# Physics
# Introduce - Apply - Assess

| **Paper 1** | **Paper 2** |
|---|---|
| Topic 1 Key Concepts | Topic 8 Forces Doing Work |
| Topic 2 Motion and Forces | Topic 9 Forces and Effects |
| Topic 3 Conservation of Energy | Topic 10 Electricity |
| Topic 4 Waves | Topic 11 Static Electricity |
| Topic 5 Light and EM | Topic 12 Magnetism and Motors |
| Topic 6 Radioactivity | Topic 13 Electromagnetic Induction |
| Topic 7 Astronomy | Topic 14 Particle Model |
|  | Topic 15 Forces and Matter |

# Forces

# Overview
# Forces

## Forces and their Interactions

- Scalar and Vector Quantities
- Contact and Non-contact Forces
- Gravity
- Resultant Forces

## Work Done and Energy Transfer

## Forces and Elasticity

## Moments, Levers and Gears (Physics Only)

## Pressure and Pressure Differences in Fluids (Physics Only)

- Pressure in a Fluid 1
- Pressure in a Fluid 2 (HT Only)
- Atmospheric Pressure

# Overview
# Forces

## Forces and Motion

- Distance and Displacement
- Speed
- Velocity
- The Distance-Time Relationship
- Acceleration

## Forces, Accelerations and Newton's Laws of Motion

- Newton's First Law
- Newton's Second Law
- Newton's Third Law

## Forces and Braking

- Stopping Distance
- Reaction Time
- Factors Affecting Braking Distance 1
- Factors Affecting Braking Distance 2

## Momentum (HT Only)

- Momentum is a Property of Moving Objects
- Conservation of Momentum
- Changes in Momentum (Physics Only)

# LearnIT!
# KnowIT!

## Forces

- Scalar and Vector Quantities
- Contact and Non-contact Forces
- Gravity
- Resultant Forces

# Scalars and Vectors

Materials in a classroom can be grouped into two groups – metals and non-metals.

Things we measure can be put into two groups as well – scalars and vectors.

Scalars: Things that we measure that have a magnitude (size) only are scalars.

Vectors: Things that we measure that have both magnitude and direction are vectors.

Sometimes direction is really important. In a crash the direction, as well as the speed, of the vehicles will determine how much damage is caused.

# Examples of Scalars and Vectors

**Some examples of scalars and vectors are shown in the table below.**

| Scalars | Vectors |
|---|---|
| Time | Forces (including weight) |
| Mass | Displacement |
| Temperature | Velocity |
| Speed | Acceleration |
| Direction | Momentum |

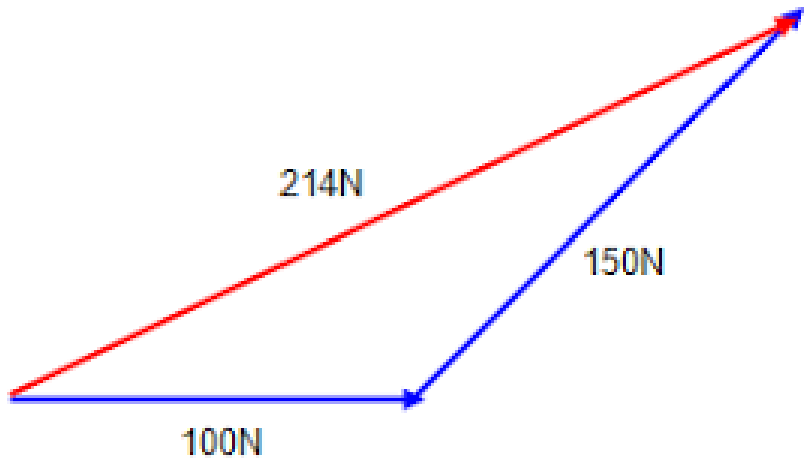
# Representing Vectors

Vectors can be shown by arrows.

The length of the arrow shows the size, or magnitude, of the force.

The direction of the arrow shows the direction of the force.

The vector arrows can be added together to show the resultant of two of more vectors.



# Contact and Non-contact Forces

**Forces can be placed into two groups. There are forces that act on contact and there are forces that act at a distance.**

| Contact Forces | Non-Contact Forces |
|---|---|
| Air Resistance | Gravity |
| Friction | Magnetism |
| Tension | Electrical Force |
| Normal Force | Nuclear Force |

# Gravity

Gravity is a non-contact force.

Gravity is the force responsible for the formation of galaxies, stars and planets.

Weight is the force acting on an object due to gravity. The force of gravity close to the Earth is due to the gravitational field around the Earth.

The weight of an object depends on the gravitational field strength at the point where the object is.

# Calculating Weight

The weight of an object can be calculated using the equation:

Weight (N) = Mass (kg) x Gravitational field strength (N/kg)

$$W = m\,g$$

It is useful to note that the gravitational field strength, g, on Earth is about 10 N/kg.

This means that a one kilogram mass would have a weight of 10 N. This can also be found using a calibrated spring balance (a newtonmeter).

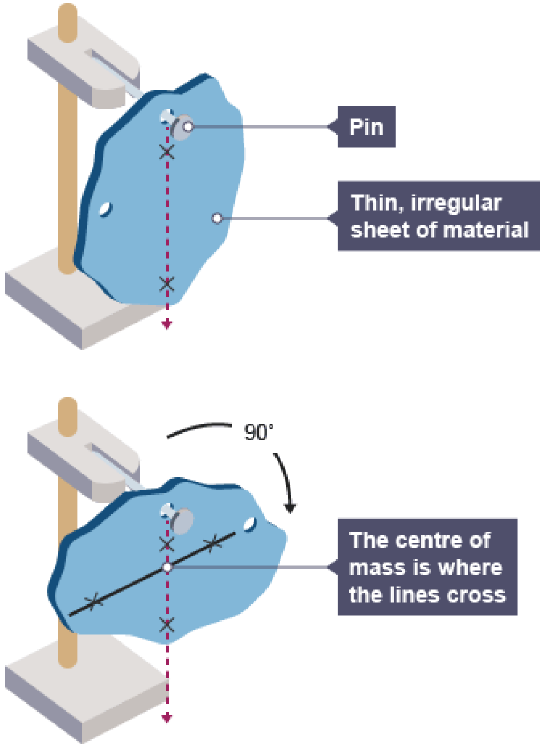
The value of the gravitational field strength will depend on where you are. Your weight on top of a mountain will differ slightly from your weight at sea level. On the Moon your weight will be approximately one sixth of your weight on Earth.

Weight and mass are directly proportional.

# Centre of Mass

The weight of an object may be considered to act at a single point referred to as the object's '**centre of mass**'.

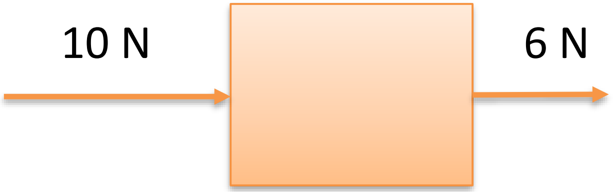
The centre of mass of an irregularly shaped 2-D object can be found by using a pin, some string and a small mass. By pinning the 2-D object up on a board with the string hanging from the pin (with the small mass on the end) the string will go through the centre of mass – mark with a line. Rotate the object and re-hang on the board. Draw a line to show where the string hangs. Where the lines cross is the centre of mass of the shape.



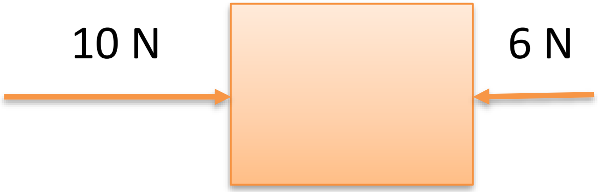
# Resultant Forces

**A number of forces acting on an object may be replaced by a single force that has the same effect as all the original forces acting together. This single force is called the resultant force.**

**When two forces act in a line the resultant force is the vector addition of the two vectors.  Remember the direction is important.**



**R = 16 N to the right**



**R = 4 N to the right**

# Calculating Resultant Force

**Example 1:**

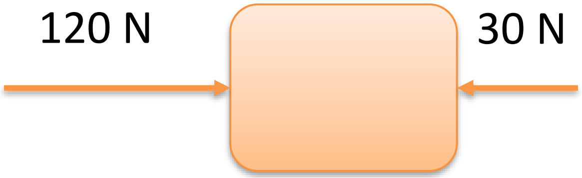
**A box is pushed along the floor with a force of 120 N. There is a resistive force of 30 N. Work out the resultant force on the box.**

**Solution:**

**Resistive forces act in the opposing direction to motion.**

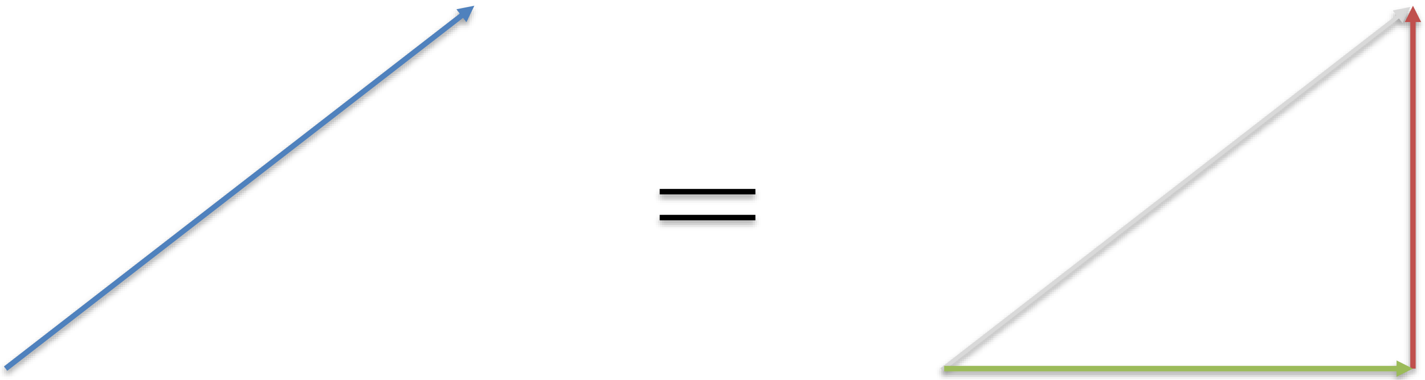
**Addition of the forces gives:**

**120 N + -30 N = 90 N in direction of 120 N force**



# Calculating Resultant Force… continued

**A single force can be resolved into two components acting at right angles to each other. The two component forces together have the same effect as the single force.**



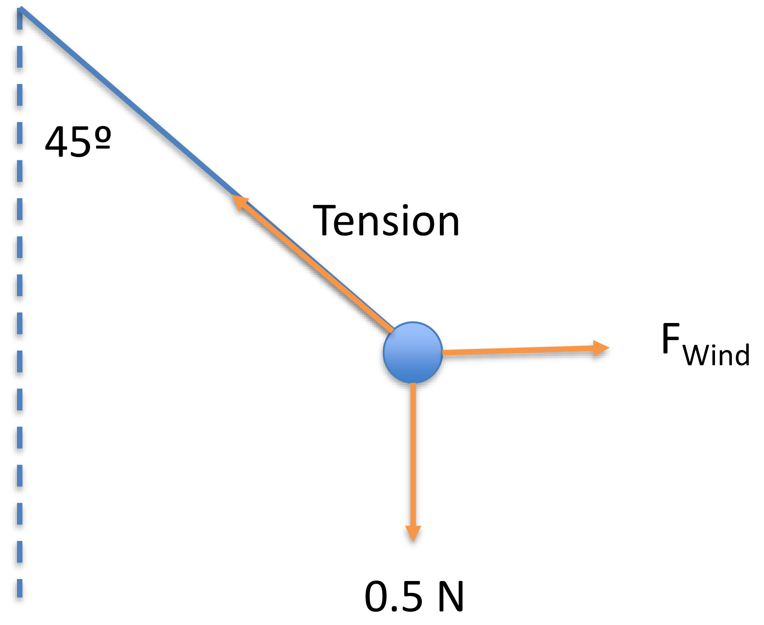
# Example

A pendulum has a **weight of 0.5 N**.

On a windy day the pendulum is hung outside and the pendulum now hangs at an **angle of 45º**.

Assuming the wind hits the pendulum moving horizontally, draw a **free body diagram** to represent the forces acting.

Solution



# QuestionIT!

**Forces**

- Scalar and Vector Quantities
- Contact and Non-contact Forces
- Gravity
- Resultant Forces

1. What is a scalar quantity?

2. Explain how a car can be moving at a constant speed but have changing velocity.

3. State whether the following quantities are scalars or vectors:

Acceleration Mass Momentum Time

4. Gravity is a force that acts at a distance.
   Name two other forces that act at a distance.

5. Name three contact forces.

6. A boy has a mass of 40 kg. Calculate the boy's weight.
   Take g = 10 N/kg.

7. Name a piece of scientific equipment that you would use to find the weight of a block in a science laboratory.

8. The object below has two forces acting on it, shown by the arrows.

Draw an arrow to show the resultant force on the object

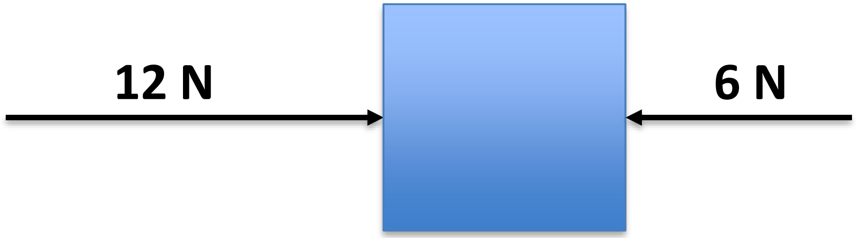
9. On The Moon an astronaut has a weight of 130 N. The gravitational field strength on The Moon is 1.7 N/kg. The gravitational field strength on the Earth is 10 N/kg.

   Calculate the weight of the astronaut on the Earth.

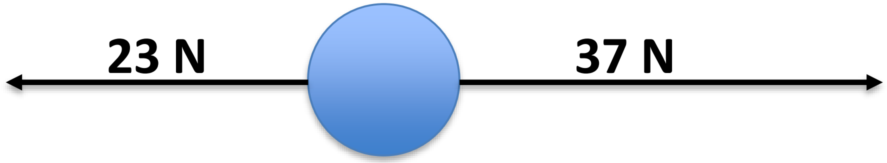
10. A child cuts out a picture of a snowman on a piece of card. How could you determine the centre of mass of the snowman?

11. Calculate the resultant force acting on the objects below:

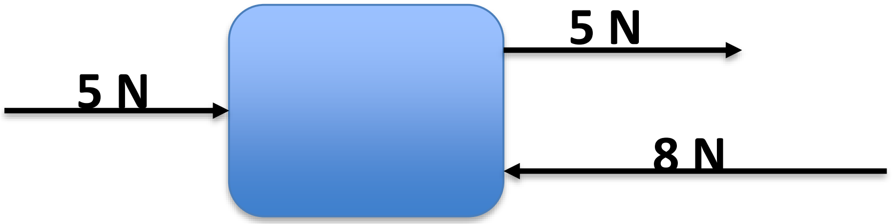
**a)**



**b)**



**c)**



# AnswerIT!

## Forces

- Scalar and Vector Quantities
- Contact and Non-contact Forces
- Gravity
- Resultant Forces

1. **What is a scalar quantity?**
   **Scalars quantities have magnitude ONLY i.e. no direction.**

2. **Explain how a car can be moving at a constant speed but have changing velocity.**
   **As velocity is a vector if the direction of the car changes the velocity will change, at a constant speed.**

3. **State whether the following quantities are scalars or vectors:**

| Acceleration | Mass | Momentum | Time |
|---|---|---|---|
| Vector | Scalar | Vector | Scalar |

4. Gravity is a force that acts at a distance.
   Name two other forces that act at a distance.
   Magnetism Electrical Force Nuclear Force

5. Name three contact forces.
   Tension Friction (including air resistance) Normal Force

6. A boy has a mass of 40 kg. Work out the boy's weight.
   Take g = 10 N/kg.
   Using

$$W = mg$$

Substitution gives

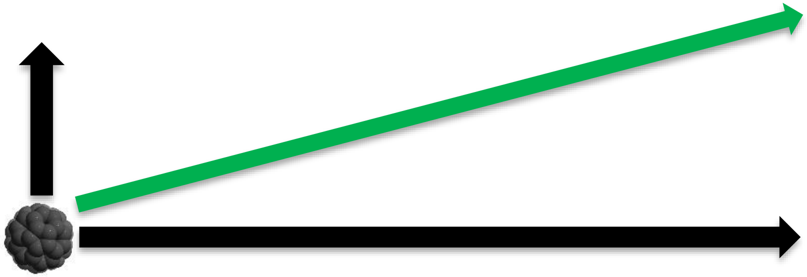
$$W = 40 \times 10$$

Answer

$$W = 400\ \text{N}$$

7. Name a piece of scientific equipment that you would use to find the weight of a block in a science laboratory.
   A newtonmeter

8. The object below has two forces acting on it, shown by the arrows.



Draw an arrow to show the resultant force on the object

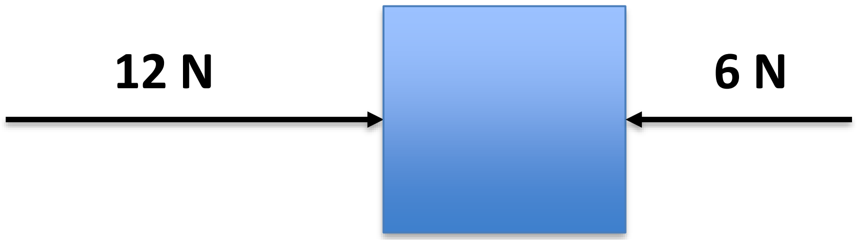
9. On The Moon an astronaut has a weight of 130 N. The gravitational field strength on The Moon is 1.7 N/kg. The gravitational field strength on the Earth is 10 N/kg.
   Work out the weight of the astronaut on the Earth.
   Using W = mg
   Mass of astronaut = 130 / 1.7
   Mass of astronaut = 76.5 kg

   Using W = mg
   Weight of astronaut on Earth = 76.5 x 10
   Weight of astronaut on Earth = 765 N

10. A child cuts out a picture of a snowman on a piece of card.
    Describe how you could determine the centre of mass of the snowman.
    Hang the picture using a pin so that the shape is free to rotate.
    Have a plumb line hanging from the pin.
    Mark the path of the plumb line against the picture.
    Hang the picture from another point.
    Mark the path again.
    Where the lines cross is the centre of mass of the picture.

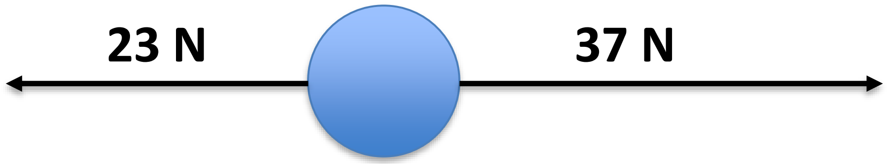
11. **Calculate the resultant force acting on the objects below:**

a)



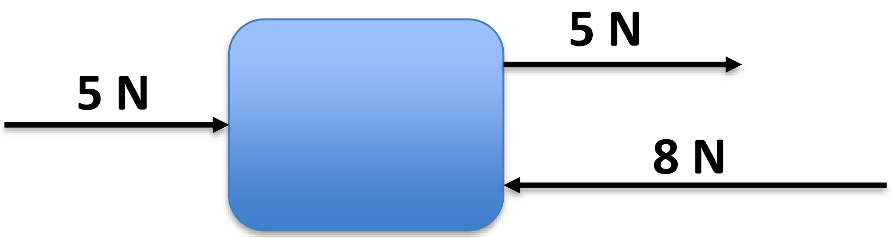
Resultant Force = 6 N Right

b)



Resultant Force = 14 N Right

c)



Resultant Force = 2 N Right

# LearnIT!
# KnowIT!

## Work Done and Energy Transfer

# Work Done

When a force causes an object to move through a distance work is done on the object. So a force does work on an object when the force causes a displacement of the object.

Work done can be calculated using the equation:

Work done (J) = Force (N) x Distance (m)

$$W = F s$$

Note: The distance moved has to be in the direction the force is acting on the object.

# Work Done Calculations

**A box is pushed 3 m across the floor with a force of 120 N.**

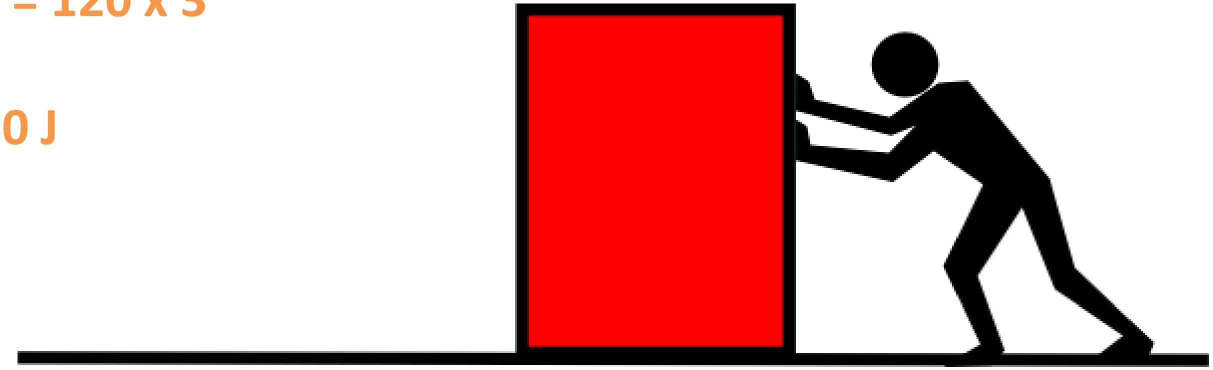
**Work out the work done in moving the box.**

**Solution**

**Equation: work done = force x distance**

**Substitution: work done = 120 x 3**

**Answer: work done = 360 J**



# Work Done Calculations

**A man with a mass of 70 kg gets onto a moving escalator.**

**The escalator moves 15 m horizontally and 8 m vertically.**

**Calculate the work done by the motor against gravity.**

**Take g = 10 N/kg.**

Solution

Gravity acts downwards, so the distance moved against gravity is 8 m.
Sine W = mg; the weight of the man is 700 N.

Using: work done = force x distance
work done = 700 x 8
work done = 5600 J

# Work Done Against Frictional Forces

When work is done against frictional forces on an object there is a temperature increase of the object.

A bicycle pump gets hot in use as work is done in compressing the gas, causing the pump to get hotter.

# QuestionIT!

## Work Done and Energy Transfer

## Work Done and Energy Transfer- QuestionIT

1. A piano is pushed across a wooden floor with a force of 2500 N. The piano moves a distance of 3.5 m. Calculate the work done moving the piano.

2. Work done is usually measured in joules. An alternative unit for work done is (circle the correct answer).

   kg/m$^3$ Nm W N/m2 N/kg

3. Why does a bicycle pump get hotter when used to pump up a tyre?

4. A box with a weight of 120 N is lifted up 1.8 m onto a shelf. Calculate the work done in lifting the box.

5. When a book is lifted 3 m the work done on the book is 1.2 J. Calculate the weight of the book.

# AnswerIT!

## Work Done and Energy Transfer

# Work Done and Energy Transfer- QuestionIT

1. A piano is pushed across a wooden floor with a force of 2500 N.
   The piano moves a distance of 3.5 m.
   Work out the work done moving the piano.
   Using W = F s
   Work done = 2500 x 3.5
   Work done = 8750 J

2. Work done is usually measured in joules. An alternative unit for work done is (circle the correct answer).

   $kg/m^3$ [✓ Nm] W N/m2 N/kg

3. Why does a bicycle pump get hot when used to pump up a tyre?
   Work is done in compressing the air
   Causing the molecules to increase the frequency of their collisions
   Causing frictional heating and an increase in the temperature.

4. **A box with a weight of 120 N is lifted up 1.8 m onto a shelf. Calculate the work done in lifting the box.**

   Using Work done = force x distance

   Work done = 120 x 1.8

   Work done = 216 J

5. **When a book is lifted 3 m the work done on the book is 12.6 J. Calculate the weight of the book.**

   Using

   Work done = force x distance

   Rearranging gives

   Force = work done / distance

   Substitution gives

   Force = 12.6 / 3

   Answer

   Force = 4.2 N

# LearnIT!
# KnowIT!

## Forces and Elasticity

# Springs

**Springs are used in many everyday objects. Springs are found in beds, in motorcycle and bike suspension, weighing scales and trampolines.**

**Springs can either be used in tension (where the spring is stretched) or compression (where the spring is squashed).**

**Springs have a store of elastic potential energy when they have changed shape.**

Not all springs are cylindrical in shape.

# Uses of Springs

**Some common uses of springs, in compression and tension, include:**

| Uses of Springs in Compression | Uses of Springs in Tension |
|---|---|
| Ball Point Pen | Trampolines |
| Beds (mattresses) | Garage Doors |
| Suspension Springs (bikes) | Newtonmeter |
| Electrical Switches | Exercise Equipment (Chest Expander) |

# Elastic and Inelastic Deformation

To stretch a spring at least two forces are required – otherwise the whole spring will move.

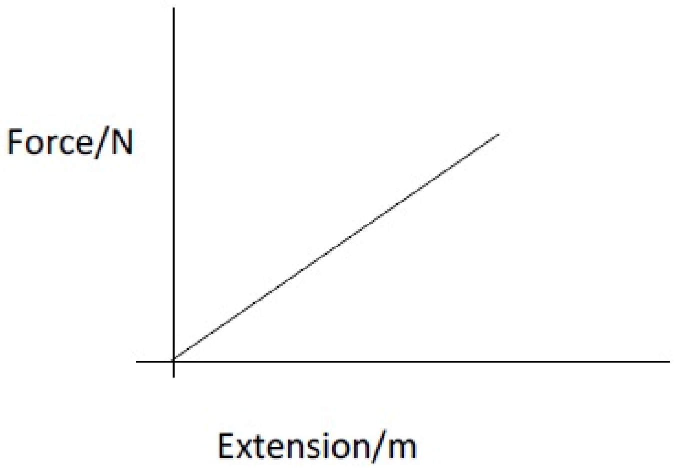
When a spring is stretched, the spring may return to it's original shape.  In this case the deformation of the spring is said to be elastic.

If the spring is stretched too far then the spring will never return to it's original length.  The deformation is said to be inelastic.

# Limit of Proportionality

**The extension (the length of a spring minus the original length) of a spring is directly proportional to the force applied – provided that the limit of proportionality is not exceeded.**

**This means that if the force on the spring is doubled then the extension of the spring will be doubled too.**



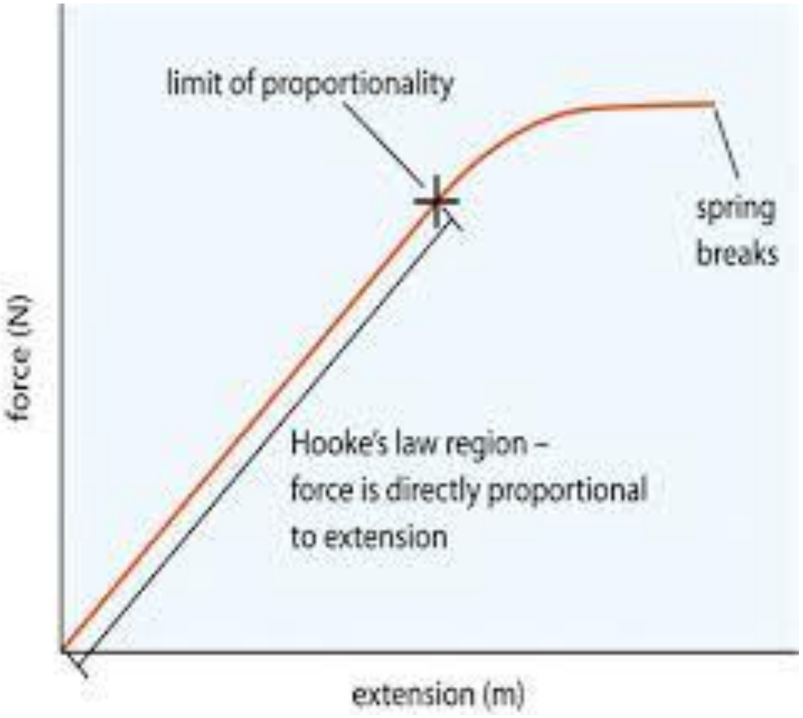
A graph of force against extension for a spring that has not been stretched beyond the limit of proportionality.

# Permanent Deformation of a Spring

**If the force applied to a spring is too great the the spring will be inelastically deformed.**

**A graph showing force against extension for a spring stretched beyond it's limit of proportionality will no longer be a straight line through 0,0.**

**The graph opposite shows the force – extension graph for a spring stretched beyond it's limit of proportionality.**

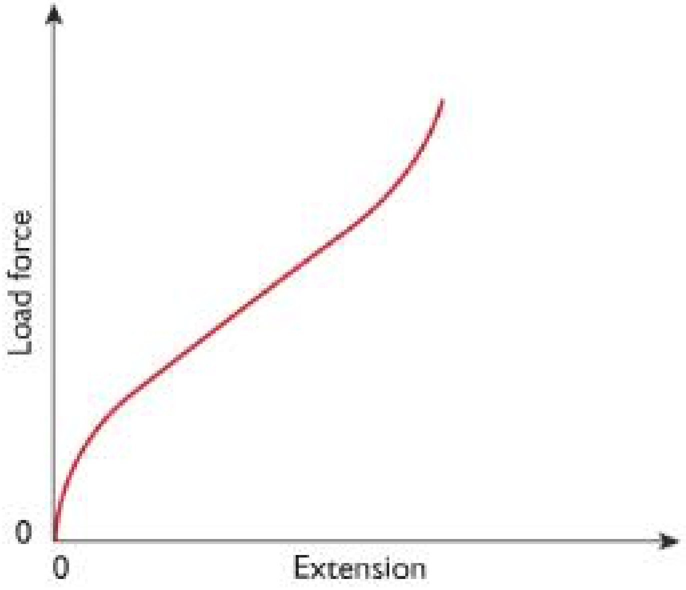


# Stretching Other Materials

**Objects and materials other than metal springs can be stretched.**

**An elastic band is an example of a material that can be stretched and stores elastic potential energy.**

**The extension of an elastic band is not directly proportional to the force applied. A graph of extension against length for an elastic band will produce a curve, yet the material may still go back to it's original shape.**



# Spring Constant

**The amount a spring stretches depends on the force applied to the spring and also to the spring constant of the spring.**

**The spring constant of a spring is measured in newtons per meter (N/m). The higher the spring constant the greater the force required to produce a given extension, in metres.**

**The spring constant can be found using the equation:**

**Force (N) = Spring Constant (N/m) x Extension (m)**

$$F = k\,e$$

**This relationship can be applied to springs in both compression and tension, as long as the limit of proportionality is not exceeded.**

# Spring Constant Calculation

**Example:**

**A trampoline spring has a spring constant of 2200 N/m.**

**Work out the extension of the trampoline spring if a weight of 600 N is applied.**

**Solution:**

**Using the equation**

$$F = k\,e$$

**Substitution gives**

$$600 = 2200 \times e$$

**Rearranging**

$$600 / 2200 = e$$

**Answer:**

**0.27 m**

# Energy Stored in a Spring

To stretch or compress a spring you must do work on it. This means that you have transferred energy to the spring, so the spring now has a store of elastic potential energy. Provided the spring is not inelastically deformed the work done in stretching the spring is equal to the elastic potential energy stored in the spring.

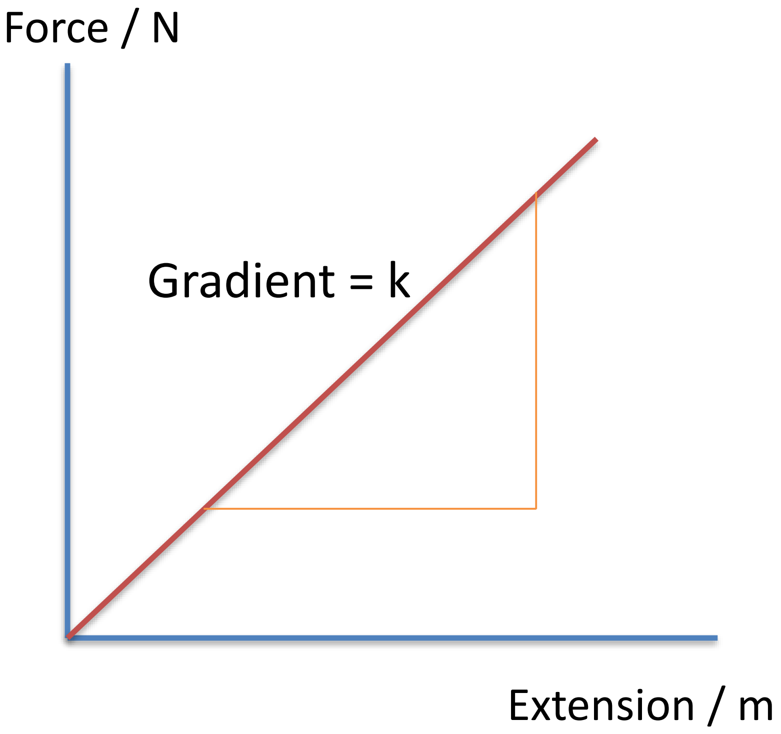
To calculate the amount of energy stored in a spring you need to use the equation:

Elastic Potential Energy (J) = 0.5 x spring constant (N/m) x (extension)$^2$ (m)

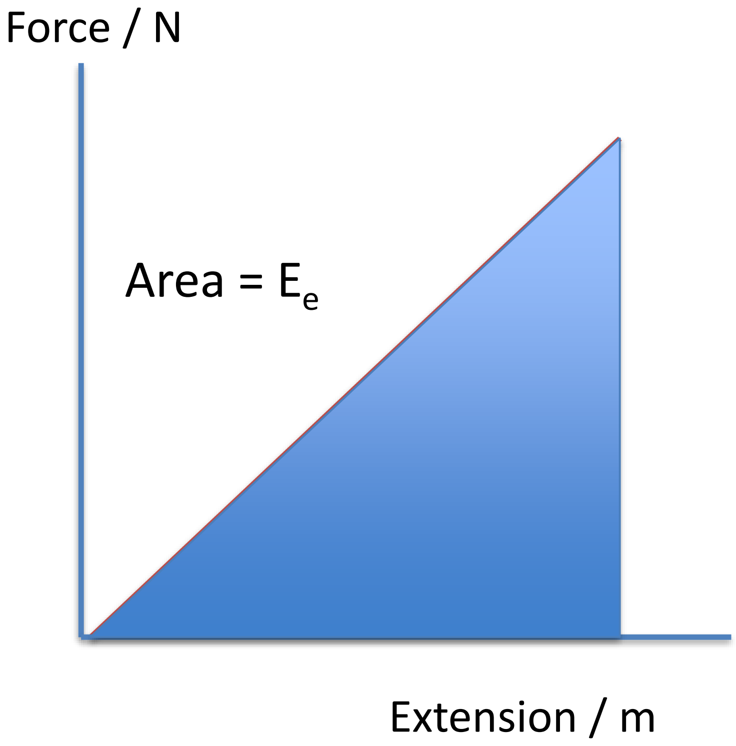
$$E_e = \frac{1}{2} k e^2$$

# Graphs of Force Against Extension

**The gradient of a force against extension graph gives you the spring constant of the spring.**



**The energy stored as elastic potential energy is the area under a force against extension graph.**



# Energy Stored in a Spring Calculations

**Example:**

A trampoline spring has a spring constant of 1400 N/m.

The spring has a 50 N load added to the spring.

Work out the amount of elastic potential energy stored in the spring when the 50 N load is added to the spring.

**Solution:**

Step 1: Determine the extension of the spring using $F = k\ e$

Extension = 50 / 1400
Extension = 0.0357 m

Step 2: Calculate the energy stored in the spring using $E_e = \frac{1}{2}\ k\ e^2$

$$E_e = \frac{1}{2} \times 1400 \times 0.0357^2$$
$$E_e = 0.9\ J$$

# QuestionIT!

## Forces and Elasticity

1. What type of energy is stored in a stretched spring?

2. What is the least number of forces required to stretch a spring?

3. A student investigates the stretching of a spring. The student adds weight to the spring and measures the extension.

   Sketch the force – extension graph the student would expect for the spring.

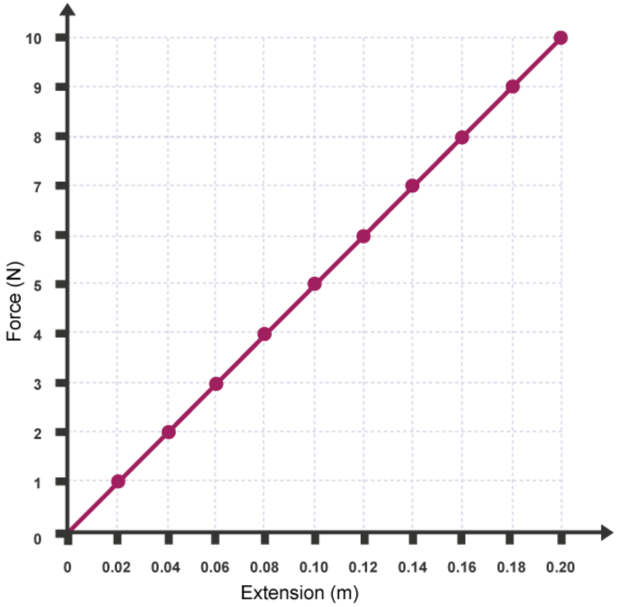
## Work Done and Energy Transfer- QuestionIT

4. A spring is stretched beyond its elastic limit. Describe the effect that this would have on the spring.

5. Explain how the extension of a spring is determined.

6. Motorcycles use springs for their suspension. The spring is compressed when the motorcycle rides over bumps.
   A force of 240 N compresses the spring 2 cm.
   Calculate the spring constant of the motorcycle spring.

7. The graph below shows the force-extension graph for a spring.



a) Calculate the spring constant of the spring.

b) Calculate the energy stored in the spring when it is stretched 50 cm.

# AnswerIT!

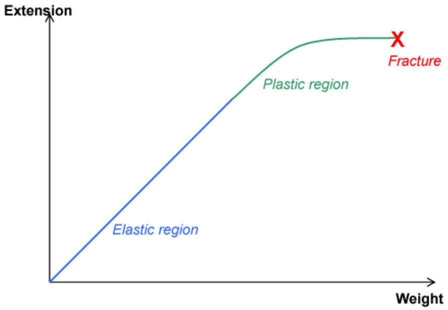
## Forces and Elasticity

Work Done and Energy Transfer - **AnswerIT**

1. **What type of energy is stored in a stretched spring?**
   **Elastic Potential Energy**

2. **What is the least number of forces required to stretch a spring?**
   **2**

3. **A student investigates the stretching of a spring. The student adds weight to the spring and measures the extension.**
   **Sketch the force – extension graph the student would expect for the spring.**



4. A spring is stretched beyond its elastic limit. Describe the effect that this would have on the spring.

   The spring would be inelastically deformed
   so would not return to its original shape

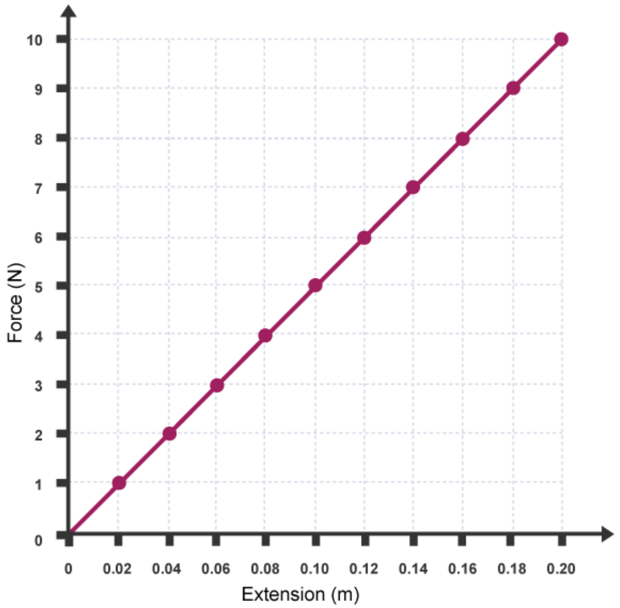
5. Explain how the extension of a spring is determined.

   The length of the extended spring
   minus the original length

5. Motorcycles use springs for their suspension.
   The spring is compressed when the motorcycle rides over bumps.
   A force of 240 N compresses the spring 2 cm.
   Calculate the spring constant of the motorcycle spring in N/m.

   Using $F = k\ e$
   Rearranging gives $k = F/e$
   Substitution gives $k = 240 / 0.02$
   Spring constant is 12 000 N/m

7. **The graph below shows the force-extension graph for a spring.**



a) **Calculate the spring constant of the spring.**

Using k = F / e k = 7 / 0.14 spring constant = 50 N/m

b) **Calculate the energy stored in the spring when it is stretched 50 cm.**

Using $E_p = ½ k e^2$ $E_p = 0.5 \times 50 \times (0.5)^2$

Elastic Potential Energy = 6.25 J

# LearnIT!
# KnowIT!

## Moments, Levers and Gears (Physics Only)

# Moments

**A force or a system of forces may cause an object to rotate.**

**Everyday examples of force causing a rotation motion include door handles, steering wheels and see-saws.**

**The turning effect of a force is called the moment of the force. The size of the moment is determined by the equation:**

**Moment of a force (Nm) = Force (N) × Distance (m)**

$$M = F\,d$$

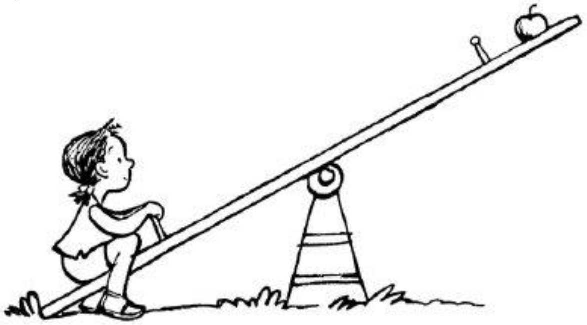
**The distance, d, is the perpendicular distance from the pivot to the line of action of the force.**

# Moment Calculations

**Example:**

**A child with a weight of 400 N sits on see-saw. The child sits a distance of 1.2 m from the pivot.**

**Work out the moment of the turning force.**



**Solution:**

**Using:**

$$M = F\,d$$

**Substitution gives:**

$$M = 400 \times 1.2$$

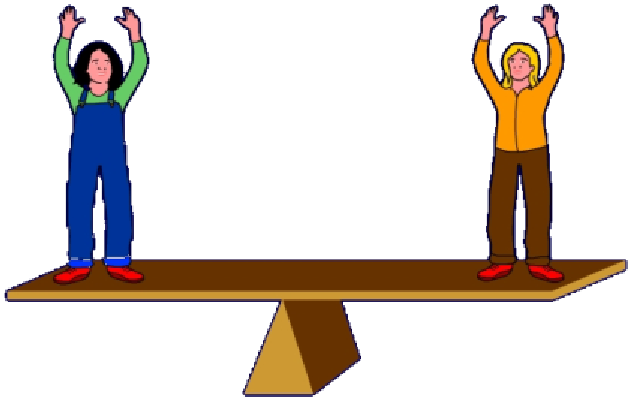
**Answer:**

$$M = 480\ \text{Nm}$$

# Balanced Moments

When two children are on a see-saw the see-saw may be balanced and the children will not move.

In this case the clockwise moment is balanced by the anti-clockwise moment – so the two moments are equal.



As both the clockwise and anti-clockwise moments are balanced:

$$F_c\, d_c = F_a\, d_a$$

Where the subscript denotes the direction (clockwise or anti-clockwise).

# Balanced Moments Calculations

**Example:**

A see-saw has two children sat either side of the pivot.

The child on the left-hand side has a weight of 370 N and site 1.3 m from the pivot.

The child on the right sits 2.0 m from the pivot.

Work out the weight of the child on the right-hand side of the pivot if the see-saw is balanced.

Solution:

As both the clockwise and anti-clockwise moments are balanced:

$$F_c d_c = F_a d_a$$

$$370 \text{ x } 1.3 = F_a \text{ x } 2.0$$

$$481 / 2.0 = F_a$$

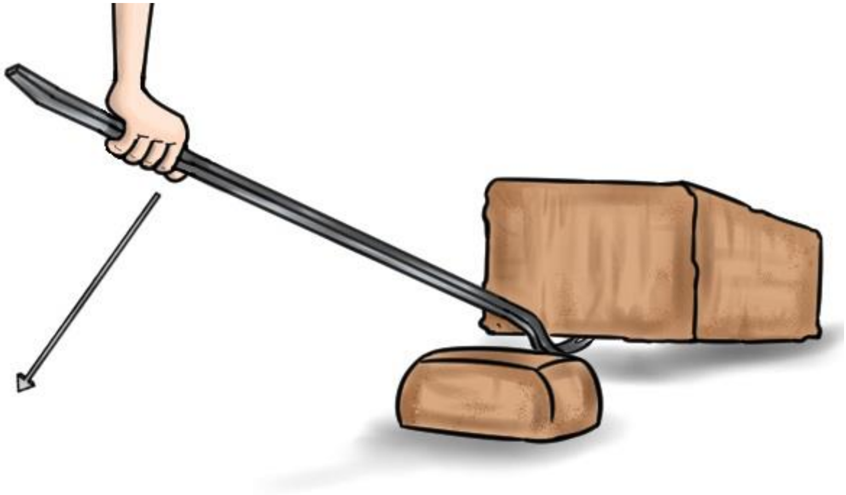
$$F_a = 240.5 \text{ N}$$

# Levers

**Levers are used to increase the force applied to an object, usually to lift it up from a surface.**

**A crowbar is an example of a lever. Crowbars can be used to lift up floorboards that have been nailed down.**

**Levers must have a pivot to rotate around and will work on the principle of moments.**



By pushing down on the crowbar the object is lifted upwards.

