremely dense core made of neutrons, called a **neutron star**.

Black hole

If the core remnant has a **huge mass**, it collapses inwards to a point. Nothing can stop the collapse. This is where things get very weird, as the star is still there, with a high mass and strong gravity, but it is effectively a point in space. This is called a **black hole**.

Questions

1. The Sun is currently a main sequence star, in the middle of its evolutionary path.
Describe the next two stages in the evolution of stars like the Sun.

Answer

- The sun will eventually increase in size, and cool to become a red giant.
- After that, it will shrink to a much smaller size, and heat up to become a white dwarf.

2. Very large main sequence stars will eventually run out of hydrogen in the star's core. Describe the next stages in a life cycle of a star.

Answer

A very large main sequence star will

- Eventually increase in size to become a red supergiant.
- It then explodes. This is called a supernova.

- The star remnant then collapses to form a neutron star, or - if it is a huge remnant - to form a black hole.

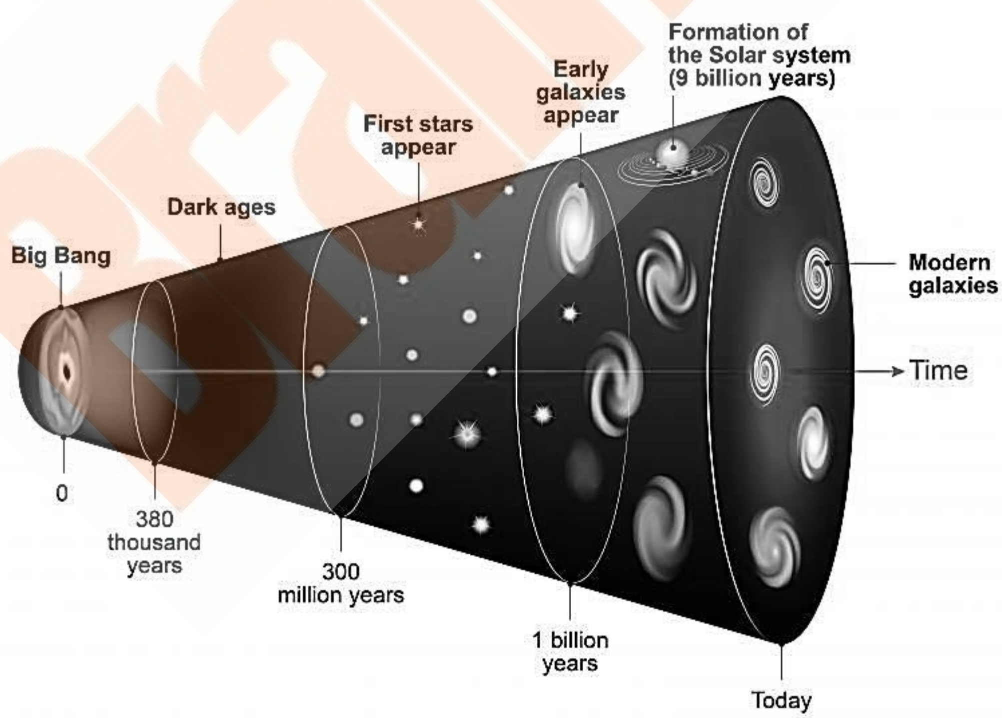
3. Explain what is meant by a nebula.

Answer

A nebula is a large cloud containing gases (like hydrogen and helium) / dust.

The Big Bang theory

This theory states that the Universe started at **a single point**. In an enormous release of energy (the Big Bang) all matter was created and moved outward from this point. Eventually the matter formed dust clouds, stars and the galaxies we see today. However, these galaxies are still moving outwards - the universe is still **expanding** and **cool**

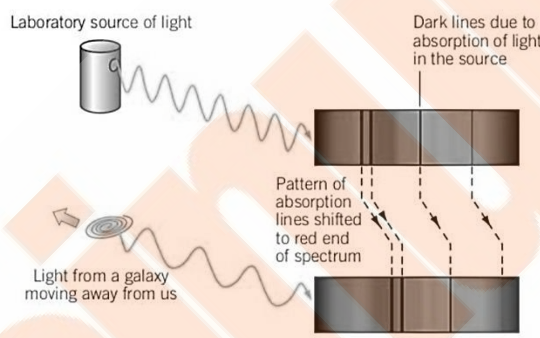


- Key pieces of evidence led to this being the main theory that is supported today. The two pieces of evidence are the **red-shift** of distant galaxies, and **CMB radiation**

1-Red-shift

When very distant galaxies were first observed, astrophysicists noticed that **frequencies** produced by the hydrogen in stars had been shifted to longer wavelengths.