# Moments, Levers and Gears

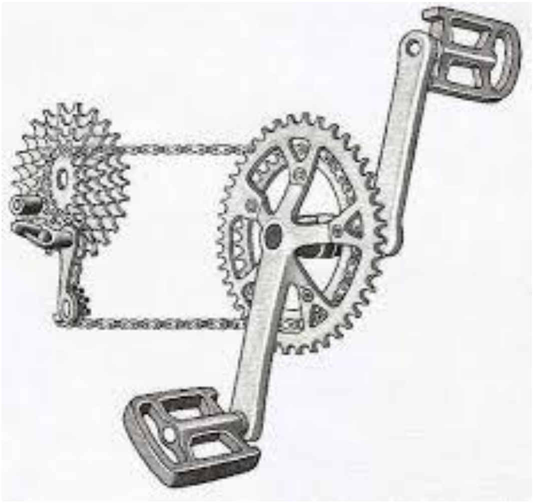
## Gears

A gear is a wheel that has teeth on it (also known as a cog), as shown in the diagram opposite. For gears to do work you need at least two gears.

Gears are used to transmit rotational forces from one place to another.

On a bicycle the gears are connected through a chain, though gears can be connected together so that the teeth of the gears interlock.

When the large gear rotates once the smaller gear may rotate many times.

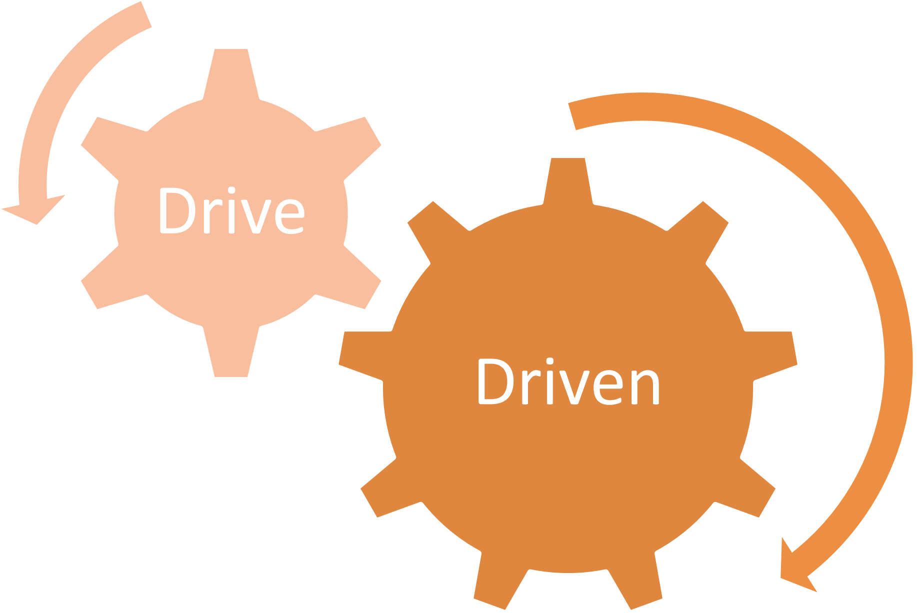


Sometimes gears are connected by a chain.

# Rotating Gears

When two cogs are in contact with their teeth interlocking, the driven cog will rotate in the opposite direction to the drive cog.

If the drive cog in a gear spins clockwise then the driven cog will spin anti-clockwise.

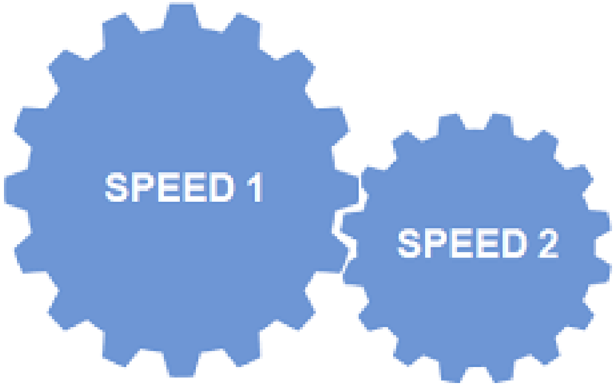


# Speed of Gears

**When a large cog is driving a small cog, then the small cog will rotate faster than the large cog.**

**Halving the number of teeth on the small cog will double the speed of the small cog.**

**Going from a large cog to a smaller cog will increase the speed of rotation.**



Speed 2 will be faster than Speed 1 as there are fewer teeth on the cog.

# QuestionIT!

## Moments, Levers and Gears (Physics Only)

## Moments, Levers and Gears - QuestionIT

1. State the equation used to find the moment of a force.

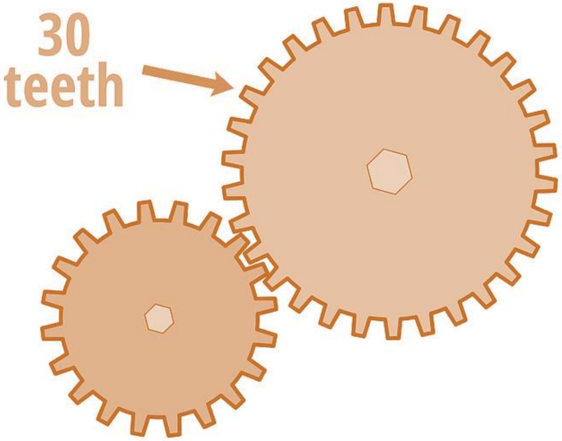
2. A 30 cm long spanner is used to undo a nut. A force of 20 N is applied to the end of the spanner.
   Calculate the moment of force applied to the spanner.

3. Two children sit on a see-saw on opposite sides of the pivot. One child has a weight of 340 N and sits 1.2 m from the pivot. If the other child has a weight of 420 N how far does this child need to sit from the pivot for the see-saw to be balanced?

4. A crowbar is used to lift up a floor board. The crowbar has a length of 40 cm from the pivot to the end of the crowbar, and the distance from the bend to the lifting point is 12 cm.
   If the force applied to the end of the crowbar is 300 N, work out the size of the force applied to the floor board.

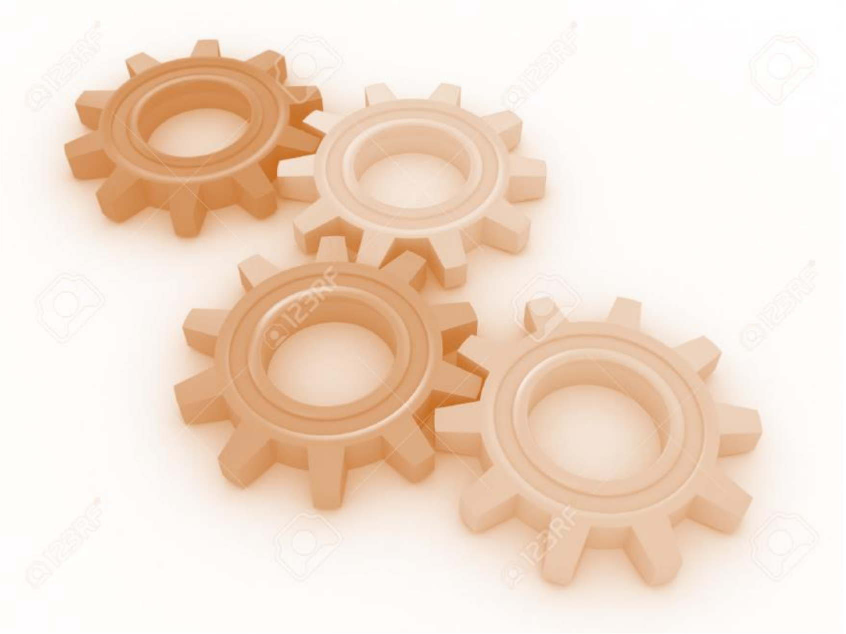
5. A box with a weight of 400 N is raised using a lever 2 m long. The lever rotates around a pivot 50 cm from the lifting end of the lever. Work out the force applied to the end of the lever.

6. The 30 tooth large cog is made to rotate in a clockwise direction. In which direction will the smaller cog rotate?



7. In the gear system shown above, the 30 tooth cog rotates once every 5 seconds. The smaller cog has 20 teeth. Calculate how long it will take to the smaller cog to complete one revolution.

8. Look at the following gear system. In which direction will the yellow cog rotate if the red cog is made to rotate anti-clockwise?



# AnswerIT!

## Moments, Levers and Gears (Physics Only)

## Moments, Levers and Gears - QuestionIT

1. **State the equation used to find the moment of a force.**
   Moment = force x distance

2. **A 30 cm long spanner is used to undo a nut.**
   **A force of 20 N is applied to the end of the spanner.**
   **Work out the moment of force applied to the spanner.**
   Moment = force x distance
   Moment = 20 x 0.3
   Moment = 6 Nm

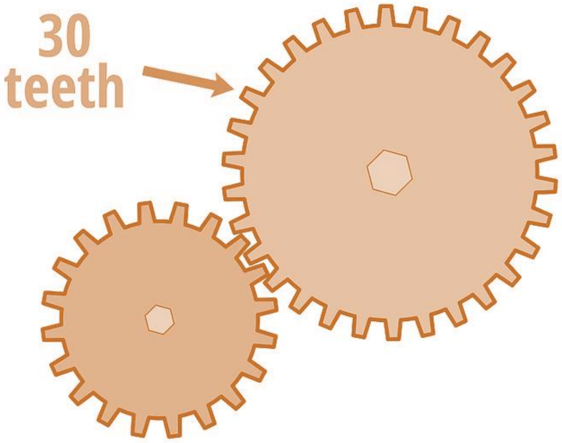
3. **Two children sit on a see-saw on opposite sides of the pivot.**
   **One child has a weight of 340 N and sits 1.2 m from the pivot.**
   **If the other child has a weight of 420 N how far does this child need to sit from the pivot for the see-saw to be balanced?**
   Clockwise and anti-clockwise moments must be balanced
   so, 340 x 1.2 = 420 x distance from pivot
   so, distance from pivot = 0.97 m

Moments, Levers and Gears - QuestionIT

4. A crowbar is used to lift up a floor board. The crowbar has a length of 40 cm from the pivot to the end of the crowbar, and the distance from the bend to the lifting point is 12 cm.
If the force applied to the end of the crowbar is 300 N, work out the size of the force applied to the floor board.
As the moment on either side of the pivot is equal
300 x 0.4 = force x 0.12
So, force applied to the floor board = 1000 N

5. A box with a weight of 400 N is raised using a lever 2 m long. The lever rotates around a pivot 50 cm from the lifting end of the lever. Work out the force applied to the end of the lever.
As the moment on either side of the pivot is equal
Force Applied x 1.5 = 400 x 0.5
Force applied = 133.3 N

6. **The 30 tooth large cog is made to rotate in a clockwise direction. In which direction will the smaller cog rotate?**



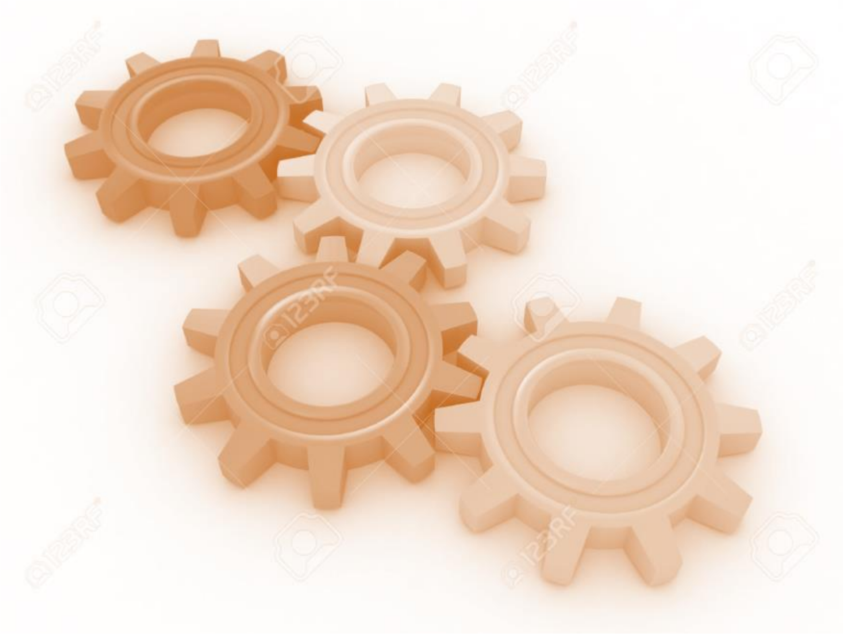
**Anti-clockwise**

6. **In the gear system shown above, the 30 tooth cog rotates once every 5 seconds. The smaller cog has 15 teeth. Calculate how long it will take to the smaller cog to complete one revolution.**

**2.5 seconds**

**As there are half the number of teeth the cog will spin twice as fast.**

8. **Look at the following gear system.**
**In which direction will the yellow cog rotate if the red cog is made to rotate anti-clockwise?**



**Clockwise**

**If red spins anti-clockwise then the green will spin clockwise, blue anti-clockwise making the red cog spin clockwise.**

# LearnIT!
# KnowIT!

## Pressure and Pressure Differences in Fluids (Physics Only)

- Pressure in a Fluid 1
- Pressure in a Fluid 2 (HT Only)
- Atmospheric Pressure

# Pressure in a Fluid 1

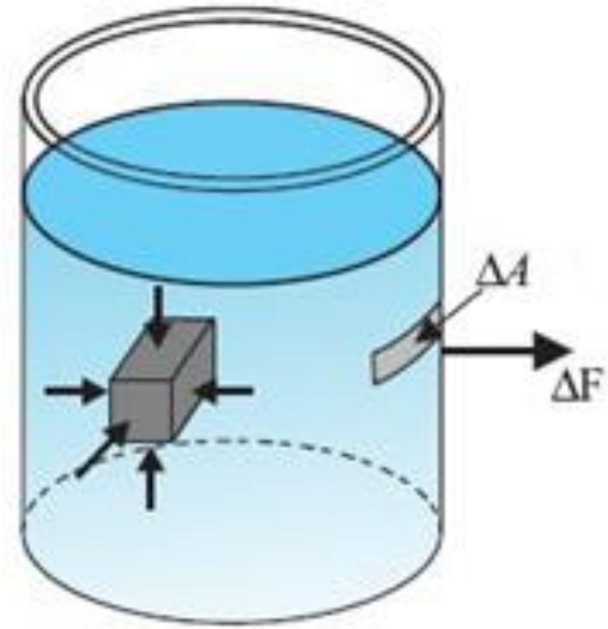
Fluids are substances that flow. Liquids and gases are both fluids.

When there is a pressure in a fluid a force is produced at right angles to the surface containing the fluid.

The size of the force acting at the surface of a fluid can be calculated using the equation:

$$\text{Pressure (Pa)} = \frac{\text{Force normal to a surface (N)}}{\text{Area of that surface (m}^2\text{)}}$$

$$p = \frac{F}{A}$$



The pressure in a fluid produces a force at right angles to the surface .

# Pressure in a Fluid 1: Equations

**Example:**

**Work out the pressure in a fluid when the fluid applies a force of 12 N on a surface of area 0.02 m$^2$.**

**Solution:**

**Using the equation:**

**pressure = force / area**

**Substituting:**

**pressure = 12 / 0.02**

**Answer:**

**pressure = 600 Pa**

# Pressure in a Fluid 2

When a submarine is underwater there is a pressure acting. The pressure depends on the depth of the submarine, the density of the water it is in (salt water is more dense than fresh water) and on the gravitational field strength.

The equation that links pressure, gravitational field strength, density and height of column is:

Pressure (Pa) = Height of column (m) x Density of liquid (kg/m$^3$) x Gravitational field strength (N/kg)

$$p = h \rho g$$

# Pressure Differences

When a 2 litre bottle has holes drilled into the sides and is then filled with water leaks out.  The water that escapes out the bottom of the bottle comes out faster than the water from the top hole – so it travels further.

This is due to the pressure at the bottom of the bottle being greater than the pressure at the top of the bottle – there is a greater height of the column of water above the hole at this point, so there is more weight pushing down per unit area.

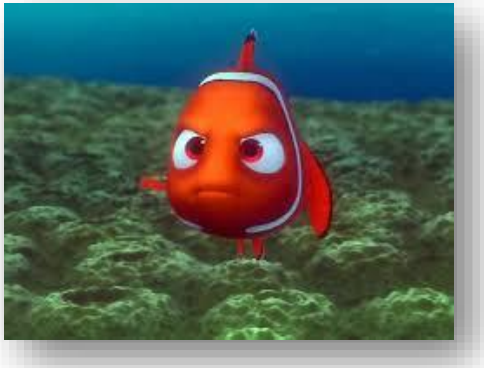
# Floating

A submarine can float mid-water. This happens when the weight of the submarine equals the upthrust from the water.

The upthrust on the submarine depends on the pressure difference between the top of the submarine and the bottom of the submarine. When the pressure difference between the top and the bottom of the submarine equals the weight of the submarine then it will float.

Submarines can adjust the depth they float at by adding or removing water from ballast tanks. Scuba divers use air in a jacket to control their depth. Fish have swim bladders which serve a similar purpose.





# Pressure Calculations

**Example:**

**The top of a submarine is 50 m underwater. The density of seawater is 1030 kg/m$^3$. Work out the pressure on the top of the submarine.**
**Take g = 10 N/kg.**

**Solution:**

| | |
|---|---|
| **Using the equation** | **$p = h \rho g$** |
| **Substitution gives** | **$p = 50 \times 1030 \times 10$** |
| **Answer** | **pressure = 515 000 Pa** |

# Upthrust Calculations

**Example:**
**Calculate the upthrust on a submarine that has a height of 15 m and is submerged at a depth of 60 m (to the top of the submarine). The submarine has a surface area of 100 $m^2$ on the top and on the bottom of the submarine.**

**Take the density of sea water to be 1100 $kg/m^3$ and the gravitational field strength of the Earth to be 10 N/kg.**

**Solution:**
**The difference in pressure between the top and bottom of the sub is due to a difference in height of the column of water of 15 m.**
**So, using the equation:** $p = h \rho g$

$P = 15 \text{ x } 1100 \text{ x } 10$

$P = 165{,}000$ Pa

**Since Pressure = force / area**

**force (upthrust) = 165 000 x 200 = 33 000 000 N**

# The Earth's Atmosphere

The Earth's atmosphere is a very thin (relative to the size of the Earth) layer of gas. The density of this layer of gas gets lower as you go higher.

The weight of air pushing down on a surface decreases with height. With fewer particles the higher up you go there will be fewer collisions, per unit time, with a surface. This means that the atmospheric pressure decreases with height.

When air molecules collide with a surface it creates air pressure. The more molecules that collide with a surface in a given time, the greater the pressure on that surface.

# QuestionIT!

## Pressure and Pressure Differences in Fluids (Physics Only)

- Pressure in a Fluid 1
- Pressure in a Fluid 2 (HT Only)
- Atmospheric Pressure

1. In a bath full of water a force of 1250 N acts on an area of 0.5 $m^2$ at the bottom of the bath.
   Calculate the pressure acting on the bottom of the bath.

2. A pressure of 4000 Pa acts in a hydraulic brake fluid. The surface of the slave cylinder inside the brake system has a surface area of 0.03 $m^2$.
   Calculate the force acting on the slave cylinder.

## Pressure and Pressure Difference in Fluids 2 Higher Tier - QuestionIT

3. A beaker is filled to a depth of 10 cm with water. Water has a density of 1000 kg/m$^3$. Calculate the pressure acting at the bottom of the beaker.
   Take g = 10 N/kg.

4. A scuba diver is diving in the sea. The pressure acting on the scuba diver is 267 800 Pa. Salt water has a density of 1030 kg/m$^3$.
   Calculate the depth of the scuba diver.

5. A boat floats in sea water (density = 1030 kg/m$^3$). The boat has a surface area of 15 m$^2$ in contact with the water and has a pressure of 4120 Pa acting on it.
   Find the depth the boat floats at.
   Take g = 10 N/kg.

6. Explain why the atmospheric pressure on the top of Mount Everest is lower than the atmospheric pressure at sea level.

# AnswerIT!

## Pressure and Pressure Differences in Fluids (Physics Only)

- Pressure in a Fluid 1
- Pressure in a Fluid 2 (HT Only)
- Atmospheric Pressure

## Pressure and Pressure Difference in Fluids - AnswerIT

1. **In a bath full of water a force of 1250 N acts on an area of 0.5 $m^2$ at the bottom of the bath.**
   **Calculate the pressure acting on the bottom of the bath.**

   Pressure = Force / Area
   Pressure = 1250 / 0.5
   Pressure = 2500 Pa

2. **A pressure of 4000 Pa acts in a hydraulic brake fluid. The surface of the slave cylinder inside the brake system has a surface area of 0.03 $m^2$.**
   **Calculate the force acting on the slave cylinder.**

   Pressure = Force / Area
   Force = Pressure x Area
   Force = 4000 x 0.03
   Force = 120 N

## Pressure and Pressure Difference in Fluids 2 Higher Tier - AnswerIT

3. A beaker is filled to a depth of 10 cm with water. Water has a density of 1000 kg/$m^3$. Calculate the pressure acting at the bottom of the beaker. Take g = 10 N/kg.

    Convert 10 cm into standard units: 10 cm = 0.1 m
    Pressure = height of column x density x gravitational field strength
    Pressure = 0.1 x 1000 x 10
    Pressure = 1000 Pa

4. A scuba diver is diving in the sea. The pressure acting on the scuba diver is 267 800 Pa. Salt water has a density of 1030 kg/$m^3$.
   Calculate the depth of the scuba diver.

    Pressure = height of column x density x gravitational field strength

Rearranging gives

    Height of column = Pressure / (density x gravitational field strength)
    Height of column = 267 800 / (1030 x 10)
    Height of column = 26 m
    Therefore the scuba diver is at a depth of 26 m.

5. A boat floats in sea water (density = 1030 kg/m$^3$). The boat has a surface area of 15 m$^2$ in contact with the water and has a pressure of 4120 Pa acting on it.
Find the depth the boat floats at.
Take g = 10 N/kg.

Pressure = height of column x gravitational field strength x density
4120 = height of column x 10 x 1030
4120 / (10 x 1030) = height of column
Height of column = 0.4 m
Therefore the depth of the boat is 0.4 m.

6. Explain why the atmospheric pressure on the top of Mount Everest is lower than the atmospheric pressure at sea level.

At sea level there is more air above you
This gives a greater weight of air pushing on you per unit area
Increasing the pressure

# LearnIT!
# KnowIT!

## Forces and Motion

- Distance and Displacement
- Speed
- Velocity
- The Distance-Time Relationship
- Acceleration

# Definitions

**Distance**: How far an object has travelled. Distance is a scalar quantity.

**Displacement:** How far an object has travelled in a straight line from the starting point to the finishing point and the direction of that line. Displacement is a vector quantity.

Examples:

A runner runs around a track. The track is 400 m long.

After completing one complete circuit of the track the runner has travelled a distance of 400 m. After the one complete circuit the runner ends up at their starting point. This means that their displacement is 0 m.

# Calculations

**For an object moving at a constant speed the distance travelled in a specific time can be calculated using the equation:**

**Distance travelled (m) = Speed (m/s) x time (s)**

$$s = v\,t$$

## Speed and Velocity

# Definitions

**Speed** is the rate of change of distance. This can be found using the equation:

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

**Speed** is a **scalar** quantity which means that it has **magnitude** but no **direction**.

**Velocity** is the rate of change of distance. Velocity is found using the equation:

$$\text{velocity} = \frac{\text{displacement}}{\text{time taken}}$$

**Velocity** is a **vector** quantity which means that is has **magnitude** and **direction**.

# Speed Calculations

**Example 1:**

**A bike travels 800 m in 160 seconds. Calculate the speed of the bike.**

**Solution 1:**

**Using the equation:** Speed = distance / time
Speed = 800 / 160
Speed = 5 m/s

**Example 2:**

**A car travels a distance of 300 miles at an average speed of 50 mph. Calculate how long it will take to complete the car journey.**

**Solution 2:**

**Rearranging the speed equation gives:** time = distance / speed
time = 300 / 50 = 6 hours

# Velocity Calculations

**Example 1:**

**A track runner runs around a 400 m athletics track 4 times in 3 minutes and 10 seconds.**

**Work out:**

**a) The speed of the track runner**

Speed = distance / time
Speed = 1600 / 190
Speed = 8.4 m/s

**b) The average velocity of track runner.**

As the displacement at the end of the run is 0 m (they end up where they started after four loops of the track) their average velocity is 0 m/s.

# Typical Speeds

**These are the typical speeds of everyday situations that you should know for your exam.**

| Situation | Typical Speed/ m/s |
|---|---|
| Walking | 1.5 |
| Running | 3 |
| Cycling | 6 |

**The speed of sound in air is 330 m/s (though this does changes with temperature and pressure).**

# Average and Instantaneous Speed

**Average speed** is the speed of an object over the entire journey. The average speed is found by using the total distance travelled divided by the total time taken.

$$\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$$

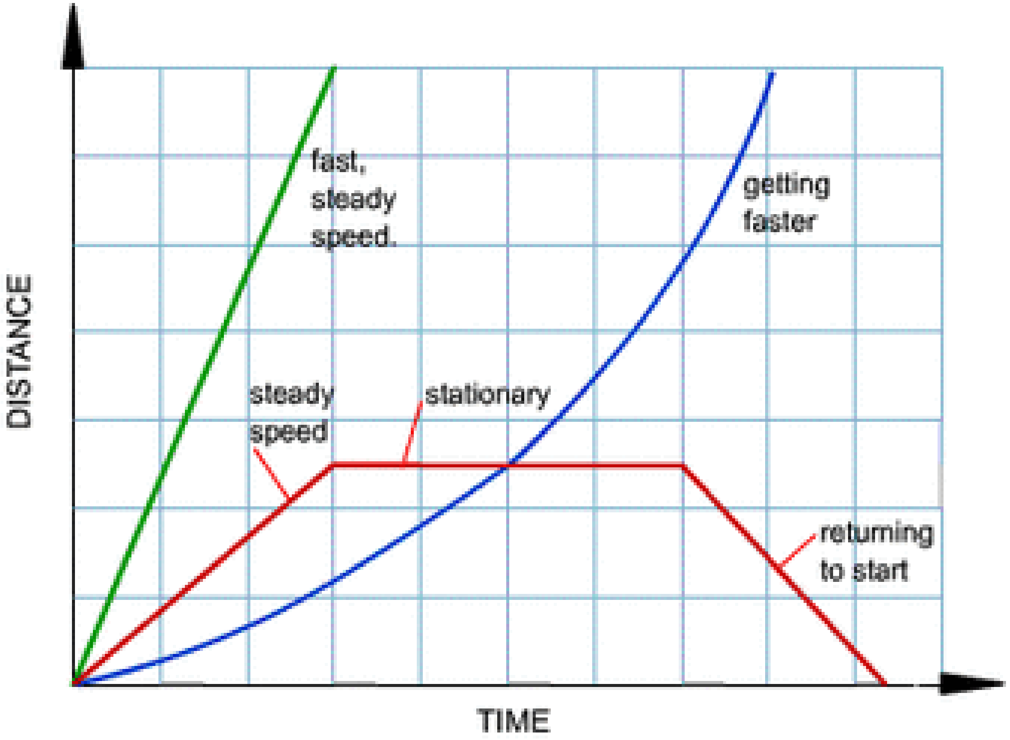
**Instantaneous speed** is the speed of an object at a given moment in time. The speedometer in a car gives the instantaneous speed of the car.

# Distance-Time Graphs

Distance-time graphs can be used to represent the motion of an object.

The different gradients (steepness) of line on the graphs show different motions of the object.

The shapes of line that you need to know are shown opposite.



# Calculating Speed from a Distance-Time Graph

**From the shapes of distance-time graphs it is possible to compare the speeds of different objects. The steeper the gradient of a line on a distance-time graph the faster the object is travelling.**

**The gradient of the line on a distance-time graph is the speed of the object.**

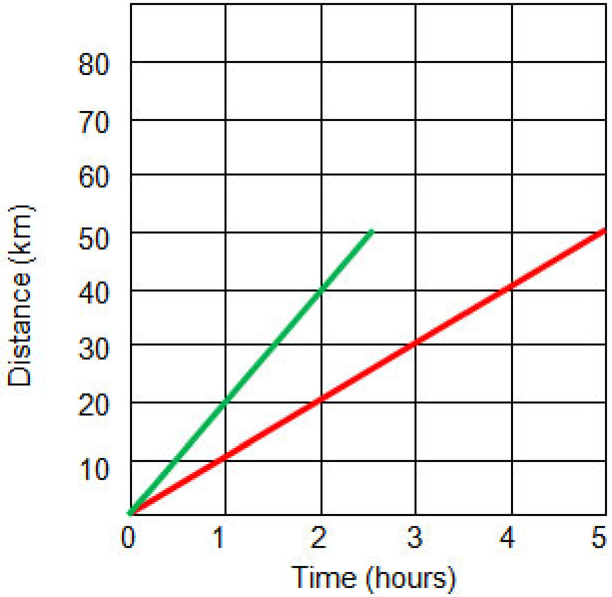
**Example:**

**Work out the speed of the objects shown by the red and green line.**

**Solution:**

**Red = distance / time = 30 / 3 = 10 km/h**

**Green = distance / time = 40 /2 = 20 km/h**



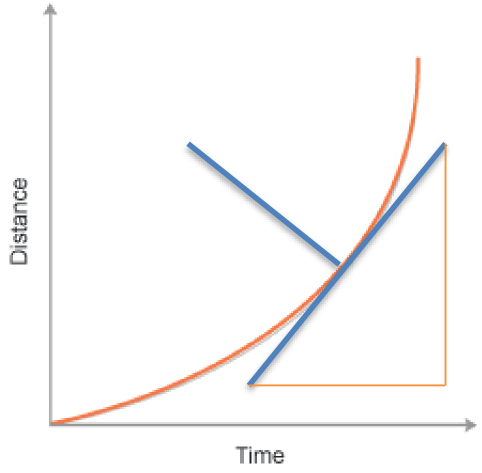
# Calculating Instantaneous Speed

**Higher Tier Only**

When an object is accelerating the line on a distance-time graph is curved.

To find the instantaneous speed of the object at any point along the curve the tangent to the line must first be found – then the gradient of the tangent shows the speed.

To draw the tangent of a curve you should draw a line perpendicular to your curve to start with, then draw a straight line at right-angles to this across your curve – this is your tangent. The longer the line that you draw at this point the easier and more accurate your speed calculation will be.



# Acceleration

When objects accelerate they can be changing speed or changing direction or changing both speed and direction.

Acceleration is the rate of change of velocity, and since velocity is a vector so is acceleration.

The average acceleration of an object is found using the equation:

$$\text{Acceleration (m/s}^2\text{)} = \frac{\text{change in velocity (m/s)}}{\text{Time taken (s)}}$$

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

An acceleration of 3 m/s$^2$ means that an object is getting 3 m/s faster every second.

Equivalent units for acceleration are: m/s/s and ms$^{-2}$.

# Negative Acceleration

As acceleration is a vector the direction is important.

When a moving object has a negative acceleration it can either be slowing down (often just called decelerating) or it could be increasing speed in the opposite direction.

If a car is moving along a straight motorway at 70 mph and then has a negative acceleration the car will slow down.

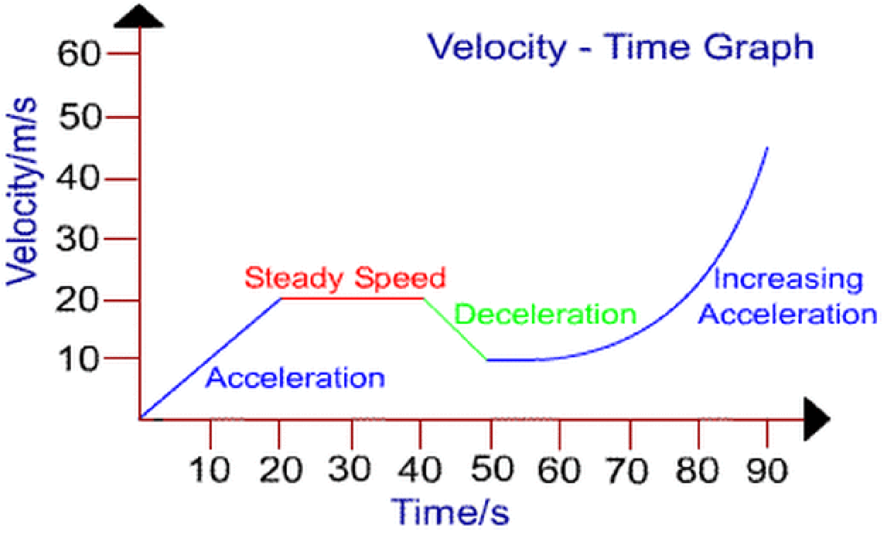
On the on the other hand if the positive direction is chosen to be upwards then a ball that is dropped will have a negative acceleration (as it is in the opposite direction) and will continue to speed up (accelerate) in the opposite direction.

# Velocity-Time Graphs

A velocity-time graph gives more information than a distance-time graph. As well as speed, distance travelled and time, a velocity-time graph will give the acceleration of the object.

Although the line shapes look the same as a distance-time graph, as the axes are different the line meanings are different.

Below are the line shapes for velocity-time graphs.



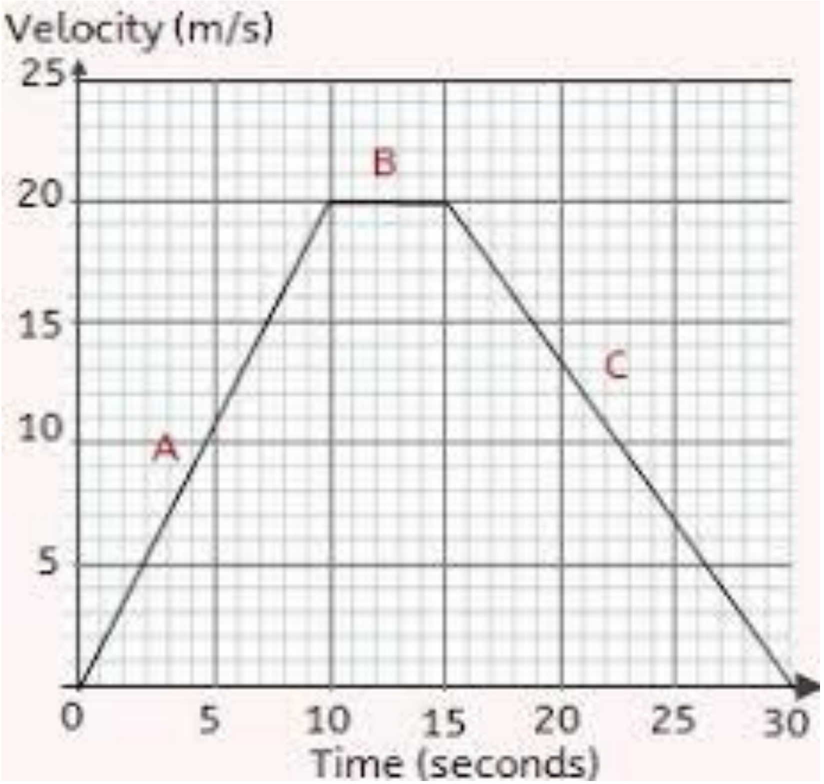
# Velocity-Time Graph Calculations

**The following information can be gathered from a velocity time graph:**

**The velocity: From reading off the axes on the graph.**

**The acceleration: Found from the gradient of the line on the velocity-time graph.**

**The distance travelled: The area under the line on a velocity-time graph is the distance travelled.**

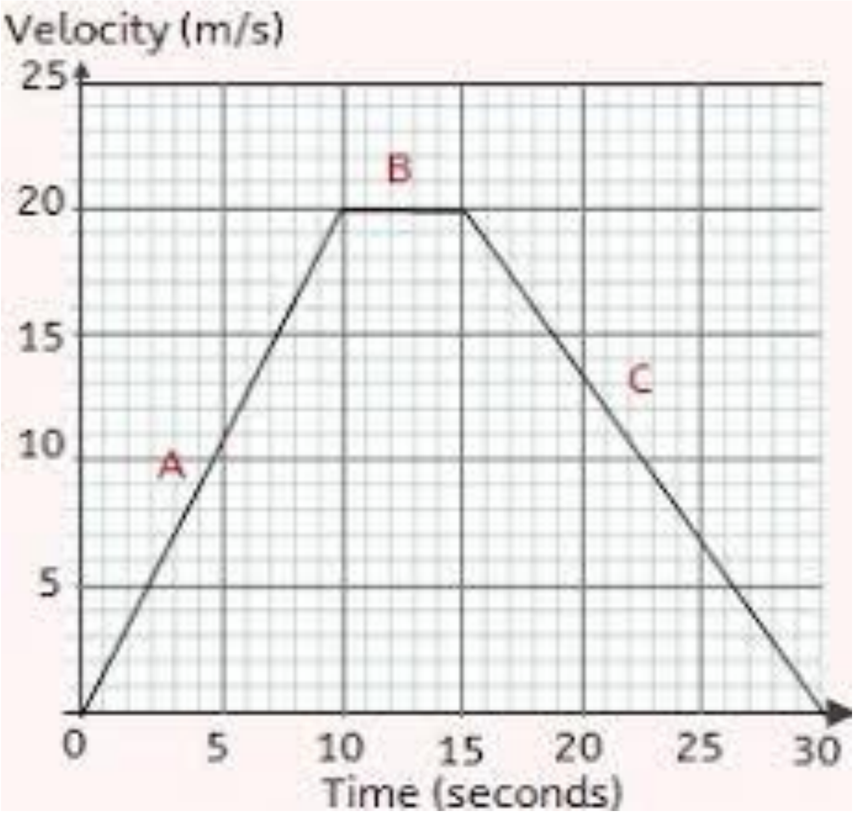


# Interpreting Velocity-Time Graphs

**Example:**
**Describe fully the motion shown in the velocity-time graph.**

**Solution:**

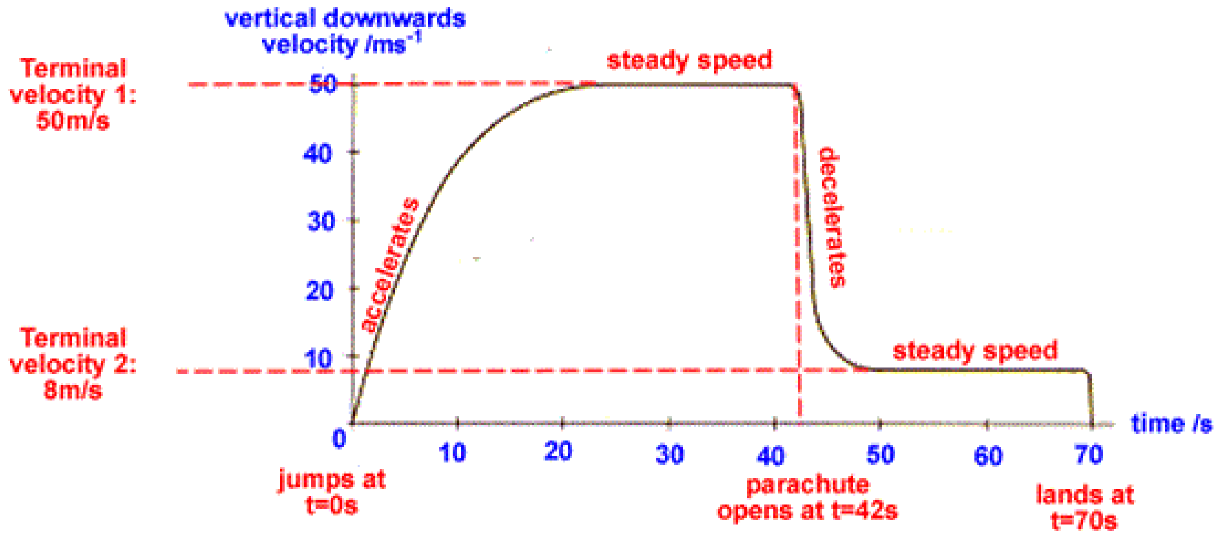
From 0 to 10 s: Constant rate of acceleration of 2 m/$s^2$.
From 10 to 15 s: Constant speed of 20 m/s.
From 15 to 30 s: Constant rate of deceleration of 1.33 m/$s^2$.
Distance-travelled is the area under the line = 100 m + 100 m + 150 m = 350 m



# Terminal Velocity of Falling Objects

**When a skydiver jumps out of a plane they may reach terminal velocity.**

**At terminal velocity the pull of gravity (the skydiver's weight) is equal in size and opposite in direction to the air resistance on the skydiver. As there is no resultant force there is no acceleration and the skydiver will fall at a steady speed.**



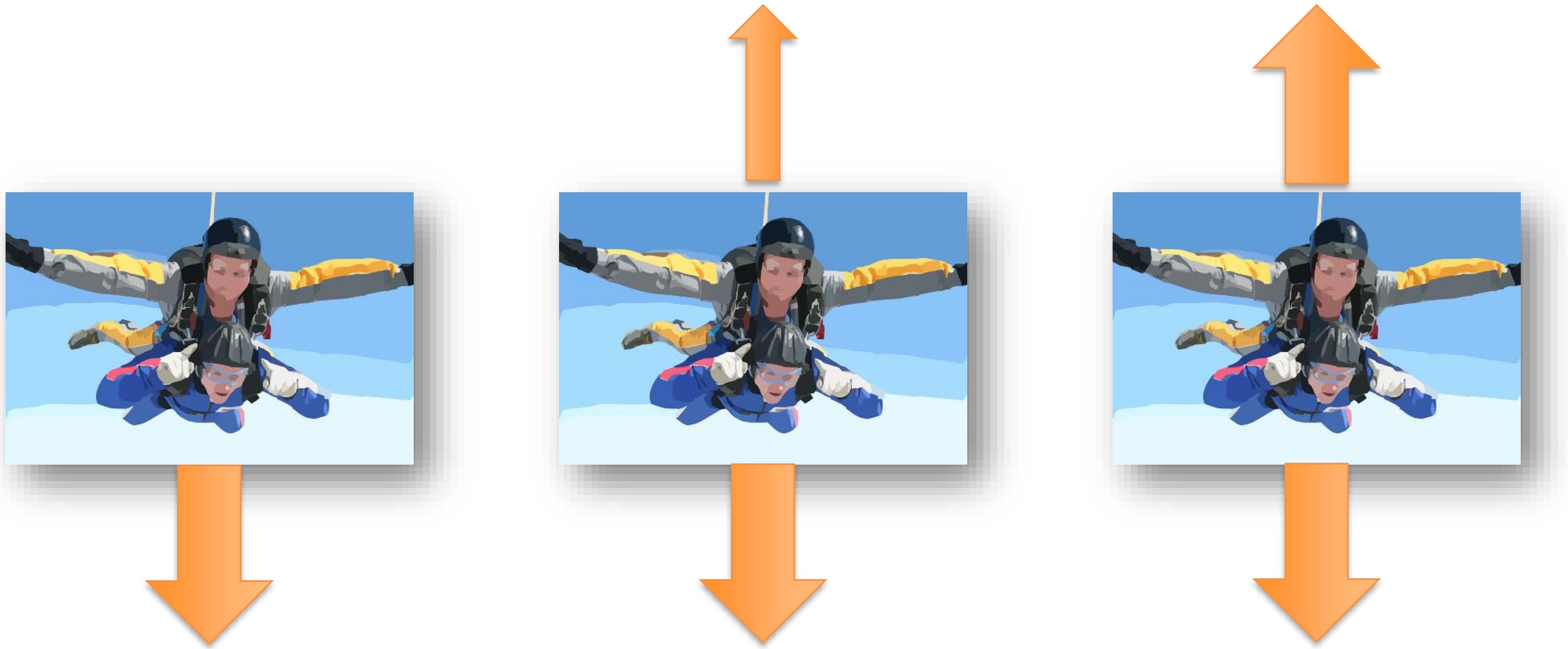
# Forces acting on a Skydiver

During the course of a skydive the weight of a skydiver will not change. As a result of this the skydiver will have a constant pull downwards caused by the gravitational attraction of the Earth.

Also acting on the skydiver is air resistance, or drag. As the skydiver moves through the air faster the skydiver will experience more drag.

Drag reduces the acceleration the skydiver experiences, from 10 $m/s^2$ when they have just jumped out of the plane to 0 $m/s^2$ when they reach terminal speed.

# More Forces acting on a Skydiver



As the skydiver falls faster the amount of drag experienced increases, reducing the skydiver’s acceleration, until weight and drag are equal in size.  At this point the skydiver will be falling with terminal velocity.

# Uniform Acceleration

**The equation for uniform acceleration is:**

**(Final velocity)$^2$ – (Initial velocity)$^2$ = 2 x Acceleration x Distance**
**(m/s) (m/s) (m/s$^2$) (m)**

$$v^2 - u^2 = 2\,a\,s$$

**This equation is often used when an object is falling under gravity and assumes the acceleration due to gravity to be constant (so ignoring air resistance).**

**The acceleration of an object due to gravity is taken to be about 9.8 m/s$^2$. This is often rounded up to 10 m/s$^2$.**

# Uniform Acceleration Calculations

**Example:**

A stone is dropped off a 30 m high cliff.
The stone falls under gravity ($g = 9.8\ m/s^2$).
Work out the speed of the stone as it hits the floor.

**Solution:**

As the stone is dropped the initial speed is 0 m/s.
Using

$$v^2 - u^2 = 2\ a\ s$$

$$v^2 = 2\ a\ s + u^2$$

$$v^2 = 2 \times 9.8 \times 30 + 0^2$$

$$v^2 = 588$$

$$v = \sqrt{588} = 24.2\ m/s$$

# QuestionIT!

## Forces and Motion

- Distance and Displacement
- Speed
- Velocity
- The Distance-Time Relationship
- Acceleration

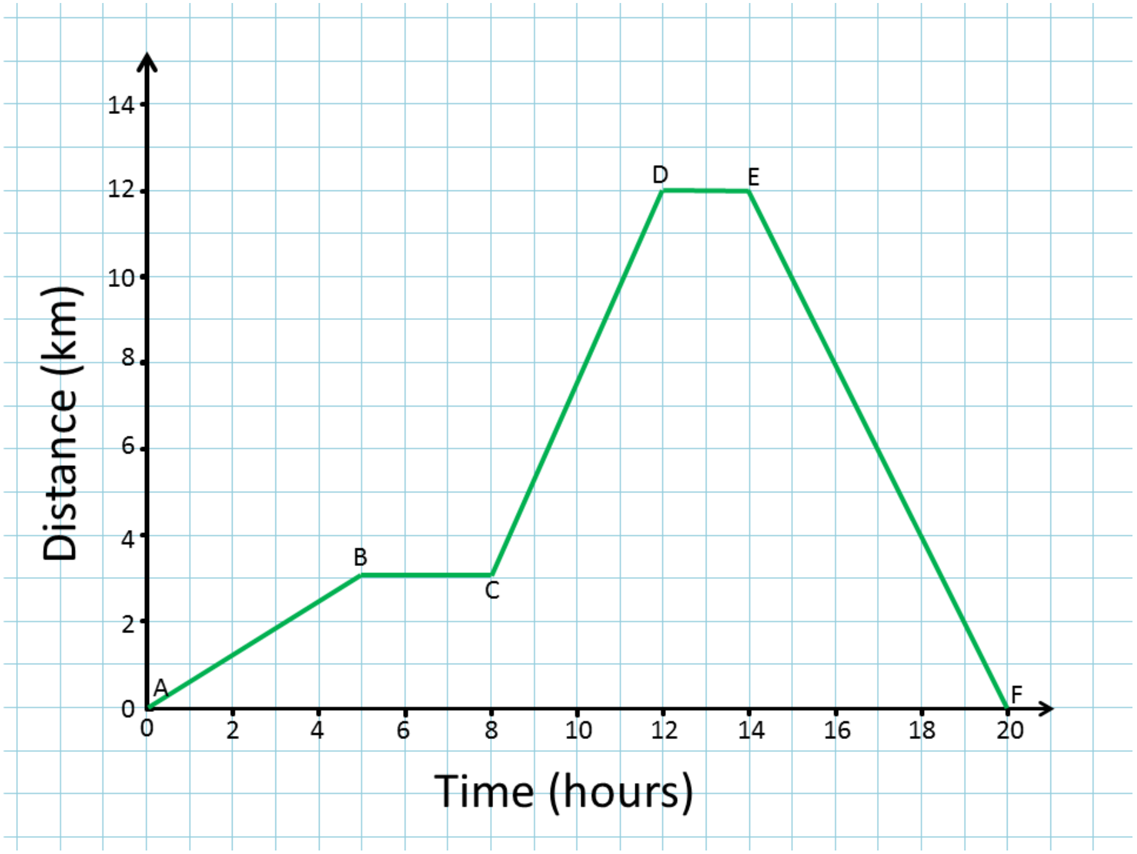
1. State the typical speed of a person
    a) Walking
    b) Cycling
2. State the equation that links speed, distance and time.
3. Describe the difference between speed and velocity.

4. A car moves round a circular track at 120 mph.
   Give the average velocity of the car. Explain your answer.

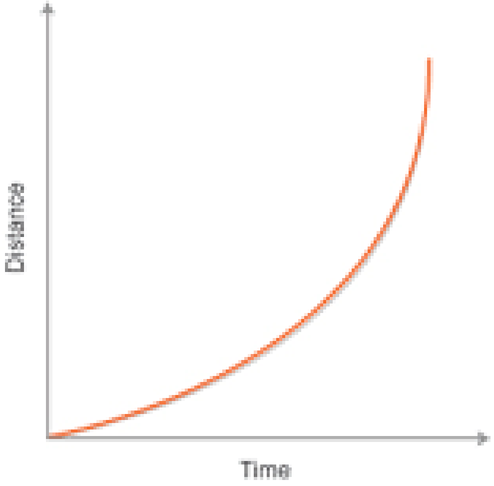
5. A motorcycle travels a distance of 420 miles in 8.5 hours.
   Give the average speed of the motorcycle.

6. Describe the difference between instantaneous speed and average speed.

7. Describe fully the motion shown in the distance-time graph shown below.



8. Describe how you would find the instantaneous speed of an object from a distance-time graph where the line is a curve.



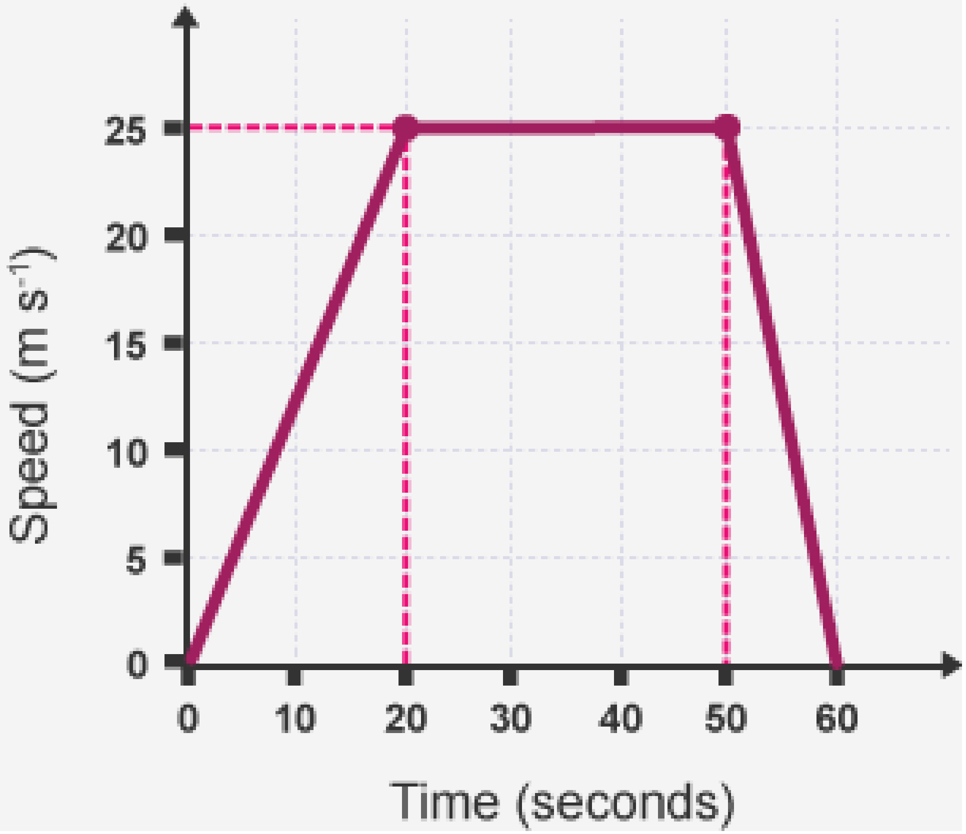
9. State the equation that links acceleration, change in velocity and time taken.

10. Describe what is meant by a negative acceleration.

10. Give the units of acceleration.

12. Describe how the distance travelled by an object can be found from a velocity-time graph.

13. Describe fully the motion shown in the velocity-time graph shown below.



14. A stone is dropped off a cliff.
The stone hits the floor at 30 m/s.
Calculate the height of the cliff.
Take g = 9.8 m/s$^2$

15. Explain how the motion of a skydiver changes from the moment they jump out of the plane until they land.

# AnswerIT!

**Forces and Motion**

- Distance and Displacement
- Speed
- Velocity
- The Distance-Time Relationship
- Acceleration

1. **State the typical speed of a person**

   a) **Walking**

   1.5 m/s

   b) **Cycling**

   6 m/s

2. **State the equation that links speed, distance and time.**

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

3. **Describe the difference between speed and velocity.**

   Speed is a scalar quantity – it has magnitude but no direction.
   Velocity is a vector – it has magnitude and direction.

**4. A car moves round a circular track at 120 mph.**
**Give the average velocity of the car. Explain your answer.**

Average velocity is 0 m/s
As on completion of every lap the car has a displacement of 0 m
and velocity is found using displacement / time
the average velocity must be 0 m/s

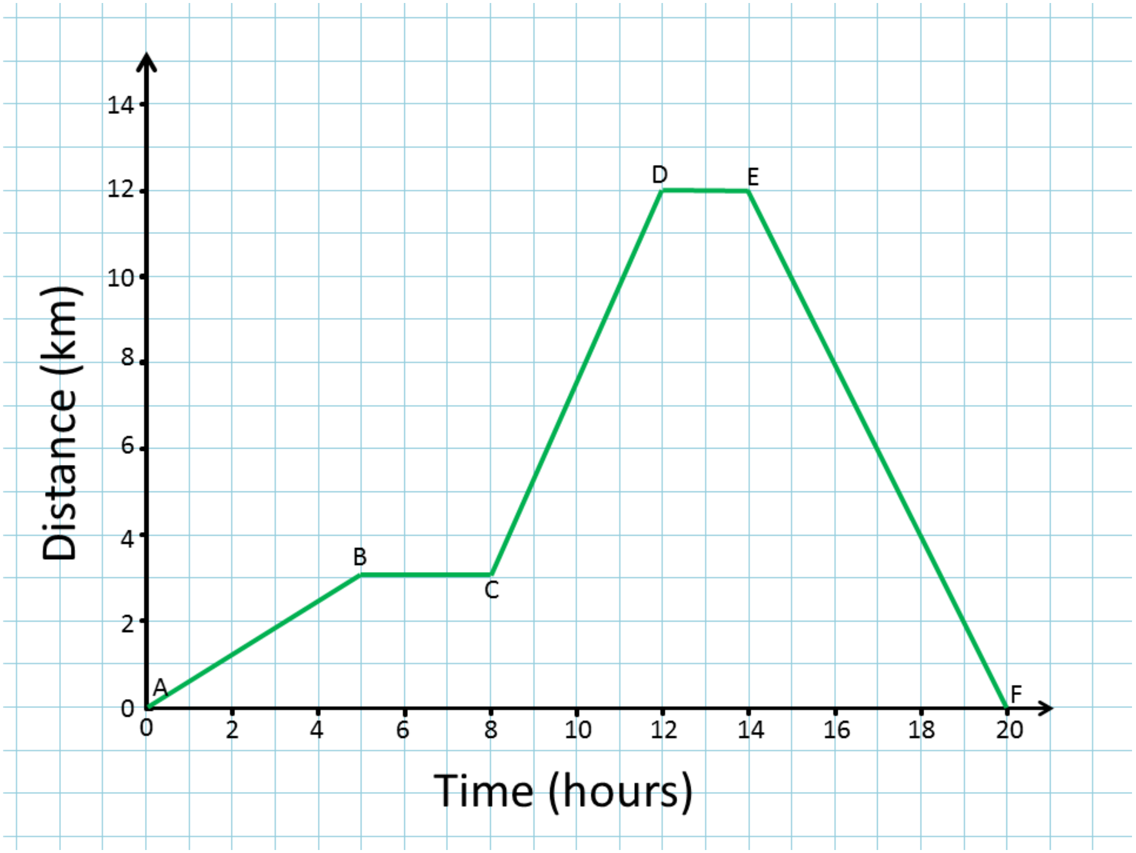
**5. A motorcycle travels a distance of 420 miles in 8.5 hours.**
**Give the average speed of the motorcycle.**

speed = distance / time
speed = 420 / 8
speed = 52.5 mph

**6. Describe the difference between instantaneous speed and average speed.**

Instantaneous speed is the speed at a given moment in time.
Average speed is the speed over the whole journey including periods of acceleration and deceleration.

7. **Describe fully the motion shown in the distance-time graph shown below.**



A to B: Constant speed of 0.6 km/s

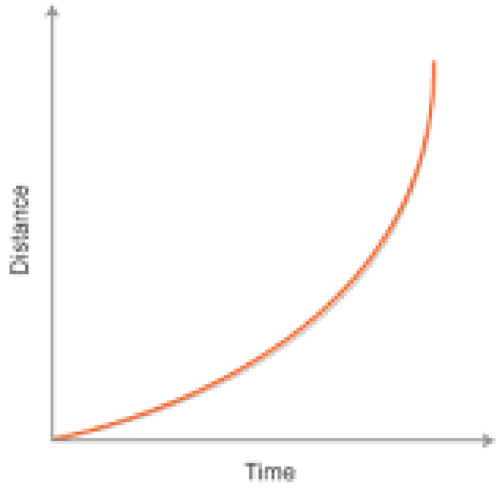
B to C: Stationary (for 4 s)

C to D: Constant speed of 2.25 km/s

D to E: Stationary (for 2 s)

E to F: Constant speed of 2 m/s going back to the origin

8. Describe how you would find the instantaneous speed of an object from a distance-time graph where the line is a curve. (Higher Tier Only).



Draw the tangent to the curve.

Find the gradient of the line you have drawn.

The gradient of the line is the instantaneous speed.

9. State the equation that links acceleration, change in velocity and time taken.

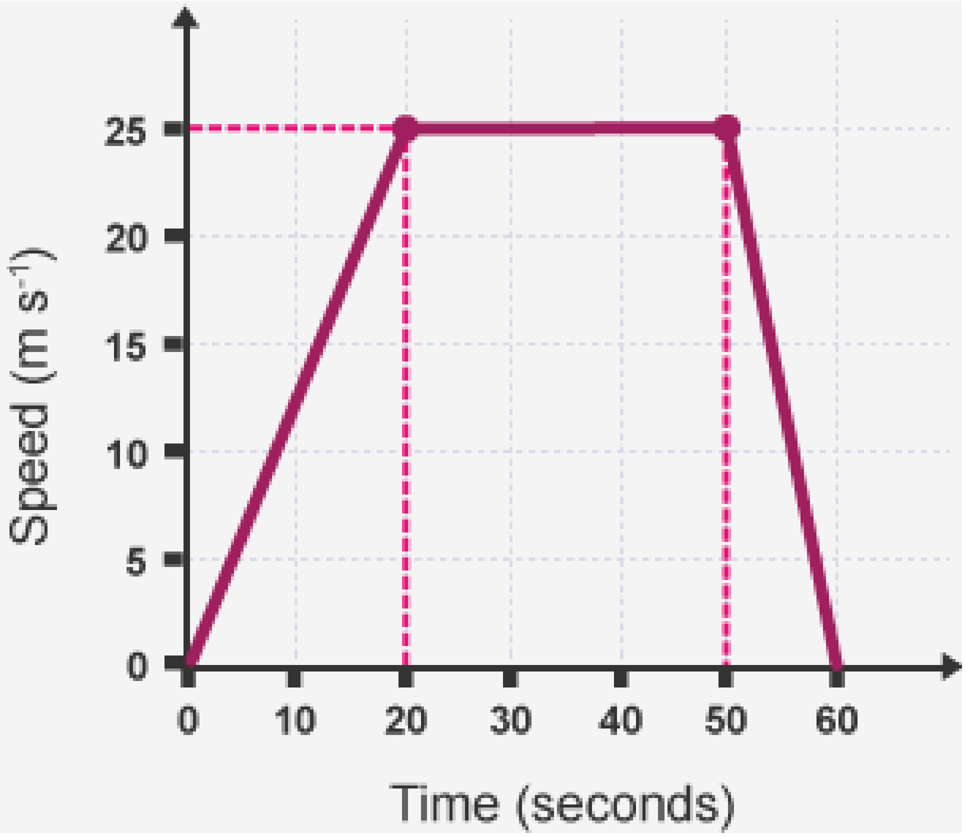
acceleration = change in velocity / time taken

10. Describe what is meant by a negative acceleration.
    A negative acceleration means that the object is slowing down or speeding up in the opposite direction (to that which has been assumed to be positive).

11. Give the units of acceleration.
    $m/s^2$ or $m/s/s$ or $ms^{-2}$

12. Describe how the distance travelled by an object can be found from a velocity-time graph.
    The area under the line on a velocity-time graph represents the distance travelled by that object.

## 13. Describe fully the motion shown in the velocity-time graph shown below.



From 0 to 20 s: Constant rate of acceleration of 1.25 m/s$^2$

From 20 to 50 s: Constant speed of 25 m/s

From 50 to 60 s: Constant rate of deceleration of 2.5 m/s$^2$

Total distance travelled over the 60 seconds is:
250 m + 750 m + 125 m = 1125 m

14. A stone is dropped off a cliff.
The stone hits the floor at 30 m/s.
Calculate the height of the cliff.
Take $g = 9.8 \text{ m/s}^2$

Since the stone is dropped $u = 0$ m/s

| | |
|---|---|
| Using | $v^2 - u^2 = 2 a s$ |
| Substituting gives | $30^2 - 0^2 = 2 \times 9.8 \times s$ |
| Simplifying gives | $900 = 19.6 \times s$ |
| Rearranging gives | $900 / 19.6 = s$ |
| Therefore | $s = 45.9$ m |

15. **Explain how the motion of a skydiver changes from the moment they jump out of the plane until they land.**

- Skydiver accelerates due to gravity (at a rate of 10 $m/s^2$)
- As the skydiver picks up speed the drag they experience increases
- But the gravitational attraction stays the same
- so the acceleration of the skydiver decreases in size.
- When drag and weight are equal in size but opposite in direction the skydiver will fall with terminal speed
- as there is no resultant force so no acceleration
- When the parachute is opened there is an increase in drag
- Decelerating the skydiver
- Until weight and drag are equal in size but opposite in direction
- Then the skydiver falls at a new (lower) terminal speed
- Which is lower as the the large surface area of the parachute increases the amount of drag at a given speed.
- Skydiver decelerates to 0 m/s when they hit the ground.

# LearnIT!
# KnowIT!

## Forces, Accelerations and Newton's Laws of Motion

- Newton's First Law
- Newton's Second Law
- Newton's Third Law

# Newton’s First Law of Motion

**If the resultant force acting on an object is zero and:**

- **the object is stationary, the object remains stationary**

- **the object is moving, the object continues to move at the same speed and in the same direction. So the object continues to move at the same velocity.**

**The velocity of a vehicle will only change if there is a resultant force acting upon it. If the driving and resistive forces are balanced (there is no resultant force) then the vehicle will continue with a steady velocity (speed and direction).**

# Inertia – Higher Tier Only

Inertia is a property of matter. It is the resistance of the object to change its motion (speed and/or direction).

Mass is a measure of the amount of inertia an object has. The more inertia (or mass) an object has the harder it is to get that object to change its motion.

To find out which of two objects has the most inertia:

- Apply an equal force to both of them when they are at rest.
- The one that has the greatest acceleration has the lowest inertia – it was easier to get it to change its motion.

# Newton’s Second Law of motion

**The acceleration of an object is proportional to the resultant force acting on the object, and inversely proportional to the mass of the object.**

**In equation form, Newton’s Second Law is written as:**

$$\text{Force (N)} = \text{Mass (kg)} \times \text{Acceleration (m/s}^2\text{)}$$

$$F = m\,a$$

**Inertial mass is the ratio of force divided by acceleration.**

# Using F = m a

**Example 1:**

**A motorcycle has a mass of 240 kg and accelerates at a rate of $4\ m/s^2$. Work out the driving force of the motorcycle.**

**Solution:**

**Using**

$$F = m\ a$$
$$F = 240 \times 4$$
$$F = 960\ N$$

# Using F = m a

**Example 2:**

**A car brakes sharply from a velocity of 30 m/s to rest in 4.2 s.**
**The braking force applied by the brakes was 4800 N.**
**Work out the mass of the car.**

**Solution:**

**Finding the acceleration of the car:**

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

$$\text{acceleration} = 7.1\ \text{m/s}^2$$

**Substituting gives**

$$F = m\ a$$

$$4800 = m \times 7.1$$

$$m = 672\ \text{kg} \quad \text{allow } 676\ \text{kg if acceleration was rounded down}$$

# Newton's Third Law of motion

**Whenever two objects interact, the forces they exert on each other are equal in size and opposite in direction.**

**Examples:**

**When a car crashes into a crash barrier, the force acting on the car and the force acting on the barrier are equal and opposite.**

**A pen falling will be pulled down by the Earth, and the Earth will be pulled up by the pen.**

# QuestionIT!

## Forces, Accelerations and Newton's Laws of Motion

- Newton's First Law
- Newton's Second Law
- Newton's Third Law

1. Describe why a cannon ball, when fired from a cannon does not continue to move with constant velocity.

2. What is the inertia of an object a measure of?

3. State the equation commonly used for Newton's second law.

4. A car has a driving force of 1200 N and a mass of 700 kg.
   Calculate the acceleration of the car.

5. A skydiver has a weight of 686 N and a mass of 70 kg.
   Calculate the acceleration of the skydiver the moment he jumps out of the plane.

6. A motorcycle has a driving force of 1400 N and an acceleration of 6 $m/s^2$.
   Calculate the mass of the motorcycle.

7. A father and his daughter were ice skating. The father has a mass of 75 kg and his daughter has a mass of 30 kg. The father pushed his daughter and she feels a force of 50 N.
   Calculate the force on the father.

8. A car crashed into a crash barrier. The force exerted by the barrier on the car was 4500 N. Describe the force exerted by the car onto the barrier.

# AnswerIT!

## Forces, Accelerations and Newton's Laws of Motion

- Newton's First Law
- Newton's Second Law
- Newton's Third Law

1. Describe why a cannon ball, when fired from a cannon does not continue to move with constant velocity.

- Gravity acts pulling the cannon ball downwards
- So, there is a resultant force
- Objects will only continue with uniform motion when no resultant force acts.

2. What is inertia of an object a measure of?

How easy, or difficult, it is to get the object to change its motion.
The more inertia an object has the harder it is to get it to change its motion.

3. State the equation commonly used for Newton's second law.

force = mass x acceleration

4. **A car has an acceleration of 1.7 m/s$^2$ and a mass of 700 kg.
Calculate the driving force of the car.**
Using F = m a
force = 700 x 1.7
force = 1190 N

5. **A skydiver has a weight of 686 N and a mass of 70 kg.
Calculate the acceleration of the skydiver the moment he jumps out of the plane.**
acceleration = force / mass
acceleration = 686 / 70
acceleration = 9.8 m/s$^2$

6. **A motorcycle has a driving force of 1400 N and an acceleration of 6 m/s$^2$.
Calculate the mass of the motorcycle.**
mass = force / acceleration
mass = 1400 / 6
mass = 233 kg

7. A father and his daughter were ice skating.
The father has a mass of 75 kg and his daughter has a mass of 30 kg.
The father pushed his daughter and she feels a force of 50 N.
Calculate the force on the father.
50 N
From Newton's third law: whenever two objects interact, the forces they exert on each other are equal in size and opposite in direction.

8. A car crashed into a crash barrier. The force exerted by the barrier on the car was 4500 N. Describe the force exerted by the car onto the barrier.
The force exerted by the car onto the barrier is 4500 N.
From Newton's third law: whenever two objects interact, the forces they exert on each other are equal in size and opposite in direction.

# LearnIT!
# KnowIT!

## Forces and Braking

- Stopping Distance
- Reaction Time
- Factors Affecting Braking Distance 1
- Factors Affecting Braking Distance 2

## Stopping Distance

# Definitions

**Thinking Distance:** Thinking distance is the distance that you travel while reacting to a stimulus until you get your foot onto the brake pedal. Thinking distance depends on reaction time, but these are not the same thing.

**Braking Distance:** Braking distance is the distance you travel from pressing the brake pedal until you come to a stop.

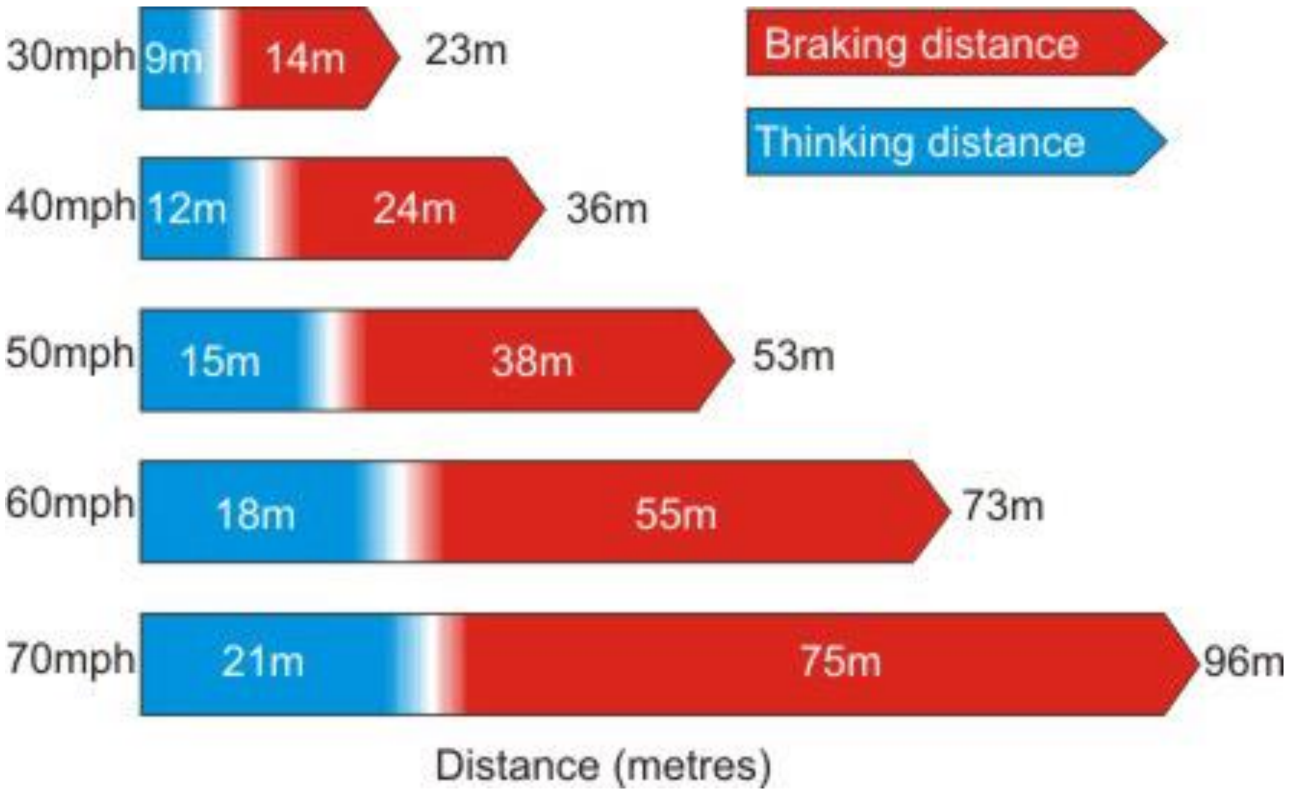
**Stopping Distance:** Stopping distance is the sum of thinking distance and braking distance, usually shown as:

Stopping distance = Thinking distance + Braking distance

# How Speed Affects Stopping Distance

**Increasing the speed of a vehicle will increase its stopping distance.**

**The highway code shows the stopping distances for cars at various speeds…**



As you can see, when speed increases so does the overall stopping distance.

Also, it is both parts of the overall stopping distance – thinking and braking distance – that increases.

# Speed and Thinking Distance

From the highway code it is possible to see patterns in the data.

When you double your speed your thinking distance will also double. This is shown by the thinking distance being 9 m at 30 mph and 18 m at 60 mph. The reason this happens is because your reaction time does not change but you will now travel further while you react:

If you take 0.5 seconds to react then at a speed of 10 m/s you would travel 5 m while reacting to a stimulus. If the speed doubled to 20 m/s then you would now travel 10 m while reacting to the stimulus – the thinking distance has doubled when the speed has doubled.

# Speed and Braking Distance

**Doubling your speed will more than double your braking distance.  In fact doubling the speed of a vehicle will cause the braking distance to quadruple.**

**At 30 mph the braking distance is 14 m and at 60 mph the braking distance is 55 m (according to the highway code) which is approximately  four times greater:  The difference of 1 m is accounted for by rounding.**

**When the speed of a vehicle doubles the kinetic energy of the vehicle is four times greater.  This happens because kinetic energy is found using the equation:**

$$\text{kinetic energy} = \tfrac{1}{2} \times \text{mass} \times (\text{velocity})^2$$

**As there is four times the kinetic energy it takes four times longer to stop at a given braking force.**

# Reaction Time

**A typical person's reaction time varies from 0.2 to 0.9 seconds.**

**There are a number of factors that will affect your reaction time, and in turn thinking distance.**

**These factors include:**

| Factor | Affect on Reaction Time |
|---|---|
| Alcohol | Increases |
| Caffeine | Decreases |
| Tiredness | Increases |
| Distractions | Increases |

**Drugs can either increase or decrease reaction times as some drugs are stimulants and some are depressants.**

# Measuring Reaction Time

A person's reaction time is very short. Trying to measure this reaction time is going to be difficult but there are ways of measuring it.

1. There are online tests that display a stimulus and measures the time taken to respond to the stimulus – often by clicking a mouse button.

2. Ruler drop. This is where a ruler is dropped through your hand. As soon as you see the ruler move you close your hand. The distance that the ruler moves through your hand corresponds to a given reaction time - these can be found online at:

http://www.topendsports.com/testing/tests/reaction-stick.htm

# Factors Affecting Braking Distance

**There are a number of factors that affect the braking distance of a vehicle. Some of these are shown in the table below:**

| Factor Affecting Braking Distance | How this factor affects braking distance |
|---|---|
| Speed | Increasing speed increases braking distance |
| Weight of Vehicle | Increasing weight of vehicle increases braking distance |
| Icy Roads | Braking distance increases due to reduced friction between tyre and road |
| Wet Roads | Braking distance increases due to reduced friction between tyre and road |
| Poor Brake Condition | Braking distance increases |
| Bald Tyres | Braking distance increases when wet. |

## Factors Affecting Braking Distance 2

# Braking Force

When a force is applied to the brakes of a vehicle, work done by the frictional forces between the brake pads and the brake disc reduces the kinetic energy of the vehicle and the temperature of the brakes increases.

The greater the speed of a vehicle the greater the braking force needed to stop the vehicle in a certain distance.

The greater the braking force the greater the deceleration of the vehicle. Large decelerations may lead to brakes overheating and/or loss of control.

# QuestionIT!

## Forces and Braking

- Stopping Distance
- Reaction Time
- Factors Affecting Braking Distance 1
- Factors Affecting Braking Distance 2

# Forces and Braking - QuestionIT

1. Define thinking distance.

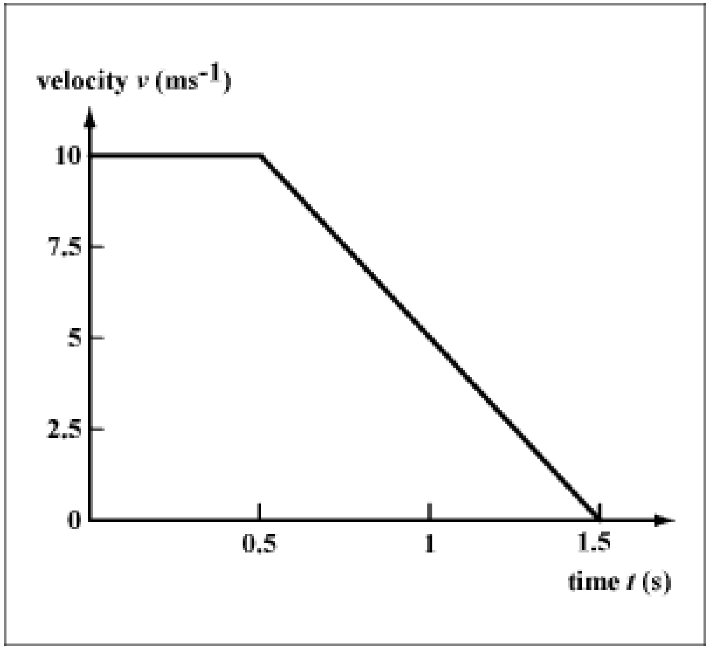
2. Complete the equation:

Stopping distance = ……………………………… + ……………………………….

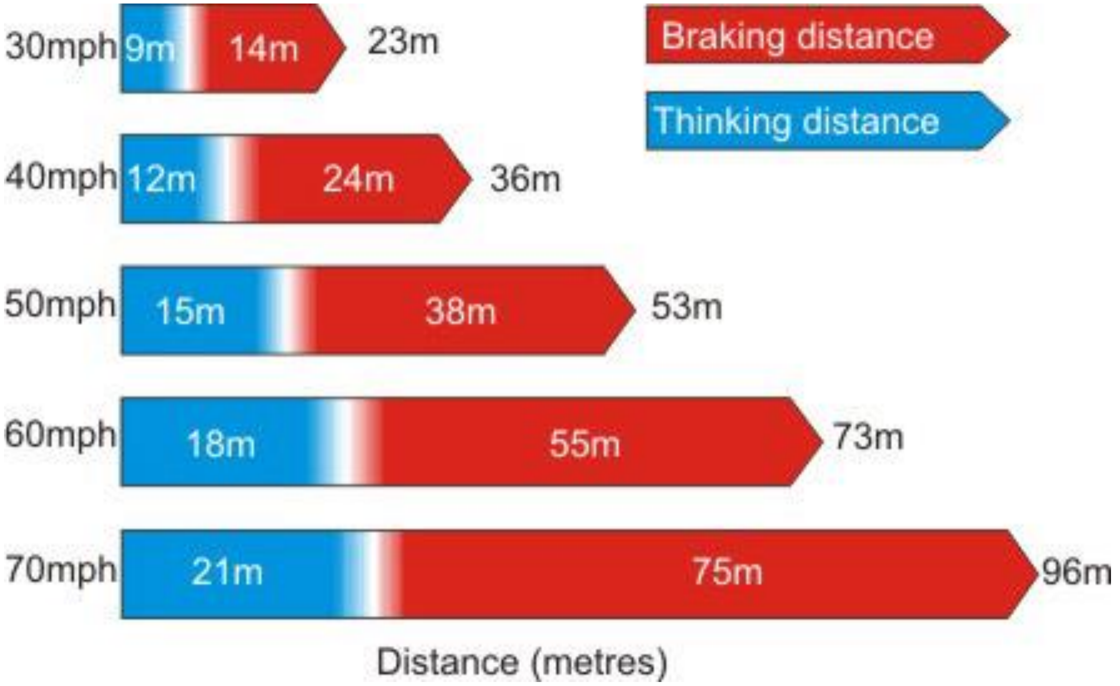
3. Describe how the speed of a vehicle affects the thinking distance.

4. A driver sees a car braking sharply in front of him. The driver takes 0.5 s to react to the stimulus and then brakes. Figure 1 shows the velocity-time graph for the motion of the vehicle from seeing the stimulus to stopping. Calculate the stopping distance of the vehicle.

**Figure 1**



5. The highway code shows the stopping distances for vehicles up to 70 mph. In 2011 the government proposed a new 80 mph speed limit for UK motorways.
   Use the information in the diagram, and your own knowledge, to determine the overall stopping distance of a vehicle at 80 mph.



6. Describe how you could measure the reaction time of a person.

7. Explain the dangers caused by large decelerations of a vehicle.

8. Put the following factors under the correct headings to show whether the factor affects thinking distance, braking distance or both thinking and braking distance.

Speed Mass Icy roads Tiredness

Poor brakes Mobile Phone use Alcohol Bald tyres

| Thinking Distance | Braking Distance | Both |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

# AnswerIT!

## Forces and Braking

- Stopping Distance
- Reaction Time
- Factors Affecting Braking Distance 1
- Factors Affecting Braking Distance 2

Forces and Braking - AnswerIT

1. **Define thinking distance.**
   The distance travelled while the driver reacts to a stimulus until the driver gets their foot onto the brake pedal (but before the brake pedal is pressed).

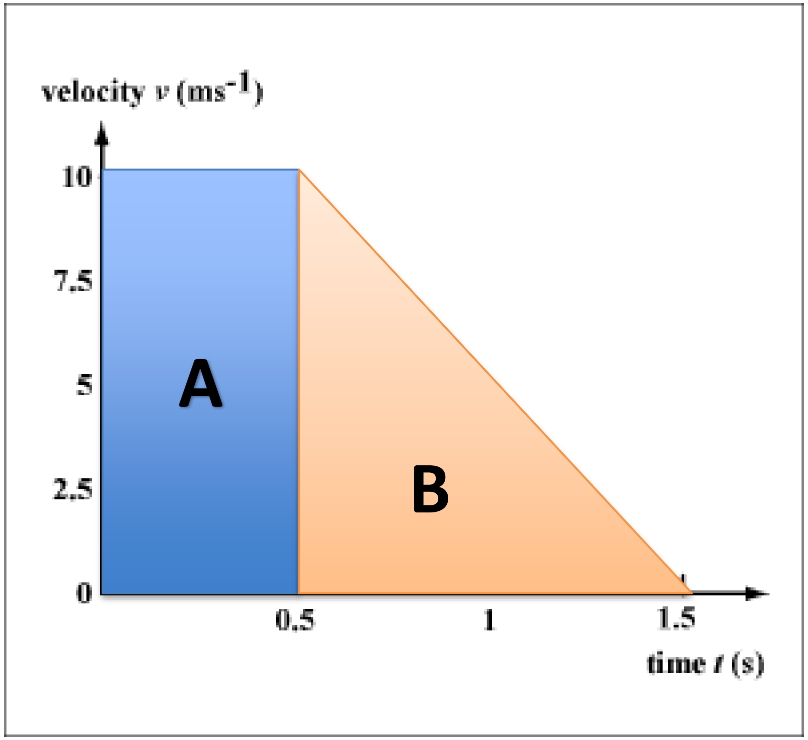
2. **Complete the equation:**

   **stopping distance =** thinking distance **+** braking distance

3. **Describe how the speed of a vehicle affects the thinking distance.**
   Increasing speed increases thinking distance
   Doubling your speed doubles the thinking distance.

4. A driver sees a car braking sharply in front of him. The driver takes 0.5 s to react to the stimulus and then brakes. Figure 1 shows the velocity-time graph for the motion of the vehicle from seeing the stimulus to stopping. Calculate the stopping distance of the vehicle.

**Figure 1**



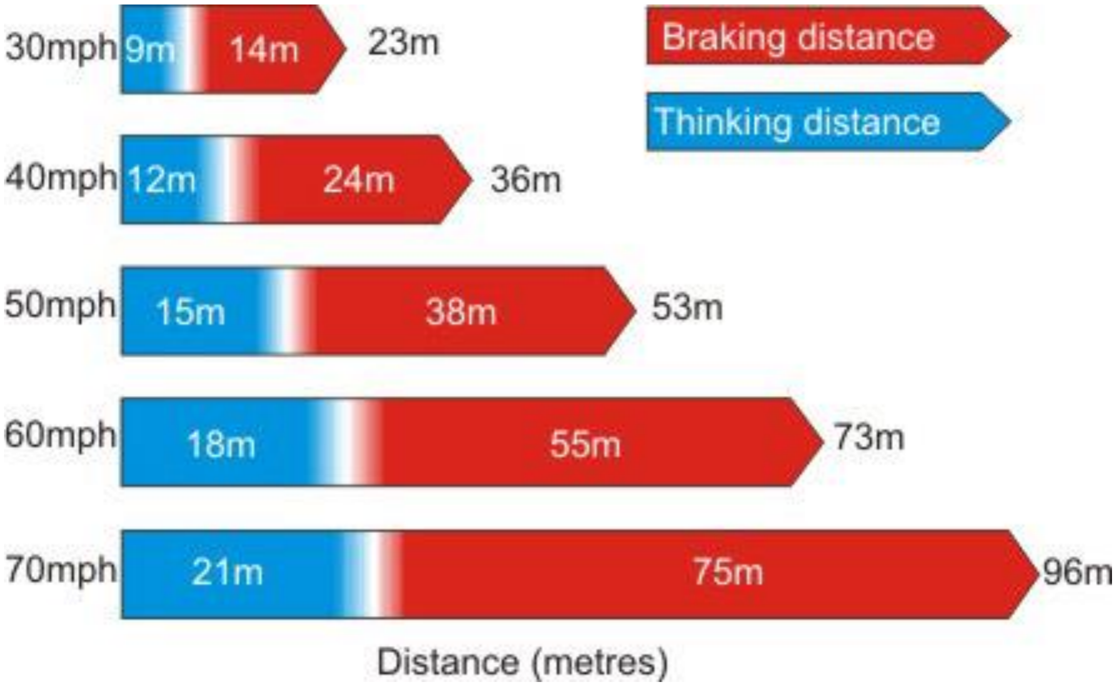
stopping distance = area under line

stopping distance = Area A + Area B

stopping distance = 5 + 5

stopping distance = 10 m

5. **The highway code shows the stopping distances for vehicles up to 70 mph. In 2011 the government proposed a new 80 mph speed limit for UK motorways.**
   **Use the information in the diagram, and your own knowledge, to determine the overall stopping distance of a vehicle at 80 mph.**



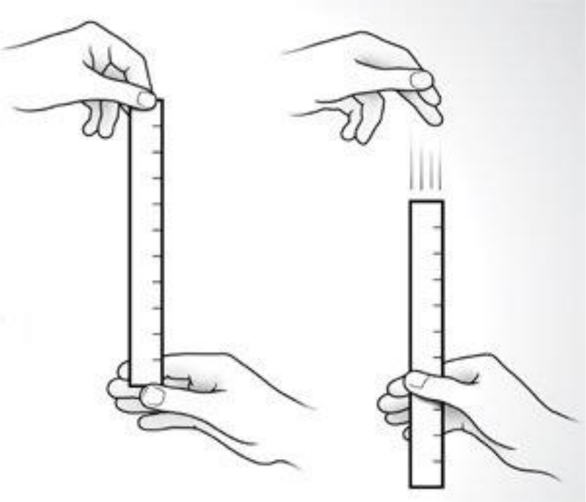
When speed doubles thinking distance doubles and braking distance quadruples. So,

At 80 mph:

Thinking distance = 24 m
Braking distance = 96 m
Stopping distance = 120 m

6. **Describe how you could measure the reaction time of a person.**

- Get the person to stand with their hand open
- Place a ruler at the top a the person's hand
- Drop the ruler through their hand
- When the person sees the ruler move they need to close their hand
- The distance the ruler travels corresponds to the thinking distance



6. **Explain the dangers caused by large decelerations of a vehicle.**

- Large decelerations can cause the brakes to overheat and become less effective
- Large decelerations can also cause a loss of control
- Large decelerations can also exert large forces of people within a vehicle.

8. Put the following factors under the correct headings to show whether the factor affects think distance, braking distance or both thinking and braking distance.

Speed

Mass

Icy roads

Tiredness

Poor brakes

Mobile Phone use

Alcohol

Bald tyres

| Thinking Distance | Braking Distance | Both |
|---|---|---|
| Tiredness | Mass | Speed |
| Mobile Phone use | Icy roads | |
| Alcohol | Poor brakes | |
| | Bald tyres | |

# LearnIT!
# KnowIT!

## Momentum (HT Only)

- Momentum is a Property of Moving Objects
- Conservation of Momentum
- Changes in Momentum (Physics Only)

# Momentum

Momentum is a vector quantity.

The momentum of an object only depends on it's mass and it's velocity.

The equation linking momentum, mass and velocity is:

Momentum (kg m/s) = Mass (kg) x Velocity (m/s)

$p = m v$

From this equation we can see that if an object is not moving (it has a velocity of 0 m/s) then it has no momentum.

# Conservation of Momentum: Crashes

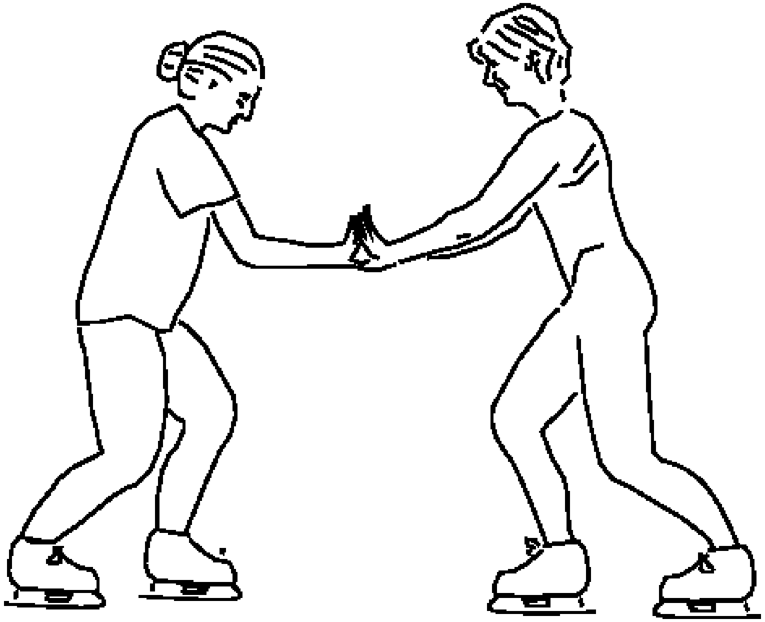
Momentum is a conserved quantity. The momentum of a system remains the same before and after an event.

e.g. In a car crash the momentum of the vehicles before the crash equals the momentum of the vehicles after the crash.

# Conservation of Momentum: Explosive Events

In an explosion the momentum of the system is also conserved. This may seem strange as everything is stationary to begin with, but after the explosion parts are moving to the left and right and these cancel – since velocity is a vector and depends on direction.

An example of an explosive event is two ice skaters pushing themselves apart, where the momentum of each ice skater is equal in size and opposite in direction to the other. This then adds to be 0 kgm/s, which is what it was at the start.



# Changes in Momentum

The force acting on an object is usually found using the equation **F = m a**.

However, as the acceleration of an object is found using the equation:

$$\text{Acceleration (m/s}^2\text{)} = \frac{\text{Change in speed (m/s)}}{\text{Time taken (s)}}$$

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

Combining the two equations gives:

$$F = \frac{m\,\Delta v}{\Delta t}$$

The quantity $m\Delta v$ is the change in momentum of an object.
So, **force is the rate of change of momentum**.

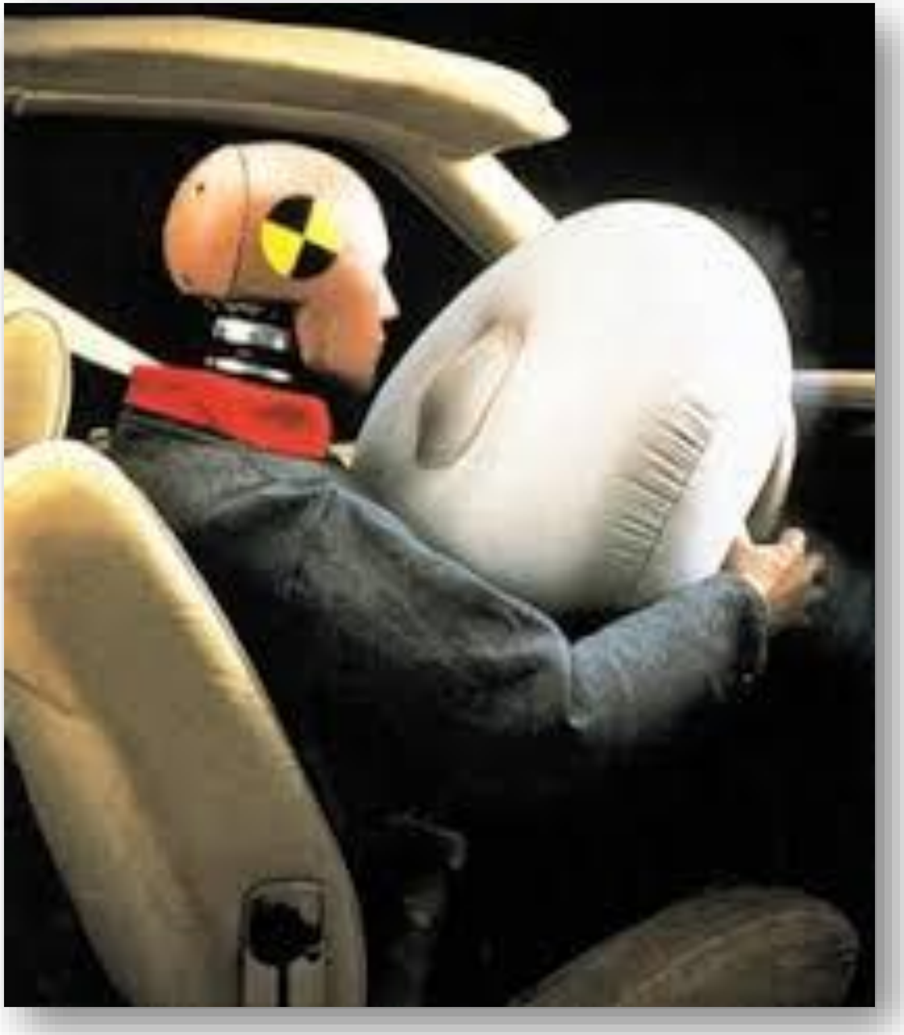
# Changes in Momentum: Safety Features

Cars have air bags to reduce the injuries caused in a crash.