- wavelength red end of the spectrum. This effect is called **red shift**.



Remember Doppler Effect A source of waves moving away from us produces a shift in the wavelength of light towards longer wavelengths. That is what is being observed here - distant galaxies are moving away from us at very high speeds. In fact, the **further** the **distance** to the galaxy, the **faster** the **recession velocity** (recession means 'moving away'). This higher velocity leads to a higher red shift.

2-cosmic microwave background radiation

If the big bang happened, releasing a vast quantity of matter and radiation, then the radiation remaining should now be enormously red-shifted into the microwave region of the EM spectrum. Penzias and Wilson had discovered what we now call the **cosmic microwave background radiation (CMB radiation)**, exactly as predicted by the Big Bang theory.

The CMB radiation, along with the red shift of distant galaxies has provided astrophysics with enough evidence for them to be reasonably certain that the Big Bang theory is correct. The universe did have a starting point

Questions

In 1964, CMB radiation was discovered.

- **a) State what is meant by CMB radiation.**
- **b) Explain why CMB radiation supports the Big Bang theory for the origins of the universe.**

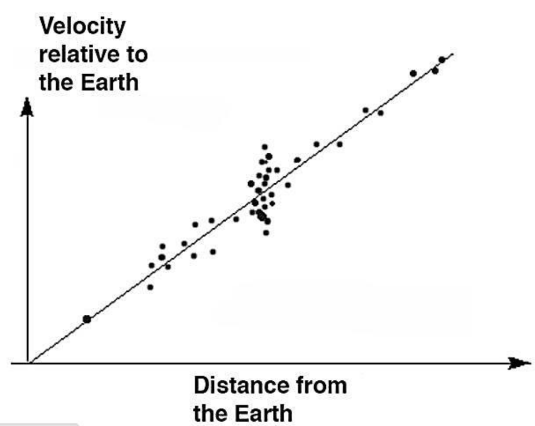
Answer

a) CMB radiation is cosmic (from space) microwave background (all around us) radiation.

b) This radiation is predicted from the big bang theory: Any radiation produced in the big bang should now be red-shifted to microwave radiation, but should be observable in all directions.

The Hubble constant

- Hubble's Law states that a galaxy's **recessional velocity** (its velocity away from us) is **directly proportional** to the galaxy's **distance** from Earth.
- A **graph** of recessional velocity against distance from Earth is a **straight line** passing through the origin.
- This graph shows that galaxies that **are further away** from Earth are **moving away** even faster than those closer to Earth. The Hubble constant is equal to the gradient of the graph



$$v = H_0 d$$

$v = recessional\ velocity\ of\ galaxy$
$H_0 = Hubble\ constant$
$d = distance\ to\ galaxy$

- ✓ the time it has taken for the galaxies to reach their current is given by

$$t = — = —$$

- ✓ so you can take — as an estimate for the age of the universe

This is further evidence that all matter in the universe came from hot dense point

Questions

A galaxy is found to be moving away with a speed of 2.1×10^7 m s^{-1}. The galaxy is at a distance of 9.5×10^{24} m from Earth Assuming the speed has remained constant, what is the age of the universe in years?

<u>Answer</u>

$$\mathbf{v = H_0 d}$$

Rearrange for the Hubble constant H_0, and calculate

$$H_0 = \frac{v}{d} = \frac{2.1 \times 10^7}{9.5 \times 10^{24}} = 2.2 \times 10^{-18}\ s^{-1}$$

Write the equation for the age of the universe T_0, and calculate

$$T_0 = \frac{1}{H_0} = \frac{1}{2.2 \times 10^{-18}} = 4.52 \times 10^{17}\ s$$

Convert from seconds into years

$$T_0 = \frac{4.52 \times 10^{17}}{(365 \times 24 \times 60 \times 60)} = 1.43 \times 10^{10} \text{ years}$$

Therefore, the age of the universe is estimated to be about **14.3 billion years**