**Air bags** work by **increasing the time** of impact – it takes a person's head longer to come to a stop (compared to hitting the steering wheel).

As the time of impact increases the force acting on the person's head decreases since:

$$F = m\frac{\Delta v}{\Delta t}$$



# Changes in Momentum:  Safety Features continued…

**Seatbelts also increase the time it takes a person to stop.**

**By increasing the time it takes to stop the force acting is reduced as,**

$$F = m\frac{\Delta v}{\Delta t}$$

# QuestionIT!

## Momentum (HT Only)

- Momentum is a Property of Moving Objects
- Conservation of Momentum
- Changes in Momentum (Physics Only)

# Momentum - QuestionIT

1. State the units of momentum.

2. State the equation that links mass, momentum and velocity.

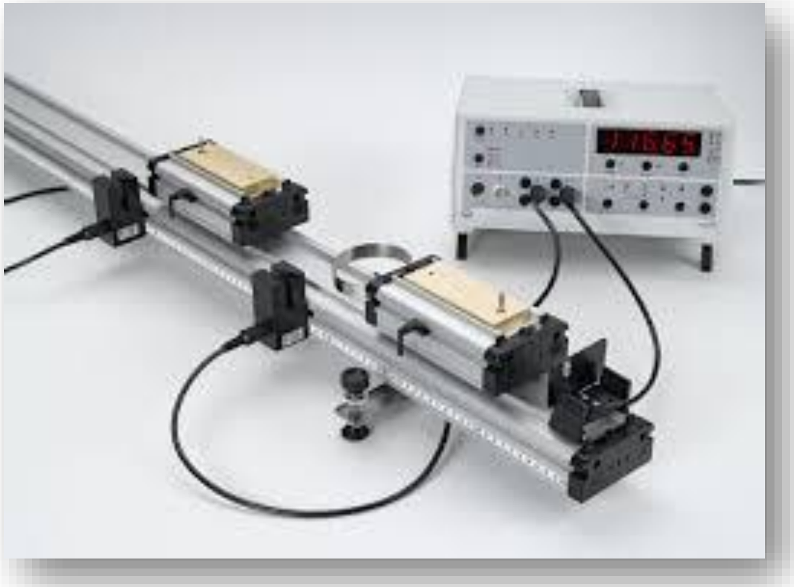
3. Momentum is a conserved quantity.
   Explain what is meant by a conserved quantity.

## Momentum - QuestionIT

4. A football has a mass of 0.75 kg and is kicked with a speed of 12 m/s.
   Calculate the momentum of the kicked football.

5. Two ice skaters push themselves apart on the ice.
   Explain how the conservation of momentum applies in this case.

6. A trolley has a mass of 1.2 kg and a speed of 4.5 m/s. The trolley crashes into a stationary trolley of mass 0.8 kg. On impact the two trolley's stick together and move off with speed, v.



a. Calculate the momentum of the trolleys before impact.

b. Calculate the speed of the trolleys after impact.

7. A gymnast falls onto a crash mat. The crash mat reduces the risk of injury to the gymnast.
   Explain how the crash mat reduces injury.

8. A car of mass 850 kg hits a crash barrier at a speed of 30 m/s. The car stops in 0.1 s. Calculate the force on the car.

# AnswerIT!

## Momentum (HT Only)

- Momentum is a Property of Moving Objects
- Conservation of Momentum
- Changes in Momentum (Physics Only)

# Momentum - AnswerIT

1. **State the units of momentum.**
   kgm/s

2. **State the equation that links mass, momentum and velocity.**
   Momentum = mass x velocity

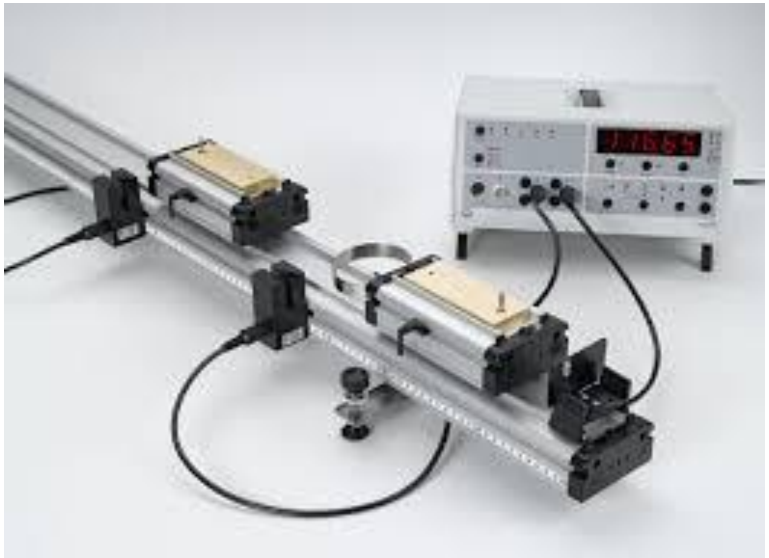
3. **Momentum is a conserved quantity.**
   **Explain what is meant by a conserved quantity.**
   The momentum before and after an event is equal in a closed system

Momentum - AnswerIT

4. A football has a mass of 0.75 kg and is kicked with a speed of 12 m/s.
Calculate the momentum of the kicked football.
Using momentum = mass x velocity
Momentum = 0.75 x 12
Momentum = 9 kgm/s

5. Two ice skaters push themselves apart on the ice.
Explain how the conservation of momentum applies in this case.
The momentum before pushing is 0 kgm/s as they are not moving
On pushing apart the momentum of each ice skater is the same size but in the opposite direction
When adding (vector addition) of the momentum of the two ice skaters sum is also 0 kgm/s
So momentum is conserved.

## Momentum - AnswerIT



6. A trolley has a mass of 1.2 kg and a speed of 4.5 m/s. The trolley crashes into a stationary trolley of mass 0.8 kg. On impact the two trolley's stick together and move off with speed, v.

a. Calculate the momentum of the trolleys before impact.

Using momentum = mass x velocity
momentum = 1.2 x 4.5
momentum = 5.4 kgm/s

b. Calculate the speed of the trolleys after impact.

Using conservation of momentum; Momentum before = Momentum after
5.4 = $\text{mass}_{\text{after}}$ x $\text{velocity}_{\text{after}}$
$\text{velocity}_{\text{after}}$ = 5.4 / 2 = 2.7 m/s

**7. A gymnast falls onto a crash mat. The crash mat reduces the risk of injury to the gymnast.**

**Explain how the crash mat reduces injury.**

**The crash mat increases the time taken to come to a stop**

**This decreases the acceleration**

**Since $F = m \frac{\Delta v}{\Delta t}$**

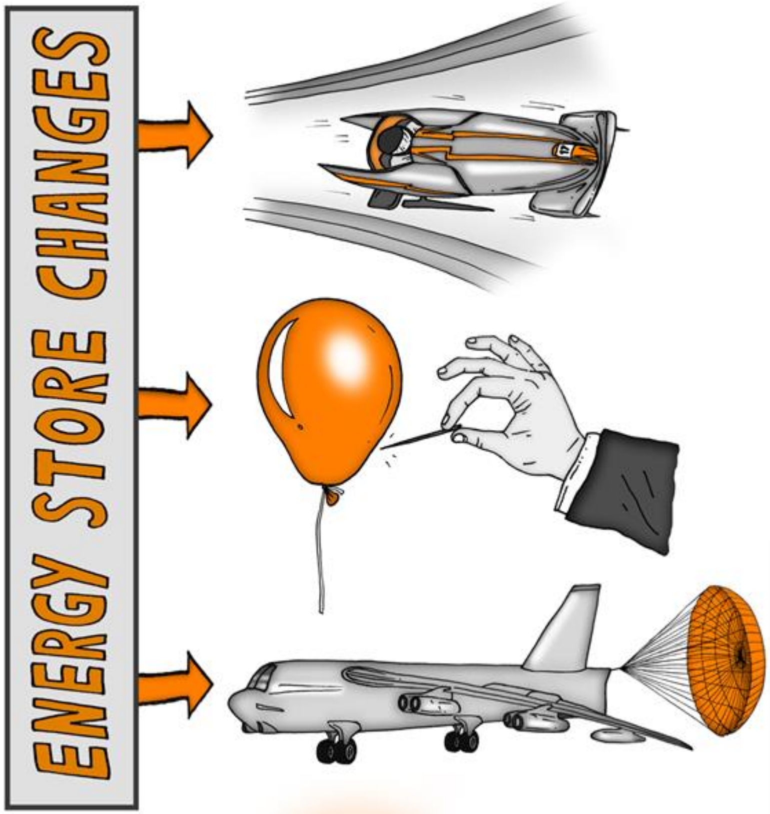
**This reduces the force acting on the gymnast**

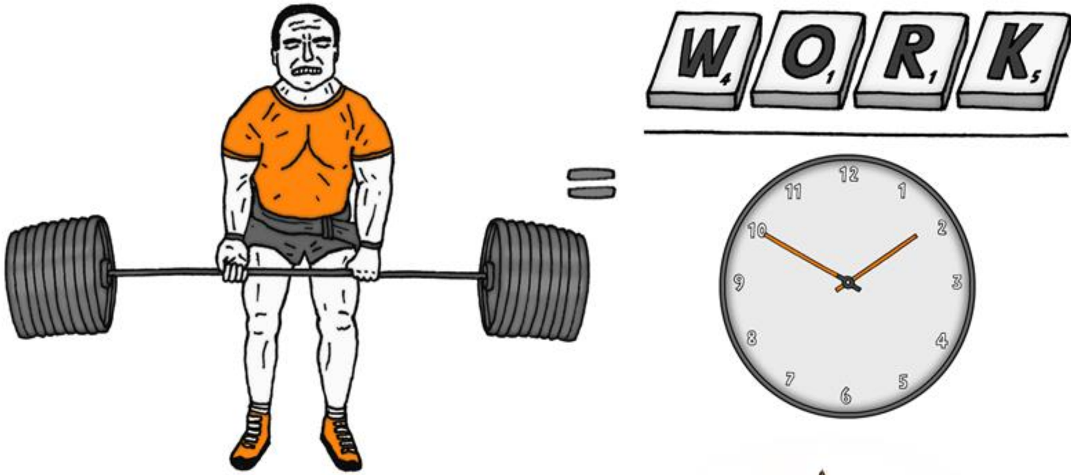
**8. A car of mass 850 kg hits a crash barrier at a speed of 30 m/s. The car stops in 0.4 s. Calculate the force on the car.**

**Using $F = m \frac{\Delta v}{\Delta t}$**

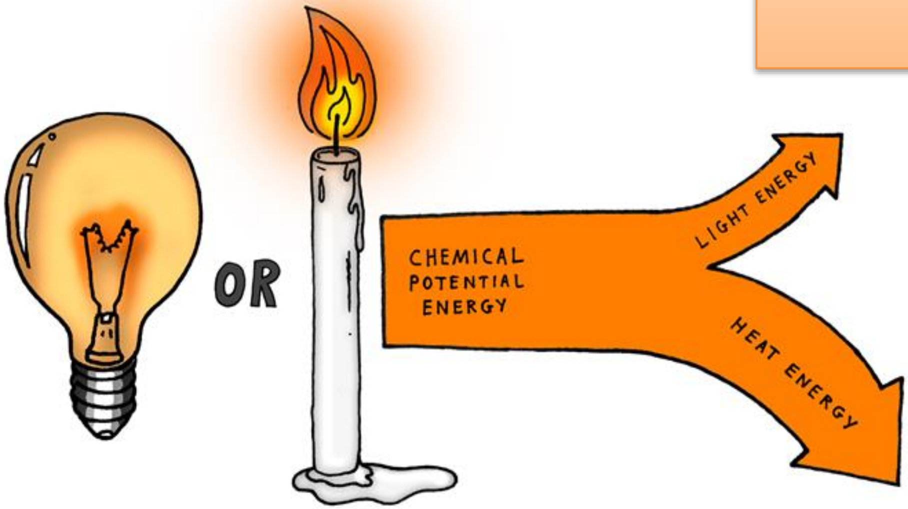
$$F = 850 \times \frac{30}{0.4}$$

$$F = 63\,750 \text{ N}$$


ENERGY STORE CHANGES


W
O
R
K
=

# Energy


OR
CHEMICAL POTENTIAL ENERGY
LIGHT ENERGY
HEAT ENERGY


STORE
Energy
OPEN

# Overview
# Energy

## Energy changes and energy stores

- Energy stores and systems
- Changes in energy
- Energy changes in systems
- Power

## Conservation and dissipation of energy

- Energy transfers in a system
- Efficiency

## Energy resources

- Renewable and non renewable energy resources
- Environmental impact of energy resources
- Patterns and trends in the use of energy resources

# LearnIT!
# KnowIT!

## Energy changes and energy stores
## Part 1

- Energy stores and systems
- Changes in energy

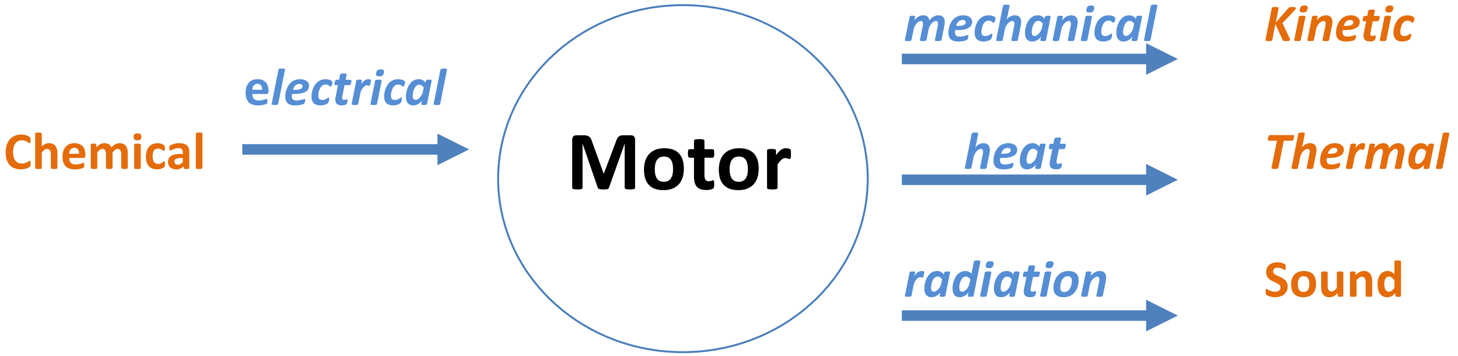
# Energy stores and systems

**An energy system is a group of objects that have the ability to do work.**

**Remember: energy can not be created or destroyed so when work is done, energy from one store is carried along a pathway to another energy store.**

**Consider the energy flow diagram for an electric shaver.**

**The battery has a store of chemical energy.**
**The current flows through an electrical pathway to the motor.**
**Energy from the motor follows a mechanical pathway to a kinetic store of the moving blades, a heat pathway to a thermal store and a radiation pathway to a sound store.**



# Energy stores and systems

| Energy stores | Examples |
|---|---|
| Chemical | In food, fuel and electric batteries |
| Kinetic | In moving objects |
| Gravitational potential | In objects raised above a planets surface |
| Elastic potential | In a stretched, compressed or twisted object |
| Internal (thermal) | In any heated object |
| Magnetic | In any object with a magnetic field |
| Electrostatic | In electrostatic forces between charges |
| Nuclear | The forces acting between atomic nuclei |

Force pathways include:

Mechanically – when a force acts and an object moves
Electrically – when an electric current flows
Heating – a temperature difference between objects
Radiation – electromagnetic waves or sound

# Energy stores and systems

Examples of energy changes in a system:

**An object thrown (projected) upwards e.g. You throw a tennis ball upwards.**

- As the **ball leaves** your **hand** it has a **store** of **kinetic energy**.
- At its **highest point** it has a **store** of **gravitational potential energy (G.P.E)**.
- As you are about to catch it just **before it hits your hand** it has a **store** of **kinetic energy.**

**A moving object hitting an obstacle e.g. A bowling ball hitting a pin**

- As you move the muscles of your arm to throw the ball the **chemical energy store** in your muscles **decreases** and the **kinetic energy store** of the bowling ball **increases**.
- At the ball hits a pin some of the **kinetic energy** has been transferred to a **store** of **internal (thermal) energy** this causes the ball and its surroundings to warm up a little.
- You will hear a **sound** when the ball hits the pin, the **energy of the sound** is also transferred to the **internal energy store** of the **surroundings**.

# Energy stores and systems

**Examples of energy changes in a system:**

**A vehicle slowing down e.g. When you apply the brakes in a lorry**

- The **moving** lorry has a **store** of **kinetic energy**.
- At the **brakes** are applied the **kinetic energy store decreases** the energy is transferred to the **internal (thermal) energy store** in the brakes and the brakes get hot.
- You will hear a **sound** when the brakes of the lorry are applied, the **energy of the sound** is also transferred to the **internal energy store** of the **surroundings**.
- When the lorry **stops** its **kinetic energy store** is **zero**.

**Bringing water to a boil on a camping stove.**

- As the fuel burns the **chemical energy store** in the fuel **decreases** and the **internal (thermal) energy store** of the water **increases.**
- The temperature of the water increases and as bubbles form the **kinetic energy store** of the water increases.

## Energy is measured in Joules (J)

**1 kilojoule (kJ) = 1000 J ($10^3$J)**

**1 megajoule = 1000 000 J ($10^6$J)**

# Energy stores and systems

**Energy change – mechanical work is the amount of energy transferred by a force**

When a pushback truck is used to move an aircraft, it does work.

Work (J) = Force (N) x Distance (along the line of the force) (m).

$$W = F\,s$$

If the aircraft has a mass of 30 000kg and it is moved a distance of 20m, calculate the work done by the pushback truck.

Force (weight) = mass x gravitational field strength

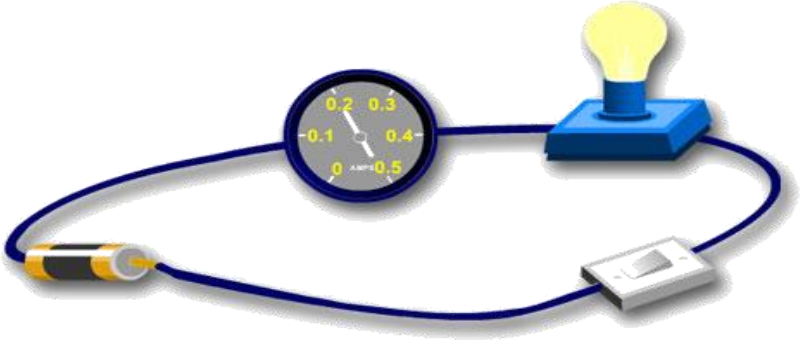
Force = 30 000 x 10 = 300 000 N

$$W = F\ \ s$$

Work = 300 000 x 20 = 6 000 000 J (6 MJ)

# Energy stores and systems

**Energy change – Electrical work is done when charge flows in a circuit is the amount of energy transferred.**



**When a current flows through a circuit, work is done (energy is transferred) and the energy store changes.**

**Energy transferred (Work) (J) = Charge flow (Q) x Potential difference (V)**

$$E = Q V$$

**In one minute, 30 Coulombs of charge flows through the bulb when a potential difference of 3 V is placed across it. Calculate the work done (energy transferred).**

$$E = Q V$$

$$E = 3 \times 30$$

**Energy transferred (Work) = 90 J**

# Changes in Energy - Kinetic Energy

Moving objects have kinetic energy.

The long-jumper is using her **kinetic energy** to carry her body as far as possible. The more kinetic energy she has, the longer her jump will be. Her kinetic energy depends on her mass (which she can not change) and her velocity (she can run faster!).

The kinetic energy of a moving object can be calculated using the equation:

**Kinetic energy (J) = 0.5 × Mass (kg)× Speed$^2$ (m/s)**

$$E_k = \frac{1}{2} m v^2$$

If her mass is 46 kg and she is travelling at 8 m/s, her kinetic energy during her jump will be:

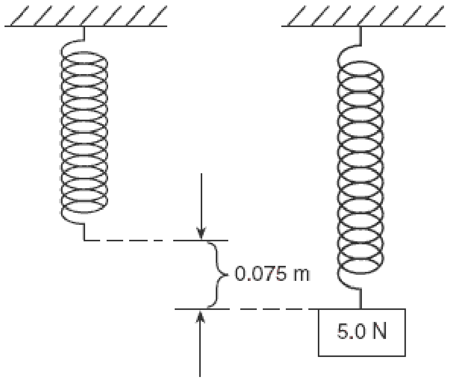
$$E_k = \frac{1}{2} m v^2$$

$$E_k = \frac{1}{2} \times 46 \times 8^2$$

**The energy transferred in the jump is:** $E_k = \underline{1472\ J}$

# Changes in Energy - Elastic Energy

Stretched or bent objects have **elastic energy ($E_e$)** if they have the ability to **recover** to their original shape and dimensions.



When a weight (force) is added to a spring it extends (gets longer).
The spring now has a store of elastic potential energy which will be released if the weight is removed.

The amount of stored elastic energy ($E_e$) can be calculated using the following equation:

**Elastic potential energy (J) = 0.5 × Spring constant (N/m) × Extension² (m)**

$$E_e = \frac{1}{2} k e^2$$

In the above example the spring has a spring constant of 670 N/m. The elastic potential energy of the spring when a 50 N load is hung from it is:

$$E_e = \frac{1}{2} k e^2$$

$$E_e = 0.5 \times 670 \times 0.075^2$$

**The elastic energy stored in the spring is:** $E_e = \underline{1.88\ J}$

# Changes in Energy – Gravitational potential energy

When an object is raised above ground level it gains **gravitational potential energy** (GPE). This **stored energy** can be released if the object is allowed to **fall**.

A pile driver is a machine that lifts a heavy weight then drops it on a post to drive it into the ground.

The amount of gravitational potential energy (G.P.E) gained by an object raised above ground level can be calculated using the equation:

**G.P.E (J) = Mass (kg) × Gravitational field strength (N/kg) × Height (m)**

$$E_p = m\,g\,h$$

The pile driver hammer has a mass of 120 kg and it is raised to a height of 4 m above the ground. How much G.P.E will it have?

$$E_p = m\,g\,h$$

$$E_p = 120 \times 10 \times 4$$

**The G.P.E gained is:** $E_p = 4800$ J

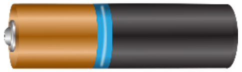
# QuestionIT!

## Energy changes and energy stores
## Part 1

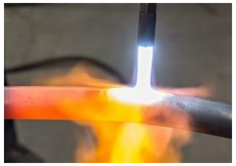
- Energy stores and systems
- Changes in energy

# Energy stores and Energy systems part 1– AnswerIT

1. What sort of energy store do the following examples have?

a. 

b. 

c. 

2. Write down the correct answer to complete the statement.

**Energy can not**…

be transferred from one source to another.

be created or destroyed.

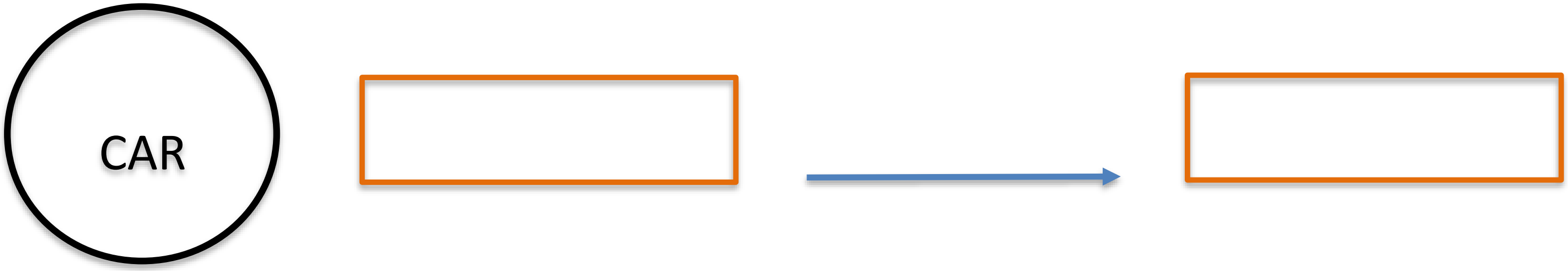
travel along a pathway to another store.

3. A basketball player throws the ball into the hoop. Describe the energy store change which has taken place.

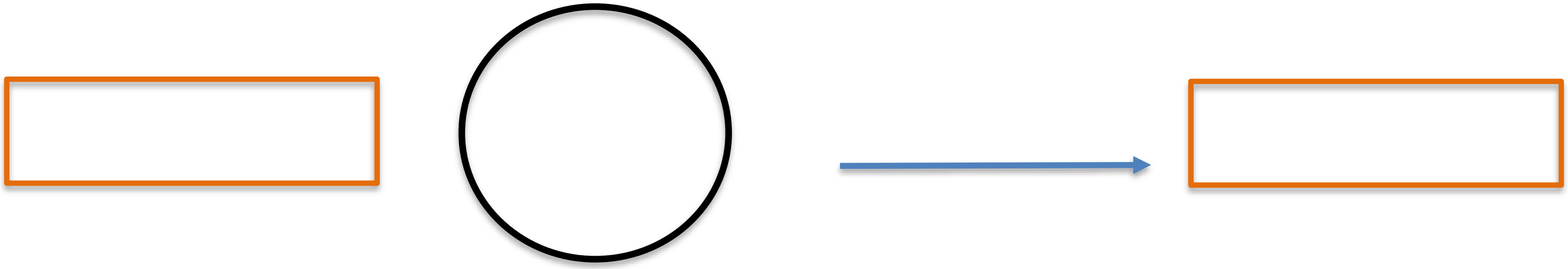
# Energy stores and Energy systems part 1– **QuestionIT**

4. Copy and Complete the **energy store** and **pathway** diagrams for the objects described.

a. A **moving** car **braking** to a stop.



b. Bringing water to the **boil** on a gas hob.



# Energy stores and Energy systems part 1 – QuestionIT

5. Describes the main change in **energy stores** for a **coal fired power station**.

a. Name the energy sources for:

i Input energy

ii Useful output energy

iii Wasted output energy.

b. In one hour, coal supplies 500 000 J of energy. The wasted energy amounts to 380 000 J.

Calculate how much useful energy is produced in one hour.

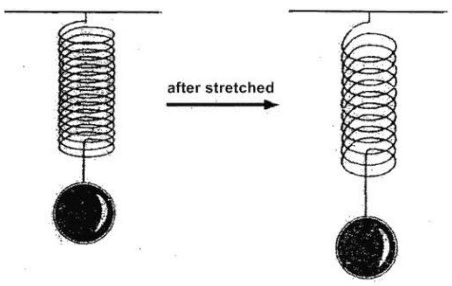
# Energy stores and Energy systems part 1 – QuestionIT

6. When a football is kicked it gains **kinetic energy**.

   a. What is the **formula** used to calculate kinetic energy?

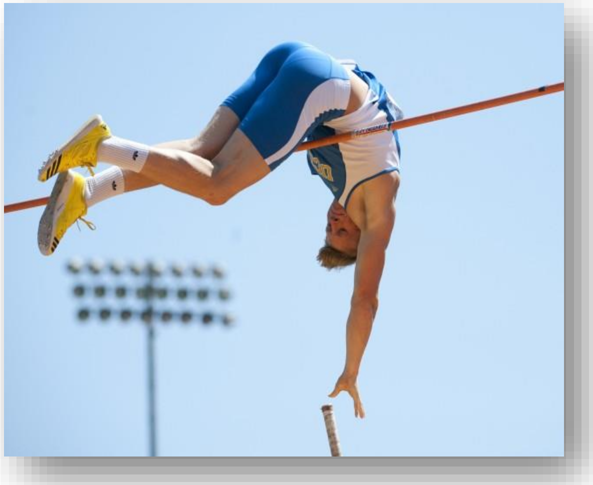
   b. The football has a mass of 0.4 kg. When the football is kicked, it has a velocity of 15 m/s.
   Calculate the **kinetic energy** of the moving football?

7. The un-stretched spring opposite has a length of 0.5 m but after a mass is added it is 0.6 m long.
   If the spring constant is 800 N/m.
   Calculate the stored **elastic potential energy**.
   $E_e = \frac{1}{2} k e^2$



# Energy stores and Energy systems part 1 – QuestionIT

8. A pole vaulter just clears the bar which is 5.1 m high. His mass is 62 kg. **(g = 10N/kg)**



a. What type of stored energy does he have as he just clears the bar?

b. Work out how much stored energy the pole vaulter has due to his position above the ground.

c. As he falls back to the ground, this energy store will be transferred into a new energy store. Name this new energy store.

d. When he lands, what happens to the energy stores described above?

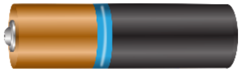
# AnswerIT!

## Energy changes and energy stores
## Part 1

- Energy stores and systems
- Changes in energy

# Energy stores and Energy systems part 1– **AnswerIT**

1. What sort of energy store do the following examples have?

a. 

b. 

c. 

**Chemical** **Elastic potential** **Thermal**

2. Write down the correct answer to complete the statement.

**Energy can not**.....

be transferred from one source to another.

be created or destroyed. ✓

travel along a pathway to another store.

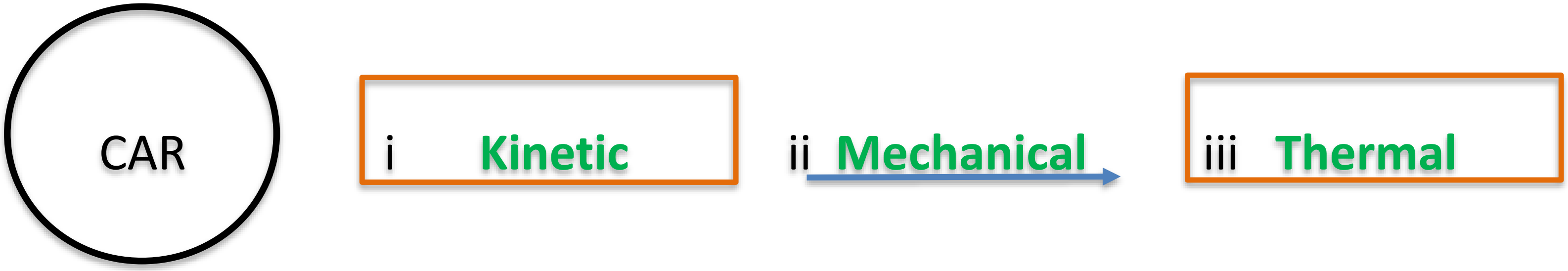
3. A basketball player throws the ball into the hoop. Describe the change in energy store that has taken place as the ball

**Kinetic** → **Gravitational**

# Energy stores and Energy systems part 1– QuestionIT

4. Copy and Complete the **energy store** and **pathway** diagrams for the objects described.

a. A **moving** car **braking** to a stop.



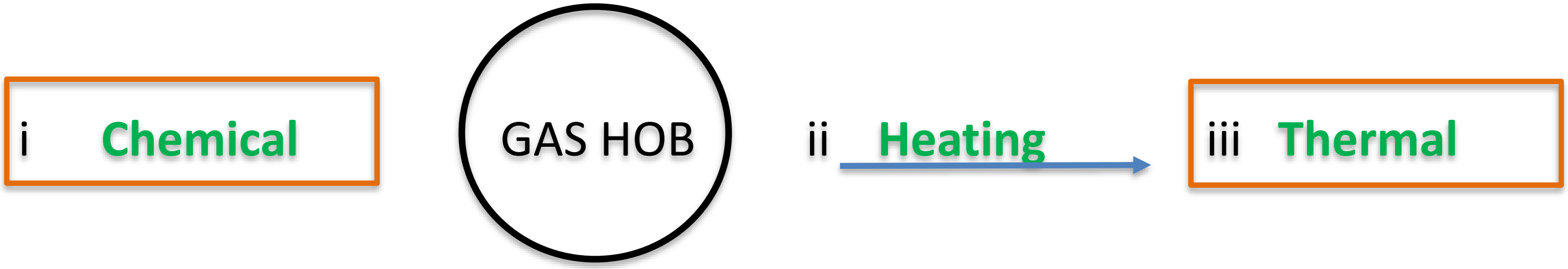
CAR

i **Kinetic**

ii **Mechanical**

iii **Thermal**

b. Bringing water to the **boil** on a gas hob.



i **Chemical**

GAS HOB

ii **Heating**

iii **Thermal**

# Energy stores and Energy systems part 1 – QuestionIT

5. Describes the main change in **energy stores** for a **coal fired power station**.

a. Name the energy sources for:

| | |
|---|---|
| i Input energy | **Chemical (Coal)** |
| ii Useful output energy | **Electrostatic (Electric current)** |
| iii Wasted output energy. | **Thermal (Waste heat)** |

b. In one hour, coal supplies 500 000 J of energy. The wasted energy amounts to 380 000 J.

Calculate how much useful energy is produced in one hour.

**500 000 – 380 000 = 120 000 J**

# Energy stores and Energy systems part 1 – QuestionIT

6. When a football is kicked it gains **kinetic energy**.

   a. What is the **formula** used to calculate kinetic energy?

   $$E_k = \tfrac{1}{2}\, m\, v^2$$

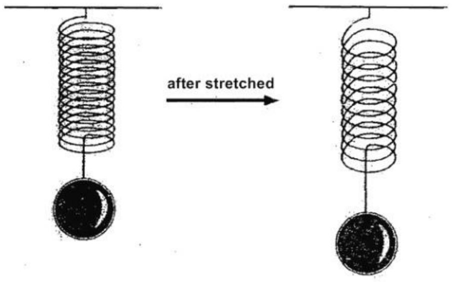
   b. The football has a mass of 0.4 kg and when kicked has a velocity of 15 m/s. Work out the **kinetic energy** of the moving ball?

   $$E_k = \tfrac{1}{2} \times 0.4 \times 15^2$$

   $$E_k = 45\ \text{J}$$

7. The un-stretched spring opposite has a length of 0.5m but after a mass is added it is 0.6 m long. If the spring constant is 800 N/m. Calculate the stored **elastic potential energy**.

   $$E_e = \tfrac{1}{2}\, k\, e^2$$



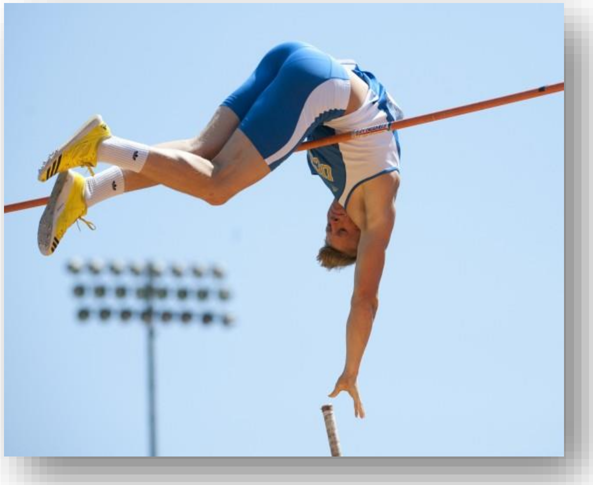
**extension of spring = 0.6 – 0.5 = 0.1 m**

$$E_e = \tfrac{1}{2} \times 800 \times 0.1^2$$

**Stored elastic potential energy of the spring = 4 J**

# Energy stores and Energy systems part 1 – QuestionIT

8. The pole vaulter just clears the bar which is 5.1 m high. His mass is 62 kg. (g = 10N/kg)



a. What type of stored energy does he have as he clears the bar?

gravitational potential energy

b. Work out how much stored energy the pole vaulter has due to his position above the ground.

GPE = m g h = 62 x 10 x 5.1 = 3162 J

c. As he falls back to the ground, this energy store will be transferred into a new energy store. Name this new energy store.

kinetic energy

d. When he lands, what happens to the energy stores described above?

dissipated as heat and sound

# LearnIT! KnowIT!

## Energy changes and energy stores Part 2

- Energy changes in systems
- Power

# Energy changes in systems

The **thermal (internal) energy store** in a system changes if its **temperature changes**.

When metal is heated in a furnace the **thermal energy store** increases. The amount of energy gained depends on the **mass** of the metal, how much the **temperature increases** and the **specific heat capacity** of the metal.

**Specific Heat Capacity ( *c* )** – the amount of energy required to raise the temperature of 1 kg of a substance by one degree Celsius.

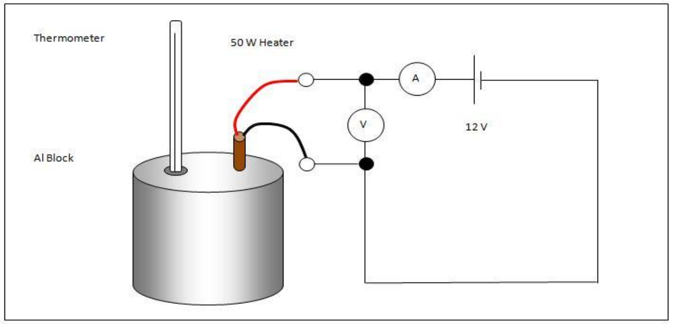
**Steel has a specific heat capacity of 450 J/kg $^{o}$C**

**Therefore a 1 kg block of steel needs 450 J of thermal energy adding to it to raise the temperature from 20 $^{o}$C to 21 $^{o}$C (1 $^{o}$C rise).**

# Energy changes in systems and power

## Specific heat capacity

The apparatus shown can be used to determine the specific heat capacity of aluminium.



**Example:** When the heater was left on for 5 mins, the heater supplied 10 800 J of thermal energy to the aluminium block.

The temperature of the 2 kg block of aluminium rose by 6 ºC.

The amount of energy stored in or released from a system as its temperature changes can be calculated using the equation:

**Change in thermal energy (J) = Mass (kg) x Specific Heat Capacity J/kgºC x Temperature Change (ºC)**

$\Delta E = m \times c \times \Delta\theta$ rearrange to give $c = \Delta E / m \times \Delta\theta$

$c = 10\ 800 / 2 \times 6$ **Specific heat capacity of aluminium = 900 J/kg ºC**

# Power

**Power** - the rate at which energy is transferred

the rate at which work is done (rate means "how quickly")

**Power** is measured in Joules / second 1 J/s = 1 Watt

An object which transfers energy does so at a certain rate.
The metal filament in this light bulb transfers the electrical energy store into heat and light.
This bulb transfers 2400 joules of energy in 60 seconds.

Power can be calculated using the following equation:

$$\text{Power (W)} = \frac{\text{Energy transferred (J)}}{\text{Time (s)}}$$

$$P = \frac{E}{t}$$

P= 2400 / 60 = 40 J/s

So this is a **40 Watt** light bulb.

# Power

**Power** - the rate at which energy is transferred

the rate at which work is done (rate means "how quickly")

## Mechanical power

**Power = work done / time**

The crane lifts the 2000 kg container through a height of 5.4m in 30s.
The power of the crane is:

**Power = Work / time**

**But: Work = force x distance**

= 20 000 N x 5.4 m = 108 000 J

Power = 108 000 J / 30 s

The Power of the crane is 3600 J/s or 3600 Watts

# QuestionIT!

## Energy changes and energy stores
## Part 2

- Energy changes in systems
- Power

# Energy stores and Energy systems part 2 – QuestionIT

1. The specific heat capacity of a substance is………
   - A. the ability of a 1 kg object to store transferred energy
   - B. the total amount of stored energy in an object
   - C. the energy needed to raise the temperature of 1 kg of a substance by 1 ºC.

2. When a bowl of water and a stone are left in hot sunshine, the stone feels much hotter than the water. Which one has the highest specific heat capacity? Explain your answer.

3. Give two alternative units of power?

# Energy stores and Energy systems part 2 – **QuestionIT**

4. A blowtorch burns butane gas to heat metal pipes.

   a. Describe the energy transfers which occur as it is used.

   ________________ energy is transferred into
   ________________ energy usefully and
   ________________ energy is wasted.

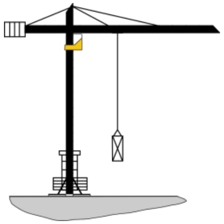
   b. Explain how some of the transferred energy is wasted.

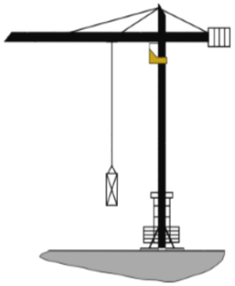
   c. The blowtorch transfers 2 kJ of energy in 4 mins. Work out the power of the blowtorch?

# Energy stores and Energy systems part 2 – QuestionIT

5. Two cranes are lifting the same load of 120 kg to a height of 15 m.

Crane A





Crane B

Crane A takes 30 s to lift the load. Crane B lifts the same load in 9 s.

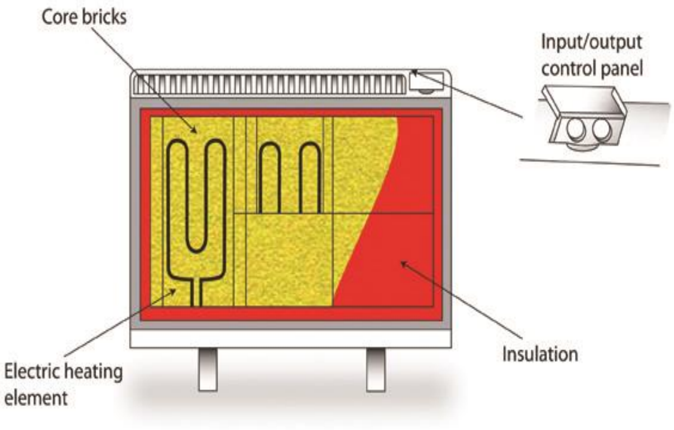
Calculate the **difference in power** of the two cranes.

# Energy stores and Energy systems part 2 – QuestionIT

6. Storage heaters contain bricks which warm up and **store the heat energy**.

   The bricks in this heater have a mass of 40 kg and are heated from 18 ºC to 40 ºC. If the specific heat capacity of the brick material is 850 J/kg ºC.

   Calculate the **change in thermal energy** during heating.



**Change in thermal energy = Mass x Specific Heat Capacity x Temperature Change**

$$\Delta E = m \times c \times \Delta\theta$$

# AnswerIT!

## Energy changes and energy stores
## Part 2

- Energy changes in systems
- Power

# Energy stores and Energy systems part 2 – **AnswerIT**

1. The specific heat capacity of a substance is ……….
   - A. the ability of a 1kg object to store transferred energy
   - B. the total amount of stored energy in an object
   - C. the energy needed to raise the temperature of 1kg of a substance by 1°C ✓

2. When a bowl of water and a stone are left in hot sunshine, the stone feels much hotter than the water. Which one has the highest specific heat capacity? Explain your answer.

   **The water has a higher heat capacity as it takes more heat energy to raise its temperature to that of the stone**

3. Give two alternative units of power?

   **Joules/second or Watts**

# Energy stores and Energy systems part 2 – AnswerIT

4. A blowtorch burns butane gas to heat metal pipes.

a. Describe the energy transfers which occur as it is used.

**Chemical** energy is transferred into

**thermal** energy usefully and

**light** energy is wasted.

b. Explain how some of the transferred energy is wasted.

**As thermal energy to the environment**

c. The blowtorch transfers 2 kJ of energy in 4 mins. Work out the power of the blowtorch?

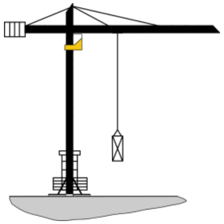
**Power = energy transferred / time = 2000 / 240**

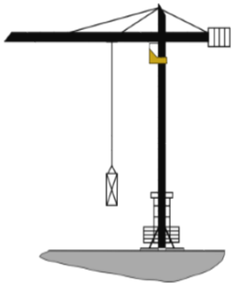
**Power of the blowtorch = 8.33Watts**

# Energy stores and Energy systems part 2 – **AnswerIT**

5. Two cranes are lifting the same load of 120 kg to a height of 15 m.

Crane A





Crane B

Crane A takes 30 s to lift the load. Crane B lifts the same load in 9 s.

Calculate the **difference in power** of the two cranes.

**Crane A power = 1200 x 15 / 30 = 600 W**

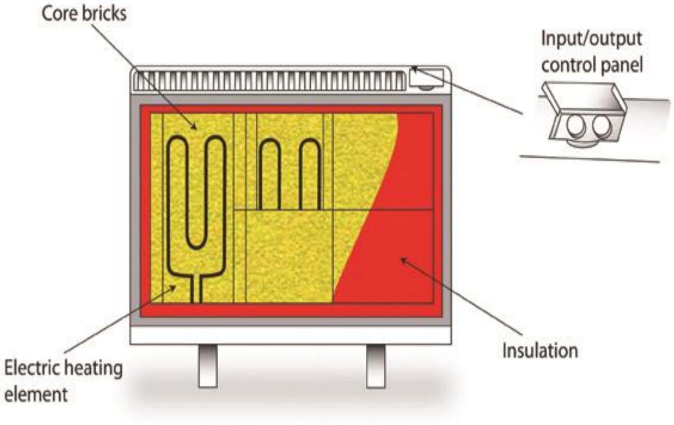
**Crane B power = 1200 x 15 / 9 = 2000W**

**Difference in power = 2000 – 600 = 1400 Watts**

# Energy stores and Energy systems part 2 – AnswerIT

6. Storage heaters contain bricks which warm up and **store heat energy**.

   The bricks in this heater have a mass of 40 kg and are heated from 18 ºC to 40 ºC. If the specific heat capacity of the brick material is 850 J/kg ºC, calculate the **change in thermal energy** during heating.



**Change in thermal energy = Mass x Specific Heat Capacity x Temperature Change**

$$\Delta E = m \times c \times \Delta\theta$$

**temperature change Δθ = 40 – 18 = 22 ºC**

**change in thermal energy ΔE = 40 x 850 x 22**

**ΔE = 748 000 J or 748 kJ**

# LearnIT! KnowIT!

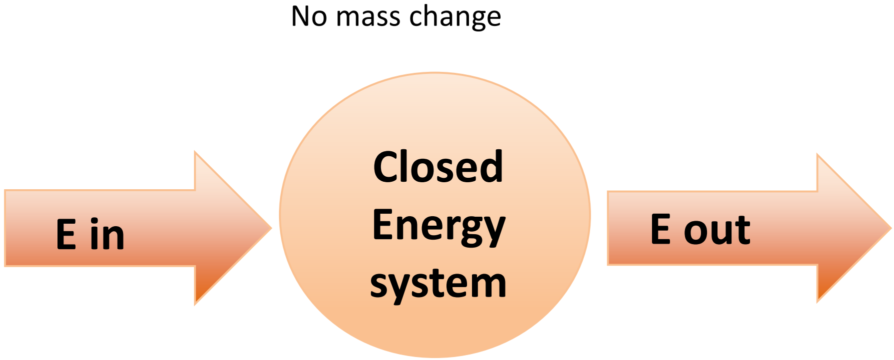
## Conservation and Dissipation of Energy

- Energy transfers in a system
- Efficiency

# Energy transfers in a system

**Energy can be stored, transferred or dissipated - but can not be created or destroyed.**

In a closed energy system there can be transfer of energy but not mass. There is **no change to the total energy in the system.**


No mass change

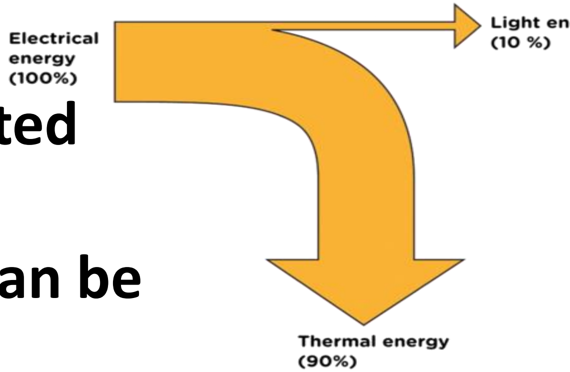
E in

**Closed Energy system**

E out

In a **closed energy system** all the energy can be accounted for even when energy stores change.

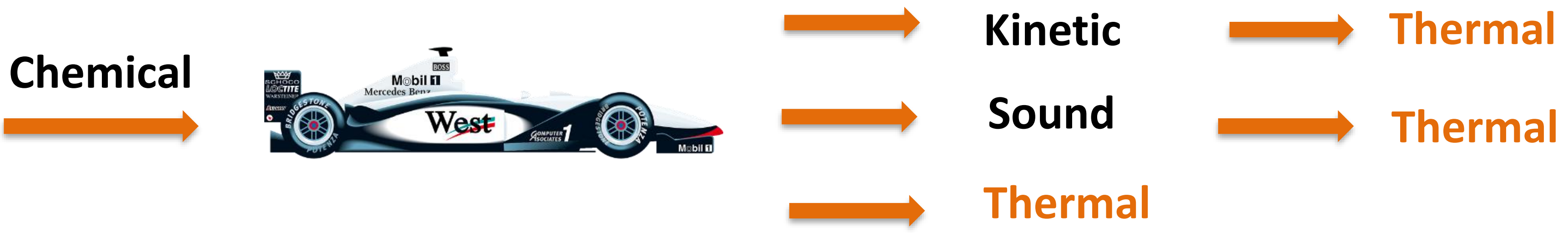
**The diagram shows the energy transfer for a light bulb. All the electrical energy store can be accounted for as light energy and thermal energy.**
**The thermal energy is not useful in this case and can be considered to be dissipated or "waste" energy.**



# Energy transfers in a system

**<u>Unwanted energy</u> transfers result in energy stores that are not useful.**

**The F1 car below shows that eventually all the chemical energy (fuel) put in the car ends up as <u>unwanted</u> thermal energy which is dissipated to the surroundings. Unwanted energy is often described as being 'wasted'**



**Chemical**

**Kinetic** → **Thermal**

**Sound** → **Thermal**

**Thermal**

**Kinetic energy is dissipated by the tyres, brakes and air resistance to become <u>unwanted</u> thermal energy stores.**
**Sound energy is absorbed by materials and becomes thermal energy.**
**Thermal energy is produced by the engine as fuel is burnt.**

**Oil is used in the engine, gearbox and other moving parts as a lubricant to reduce friction and reduce unwanted thermal energy in these parts.**

# Energy transfers in a system

Thermal insulation is often used to reduce unwanted energy transfers.

All the **energy** used to **heat a home** is eventually **transferred** as **thermal energy** to the **surroundings**.

The diagram, shows the percentage energy lost through different parts of the building.

| **Material** | **Thermal Conductivity W/m C** |
|---|---|
| **Air** | 0.03 |
| **Polyurethane foam** | 0.03 |
| **Fibreglass** | 0.04 |
| **Wool felt** | 0.05 |
| **Wood** | 0.15 |
| **Plaster** | 0.50 |
| **Glass** | 0.80 |
| **Brick** | 1.00 |
| **Concrete** | 1.04 |

The higher the thermal conductivity, the quicker heat is transferred through the material.

Houses are often built from brick, concrete, wood and glass. All have quite **high thermal conductivity** values. **Insulation** uses materials with low thermal conductivity, such as fibreglass in the loft, foam in wall cavities and trapped gases in double glazing.

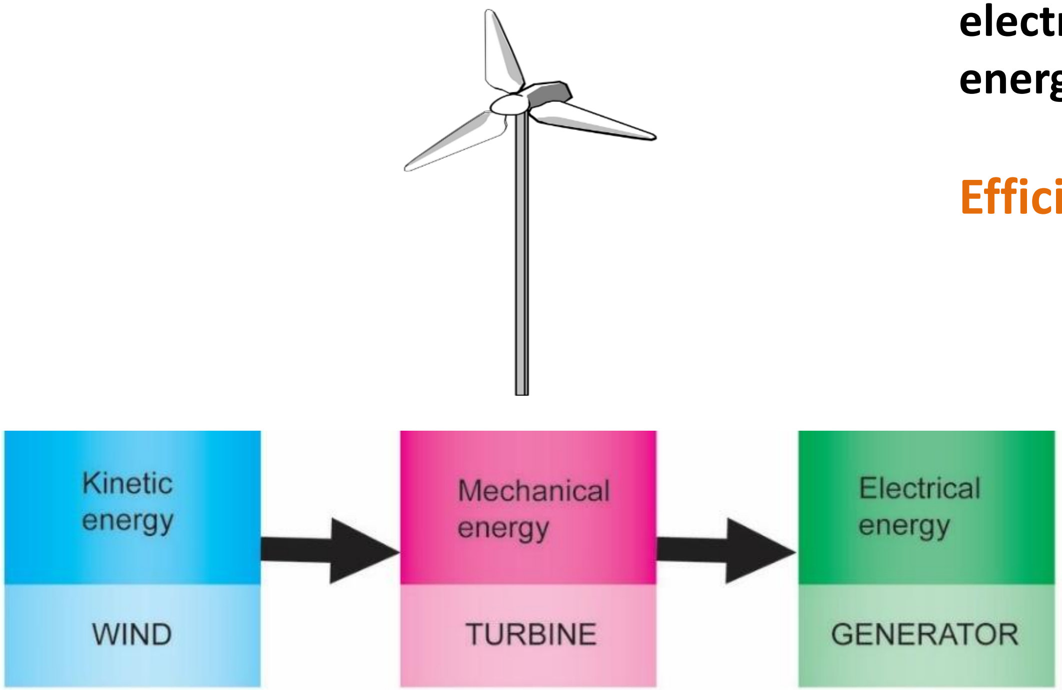
# Efficiency

The amount of useful energy you get from an energy transfer, compared to the energy put in, is called the **EFFICIENCY**

$$\text{Efficiency} = \frac{\text{useful output energy transfer}}{\text{total input energy transfer}}$$

**This calculation will result in a decimal value which can be multiplied by 100 to give a percentage efficiency.**

**A wind turbine energy transfer**



**The wind turbine produces 120 MW of electrical energy for every 500 MW of kinetic energy provided by the wind.**

$$\text{Efficiency} = \frac{\text{Useful output energy transfer}}{\text{total input energy transfer}}$$

$$= \frac{120}{500} \quad = 0.24 \text{ efficient}$$

**or 0.24 x 100 = 24 % efficient**

# Efficiency

**Efficiency** can also be calculated from the power transferred.

$$\text{Efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

**Remember that power is the time it takes to do work.**

**Work = Force x distance**

**A water pump lifting water**

**The 300 W water pump raises 200 kg of water to a height of 2 m in one minute. The efficiency of the pump is:**

$$\text{Efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Power in = 300 W

$$\text{Power out} = \frac{2000\text{ N} \times 2\text{ m}}{60} = 66.7\text{ W}$$

$$\text{Efficiency} = \frac{66.7 \times 100}{300} = 22.2\ \%$$

# QuestionIT!

## Conservation and Dissipation of Energy

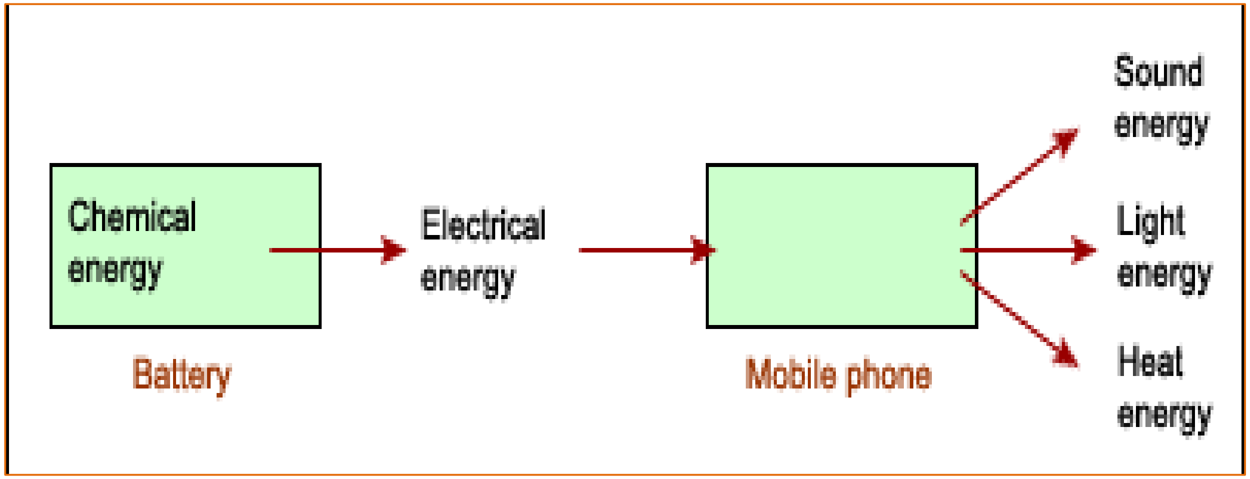
- Energy transfers in a system
- Efficiency

# Conservation and Dissipation of Energy - QuestionIT

1. In a "closed" system …………
   A. energy can be transferred but there is no net energy loss.
   B. energy and mass are transferred in and out of the system.
   C. energy cannot be transferred between different energy stores.

2. The energy transfer diagram for a mobile phone shows that 100 J of electrical energy produces 45 J of light energy and 36 J of sound energy.

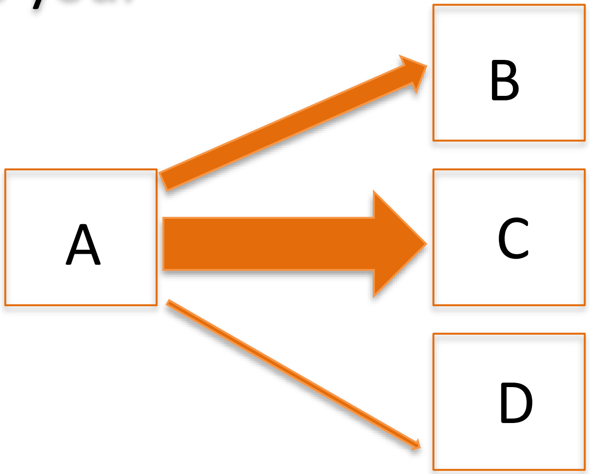
How much thermal energy will be dissipated by the phone?



# Conservation and Dissipation of Energy - **QuestionIT**

3. Describe how the thermal energy produced by a bus driving along a road is dissipated.

4. a. The diagram shows the main energy transfers for an electric fan. Complete boxes A to D showing the energy stores involved. Use the size of the arrows to help you.



b. State why the total energy supplied an electric fan must always equal the total energy transferred by the electric fan.

# Conservation and Dissipation of Energy - QuestionIT

5. a. The diagrams show two different types of loft insulation.

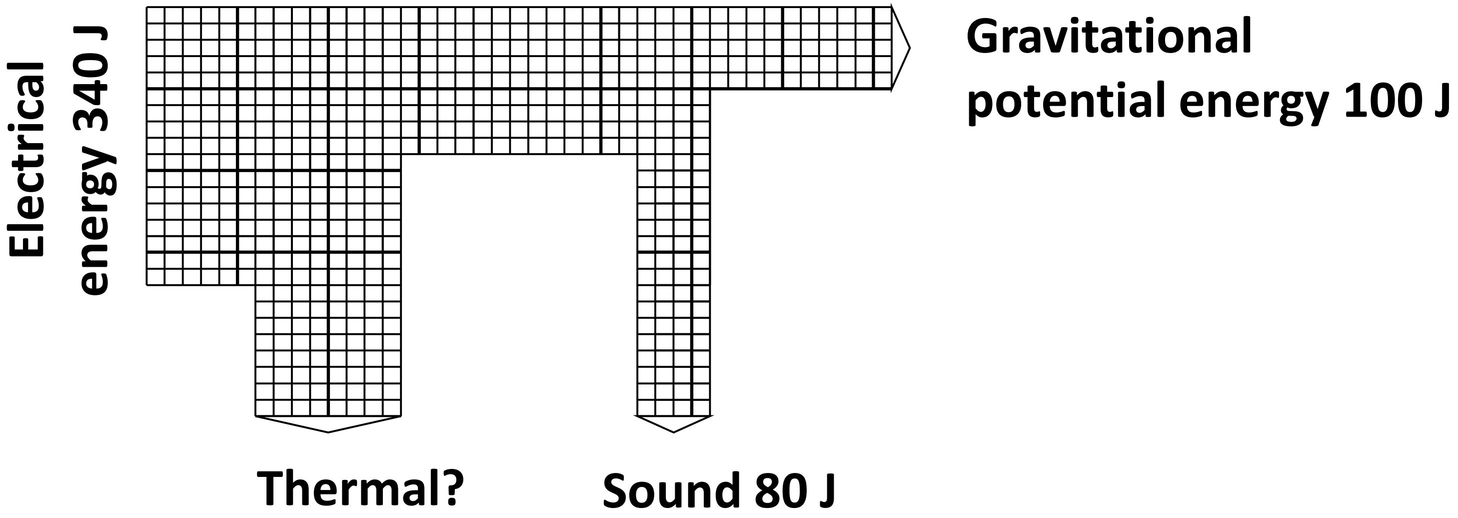
Fiberglass insulation Wool insulation

The wool needs to be thicker to have the same insulating properties. Explain which material has the highest thermal conductivity?

b. Explain how trapped air reduces the rate of heat loss, in terms of thermal conductivity.

# Conservation and Dissipation of Energy - **QuestionIT**

6. The diagram represents the energy store transfers when a motor is lifting a weight.



a. How much electrical energy is transferred to a thermal energy store?
b. What is the total amount of dissipated energy?
c. Calculate the efficiency the of the useful energy transfer

# Conservation and Dissipation of Energy - QuestionIT

7. The motor for a lift in a tall building uses 12 000 W of power. The lift and its passengers has a mass of 500 kg. The lift motor takes 10 s to raise the lift and its passengers through a height of 20 m.

Work out the percentage efficiency of the lift motor.

8. The low energy bulb below uses 18 000 J of energy in one hour. If the efficiency of the low energy bulb is 78 %.

Work out the amount of light energy given off by the bulb in one hour.

# AnswerIT!

## Conservation and Dissipation of Energy

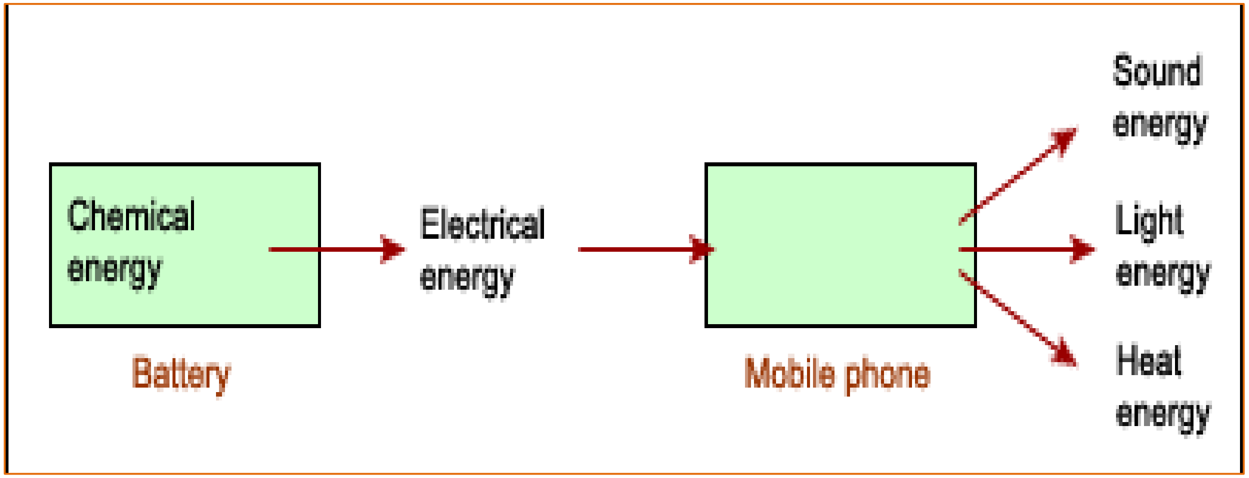
- Energy transfers in a syster
- Efficiency

# Conservation and Dissipation of Energy - **AnswerIT**

1. In a “closed” system ............
   - A. energy can be transferred but there is no net energy loss. ✓
   - B. energy and mass are transferred in and out of the system.
   - C. energy cannot be transferred between different energy stores.

2. The energy transfer diagram for a mobile phone shows that 100 J of electrical energy produces 45 J of light energy and 36 J of sound energy.

How much thermal energy will be dissipated by the phone?



**45 J + 36 J = 81 J**

**100 J – 81 J = 19 J**

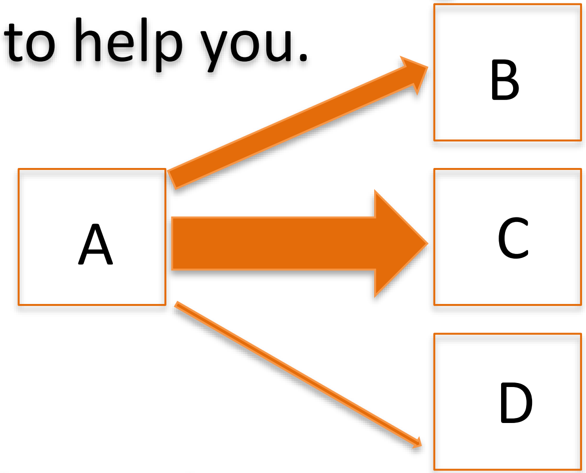
**19 J of thermal energy will be dissipated**

# Conservation and Dissipation of Energy - AnswerIT

3. Describe how the thermal energy produced by a bus driving along a road is dissipated.

**The thermal energy increases the kinetic energy of the air particles therefore warming up the surroundings.**

4. a. The diagram shows the main energy transfers for an electric fan. Complete boxes A to D showing the energy stores involved. Use the size of the arrows to help you.



**A - Electrical energy**

**B - Thermal energy**

**C - Kinetic energy**

**D - Sound energy**

b. State why the total energy supplied to an electric fan must always equal the total energy transferred by the electric fan.

**Energy can not be created or destroyed so:**

**total energy in = total energy out**

# Conservation and Dissipation of Energy - AnswerIT

5. a. The diagrams show two different types of loft insulation.

Fiberglass insulation    Wool insulation

The wool needs to be thicker to have the same insulating properties. Explain which material has the highest thermal conductivity?

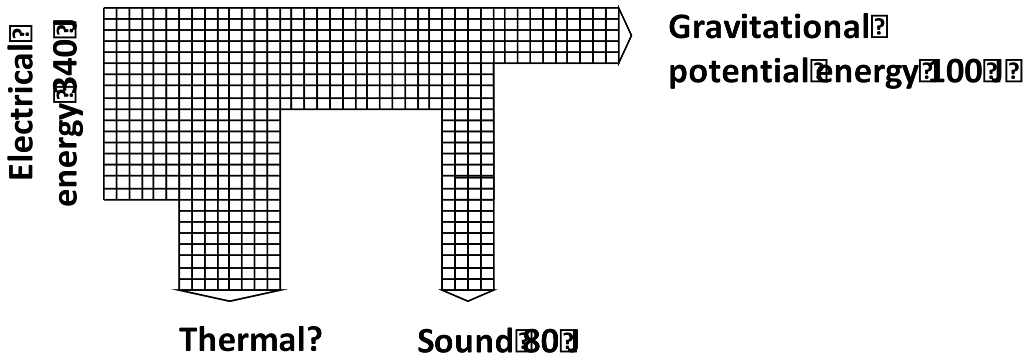
**Wool has the highest thermal conductivity as it lets thermal energy through at a faster rate so a thicker layer is needed for the same insulation as the fiberglass.**

b. Explain how trapped air reduces the rate of heat loss, in terms of thermal conductivity.

**The air trapped inside the fiberglass acts as an insulator because air has a very low thermal conductivity and thermal energy can not pass through it easily.**

# Conservation and Dissipation of Energy - AnswerIT

6. The diagram represents the energy store transfers when a motor is lifting a weight.



a. How much electrical energy is transferred to a thermal energy store?

340 – (100 + 80) = 160 J

b. What is the total amount of dissipated energy?

160 + 80 = 240 J

c. Calculate the efficiency the of the useful energy transfer

$$\text{Efficiency} = \frac{\text{useful output energy transferred}}{\text{total energy transfer input}} = \frac{100}{340} = 0.294$$

# Conservation and Dissipation of Energy - QuestionIT

7. The motor for a lift in a tall building uses 12 000 W of power. The lift and its passengers has a mass of 500 kg. The lift motor takes 10 s to raise the lift and its passengers through a height of 20 m.

Work out the percentage efficiency of the lift motor.

$$\text{Efficiency} = \frac{\text{power out x 100}}{\text{power in}} \qquad \text{Power out} = \frac{\text{work}}{\text{time}} \qquad \textit{work = force x distance}$$

$$\text{Power out} = \frac{\text{5000 N x 20 m}}{\text{10 s}} = \text{10 000 W} \qquad \text{Efficiency} = \frac{\text{10 000 x 100}}{\text{12 000}} = \text{83 \%}$$

8. The low energy bulb below uses 18 000 J of energy in one hour. If the efficiency of the low energy bulb is 78 %.

Work out the amount of light energy given off by the bulb in one hours.

$$\text{Efficiency} = \frac{\text{energy out x 100}}{\text{energy in}} \qquad \text{energy out} = \frac{\text{efficiency x energy in}}{\text{100}}$$

$$\text{Energy out} = \frac{\text{78 x 18 000 J}}{\text{100}} = \text{14 040 J}$$

# LearnIT!
# KnowIT!

## National and Global Energy resources

# National and global energy resources

| ENERGY RESOURCES | |
|---|---|
| **Non-renewable** | |
| Coal | Fossil fuels<br>They are becoming more difficult to find and extract |
| Oil | |
| Gas | |
| Nuclear | Plentiful but difficult to extract / purify |
| **Renewable** | |
| Bio-fuel | Plant matter usually used as a fuel |
| Wind | Turbines spin a generator to produce electricity |
| Hydro-electric | Falling water spins a turbine to produce electricity |
| Geothermal | Hot rocks underground produce steam |
| Tides | Rise and fall of the tide can be used to turn a turbine |
| Sun | To directly heat things or produce electricity |
| Waves | Up and down movement can turn turbines |

# National and global energy resources

**Non-renewable** energy sources are those which will **eventually run out** – there is a finite supply. New supplies are more difficult to find and extract.
**Renewable** energy sources are those which can **replenish themselves in the short term,** and so will never run out.
**Nuclear energy** resources are technically non-renewable but they can be produced on an almost indefinite basis.

How energy resources are used.
**Transport** – cars, trains, buses, planes etc.
**Electricity generation** – industry, homes, commerce, lighting etc.
**Heating** – homes, industrial processes, schools and hospitals etc.

Energy use is usually divided between the four economic sectors - **residential, commercial, transportation**, and **industrial**.

# Energy resources – Non-renewable

| | | | |
|---|---|---|---|
| **Coal** | Coal is mined then burnt to provide heat or used to generate electricity. | Large reserves of coal which are relatively inexpensive to mine.<br>All major coal mines have now closed in the UK. | Coal mining is dangerous and burning coal contributes to global warming. |
| **Oil** | Frequently burnt to produce electricity. Large quantities of oil are refined to provide fuels for transport. | Large reserves becoming more difficult to find and extract. Transport and refinement are relatively easy. | Oil reserves becoming more difficult to find and extract.<br>The need for oil in developed countries means supplies are politically sensitive.<br>Releases greenhouse gases when burnt. |

# Energy resources – Non-renewable

| | | | |
|---|---|---|---|
| **Gas** | Extracted from underground gas fields sometimes alongside oil extraction. Mainly used for electricity production, domestic heating and industrial processes that require heat. | Cleaner than burning oil or coal. Relatively easy to transport and store. | UK has good gas reserves but extraction is expensive (often under the sea) and becoming more difficult to reach. |
| **Nuclear** | Nuclear supplies (Uranium) are mined and purified. The nuclear fission releases heat which is used to produce steam. This spins a turbine and generator to make electricity | Potentially in-exhaustable energy supply even though it is extracted form resources in the ground.Very efficient process which produces lots of electricity from little nuclear fuel. | Danger of nuclear accidents releasing radioactive materials into the air or water. Security of nuclear sites can be a problem.Start-up costs and decommissioning are very expensive and no real solution to managing radioactive waste has been found. |

# Energy resources – Renewable

| | | | |
|---|---|---|---|
| **Solar** | Energy from sunlight is captured in photovoltaic cells and converted into electricity.<br>Hot water from solar panels | Renewable energy resource.<br>Individual houses can have their own electricity/hot water supply. | Manufacture and installation of solar panels/cells can be costly. |
| **Wind** | Wind turbines turn wind energy into electricity by turning a generator. | Renewable energy resource and can be used as individual units. | Manufacture and installation of wind farms can be costly.<br>Some consider an eyesore. |
| **Tidal** | The movement of tides drives turbines.<br>A tidal barrage is built across estuaries to trap water. | Ideal for an island such as the UK to potentially generate a lot of energy.<br>Tidal barrage can help prevent flooding. | Construction of barrage is very costly and can impact on wildlife.<br>Only a few estuaries are suitable. |

# Energy resources – Renewable

| | | | |
|---|---|---|---|
| **Geothermal** | In volcanic regions, cold water is pumped underground and comes out as steam. Steam can be used for heating or to power turbines creating electricity. | Renewable energy resource.<br>Used successfully in some countries, such as New Zealand and Iceland. | Can be expensive to set up and only works in areas of volcanic activity. |
| **Hydroelectric Power (HEP)** | Energy harnessed from the movement of water through rivers, lakes and dams. Used to turn turbines for electricity production. | Creates water reserves as well as energy supplies. | Costly to build.<br>Can cause the flooding of surrounding communities and landscapes. |

# Energy resources – Renewable

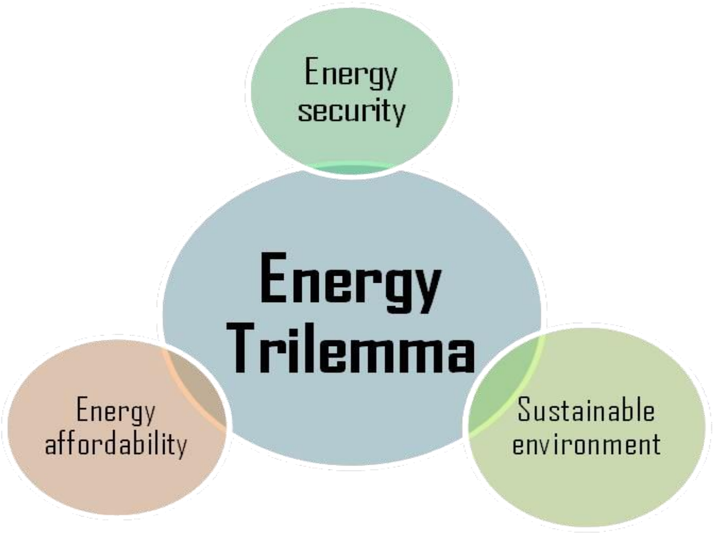
| | | | |
|---|---|---|---|
| **Biomass** | An organic material, which can be burned to provide energy, eg heat or electricity.<br>After treatment with chemicals it can be used as a fuel in vehicle engines. | It is a cheap and readily available source of energy.<br>If replaced, biomass can be a long-term, sustainable energy source. | When burned, it gives off greenhouse gases.<br>Growing takes up large amounts of arable land.. |
| **Wave** | The movement of water in and out of a cavity on the shore compresses trapped air, driving a turbine. | More likely to be small local operations, rather than done on a national scale. | Construction can be costly.<br>Only produces small amounts of electricity. |

# National and global energy resources

## Security and reliability of energy supplies

In the UK a **mix** of energy supplies are used so should one supply become **unavailable**, others can be used without **disruption** to supplies.

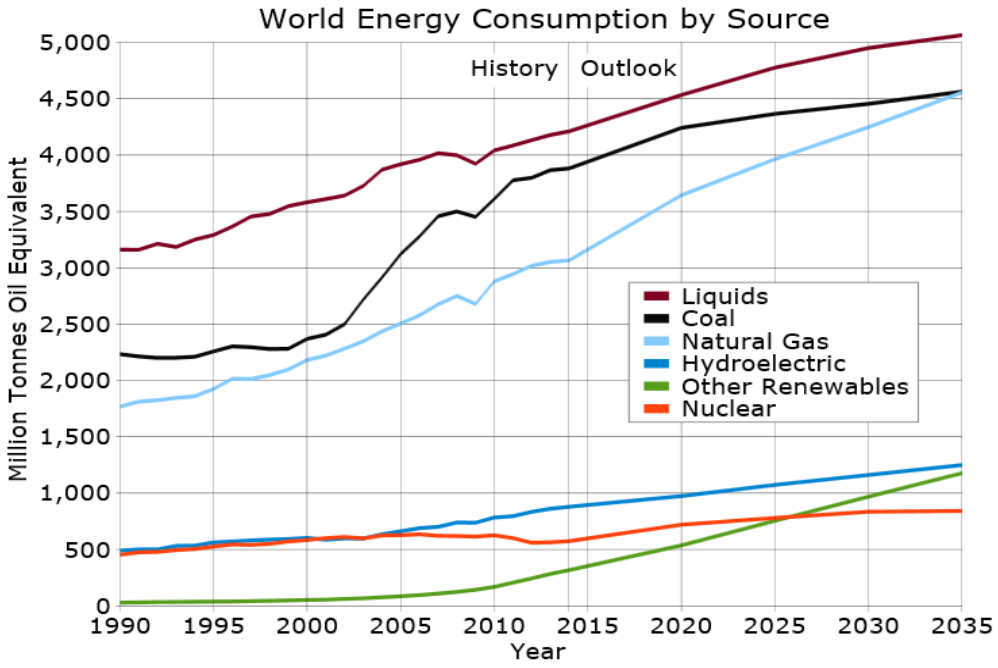
Some energy sources are more **reliable** than others. Coal, oil, gas and nuclear are reliable sources as they can supply a **continuous** flow of electricity.



Electricity from wind turbines relies on the wind blowing, solar power does not work at night and hydro-electric requires a continuous supply of water. These are considered **unreliable** sources.

# National and Global energy resources – Trends in energy use

## World energy use trends and predictions



The total amount of energy used in the world is increasing as the population increases and each person is using more energy.

**Renewable energies** only make up around 20% of total energy consumption and this trend is unlikely to change until after 2035.

- **Future world agreements on emissions are likely to determine the trend of using fossil fuels.**
- **As reserves of coal, oil and gas dwindle, an increase in the use of renewable energies is likely.**

# QuestionIT!

## National and Global Energy resources

# National and Global Energy resources – QuestionIT

1. What is a fossil fuel?

2. Copy and complete the table below by ticking the correct box for each energy source.

| Energy source | Renewable | Non-renewable |
|---|---|---|
| **Bio-fuels** | | |
| **Oil** | | |
| **Nuclear** | | |
| **Hydro-electricity** | | |
| **Wind turbines** | | |
| **Coal** | | |
| **Solar power** | | |
| **Wave energy** | | |
| **Natural gas** | | |

3. What is a renewable energy source?

# National and Global Energy resources – QuestionIT

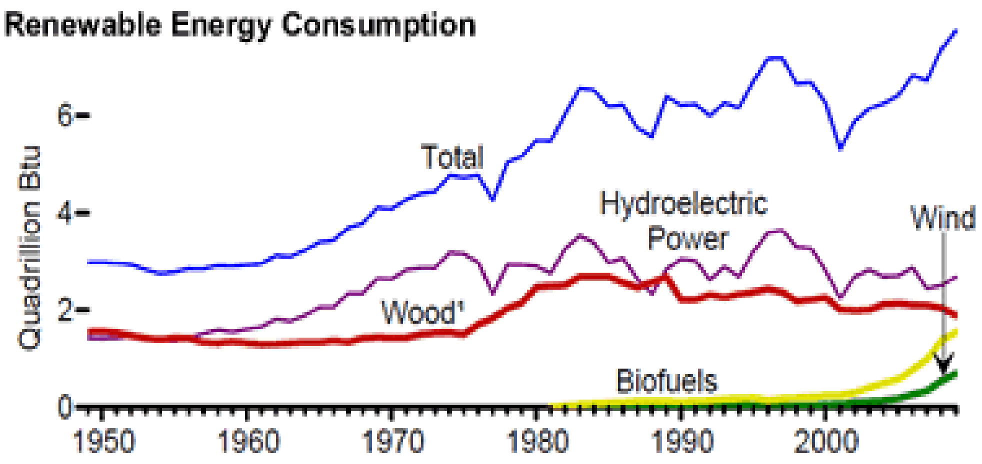
4. Why are fossil fuels considered to be a more reliable energy resource than renewable energy resources?

5. Despite a large investment by the UK government in wind power, the amount of fossil fuel used has not seen a decline. Give a possible explanation for this.

6. The UK government is committed to investing in a "blend" of energy supply types to provide the UK’s energy needs for the next 100 years. Give an advantage of this rather than using just coal.

# National and Global Energy resources – QuestionIT

7. The graph shows the world use of renewable energies over the past sixty years.



a. Why has the use of wood increased very little over this time?

b. A lot of money has been invested in wind turbines. Why does this energy source not produce as much as any other renewable resource?

# National and Global Energy resources – QuestionIT

8. Copy and complete the table to give **energy sources** that could be used in each situation.

| Energy use | Energy source 1 | Energy source 2 |
|---|---|---|
| **Running a car** | | |
| **Producing electricity** | | |
| **Heating the home** | | |
| **Powering a train** | | |

9. Describe how human activities have contributed to the greenhouse effect?

# National and Global Energy resources – QuestionIT

10. Explain how burning coal in power stations contributes to global warming.

11. Describe **two** problems associated with the storage of waste from nuclear power stations.

12. State **two** reasons why people might object to having a wind farm built close to their homes.

# AnswerIT!

## National and Global Energy resources

# National and Global Energy resources – AnswerIT

1. What is a fossil fuel? **A fuel formed in the geological past from the remains of living organisms.**
2. Copy and complete the table below by ticking the correct box for each energy source.

| Energy source | Renewable | Non-renewable |
|---|---|---|
| **Bio-fuels** | ✓ | |
| **Oil** | | ✓ |
| **Nuclear** | | ✓ |
| **Hydro-electricity** | ✓ | |
| **Wind turbines** | ✓ | |
| **Coal** | | ✓ |
| **Solar power** | ✓ | |
| **Wave energy** | ✓ | |
| **Natural gas** | | ✓ |

3. What is a renewable energy source?

**An energy source that can be replenished as it is used.**

# National and Global Energy resources – AnswerIT

4. Why are fossil fuels considered to be a more reliable energy resource than renewable energy sources?

   **Produce a consistent energy supply with no gaps in energy delivery.**

5. Despite a large investment by the UK government in wind power, the amount of fossil fuel used has not seen a decline. Give a possible explanation for this.

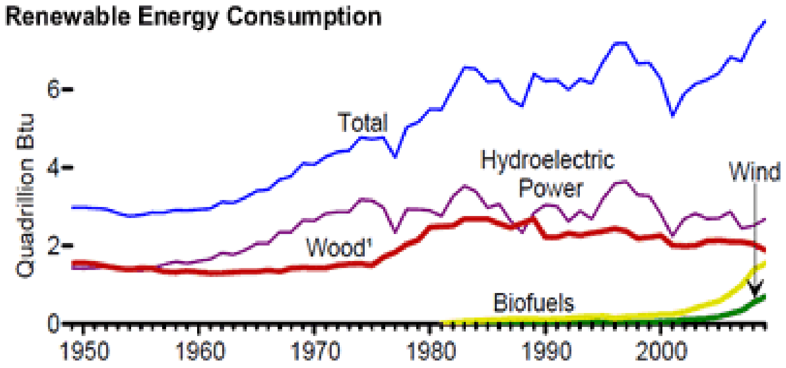
   **UK is using more energy and wind power can not meet this rise in demand.**

6. The UK government is committed to investing in a "blend" of energy supply types to provide the UK's energy needs for the next 100 years. Give an advantage of this rather than using just coal.

   **Evens out any variations in supply or cost of the energy source. Using only coal, if supplies stopped or the cost went up greatly, this would have a great impact on the consumer.**

# National and Global Energy resources – **AnswerIT**

7. The graph shows the world use of renewable energies over the past sixty years.



a. Why has the use of wood increased very little over this time?

**Limited supplies of wood and it takes a long time to grow new supplies. Also, pressure and legislation to prevent many trees from being cut down.**

b. A lot of money has been invested in wind turbines. Why does this energy source not produce as much as any other renewable resource?

**Each wind turbine only produces a small amount of electricity and not enough have been installed to match production from other renewable resources.**

8. Copy and complete the table to give **energy sources** that could be used in each situation.

| **Energy use** | **Energy source 1** | **Energy source 2** |
|---|---|---|
| **Running a car** | **Petrol, Diesel, LPG** | **Any electricity producing source** |
| **Producing electricity** | **Coal, oil, gas** | **Renewable source** |
| **Heating the home** | **Coal, gas, wood** | **Any electricity producing source** |
| **Powering a train** | **Coal, Diesel, oil** | **Any electricity producing source** |

9. Describe how human activities have contributed to the greenhouse effect.?

**Burning fossil fuels for heating, transport and industry has led to a build up of carbon dioxide in the atmosphere (along with other greenhouse gases).**

# National and Global Energy resources – AnswerIT

10. Explain how burning coal in power stations contributes to global warming.

    Carbon dioxide produced. Carbon dioxide absorbs and reflects infrared radiation leading to additional warming.

11. Describe **two** problems associated with the storage of waste from nuclear power stations.

    Waste is radioactive can cause cells to mutate.

    Radioactivity lasts for thousands of yeas so needs long term storage.

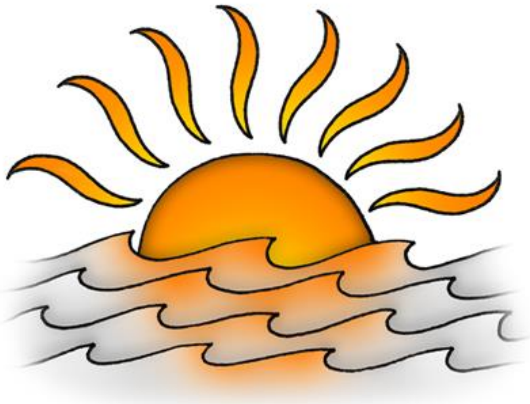
12. State **two** reasons why people might object to having a wind farm built close to their homes.

    Considered unsightly by some. Can be noisy.

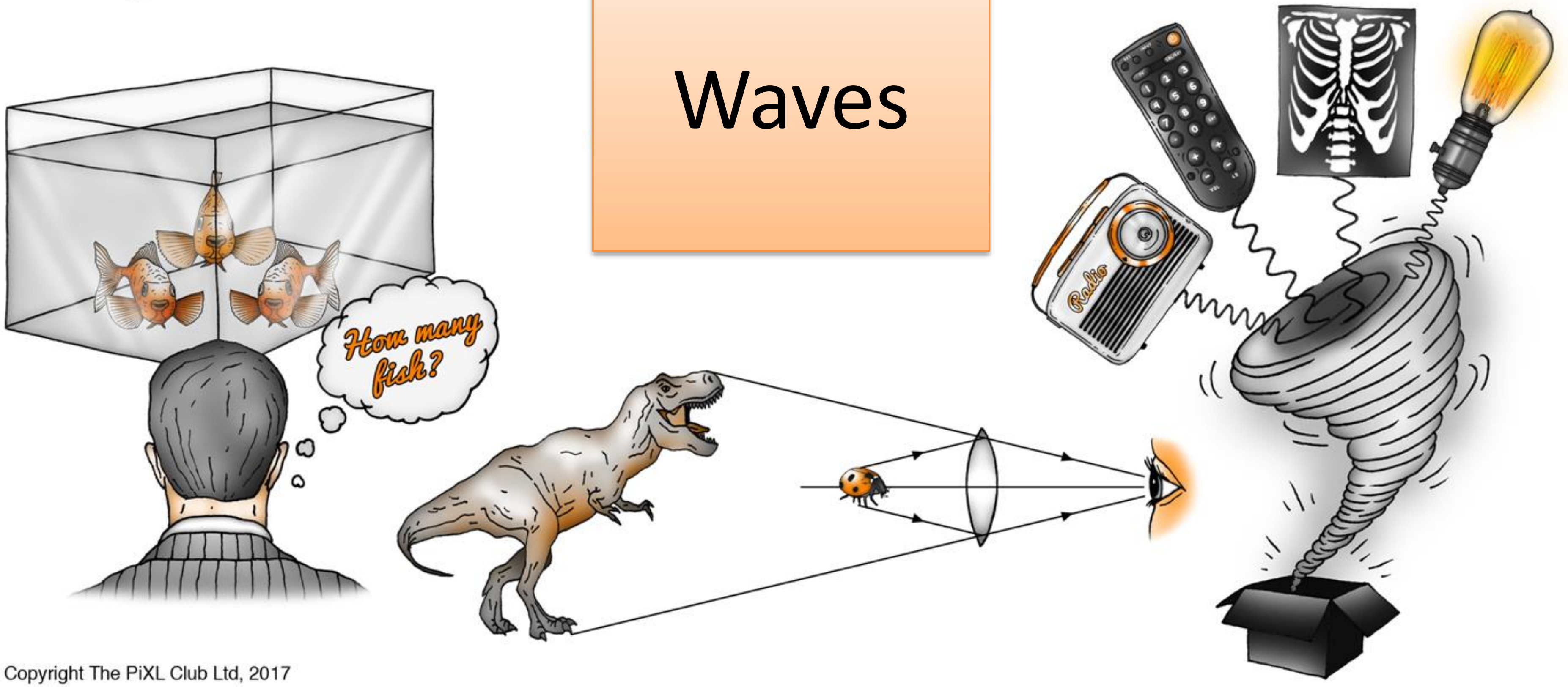
    Disruption whilst installing and maintaining.

    Produce little energy for their environmental impact.


MICRO WAVES
X RAY
INFRA-RED
RADIO WAVES
VISIBLE LIGHT
ULTRA VIOLET
GAMMA RAYS



# Waves


How many fish?
Radio

# Overview
# Waves

## Waves in air, fluids and solids

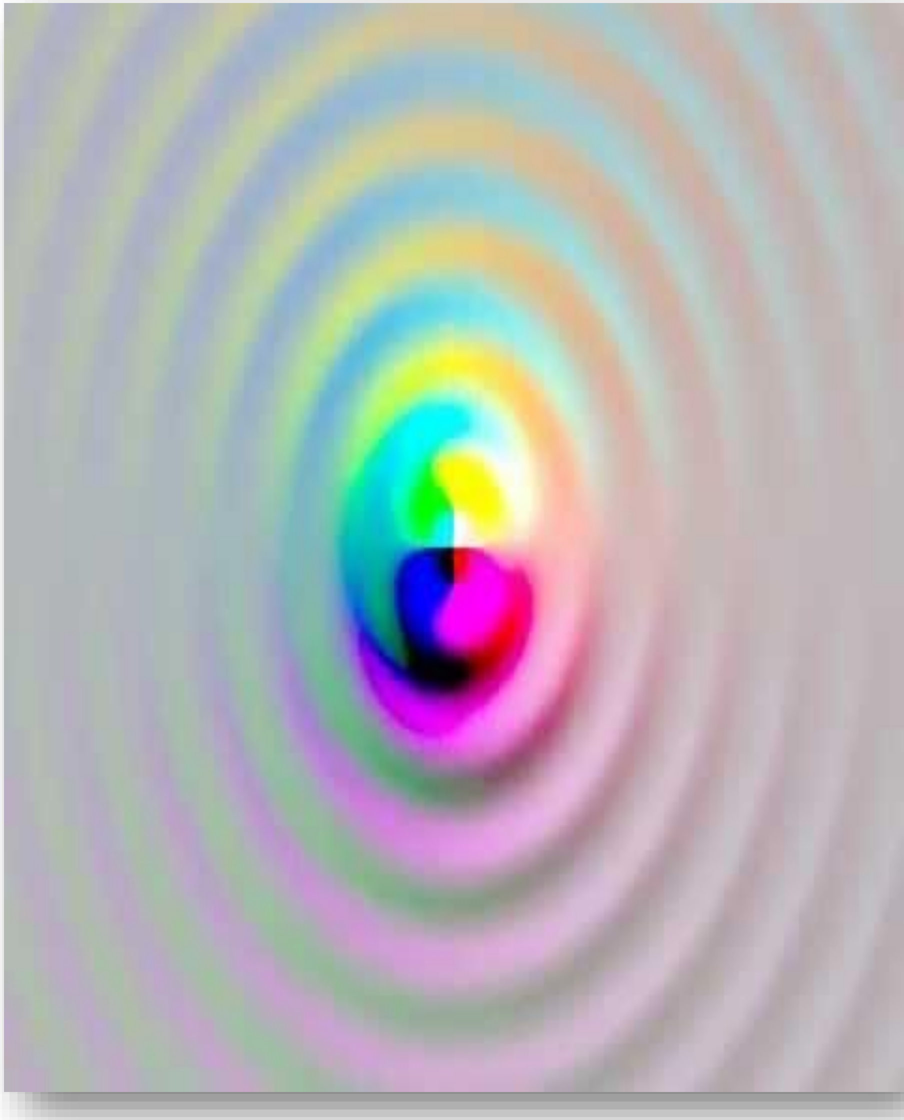
- Transverse and longitudinal waves
- Properties of waves
- Reflection of waves (physics only)
- Sound waves (physics only) (HT)
- Waves for detection and exploration (physics only) (HT)

## Electromagnetic Waves

- Types of electromagnetic waves
- Properties of electromagnetic waves
- Uses and applications of electromagnetic waves
- Lenses (physics only)
- Visible light (physics only)

## Black body radiation (physics only)

- Emission and absorption of infrared radiation
- Perfect black bodies and radiation



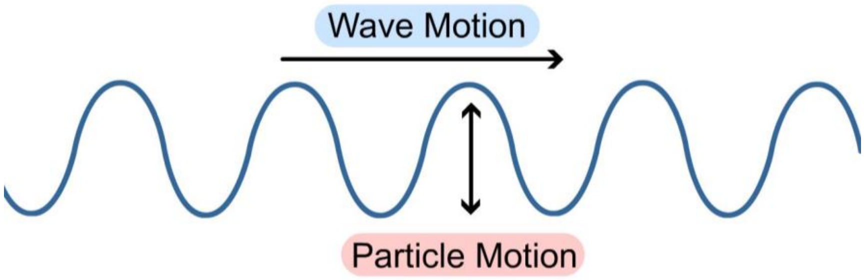
# LearnIT!
# KnowIT!

## Waves in air, fluids and solids

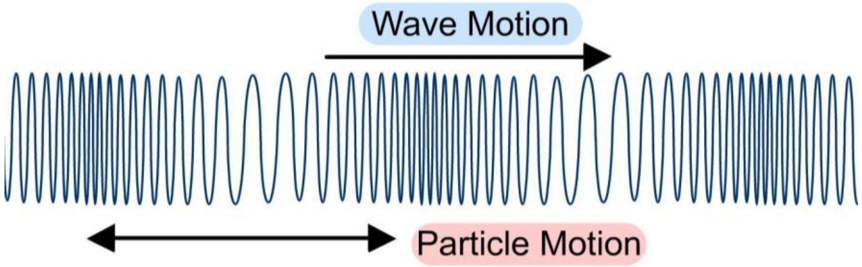
- Transverse and longitudinal waves
- Properties of waves
- Reflection of waves (physics only)
- Sound waves (physics only) (HT)
- Waves for detection and exploration (physics only) (HT)

# Transverse and Longitudinal Waves

## Transverse Wave



## Longitudinal Wave

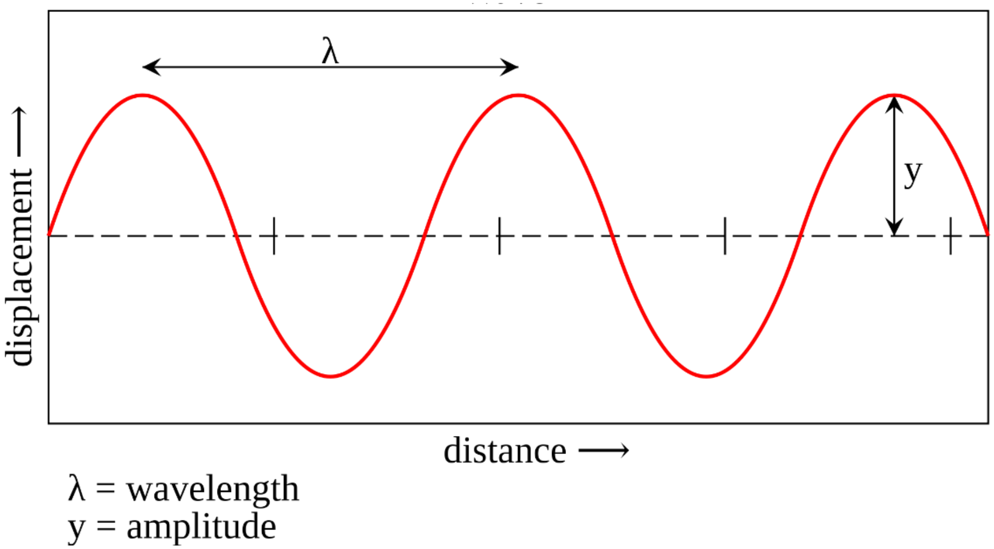


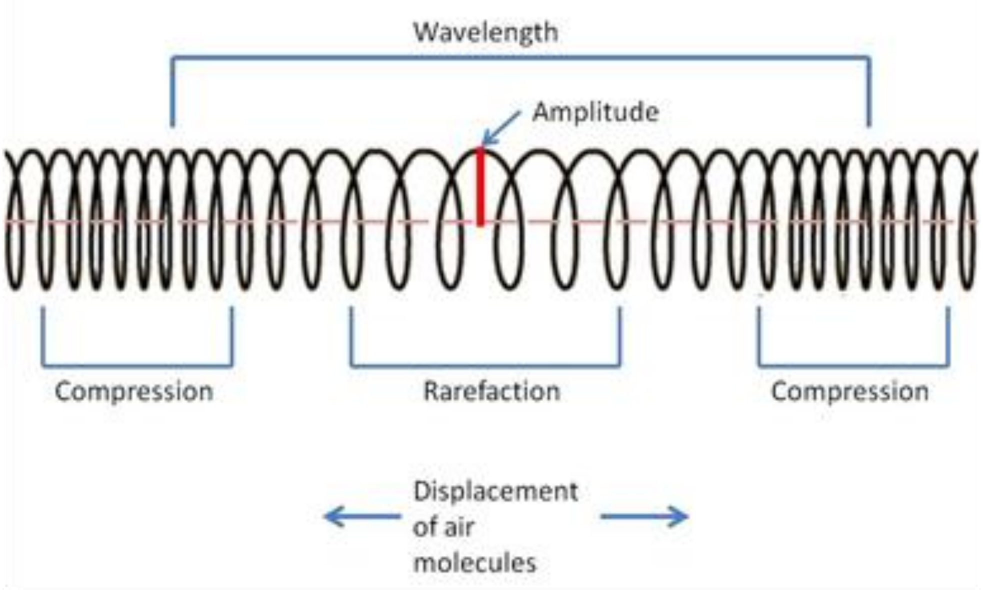
**Remember, the particles in a wave move up and down or backwards and forwards only.**
**It is energy, NOT the particles, that move from one place to another!**

In a **transverse wave** the particles within the wave move perpendicular (at 90$^{o}$) to the direction the wave is travelling.
This is the wave produced in a rope when it is flicked **up and down**.
Examples of transverse waves are:
**Water waves, electromagnetic (light) waves and guitar strings**.

**Longitudinal waves** are compression (squash) waves where the particles are vibrating in the same direction as the wave movement.
This is the wave produced when a spring is **squashed** and released.
Examples of longitudinal waves are:
**Sound waves and a type of seismic (P) wave.**

# Transverse and Longitudinal Waves





**Wavelength (m)** – the distance from one point on a wave to the same point on the next wave.
**Amplitude (m)** – the waves maximum displacement of a point on a wave from its undisturbed position.
**Frequency (Hz)** – the number of waves passing a point per second.
**Period (s)** - the time taken to produce one complete wave.

The displacement of a transverse wave is described as **peaks and troughs**. In a longitudinal wave these are described as **compressions and rarefactions**.

# Properties of waves

## Wave speed and wave period calculations

Wave speed is the speed at which energy is transferred by the wave (or how quickly the wave moves) through the medium it is travelling in.

**Wave speed (m/s) = Frequency (Hz) x Wavelength (m)** **$v = f\lambda$**

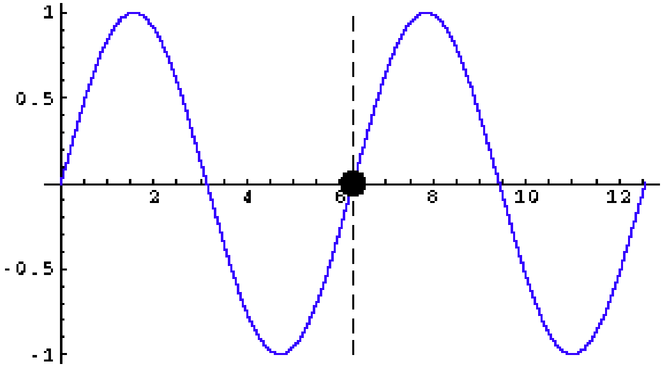
Wave period (T) is the time it takes one complete wave to pass a point (in seconds).

**Period (s) = 1 / Frequency (Hz)** **$T = 1/f$**

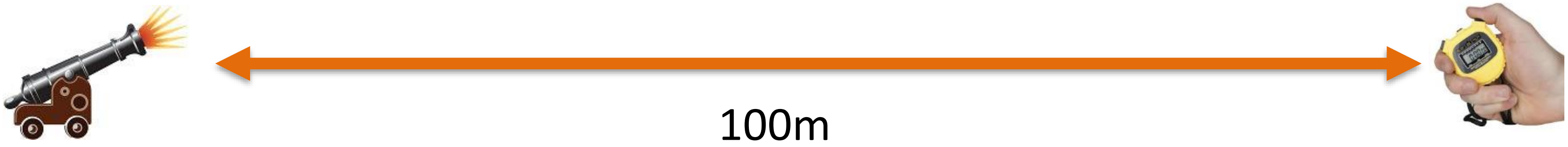
The wave opposite has a frequency of 0.5Hz and a wavelength of 6cm (0.06m). Calculate the wave period and the wave speed.

**Wave period** = **1/f** **T = 1/0.5 = 2s**

**Wave speed** = **f x λ** **v = 0.5 x 0.06 = 0.03m/s**



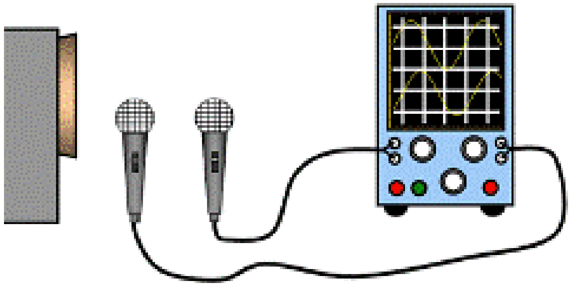
## Method for measuring the speed of sound waves in air



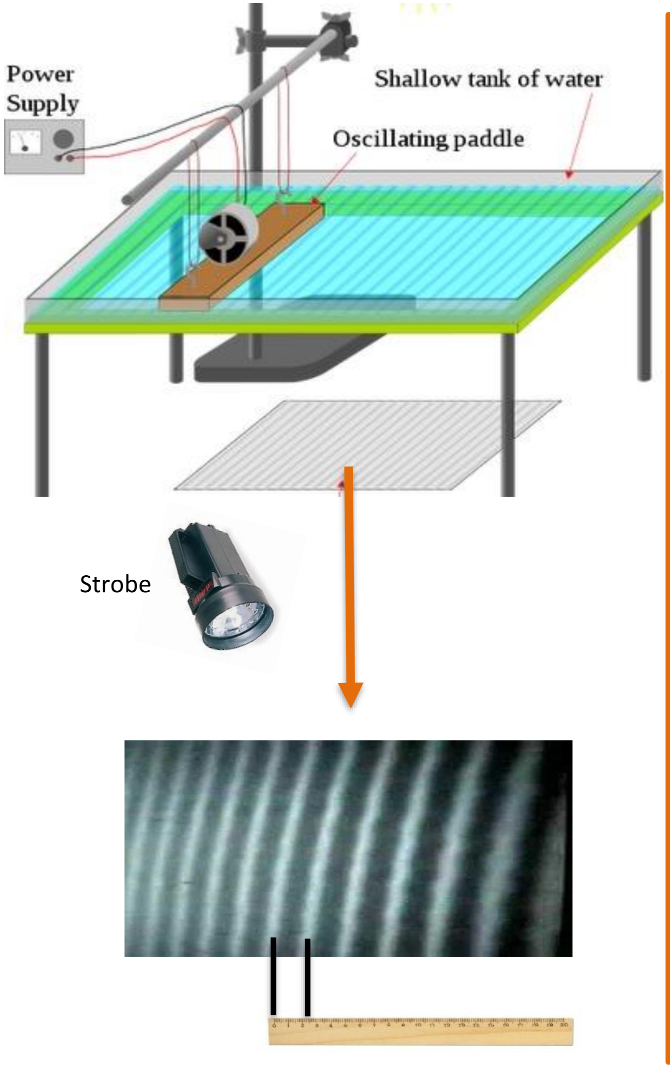
The cannon fires and the stopwatch is started (you can see a flash of light which takes almost zero time to travel 100m). When the sound reaches the observer the stopwatch is stopped. The time was **0.3s**
This will give the time for sound to travel **100m**.

**Speed (m/s) = Distance (m) / Time (s)**
**Speed of sound = 100 / 0.3 = 333.3m/s**

In the laboratory, a sound from a loudspeaker passes two microphones a set distance apart. The time recorded for the sound to travel this distance is measured and speed is calculated using the same formula as above.



# Method for measuring the speed of ripples on a water surface



A ripple tank is used to make waves which are seen under the glass tank.
A strobe light has its frequency of flashes adjusted until the wave appears stationary – **this is the frequency of the water wave.**
Then, the **wavelength** of the water wave is measured by using a ruler to measure the distance from one peak to the next peak (white line to white line). This is converted to **metres**.

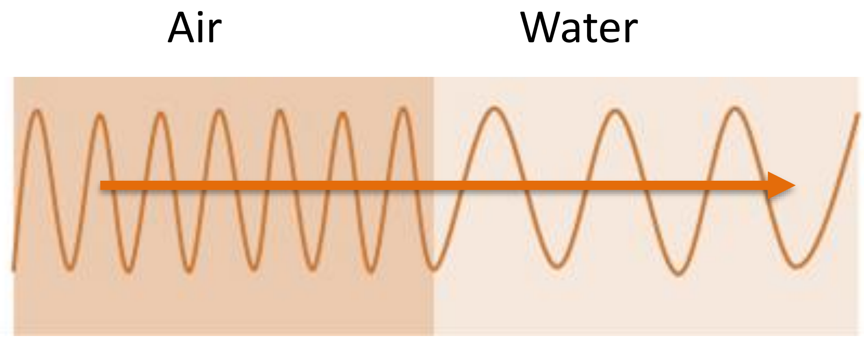
**Wave speed (m/s) = Frequency (Hz) x Wavelength (m)**

If the frequency of the water wave is 5Hz and the wavelength is 0.6cm:

**wave speed = 0.5 x 0.006 = 0.03m/s**

# Sound waves changing medium (physics only)

When a **sound wave travels from one medium to another** e.g. air to water, **the frequency remains the same**. This is because frequency is a property of the object producing the sound, not the medium it travels through.



The sound wave will travel faster in water than air.

**Remember,** **Wave speed (m/s) = Frequency (Hz) x Wavelength (m) or $f = v / \lambda$.**

So, if the **frequency remains the same**, as **velocity increases**, the **wavelength must also increase** proportionally.

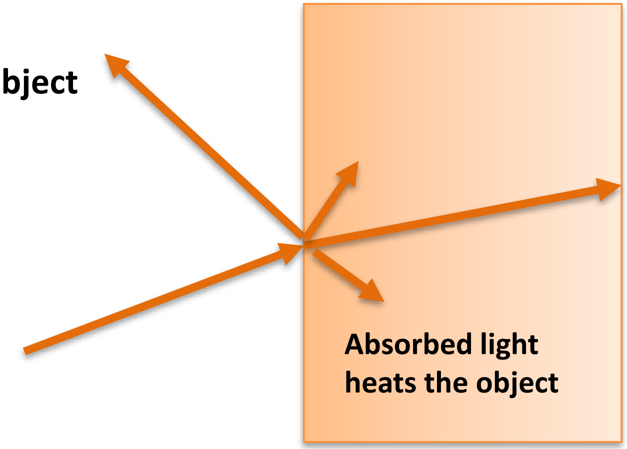
If a sound wave has a frequency of 260Hz:

Speed of sound in air = **330m/s.** Speed of sound in water = **1500m/s.**

$\lambda$ in air = 330 / 260 = **1.27m** $\lambda$ in water = 1500 / 260 = **5.77m**

# Reflection of waves (physics only)

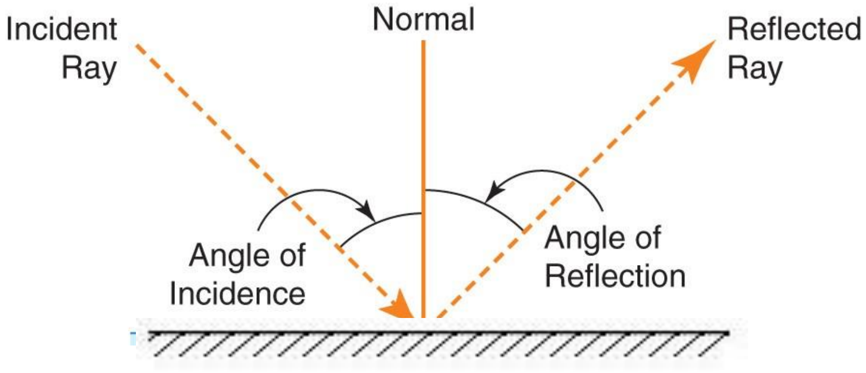
When light waves strike a boundary they can be **reflected, absorbed** or **transmitted** depending on the substance they strike.



**Reflected light bounces off the object surface**

**Transmitted light passes through the object**

**Absorbed light heats the object**



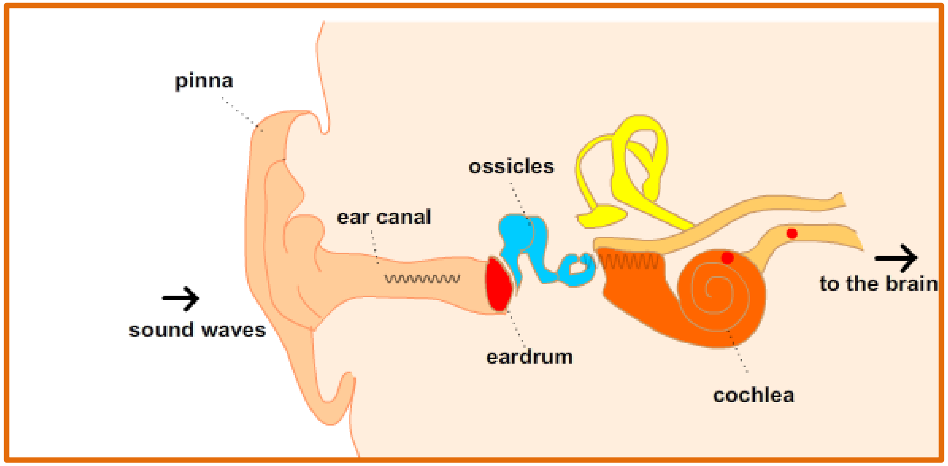
Light reflected from a specular surface, e.g. a mirror, reflects at the **same angle** it strikes the mirror.

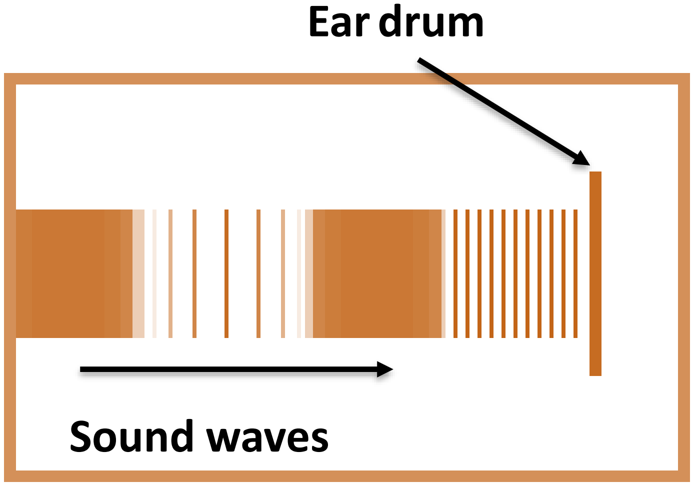
**Angle of incidence (i) = angle of reflection (r)**

# Sound waves (physics only) (HT)

Sound waves can travel through solids causing **vibrations in the solid**.

In the ear, sound waves cause the **ear drum** and other parts to vibrate which causes the sensation of sound. The conversion of sound waves to solids only happens over a **limited frequency range**. This restricts the human hearing range to between **20Hz and 20,000Hz (20kHz).**

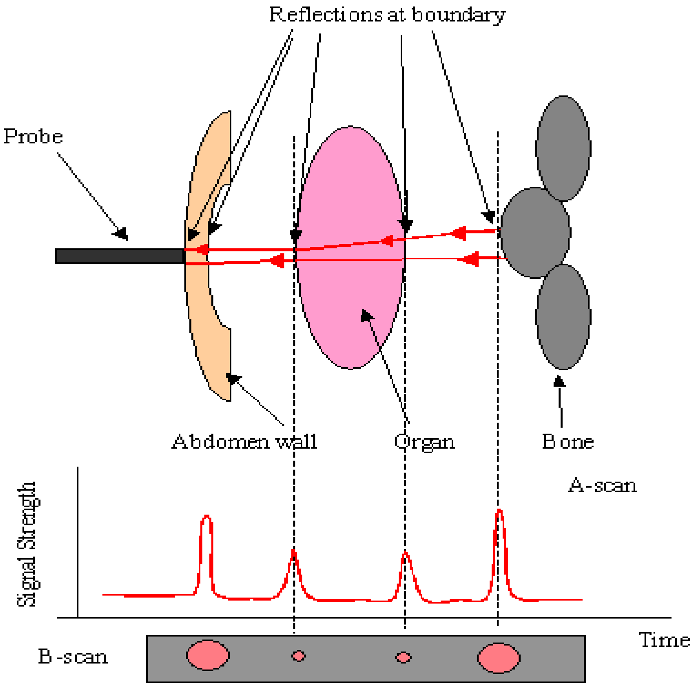




# Waves for detection (physics only) (HT)

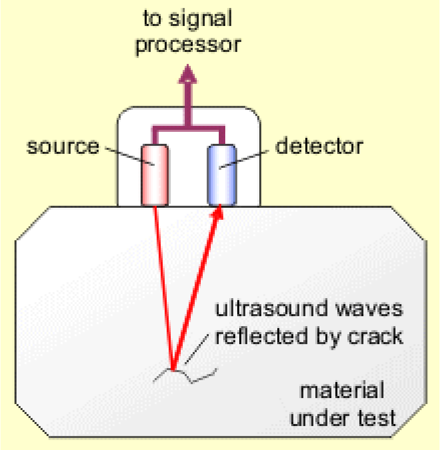
## Ultrasound waves used for detection

**Ultrasounds are sound waves with a higher frequency than humans can hear.**



Ultrasound waves are **partially reflected** when they meet **a boundary** between **two different media**.
The **time taken** for the reflections to meet a detector can be used to determine how far away the boundary is. Ultrasound waves can therefore be used for medical imaging.

A similar technique, using **higher frequencies**, can be used in industry to detect flaws and cracks inside castings. This could prevent a potentially dangerous casting being used, for example, in an aircraft engine.

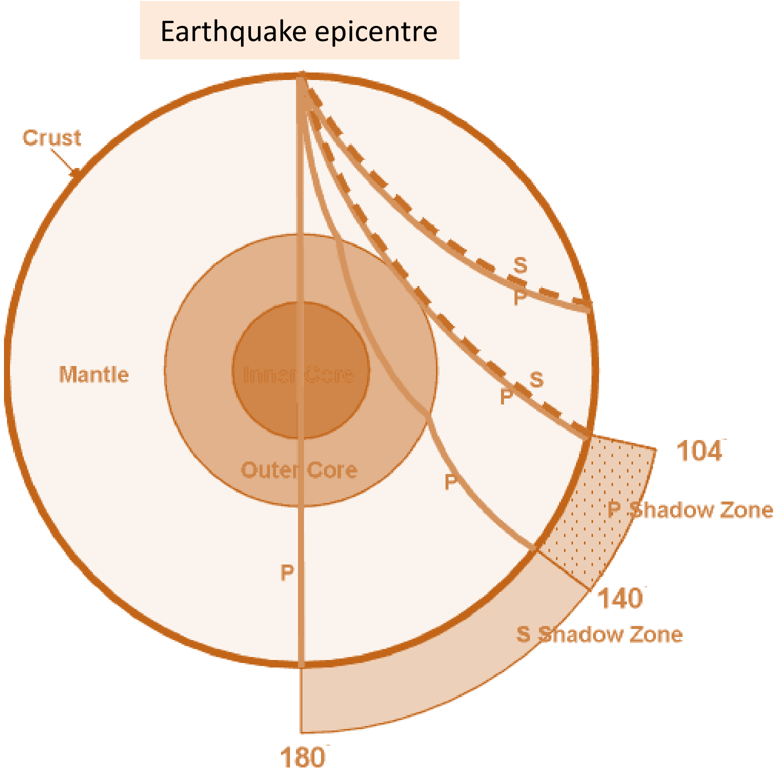


# Waves for exploration (physics only) (HT)

## Seismic waves used for exploration

Earthquakes produce P and S waves.

P waves: fast longitudinal; travel at different speeds through solids and liquids.
S waves: slower transverse; cannot travel through liquids.



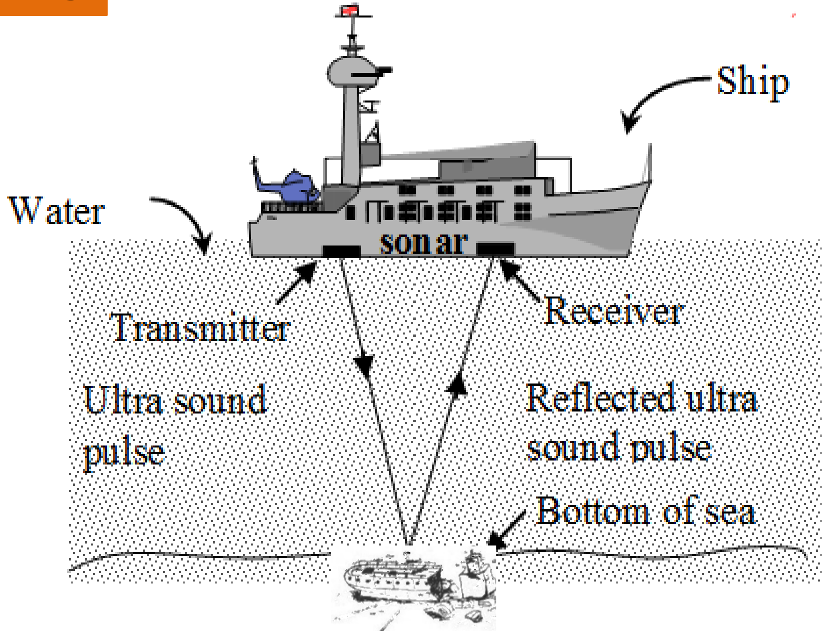
This information can be used to determine the size, density and state of the Earth’s structure. As S waves do not penetrate the outer core, they can not be used to determine whether the inner core is liquid or solid.

**The study of seismic waves provided new evidence that led to discoveries about parts of the Earth which are not directly observable.**

# Waves for exploration (physics only) (HT)

## Echo sounding

**Echo location** or SONAR uses high frequency sound waves to **detect objects in deep water** (shipwrecks, shoals of fish) and **measure water depth.**



Ultrasound waves travel at **1500m/s** in sea water. The transmitter sends out a wave which is received **4.6s** later. The depth of water under the ship can be calculated as:

**Distance (m) = speed (m/s) x time (s)** **so:** distance = **1500 x 4.6 = 6900m**

Remember, this is the time to go to the bottom and back.

Therefore depth = 6900 /2 = **3450m**

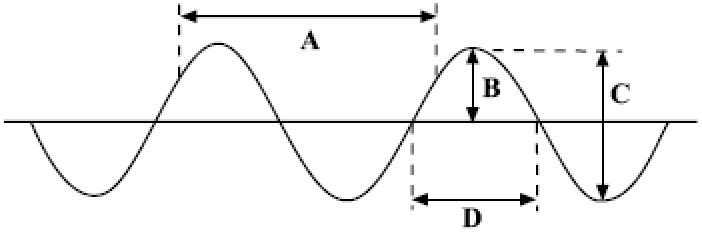
# QuestionIT!

## Waves in air, fluids and solids

- Transverse and longitudinal waves
- Properties of waves
- Reflection of waves (physics only)
- Sound waves (physics only) (HT)
- Waves for detection and exploration (physics only) (HT)

# Waves in air, fluids and solids – QuestionIT

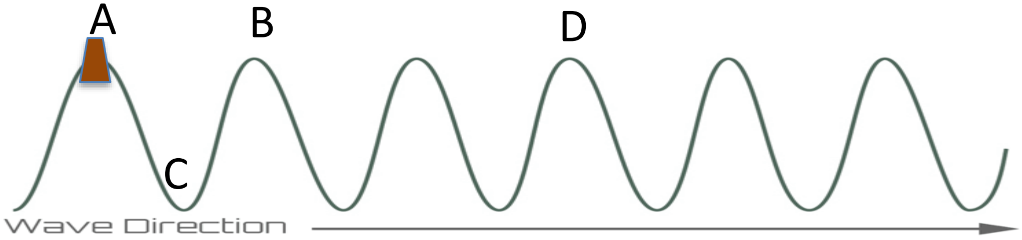
1.



a. What type of wave is shown above?
b. Which letter represents the amplitude of the wave?
c. Which letter shows the wavelength?

2. Draw a longitudinal wave and label a compression, rarefaction and the wavelength.

3. The diagram shows a cork floating on a water wave which has a frequency of 0.5 Hz. Which letter shows where the cork will be 2 seconds later?



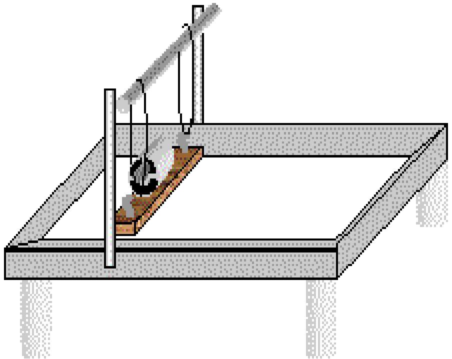
# Waves in air, fluids and solids – QuestionIT

4. What is meant by the period of a wave?

5. A wave has a period of 0.25s. Calculate the frequency of this wave.

$T = 1 / f$

6. A sound wave has a frequency of 240Hz and a wavelength of 1.38m. Calculate the velocity of this sound wave. Show clearly the formula you use for this calculation.



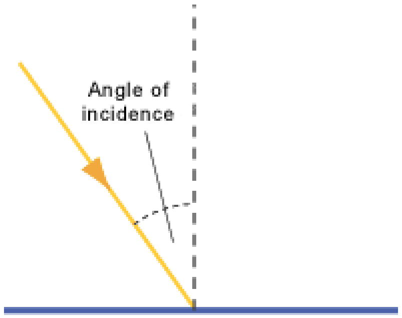
7. The diagram shows a ripple tank, used to generate waves in the laboratory. Describe the measurements that must be made in order to calculate the velocity of water waves in the tank.

# Waves in air, fluids and solids – QuestionIT

8. (Physics HT only) The sound waves from a noisy jet travel from the air into water. Which property of the wave will not change?

9. (Physics HT only) The Eiffel Tower is made of iron. The speed of sound in iron is 4000m/s. Someone at the top hits the iron with a hammer and the sound can be heard at the bottom 0.08s later. How tall is the Eiffel Tower?

10. (Physics only) The diagram shows a light ray striking a plane mirror. Copy and complete the diagram (include all labels).

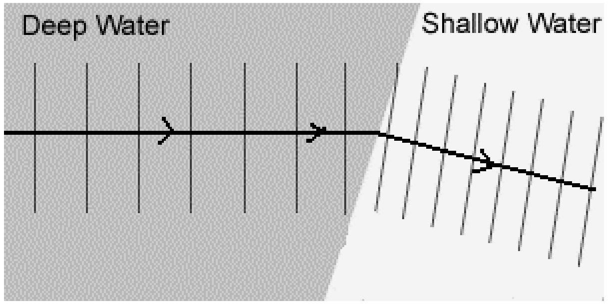


# Waves in air, fluids and solids – QuestionIT

11. (Physics only) When light strikes a black curtain, very little light gets reflected. What happens to the light?

12. (Physics only) Explain why you cannot see your reflection when you look into a piece of white plastic held in front of you.

13. (Physics only) When waves flow from deep water to shallow water the wave can bend (diffract). What happens to the speed of the wave to allow this to happen?



# Waves in air, fluids and solids – QuestionIT

14. (Physics HT only) Describe how sound waves in the air are converted to vibrations in solids by the ear.

15. (Physics HT only) Which of the following represents the frequency range of human hearing?

200Hz to 2000Hz        20Hz to 20 000Hz        2000Hz to 200 000Hz

16. (Physics HT only) What are ultrasound waves?

# Waves in air, fluids and solids (physics only) – QuestionIT

17. (Physics HT only) The picture shows the ultrasound image of an unborn baby. Explain how ultrasound is able to produce an image from the outside of the mother.

18. (Physics HT only)Seismic waves are described as P or S waves. Copy the table and put ticks in the correct column to show the difference in these two seismic waves.

| Wave type | Longitudinal wave | Fastest wave | Can travel through liquid and solid |
|---|---|---|---|
| P wave | | | |
| S wave | | | |

19. (Physics HT only) Describe how P and S seismic waves can be used to show part of the Earth’s core is liquid.

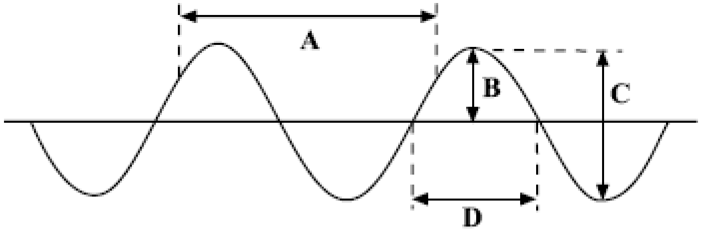
# AnswerIT!

## Waves in air, fluids and solids

- Transverse and longitudinal wav
- Properties of waves
- Reflection of waves (physics onl
- Sound waves (physics only) (HT)
- Waves for detection and explora
(physics only) (HT)

# Waves in air, fluids and solids – QuestionIT

1.

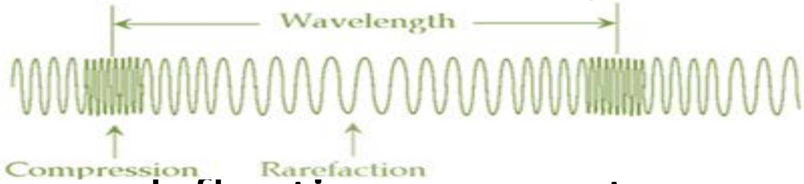


a. What type of wave is shown above? Transverse

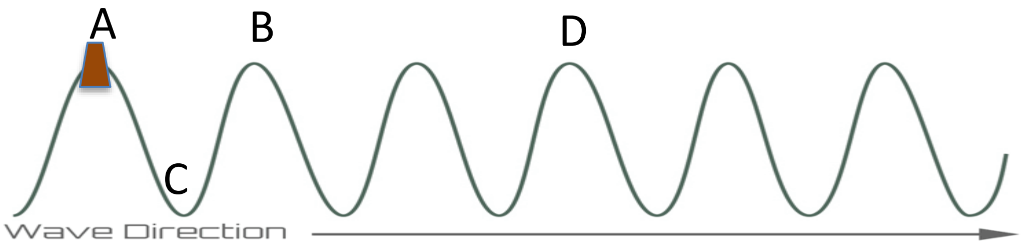
b. Which letter represents the amplitude of the wave? B

c. Which letter shows the wavelength? A

2. Draw a longitudinal wave and label a compression, rarefaction and the wavelength.



3. The diagram shows a cork floating on a water wave which has a frequency of 0.5 Hz. Which letter shows where the cork will be 2 seconds later? A



# Waves in air, fluids and solids – QuestionIT

4. What is meant by the period of a wave?

Time taken to complete 1 full wave.

5. A wave has a period of 0.25s. Calculate the frequency of this wave.

$T = 1 / f$

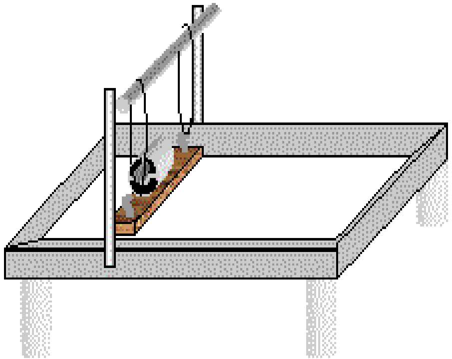
$f = 1/T$ $f = 1 / 0.25$ Frequency = 4Hz

6. A sound wave has a frequency of 240Hz and a wavelength of 1.38m. Calculate the velocity of this sound wave. Show clearly the formula you use for this calculation.

$v = f\lambda$ $v = 240 \times 1.38$

Velocity of the wave = 331.3m/s

# Waves in air, fluids and solids – QuestionIT



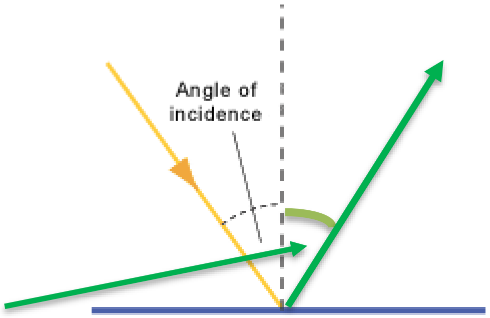
7. The diagram shows a ripple tank, used to generate waves in the laboratory. Describe the measurements that must be made in order to calculate the velocity of water waves in the tank.

Measure wave frequency with a strobe light and wavelength of a wave with a ruler then use v = f λ

or: measure time for a wave to travel a measured distance and use s = d/t

# Waves in air, fluids and solids – QuestionIT

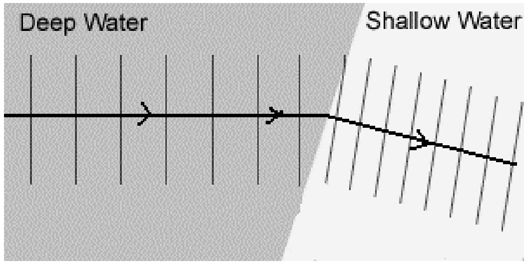
8. (Physics HT only) The sound waves from a noisy jet travel from the air into water. Which property of the wave will not change?
   Frequency.
9. (Physics HT only) The Eiffel Tower is made of iron. The speed of sound in iron is 4000m/s. Someone at the top hits the iron with a hammer and the sound can be heard at the bottom 0.08s later. How tall is the Eiffel Tower?
   **s = d/t d(height) = s x t Height = 4000 x 0.08 = 320m**
10. (Physics only) The diagram shows a light ray striking a plane mirror. Copy and complete the diagram (include all labels).
    (angle of incidence = angle of reflection)



**Angle of reflection**

# Waves in air, fluids and solids – QuestionIT

11. (Physics only) When light strikes a black curtain, very little light gets reflected. What happens to the light?
    It is absorbed by the curtain as heat energy.
12. (Physics only) Explain why you can not see your reflection when you look into a piece of white plastic held in front of you.
    Light rays are scattered in all directions – diffuse reflection.
13. (Physics only) When waves flow from deep water to shallow water the wave can bend (diffract). What happens to the speed of the wave to allow this to happen?
    Waves slow down in shallow water.
    Bottom of wave enters shallow water before top of wave. Therefore bottom of wave slows down before the top, causing the wave to bend.



## Waves in air, fluids and solids – QuestionIT

14. (Physics HT only) Describe how sound waves in the air are converted to vibrations in solids by the ear.
    Compressions in the air cause the ear drum to flex inwards and outwards. This sets up vibrations of the bones in the inner ear.
15. (Physics HT only) Which of the following represents the frequency range of human hearing?

200Hz to 2000Hz

20Hz to 20 000Hz

2000Hz to 200 000Hz

16. (Physics HT only) What are ultrasound waves?
    Sound waves with a frequency higher than humans can hear.

# Waves in air, fluids and solids – QuestionIT

17. (Physics HT only) The picture shows the ultrasound image of an unborn baby. Explain how ultrasound is able to produce an image from the outside of the mother.

Ultrasounds penetrate the body. Some of the waves are reflected when they meet a boundary between two structures. These reflected waves are received at different times and are formed into an image.

18. (Physics HT only)Seismic waves are described as P or S waves. Copy the table and put ticks in the correct column to show the difference in these two seismic waves.

| Wave type | Longitudinal wave | Fastest wave | Can travel through liquid and solid |
|---|---|---|---|
| **P wave** | ✓ | ✓ | ✓ |
| **S wave** | | | |

19. (Physics HT only) Describe how P and S seismic waves can be used to show part of the Earth's core is liquid.

Detectors on the opposite side of the Earth to the earthquake epicentre can record both P and S waves. Only P waves are detected meaning S waves can not penetrate through the Earth. As S waves can not travel through liquids, it is deduced that part of the core is liquid .

# LearnIT!
# KnowIT!

## Electromagnetic Waves

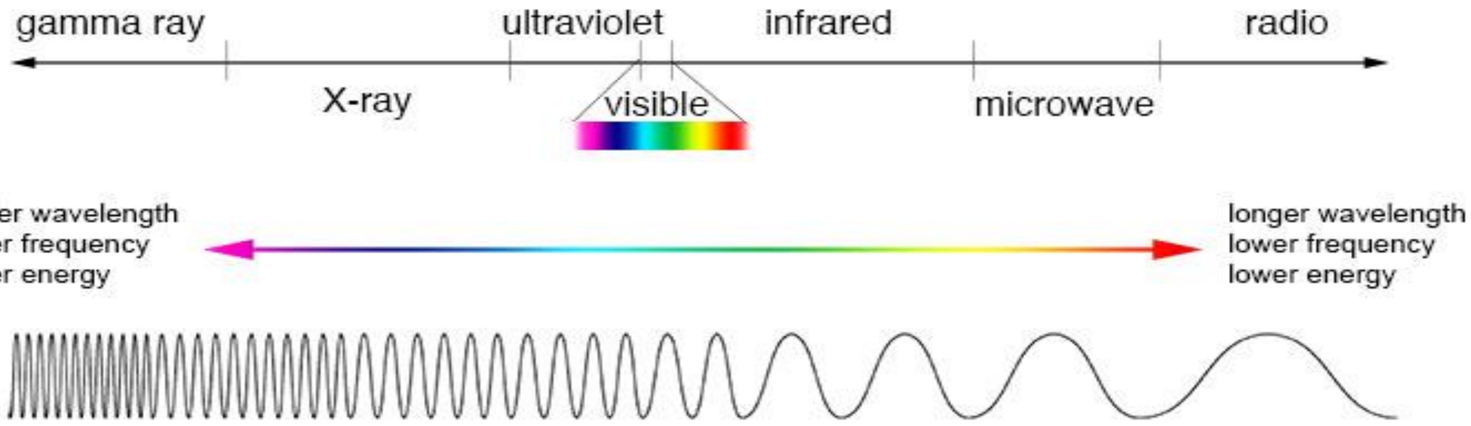
- Types of electromagnetic waves
- Properties of electromagnetic waves
- Uses and applications of electromagnetic waves
- Lenses (physics only)
- Visible light (physics only)

# Types of electromagnetic waves

**Electromagnetic waves are transverse waves that transfer energy from the wave source to an absorber.**

Electromagnetic waves form a **continuous spectrum** from the shortest gamma waves (< $10^{-11}$m wavelength) to radio waves (> 100km wavelength). **Shorter wavelengths** have a **higher frequency** and **higher energy**.

**All electromagnetic waves travel at the same velocity in a vacuum: 300 000 000m/s.**



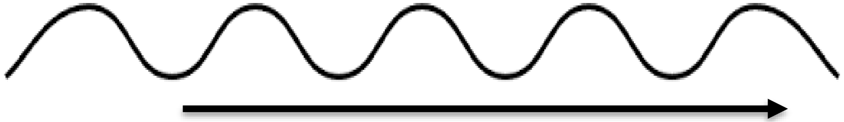
Our eyes are only able to detect a small range of these waves shown as the visible range above. Some animals can see in ultra violet and some can detect infra red.

# Types of electromagnetic waves

## Examples of transfer of energy by electromagnetic waves

**Heater**

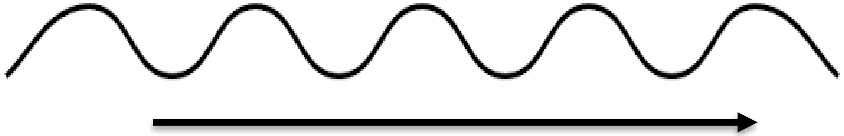
Infra red waves



**Detected by heat sensors in the hand**

**Torch**

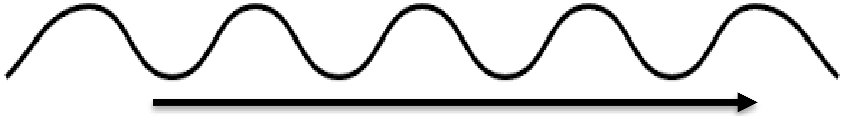
Visible light waves



**Detected by cells in the retina**

**Radio transmitter**

Radio waves



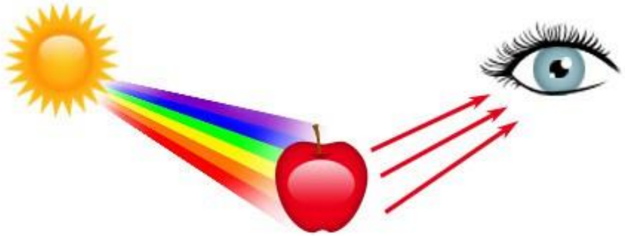
**Detected by the aerial in the radio**

# Properties of electromagnetic waves 1 (HT)

## Absorption, transmission and reflection of different wavelengths of light

Most materials absorb some of the light falling on it. A white or shiny surface reflects most of the incident light whereas a black surface absorbs most wavelengths of light.

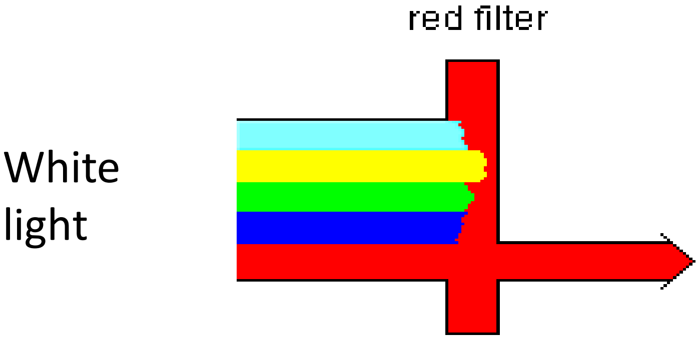
**Absorbed light** is changed into a **heat** energy store so is not re-radiated as light.



White light/sunlight is made from all the wavelengths of light in the spectrum.

A red object appears red in white light because it only **reflects** the red wavelengths of light, all other colours are absorbed.

If light **transmits** through a coloured object, the colour passing through is the colour we see. As with reflected light, all other wavelengths of light are absorbed by the transparent or translucent material.



# Properties of electromagnetic waves 1 (HT)

## Refraction of different wavelengths of light in different materials

Refraction of electromagnetic waves occurs because the **wave changes speed** when it enters a substance of different **optical density**.

The light wave will only refract if one side of the wave strikes the new material before the other side.

The amount of refraction is different for materials of different optical density as seen in Figure 1 opposite.

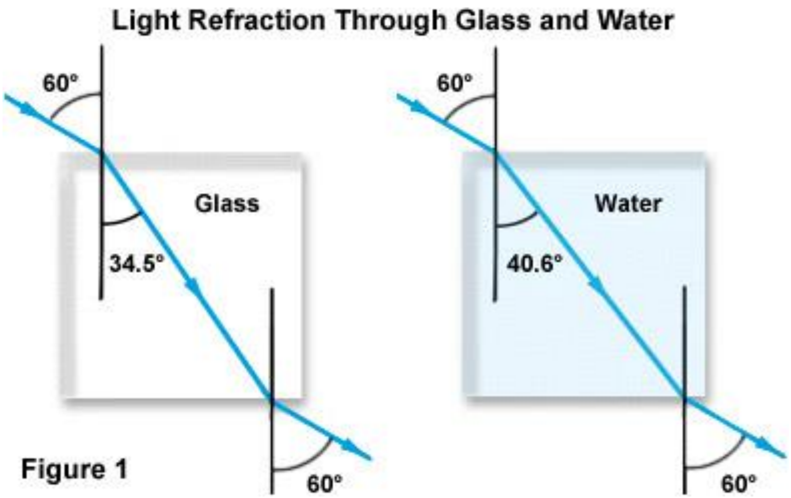
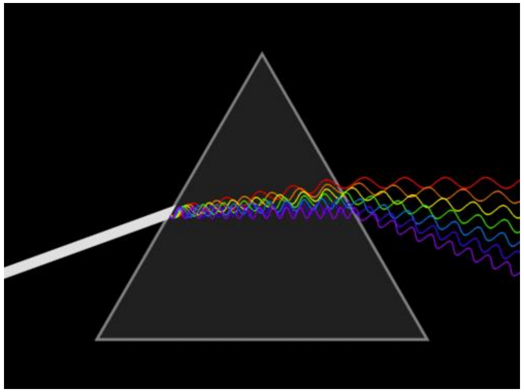


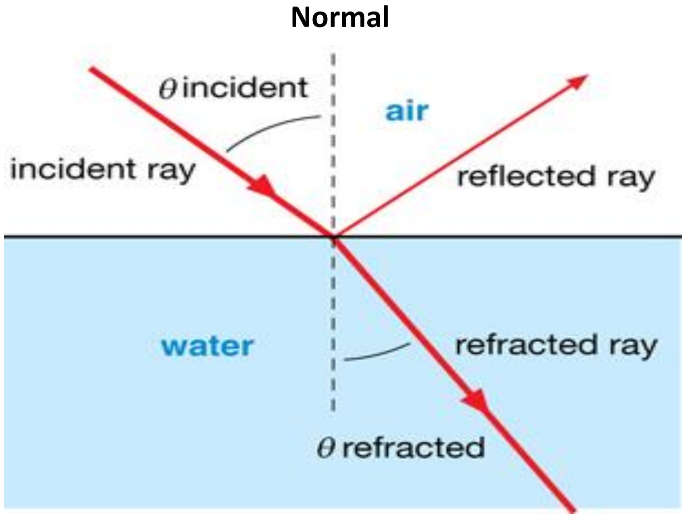
Figure 1



**Different wavelengths** of light are **diffracted by different amounts**, resulting in a spectrum of colour being produced when white light is refracted (dispersed) by a prism.

# Properties of electromagnetic waves 1

## Refraction of waves at a boundary– ray diagrams



When light strikes a transparent material, some of the light may be reflected but some will also be **refracted**.

When light enters a substance of greater density, it will be bent (refracted) **towards the normal line.**

**Angle of incidence > angle of refraction**

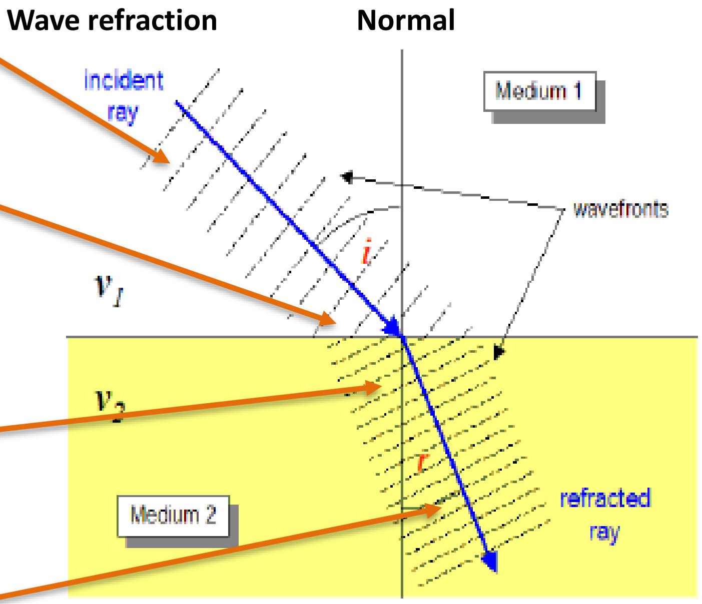
When light enters a substance of lower density, it will be bent (refracted) **away from the normal line.**

**Angle of incidence < angle of refraction**

# Properties of electromagnetic waves 1 (HT)

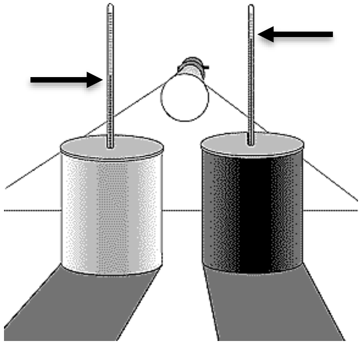
## Explaining refraction using wave front diagrams

- The incident ray is shown as wave fronts where all the waves are in phase with each other. This is drawn as a wave line at right angles to the direction in which the wave is travelling.
- The incident ray strikes the denser medium 2 at an angle.
- When the wave front hits a denser material it slows down. One side of the wave front hits before the other side, so slows down first.
- This causes the wave front to bend towards the normal line. Wave fronts will be closer together as the velocity is decreased. Frequency is unchanged.

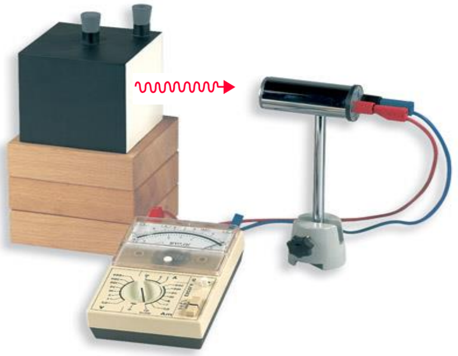


# Properties of electromagnetic waves 1 (HT)

## Absorption and radiation of infra red waves (required practical)



Black surfaces absorb infrared waves better than white or shiny surfaces.

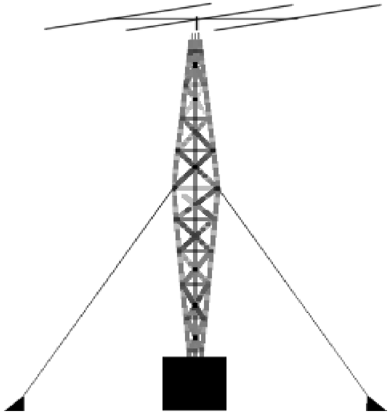


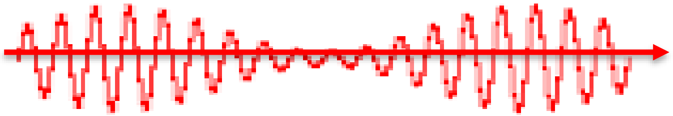
Black surfaces also emit infrared radiation quicker than light coloured surfaces

This is the reason black cars and black curtains get hot in sunshine.
Petrol storage tankers are painted white or polished to reflect the suns IR heat waves.
A black kettle would radiate IR heat quicker than a shiny silver kettle and so would cool down faster. Car radiators are painted black to help them emit IR heat quickly.

# Properties of electromagnetic waves 2 (HT)

**Radio waves**





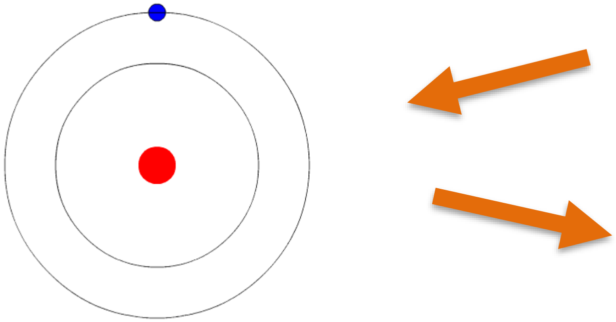
A radio wave is transmitted at the same frequency as the a.c. current which produced it.

**Radio signals** are produced when an **alternating current** is passed through a wire in a radio transmitter. The **oscillating (vibrating) particles** in the wire produce a **radio wave** which is modulated and boosted so it can carry the signal over a great distance.

When this radio signal reaches another antenna (e.g. aerial on a radio) the **radio waves cause oscillations in the wire**. This produces an alternating current of the **same frequency as the radio signal.**

# Properties of electromagnetic waves 2

## Atoms and electromagnetic waves



**Input energy** could be:
light, heat, electricity, X rays etc

**Energy out** will be a type of electromagnetic radiation i.e.
X ray, ultra violet, visible,
infra red, microwave or radio waves.

Changes within the nucleus of an atom can result in the emission of gamma waves. This occurs during the radioactive decay of some unstable atoms.

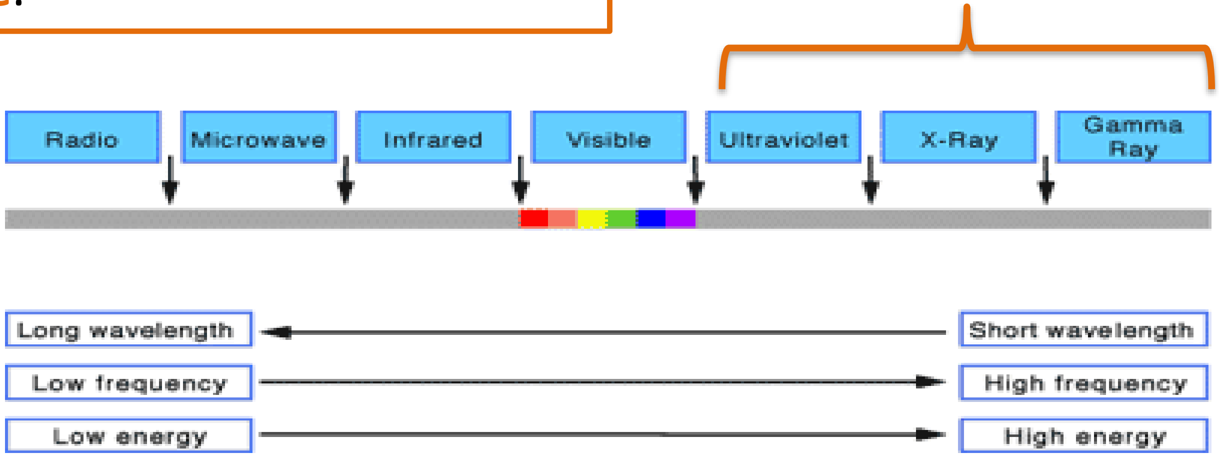
Atoms can receive energy from external sources.
This energy can cause electrons to “jump” to a **higher energy level**.
When the electron falls back to its original energy level it will release the stored energy in the form of a **photon of electromagnetic radiation.**

# Properties of electromagnetic waves 2

## Health risks of high energy electromagnetic radiations

High frequency radiations have **high energy**. They can have a **hazardous** effect on **human tissue**.

**UV, X ray and gamma waves** are high energy radiations.



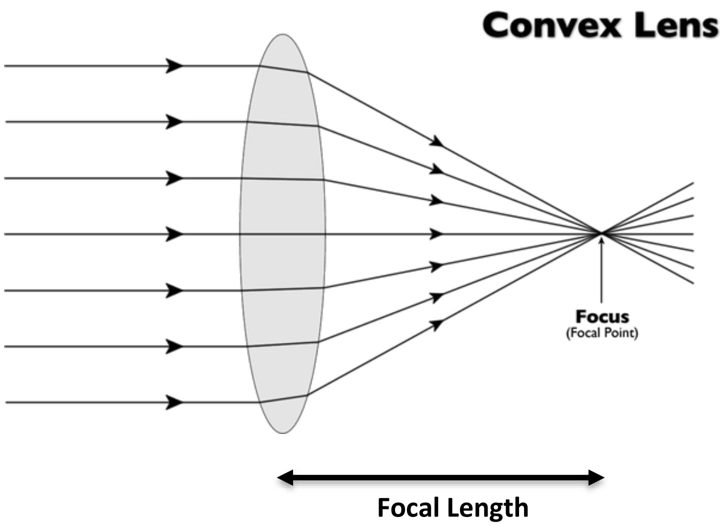
The hazard from high energy radiations also depends on the **dose**.
Radiation dose is a measure of the risk when exposed to these radiations.
Radiation dose is **measured in Sieverts**.
**Ultra violet waves** can cause sunburn, ageing of the skin and skin cancer.
**X rays and gamma rays** are ionising radiations that can cause mutations of genes which could result in cancer.

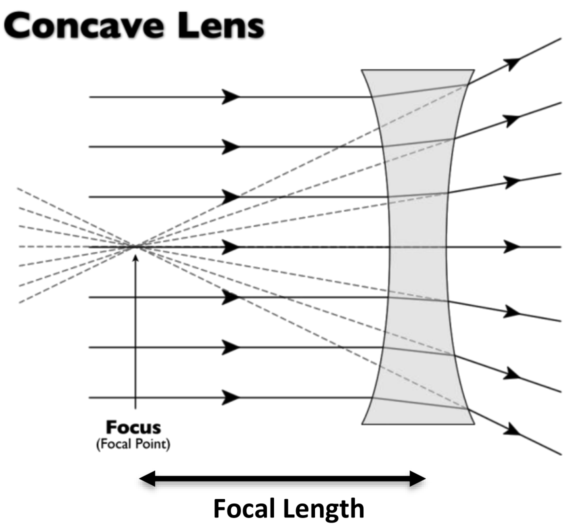
# Uses and applications of electromagnetic waves 2

| | Type | Application | Suitability (HT) |
|---|---|---|---|
| Low frequency low wavelength | Radio | Television and radio | Travel through atmosphere for long distances |
| | Microwave | Satellite communications.<br>Cooking food | Travel through atmosphere; agitates water molecules causing them to heat food |
| | Infrared | Electrical heaters, cooking food, infrared cameras | Heat energy transfer; detection of heat waves |
| | Visible | Fibre optic communications | Retina can detect light waves; light can travel through optic fibres and carry information |
| | Ultraviolet | Energy efficient lamps, sun tanning | Some materials can absorb UV and re-emit as visible, energy efficient, skin reacts to UV light causing tanning |
| High frequency short wavelength | X-rays | Medical imaging and treatment | Pass through soft tissue, penetrate materials to different extents so can produce image |
| | Gamma rays | Medical imaging and treatment | Kill tissue ; tracers can produce images of internal organs. |

# Waves – Lenses (physics only)

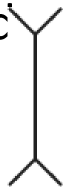
**Lenses refract light to produce an image at a principal focus.**





**Convex** lenses are also called converging lenses. They can produce **real or virtual images**.

**Concave** lenses are also called diverging lenses. They always produce **virtual images**.



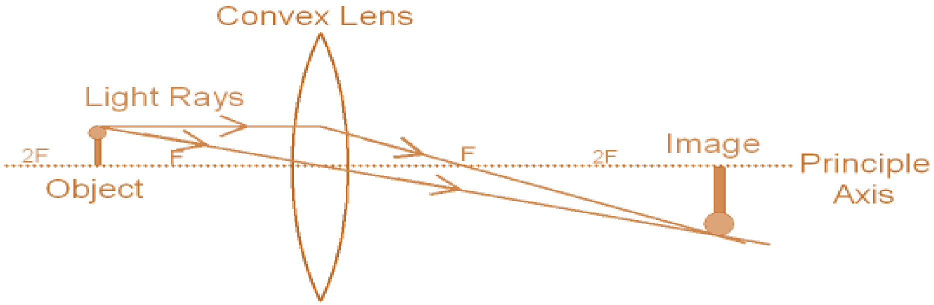
A **real image** is the image formed where the **light rays are focussed**.
A **virtual image** is one from which the light rays **appear to come from** but don't actually come from that image.

# Waves – Lenses (physics only)

Magnification of a lens is a **ratio** and so has **no units**.

Image height and object height should both be measured in **mm** or **cm**.

$$\text{Magnification} = \frac{\text{Image height}}{\text{Object height}}$$



In the above diagram, the object height is **12mm** and the image size is **24mm**. The magnification of the lens is:

$$\textbf{Magnification} = \frac{24}{12} = 2$$

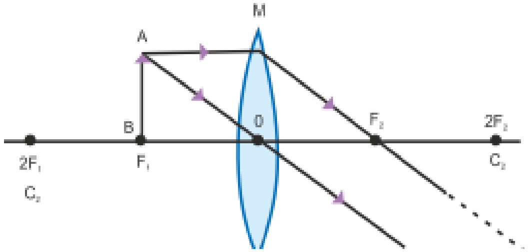
The **magnification** is **x2**. As this is a ratio there are **no units** for magnification.

The image type and magnification will also depend on the position of the object.

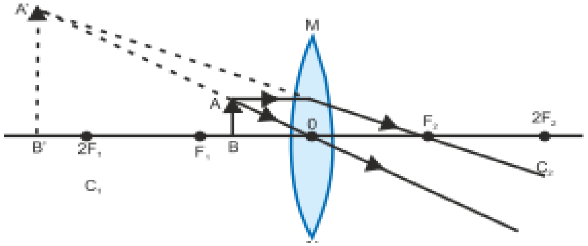
# Waves – Lenses (physics only)

The image produced by a convex lens depends on the position of the object. The object can be placed anywhere between the lens, the focal length (F) and twice the focal length (2F) of the lens.

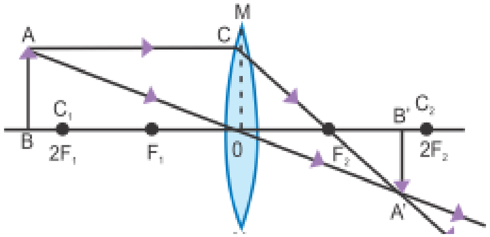
Object at the focal length (F)



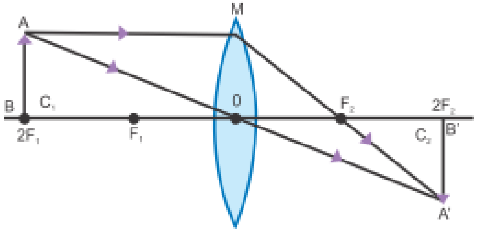
Object closer than the focal length (<F)



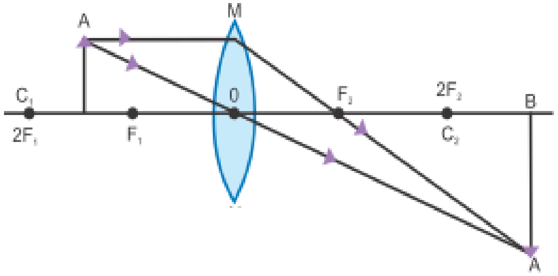
Object at more than twice the focal length (>2F)



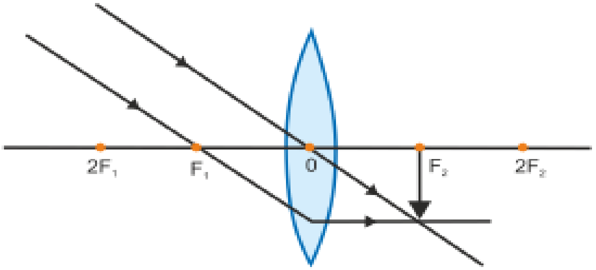
Object at twice the focal length (2F)



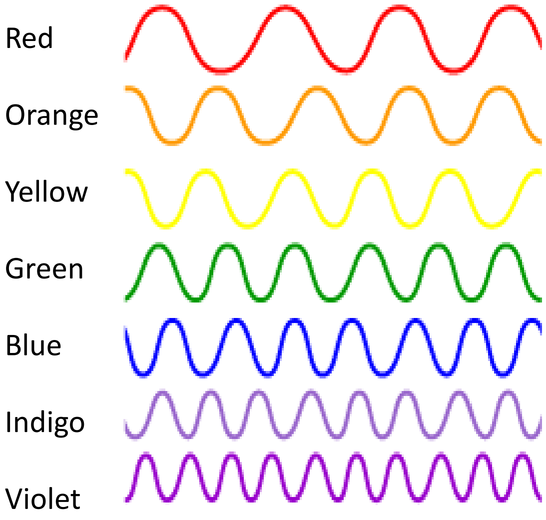
Object between F and 2F



Object at infinity

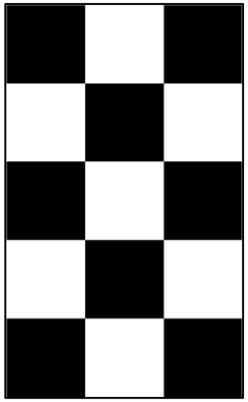


# Waves – Visible light (physics only)



Each colour within the visible spectrum has its own narrow band of **wavelength** and **frequency**.

Colour filters work by **absorbing certain wavelengths** (and colour) and **transmitting other wavelengths** (and colour).



The colour of an opaque object is determined by which wavelengths of light are more **strongly reflected**.
Wavelengths that are **not reflected are absorbed**.

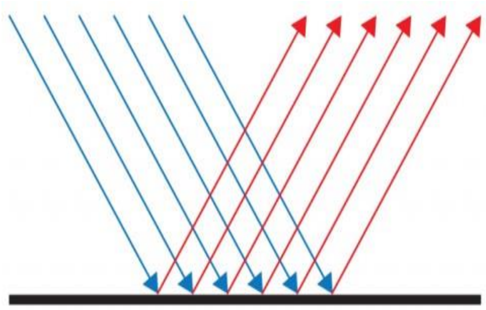
If **all wavelengths are reflected** equally the object will appear **white**. If **all the wavelengths of light are absorbed** equally the object will appear **black**.

# Waves – Visible light (physics only)

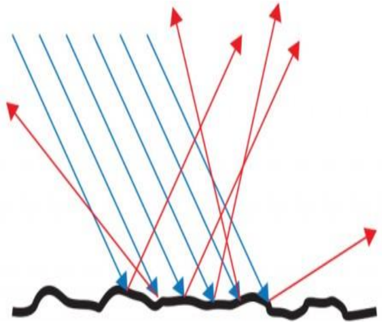
Light reflecting off a smooth, flat surface produces **specular reflection.**

When light reflects off a rough surface, **diffuse reflection** occurs. This is why you can not see your image in a piece of white paper even though it reflects most of the light striking it.

Specular reflection



Diffuse reflection



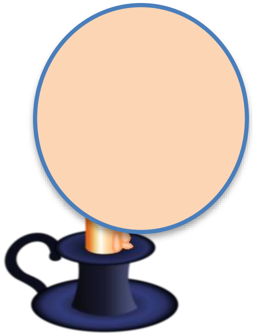
# Waves – Visible light (physics only)

**Transparent** – a material that allows objects behind it to be seen clearly as if nothing was in the way.

e.g. glass, perspex

**Translucent** – a material that allows objects to be seen through them but not as clearly or sharply as a transparent material.

e.g. tracing paper, frosted glass



**Opaque** – a material that may or may not allow light through to the object behind. It would be difficult to tell what object is behind an opaque material.

e.g. paper, wood

# QuestionIT!

## Electromagnetic Waves

- Types of electromagnetic waves
- Properties of electromagnetic waves
- Uses and applications of electromagnetic waves
- Lenses (physics only)
- Visible light (physics only)

# Electromagnetic waves – **QuestionIT**

1. What type of waves are electromagnetic waves?

2. List the main electromagnetic waves in order from lowest to highest frequency.

3. Which of the following is the speed of electromagnetic waves in a vacuum?

   300 m/s    300 000m/s    300 000 000m/s

4. Which colour of light has the longest wavelength?

5. Describe one piece of evidence to show that light waves do not need a medium to travel from one place to another.

# Properties of electromagnetic waves – **QuestionIT**

6. The four surfaces below are heated equally with infrared (IR) radiation.

Shiny black

Matt black

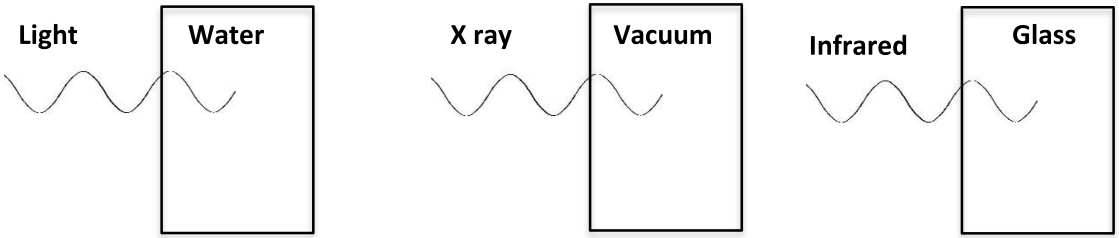
White

Shiny silver

a. Which surface will absorb the most IR radiation?

b. Which surface will reflect the most IR radiation?

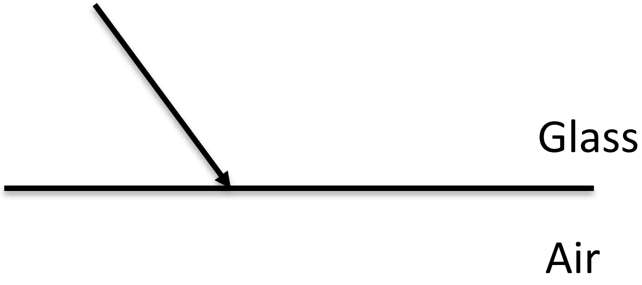
7. The diagrams show three waves travelling from air into different materials.



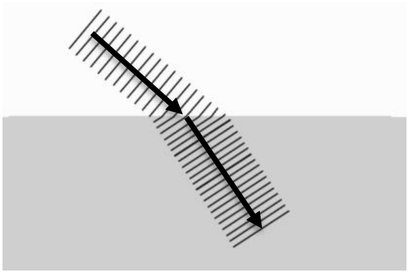
Which wave will be travelling the slowest?

# Properties of electromagnetic waves – **QuestionIT**

8. The light wave shown below meets a boundary between glass and air. Continue the light ray to show its path after passing the boundary.



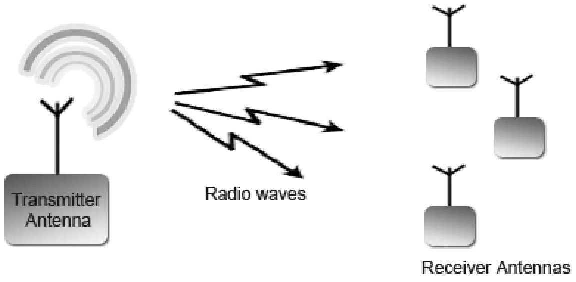
9. (HT) The wave front below is travelling from air into water. Explain why the wave front bends.



10. Infrared rays strike a black tile. Will the waves mainly be reflected, refracted or absorbed?

# Properties of electromagnetic waves – QuestionIT

11. (HT) Radio waves are transmitted through the air and received by aerials.



a. How are radio waves produced in the transmitter aerial?

b. What is produced in the receiving antenna when radio waves are absorbed?

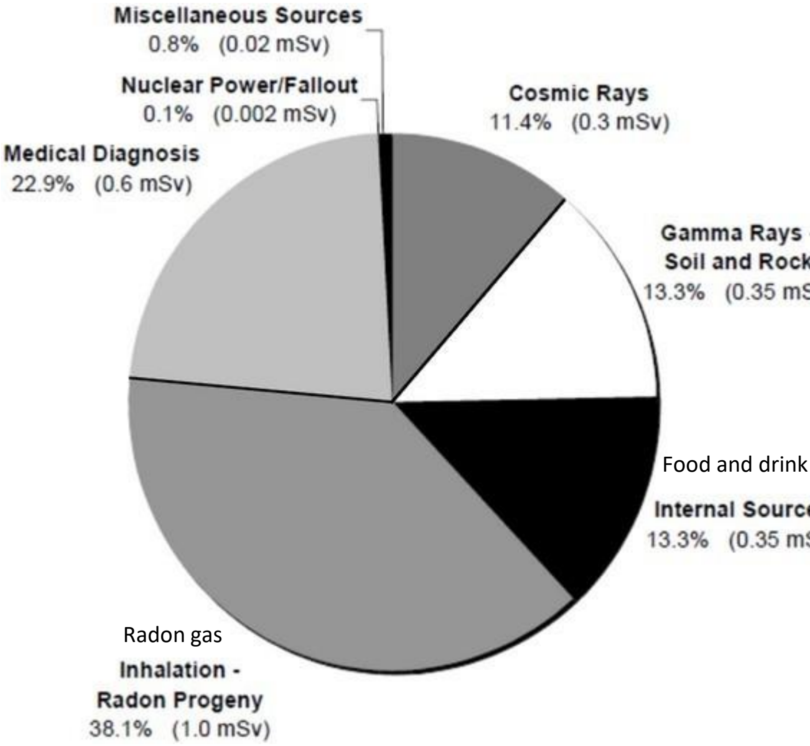
12. Most electromagnetic waves are produced from energy changes in electron levels. How does gamma wave production differ from this?

# Properties of electromagnetic waves – **QuestionIT**

13. Which three types of electromagnetic waves can cause damage to cells in the body?

14. What is meant by radiation dose?

15. The chart shows the average radiation dose a UK person is exposed to in a year.
    a) What percentage of the radiation dose comes from natural sources?
    b) Give **two** reasons why a person could receive a higher dose of background radiation.



# Uses of electromagnetic waves – **QuestionIT**

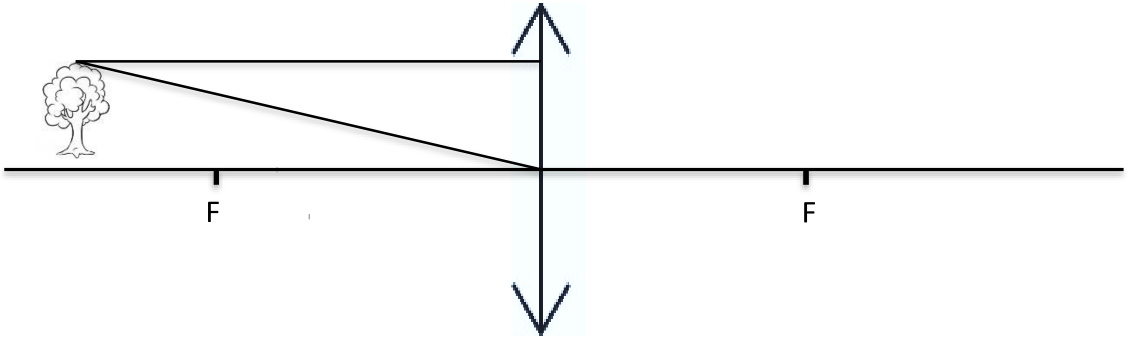
16. State which type of electromagnetic wave would be used for the following applications:

    Sun tanning; Television remote; Medical imaging

17. (HT) Explain why radio waves are suitable for transmitting TV images to the home.

# Lenses (physics only) – **QuestionIT**

18.



a. Copy and complete the two light rays on the diagram.

b. Label the principle axis, object and focal length on the diagram.

c. Describe the image produced by the above lens.

19. A 12cm object viewed in a convex lens has an image size of 54cm.
Calculate the magnification of the lens.

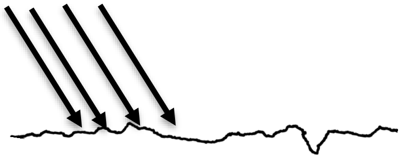
# Visible light (physics only) – QuestionIT

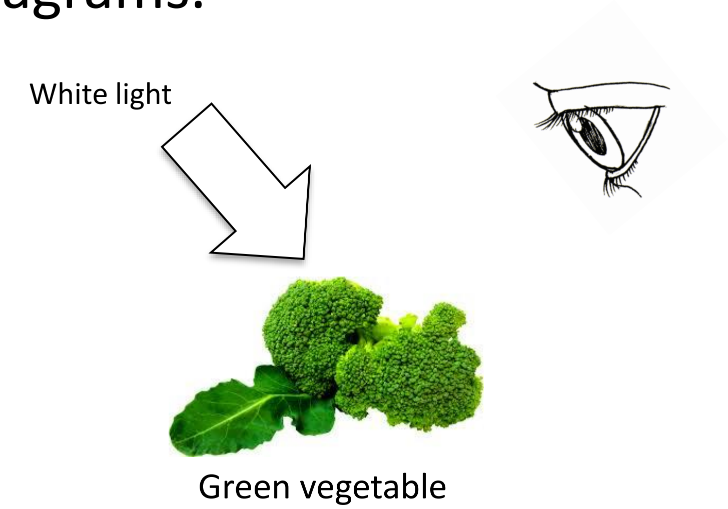
20. Describe the difference between a transparent and a translucent object.

21. A vase is illuminated with green and blue light. What colour would the vase appear if viewed through a red filter?

22. Which colour of light has the shortest wavelength?

23. Copy and complete the ray diagrams.





# AnswerIT!

## Electromagnetic Waves

- Types of electromagnetic waves
- Properties of electromagnetic waves
- Uses and applications of electromagnetic waves
- Lenses (physics only)
- Visible light (physics only)

# Electromagnetic waves – QuestionIT

1. What type of waves are electromagnetic waves?

   Transverse.

2. List the main electromagnetic waves in order from lowest to highest frequency.

   Radio microwave infrared visible ultraviolet X ray gamma ray

3. Which of the following is the speed of electromagnetic waves in a vacuum?

   300 m/s 300 000m/s 300 000 000m/s

4. Which colour of light has the longest wavelength?

   Red.

5. Describe one piece of evidence to show that light waves do not need a medium to travel from one place to another.

   Light waves travel through space which is a vacuum.

# Properties of electromagnetic waves – **QuestionIT**

6. The four surfaces below are heated equally with infrared (IR) heat.

Shiny black

Matt black

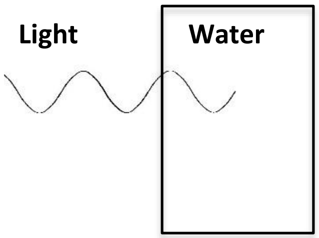
White

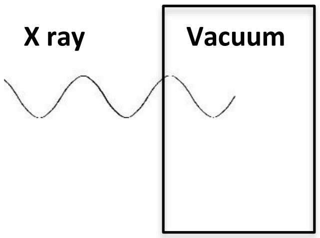
Shiny silver

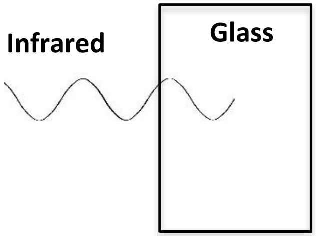
a. Which surface will absorb the most IR radiation? Matt black.

b. Which surface will reflect the most IR radiation? Shiny silver.

7. The diagrams show three waves travelling from air into different materials.



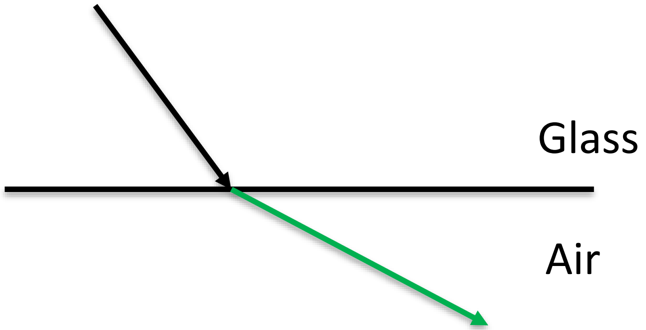




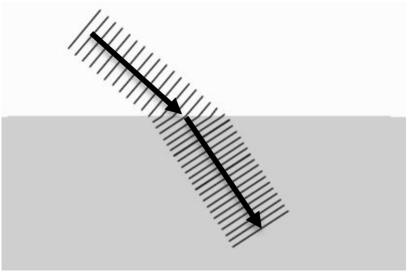
Which wave will be travelling the slowest? Glass.

# Properties of electromagnetic waves – **QuestionIT**

8. The light wave shown below meets a boundary between glass and air. Continue the light ray to show its path after passing the boundary.



9. (HT) The wave front below is travelling from air into water. Explain why the wave front bends.



Left side of wave meets the denser material first.

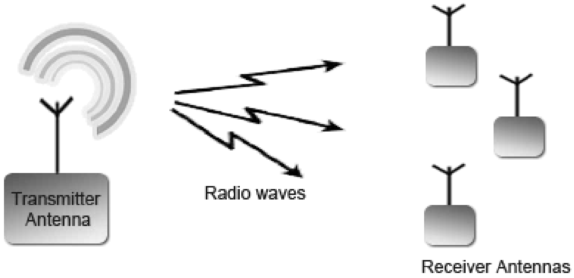
The left side will slow down before the right side.

This will cause the wave to bend.

10. Infrared rays strike a black tile. Will the waves mainly be reflected, refracted or absorbed? Absorbed.

# Properties of electromagnetic waves – QuestionIT

11. (HT) Radio waves are transmitted through the air and received by aerials.



a. How are radio waves produced in the transmitter aerial?

Produced by oscillations (vibrations) in a wire or electrical circuit.

b. What is produced in the receiving antenna when radio waves are absorbed?

An alternating current of the same frequency as the radio wave.

12. Most electromagnetic waves are produced from energy changes in electron levels. How does gamma wave production differ from this?

Gamma waves are emitted from changes in the nucleus of an atom.

# Properties of electromagnetic waves – QuestionIT

13. Which three types of electromagnetic waves can cause damage to cells in the body?

    Gamma waves, X rays and Ultraviolet.

14. What is meant by radiation dose?

    A measure of the risk of harm from exposure to radiation.

15. The chart shows the average radiation dose a UK person is exposed to in a year.

    a) What percentage of the radiation dose comes from natural sources?

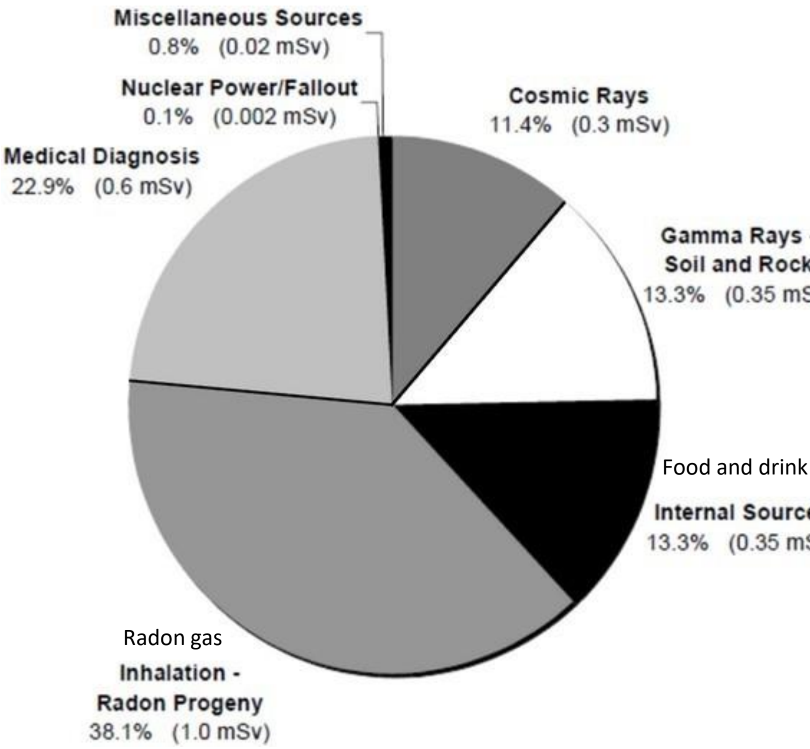
    **70 – 80%**

    b) Give **two** reasons why a person could receive a higher dose of background radiation.

    **Receive increased medical diagnosi**

    **Live in a higher radon area.**

    **Increased cosmic rays from flying.**



# Uses of electromagnetic waves – **QuestionIT**

16. State which type of electromagnetic wave would be used for the following applications:

Sun tanning; Television remote; Medical imaging

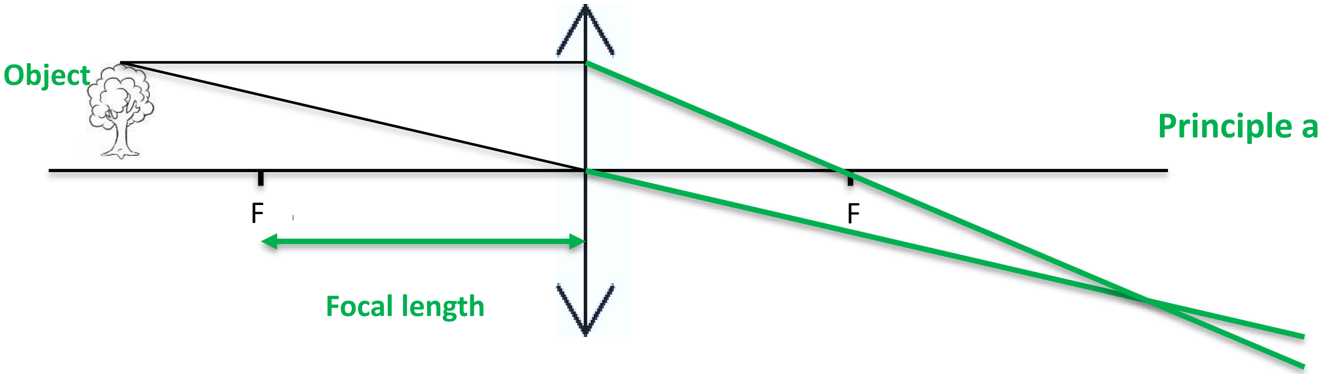
Ultraviolet Infrared X rays or gamma rays

17. (HT) Explain why radio waves are suitable for transmitting TV images to the home.

Travel long distances through the atmosphere.

# Lenses (physics only) – QuestionIT

18.



a. Copy and complete the two light rays on the diagram.

b. Label the principle axis, object and focal length on the diagram.

c. Describe the image produced by the above lens.

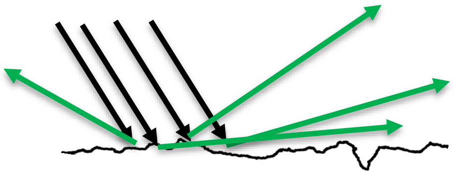
Inverted, laterally inverted, magnified, real

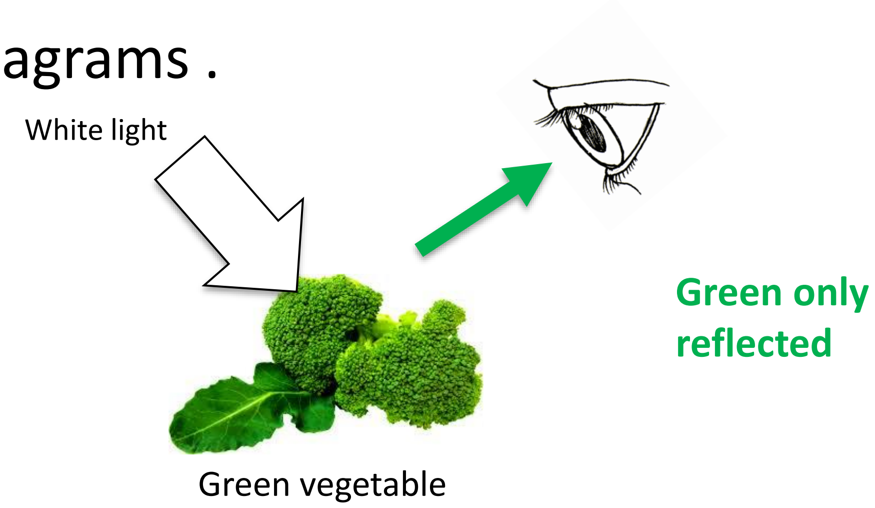
19. A 12cm object viewed in a convex lens has an image size of 54cm. Calculate the magnification of the lens.

Magnification = image height/object height = 54/12 = x4.5

# Visible light (physics only) – **AnswerIT**

20. Describe the difference between a transparent and a translucent object.
    Transparent- the object can be seen clearly.
    Translucent- object can be partially seen through it.
21. A vase is illuminated with green and blue light. What colour would the vase appear if viewed through a red filter?
    No colour (black).
22. Which colour of light has the shortest wavelength?
    Violet
23. Copy and complete the ray diagrams .





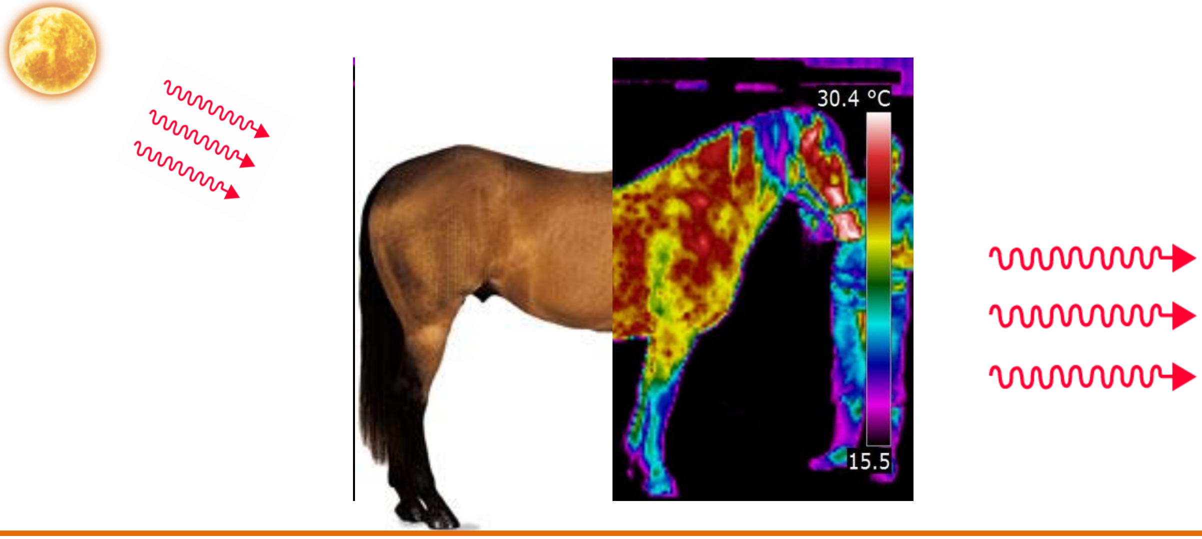
# LearnIT! KnowIT!

## Black body radiation
(physics only)

- Emission and absorption of infrared radiation
- Perfect black bodies and radiation

# Black body radiation (physics only)

All objects (bodies) absorb and reflect infrared radiation. The hotter the object is, the more infrared radiation it emits.

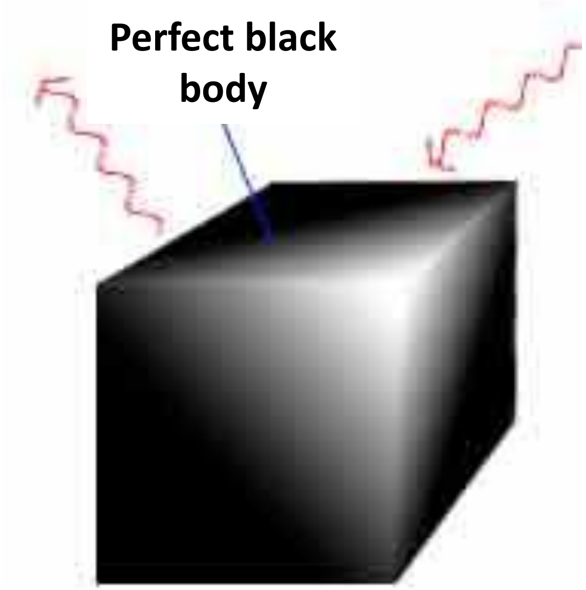


An infrared detecting camera is needed to "see" the heat radiated by the horse

The horse absorbs infrared heat from the sun and then re-radiates this heat, sometimes at a different wavelength.
The **intensity and wavelength** of energy radiated by the horse depends on its **temperature**.
If the horse is to remain at a constant temperature, it must radiate infrared heat energy at the same rate as it absorbs it. If the horse can not emit radiation as quickly as it is absorbed, its temperature will increase.

# Black body radiation (physics only)

A **perfect black body** is an object that **absorbs all of the radiation** incident on it. It **does not reflect or transmit any radiation**. Since a good absorber is a good emitter, a **perfect black body** would be the **best possible emitter**.



All bodies emit radiation.
The intensity and wavelength distribution of any emission depends on the temperature of the body.

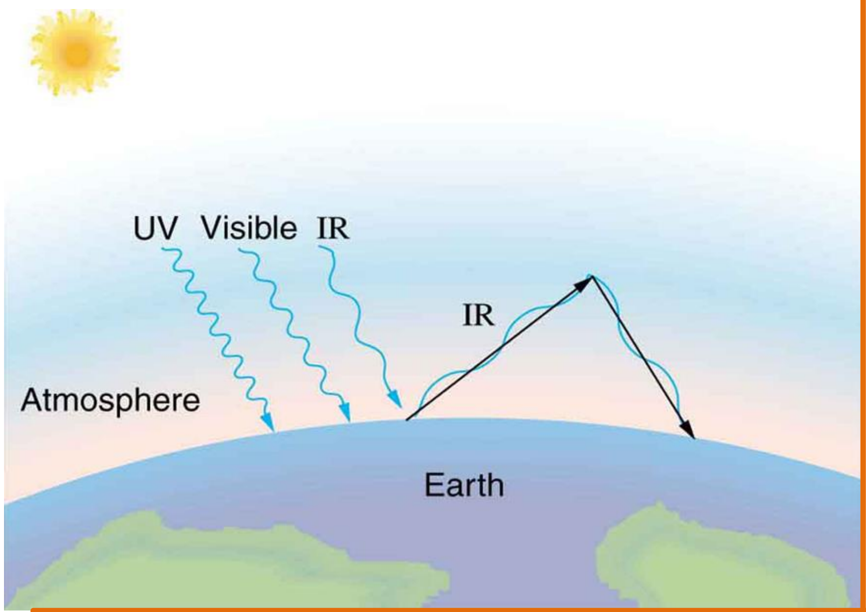
**Higher**: **Temperature**

A body at a constant temperature is absorbing radiation at the same rate as it is emitting radiation. The temperature of a body increases when the body absorbs radiation faster than it emits radiation.

The temperature of a body is related to the balance between incoming radiation absorbed and radiation emitted.

# Black body radiation (physics only)

The Earth behaves in a similar way to a black body.
Wavelengths of electromagnetic energy from the sun including **ultraviolet, visible light and infrared, penetrate the Earth's atmosphere** and heat up the surface of the Earth.



As the Earth heats up, it radiates infrared waves at a **longer wavelength** than those entering the atmosphere.
These longer wavelength infrared waves are **reflected back to Earth** by the upper atmosphere.
This prevents energy from being lost at the same rate as energy is received resulting in the Earth's temperature increasing. This is known as **global warming.**

Increased carbon dioxide in the atmosphere (from burning fuels) reduces the amount of radiation leaving the Earth. This results in a warming of the atmosphere (global warming). Snow and ice reflect incoming radiation. Global warming melts snow and ice resulting in further global warming.

# QuestionIT!

## Black body radiation
(physics only)

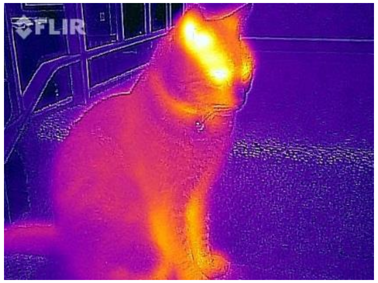
- Emission and absorption of infrared radiation
- Perfect black bodies and radiation

# Black body radiation (physics only) – QuestionIT

1. A black body is
   a. an object that emits no electromagnetic radiation.
   b. an object that absorbs all electromagnetic radiation that falls on it.
   c. an object that only emits invisible electromagnetic radiation.
   d. an object that absorbs all electromagnetic radiation that falls on it and emits no electromagnetic radiation.

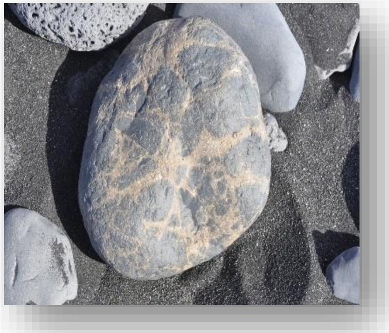
2. Explain how black body radiation differs from reflected radiation.

3. The picture shows a thermal image of a cat. Why can we not see this thermal emission from the cat without using a specialised camera?



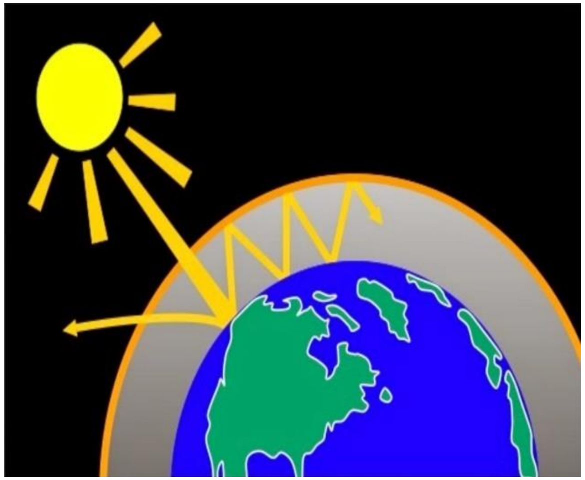
# Black body radiation (physics only) (HT) – QuestionIT

4. The stone is in the sunshine and emitting radiation.
   As the stone heats up through the day, how will the nature of the emitted radiation change?



5. If a body absorbs radiation at a faster rate than it emits radiation, what change will happen to the body?

6. The diagram shows how global warming of the Earth can occur.
   Explain what is happening in terms of changes to absorbed and emitted radiation.



# AnswerIT!

## Black body radiation
(physics only)

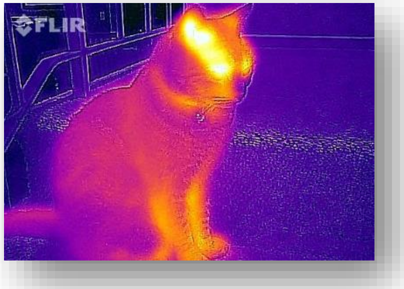
- Emission and absorption of infrared radiation
- Perfect black bodies and radiation

# Black body radiation – AnswerIT

1. A black body is
    - a. an object that emits no electromagnetic radiation.
    - **b. an object that absorbs all electromagnetic radiation that falls on it.**
    - c. an object that only emits invisible electromagnetic radiation.
    - d. an object that absorbs all electromagnetic radiation that falls on it and emits no electromagnetic radiation.
2. Explain how black body radiation differs from reflected radiation.

    **Black body radiation is radiation that is absorbed by an object and then re-radiated out, sometimes as a different wavelength.**
3. The picture shows a thermal image of a cat.

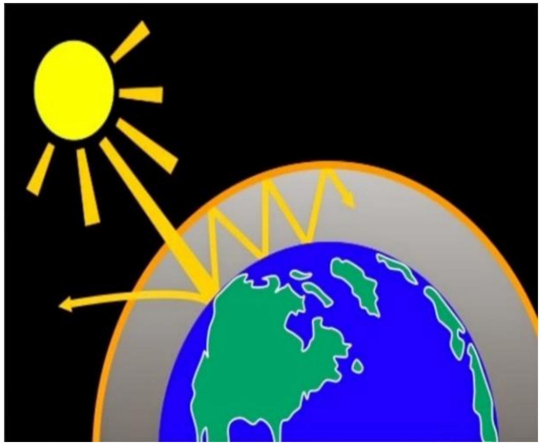
    Why can we not see this thermal emission from the cat without using a specialised camera?

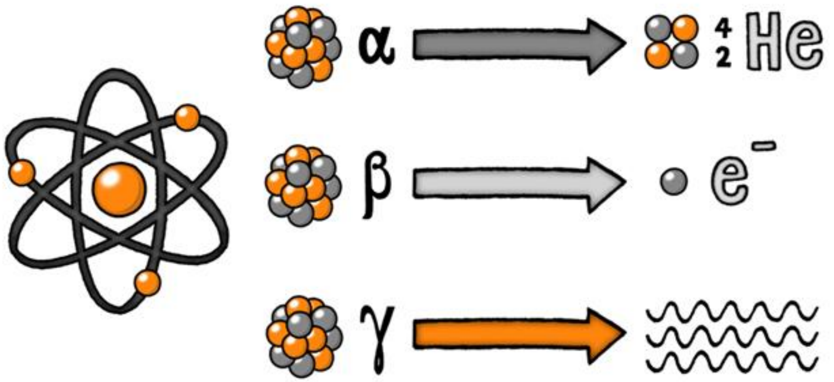


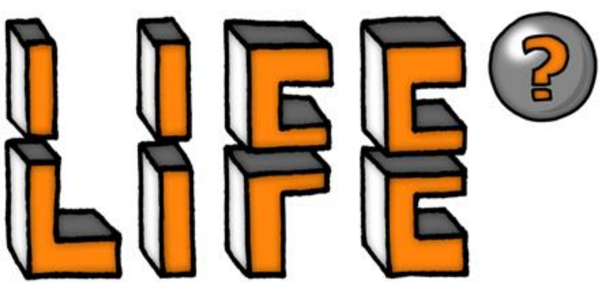
**The radiation is in the infrared range which humans can not see.**

# Black body radiation (HT) – AnswerIT

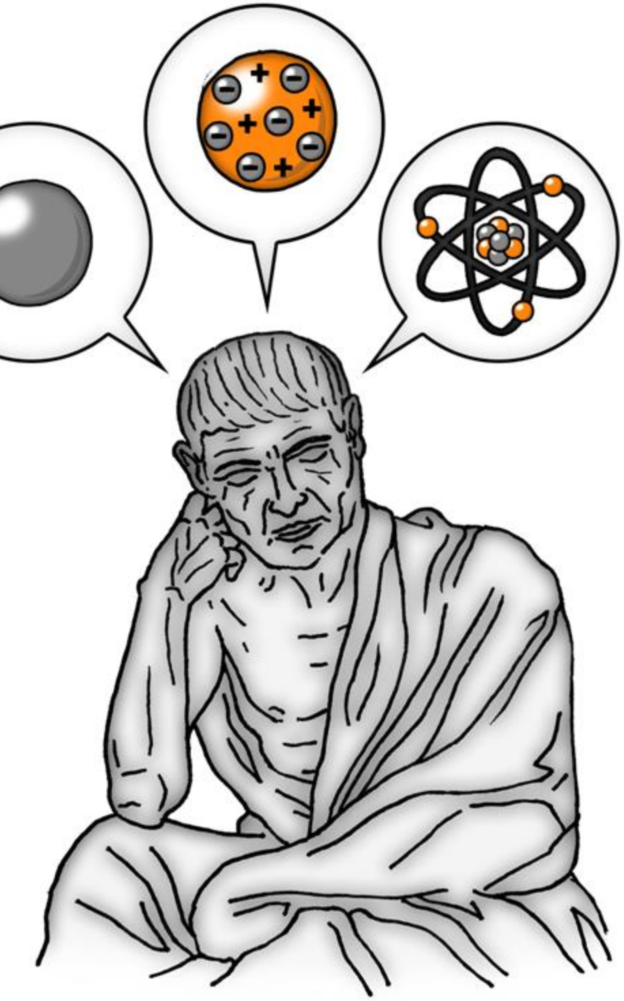
4. The stone is in the sunshine and emitting radiation. As the stone heats up through the day, how will the nature of the emitted radiation change?
   **It will be more intense and of a higher frequency.**
5. If a body absorbs radiation at a faster rate than it emits radiation, what change will happen to the body?
   **The body will increase in temperature.**
6. The diagram shows how global warming of the Earth can occur. Explain what is happening in terms of changes to absorbed and emitted radiation.
   **Radiation that can pass through the atmosphere reaches the Earth. This radiation will heat up the Earth's surface. The Earth will radiate infrared energy back out but at a wavelength that can not penetrate the atmosphere.**
   **The Earth will warm up as more radiation is being absorbed than emitted.**

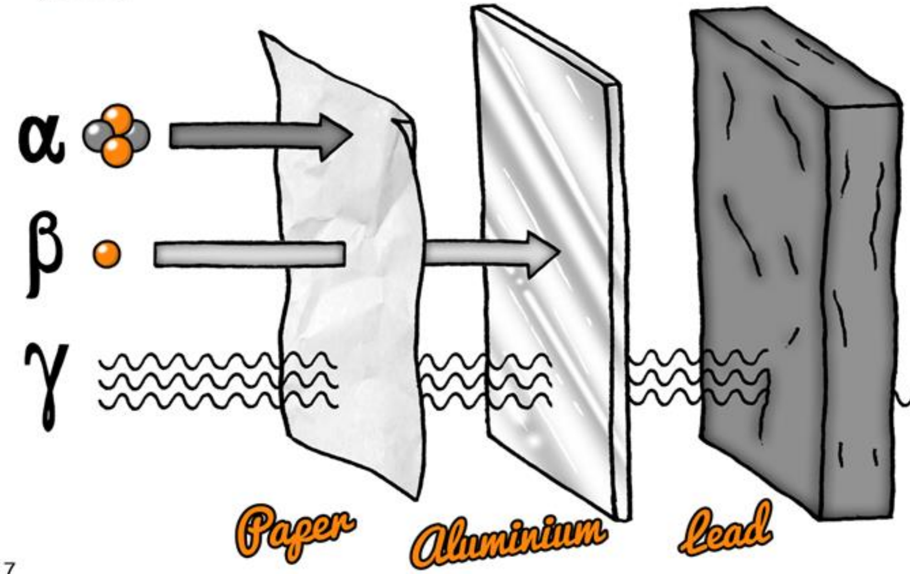






# Atomic Structure





# Overview
# Atomic structure

## Atoms and isotopes

- Structure of an atom
- Mass number, atomic number and isotopes
- Development of the atomic model

## Atoms and nuclear radiation

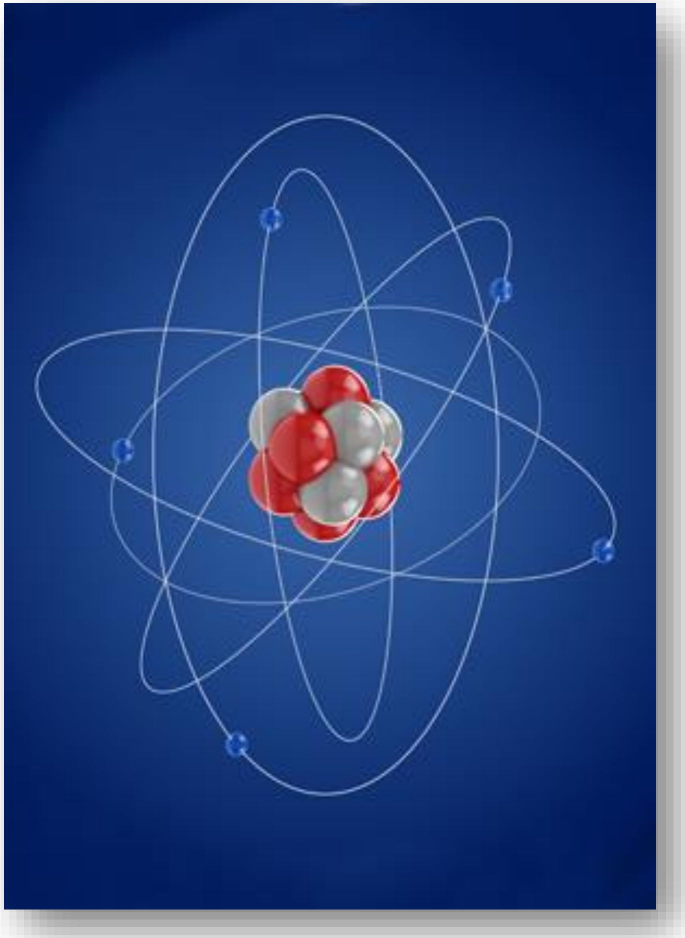
- Radioactive decay and nuclear radiation
- Nuclear equations
- Half lives and random nature of decay
- Radioactive contamination

## Hazards and uses of radioactive emissions (physics only)

- Background radiation
- Different half lives of radioactive isotopes
- Uses of nuclear radiation

## Nuclear fusion and fission (physics only HT)

- Nuclear fission
- Nuclear fusion



# LearnIT!
# KnowIT!

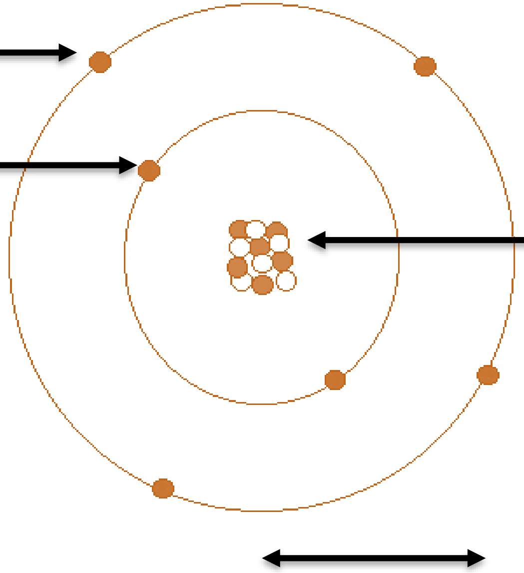
## Atoms and isotopes

- Structure of an atom
- Mass number, atomic number and isotopes
- Development of the model of the atom.

# Structure of an atom

**Atoms are made up of different numbers of protons, neutrons and electrons. Atoms have the same number of + protons as – electrons so they are electrically neutral.**

**An atom of Carbon**



**Electrons** (-1 charge) arranged in **orbits or energy levels** around the nucleus.

Energy levels can hold a maximum of:
2 e$^-$ in the first level
8 e$^-$ in the second level
8 e$^-$ in the third level

The radius of the nucleus is less than **1/10 000** the radius of the atom – the atom is **99.9999999%** empty space!

. 9 x $10^{13}$ atoms in this dot of ink

**Nucleus** made up of:

**Protons:** charge +1
**Neutrons:** charge 0

Nucleus of an atom has a positive charge

Radius of an atom **1 x $10^{-10}$m**

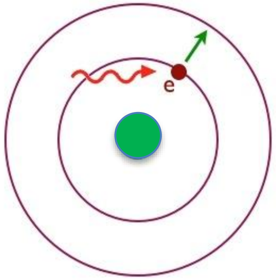
The nucleus holds **99%** of the mass of the atom

# Structure of an atom

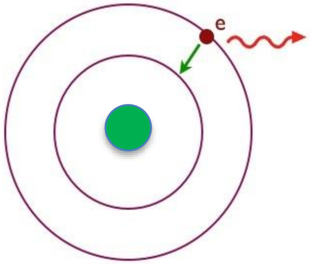
Electrons can absorb **electromagnetic radiation**. This excites the electron and can cause it to "jump" to a **higher energy level**. It can then release this energy as an electromagnetic wave by falling back to its original energy level.

Electromagnetic radiation

absorbed by the electron causes it to move to a higher energy level.



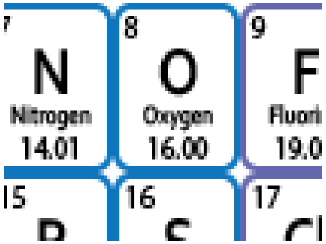
The electron can emit this stored energy as electromagnetic radiation. As it loses energy the electron returns to its original energy level.



**A photon is the amount of energy needed to make an electron jump an energy level. This same amount of energy will be emitted as a photon of electromagnetic radiation as the electron drops back to its original ground state.**

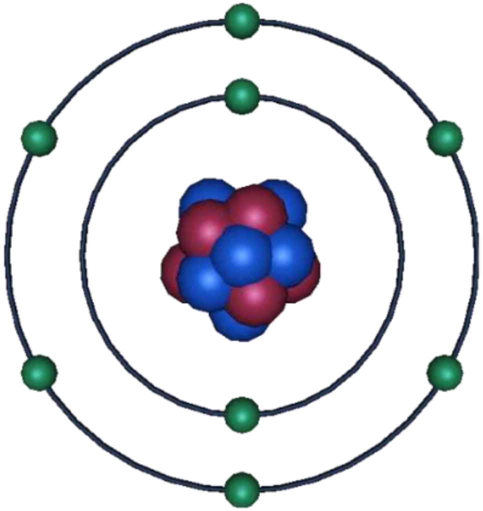
# Mass number, atomic number and isotopes

All atoms of a particular element have the **same number of protons**. The number of protons in an element is called its **atomic number**.



**Protons**
On the periodic table, **oxygen** is shown as having an **atomic number** of eight, therefore **8 protons**.

● Protons
● Neutrons
● Electrons



**Neutrons**
The total number of **protons and neutrons** in an atom is called its **mass number**. Oxygen has a mass number of 16. If it has 8 protons it must therefore have **8 neutrons** to make a mass number of 16.

**Electrons**
Atoms are electrically neutral so there must be the **same number** of electrons (-) as protons (+); **8 electrons**.

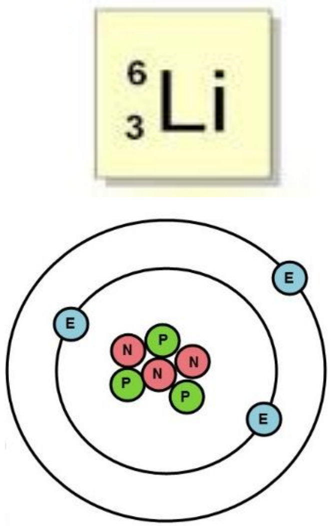
**Oxygen has: 8 protons, (16 – 8) = 8 neutrons, and 8 electrons**

# Mass number, atomic number and isotopes

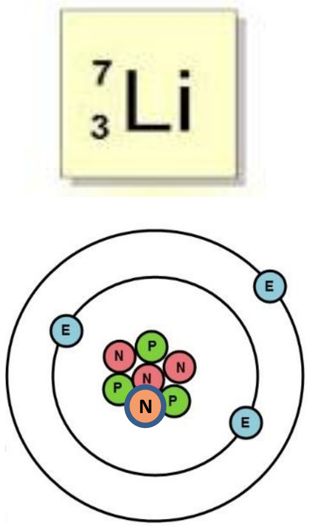
**Isotopes** are elements with **different atomic masses**.
The number of protons can not change or it would not be the same element so **an isotope is an element with different numbers of neutrons**.

Lithium has two stable isotopes, Lithium 6 and Lithium 7

Lithium 6 has
3 protons
3 neutrons



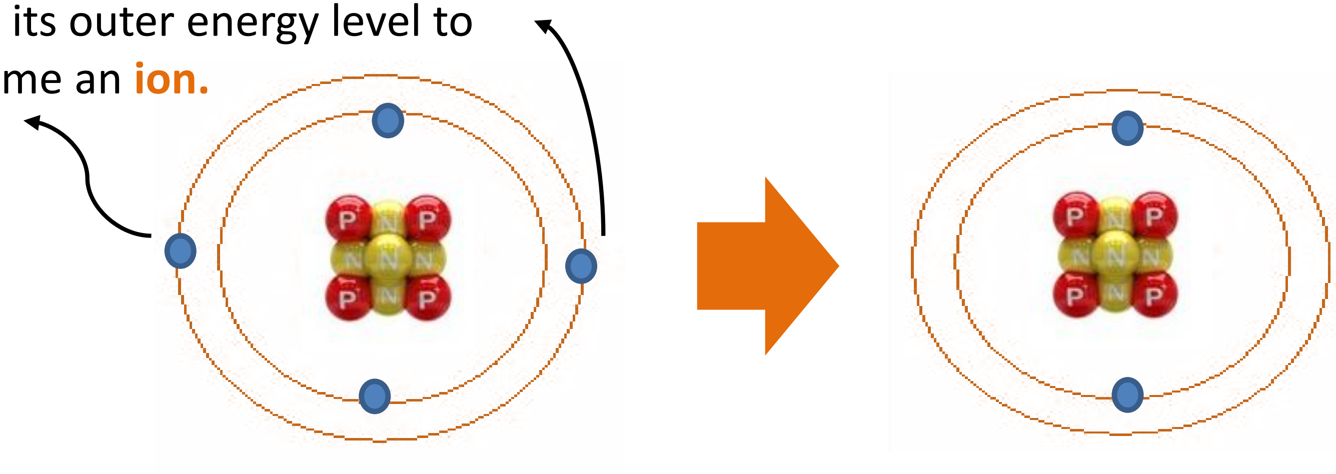
Lithium 7 has
3 protons
4 neutrons



Both isotopes have the **same number of protons** and the **same number of electrons**.
Only the number of **neutrons changes** in an isotope.

# Mass number, atomic number and isotopes

Atoms can form **ions** if they gain or lose **electrons.**
Atoms do this so they have **full outer energy levels.**



Beryllium **can lose 2 electrons** from its outer energy level to become an **ion.**

$$^{9}_{4}\mathrm{Be} \longrightarrow {}^{9}_{4}\mathrm{Be}^{2+}$$

If Beryllium
**loses 2 e$^-$**
it now has:

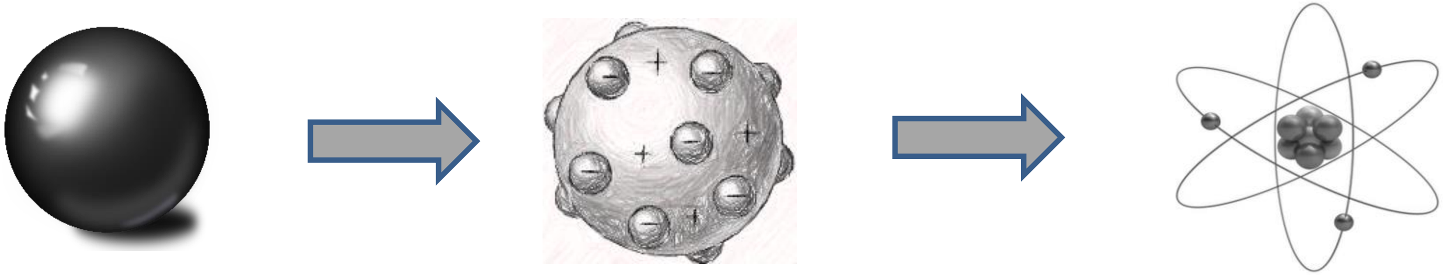
4 protons 4+
2 electrons 2-
2+

**Berylium $^{2+}$**

Atoms can **lose (-) electrons** to become **positive (+) ions**
or **gain (-) electrons** to become **negative (-) ions**.

# Development of the model of the atom

**Pre 1900** → **Pre 1911** → **1911 to present**



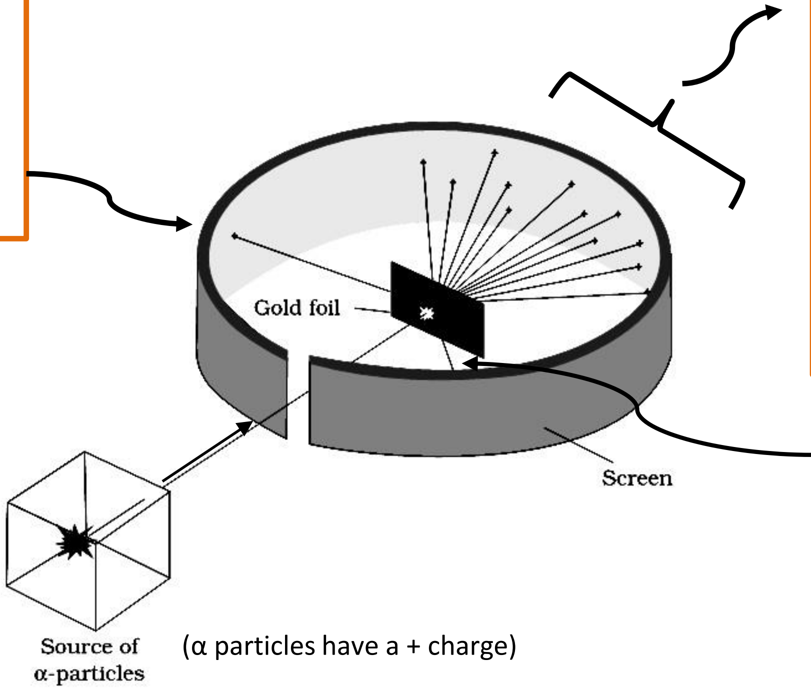
| Sphere | Plum pudding model | Nuclear model |
|---|---|---|
| **Before** the **discovery of the electron**, atoms were thought to be **tiny spheres that could not be divided**. | The **discovery of the electron** led to the **plum pudding model** of the atom. The **plum pudding model** suggested the **atom is a ball of positive charge with negative electrons embedded in it**. | • **Alpha scattering experiment** – mass of the atom is concentrated in the **nucleus, which is charged**.<br>• **Niels Bohr** – **electrons orbit nucleus** at **different distances**.<br>• **Later experiments** – **positive charge in nucleus** divided into whole number of **smaller particles with positive charge**.<br>• **James Chadwick** – 20 years after nucleus accepted – provided evidence for existence of **neutrons in nucleus**. |

## Atoms and isotopes – Development of the model of the atom

# Rutherford’s alpha scattering experiment

A beam of alpha particles are directed at a very thin gold foil screen.

A few (+) alpha particles are deflected by a positive nucleus within the gold atoms.



(α particles have a + charge)

Most (99.99%) of the alpha particles pass straight through the gold foil unaffected by its presence.

A tiny number of alpha particles are reflected because they collide with the nucleus of the gold atoms.

**Rutherford concluded that the gold atoms are mostly empty space with a positively charged nucleus that contains nearly all the mass of the atom.**

# QuestionIT!

## Atoms and isotopes

- Structure of an atom
- Mass number, atomic number and isotopes
- Development of the model of the atom.

# Atoms and isotopes - QuestionIT

1. The diameter of an atom is about 0.000 000 000 2 m. What is this distance in standard form?

2. What is the nucleus of an atom composed of?

3. Describe what happens when an electron drops to a lower energy level in an atom.

4. An atom of sodium is represented by: $^{23}_{11}\mathrm{Na}$

   Use this information to determine the number of protons, neutrons and electrons in an atom of sodium.

5. What is the electrical charge attached to:
   a neutron
   an electron
   a proton

# Atoms and isotopes - QuestionIT

6. What is the mass number and the atomic number for fluorine?

$$^{19}_{9}\mathrm{F}$$

7. Beryllium has the chemical symbol:

$$^{9}_{4}\mathrm{Be}$$

Use this information to draw a representation of an atom of beryllium.

8. A different isotope of beryllium has an extra neutron. Give the chemical symbol of this new isotope of beryllium.

# Atoms and isotopes – AnswerIT

9. The radioactive element Uranium has two common isotopes.

$$^{236}_{92}\mathrm{U} \quad \text{and} \quad ^{238}_{92}\mathrm{U}$$

Complete the table to show the number of protons, neutrons and electrons in each isotope.

| Isotope | Protons | Neutrons | Electrons |
|---|---|---|---|
| $^{236}_{92}\mathrm{U}$ | | | |
| $^{238}_{92}\mathrm{U}$ | | | |

10. Sodium can lose its outer electron to have a full outer energy level. What will the atom now become?

# Atoms and isotopes – AnswerIT

11. Which scientific discovery resulted in the solid atom theory being adapted into the “*plum pudding”* model of the atom?

12. Rutherford carried out an experiment to show alpha particles either passing through gold leaf, being scattered by it. Summarise the conclusions he made from this experiment.

13. What contribution did Niels Bohr make to the arrangement of electrons in the atomic model?

# AnswerIT!

## Atoms and isotopes

- Structure of an atom
- Mass number, atomic number and isotopes
- Development of the model of the atom.

# Atoms and isotopes - **AnswerIT**

1. The diameter of an atom is about 0.000 000 000 2 m. What is this distance in standard form?

   **$2 \times 10^{-10}$ m**

2. What is the nucleus of an atom composed of?

   **Protons and neutrons (except Hydrogen which has no neutrons).**

3. Describe what happens when an electron drops to a lower energy level in an atom.

   **It releases a photon of electromagnetic radiation.**

4. An atom of sodium is represented by: $^{23}_{11}\mathrm{Na}$

5. Use this information to determine the number of protons, neutrons and electrons in an atom of sodium.

   **Protons = 11 Neutrons = 12 Electrons = 11**

6. What is the electrical charge attached to:

| | |
|---|---|
| a neutron | **Neutral** |
| an electron | **Negative** |
| a proton | **Positive** |

# Atoms and isotopes - QuestionIT

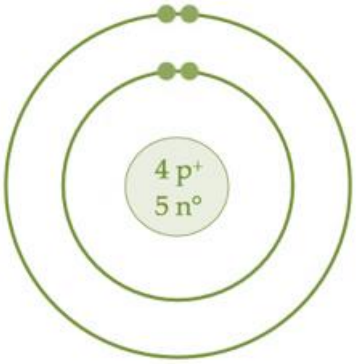
6. What is the mass number and the atomic number for fluorine?

Mass number = 19; atomic number = 9

$^{19}_{9}\mathrm{F}$

7. Beryllium has the chemical symbol:

$^{9}_{4}\mathrm{Be}$



Use this information to draw a representation of an atom of beryllium.

8. A different isotope of beryllium has an extra neutron. Give the chemical symbol of this new isotope of beryllium.

$^{10}_{4}\mathrm{Be}$

# Atoms and isotopes – AnswerIT

9. The radioactive element Uranium has two common isotopes.

$$^{236}_{92}\mathrm{U} \quad \text{and} \quad ^{238}_{92}\mathrm{U}$$

Complete the table to show the number of protons, neutrons and electrons in each isotope.

| Isotope | Protons | Neutrons | Electrons |
|---|---|---|---|
| $^{236}_{92}\mathrm{U}$ | 92 | 144 | 92 |
| $^{238}_{92}\mathrm{U}$ | 92 | 146 | 92 |

10. Sodium can lose its outer electron to have a full outer energy level. What will the atom now become?

**An ion with a charge of 1+**

# Atoms and isotopes – AnswerIT

11. Which scientific discovery resulted in the solid atom theory being adapted into the “*plum pudding*” model of the atom?

    **Discovery of the electron (in 1897).**

12. Rutherford carried out an experiment to show alpha particles either passing through gold leaf, being scattered off it. Summarise the conclusions he made from this experiment.

    **Most passing through suggests atoms are mostly empty space.**
    **Some being deflected suggests the nucleus has the same charge as the alpha particle (positive).**
    **A few reflected suggests the nucleus is where most of the mass of the atom is.**

13. What contribution did Niels Bohr make to the arrangement of electrons in the atomic model?

    **He realised that electrons orbit the nucleus in clearly defined energy levels, at different distances from the nucleus.**

# LearnIT! KnowIT!

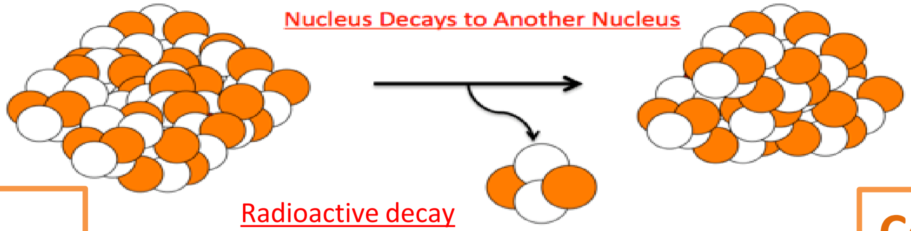
## Atoms and nuclear radiation

- Radioactive decay and nuclear radiation
- Nuclear equations
- Half life and the random nature of radioactive decay
- Radioactive contamination

# Radioactive decay and nuclear radiation

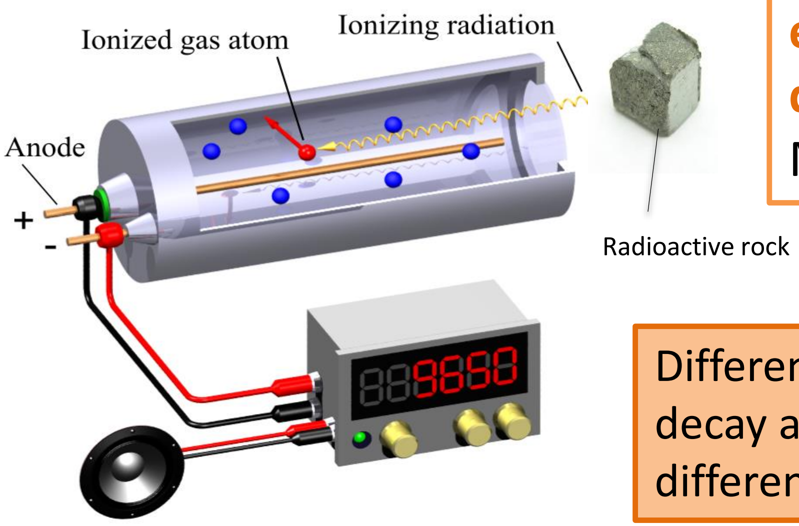
**The nuclei of some atoms are unstable.**
**To become more stable these nuclei give out radiation.**
**This process is called radioactive decay.**

Unstable atom



Stable atom

**Activity** = **rate at which a source of unstable nuclei decays**, measured in **becquerels (Bq).**

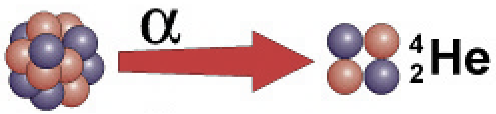


**Count-rate** = **number of decays recorded each second by a detector** (e.g. Geiger-Muller tube)

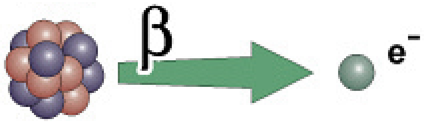
Different radioactive isotopes decay at different rates and emit different types of radiation.

# Radioactive decay and nuclear radiation

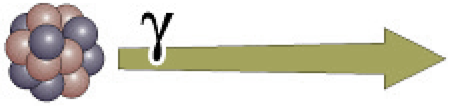
There are three types of radioactive decay, **alpha, beta and gamma**. All come from the **nucleus of the atom**. In the examples below, only the nucleus is shown.



**Alpha** (symbol α or $^4_2He$) consist of **2 protons and 2 neutrons** emitted from the nucleus. They have a **positive** charge as they contain 2 (+) protons.

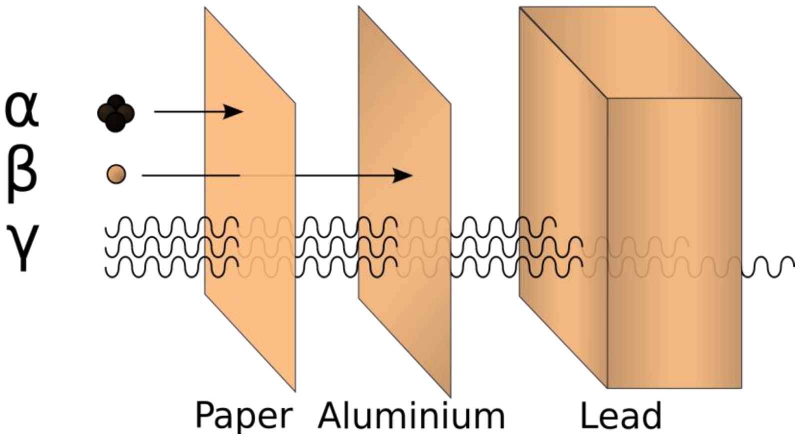


**Beta** (symbol β or $^0_{-1}e$ ) consist of an **electron** emitted from the nucleus. This results from a neutron splitting into a proton and an electron. Beta particles are **negatively** charged.



**Gamma rays** (symbol γ) are **electromagnetic radiation** emitted from the nucleus. Gamma radiation has **no mass** and **no electrical charge.**

# Properties of alpha, beta and gamma radiation.



Alpha, beta and gamma radiation can penetrate different materials due to their differing nature.

**Alpha** – easily stopped by **a few sheets of paper**.

**Beta** – penetrates paper but stopped by a thin **sheet of aluminium**.

**Gamma** – only stopped by **thick lead** or several metres of **concrete**.

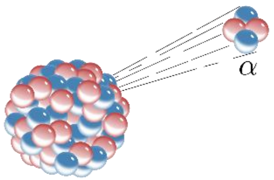
All three types of radiation cause **ionisation** of other atoms. If these atoms are in **living cells** it can cause damage which could lead to **cancer.**

| **Name** | **Symbol** | **Speed** | **Range in air** | **Ionising power** |
|---|---|---|---|---|
| **Alpha** | α | Slowest | 6 - 8 cm | High |
| **Beta** | β | Medium | 1 – 2 m | Medium |
| **Gamma** | γ | Fastest | 300 - 500 m | Low |

# Nuclear equations

**Nuclear equations show the changes to an atom when it emits radiation.**

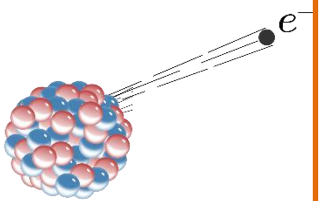
**Alpha emission**



Nucleus **loses 2 protons** and **2 neutrons**.
**Atomic number will reduce by 2 and atomic mass by 4**.

$${}^{238}_{92}\mathrm{U} \longrightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

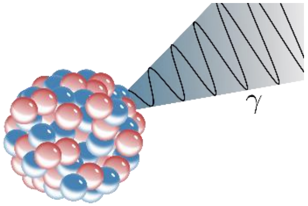
**Beta emission**



Nucleus **loses an electron** which is produced when a neutron turns into a proton. So **mass stays the same** but **atomic number of the product increases by one**.

$${}^{14}_{6}\mathrm{C} \longrightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\mathrm{e}$$

**Gamma emission**



No particles are emitted so there is **no change to the nucleus**. Atomic mass and atomic number stay the same.

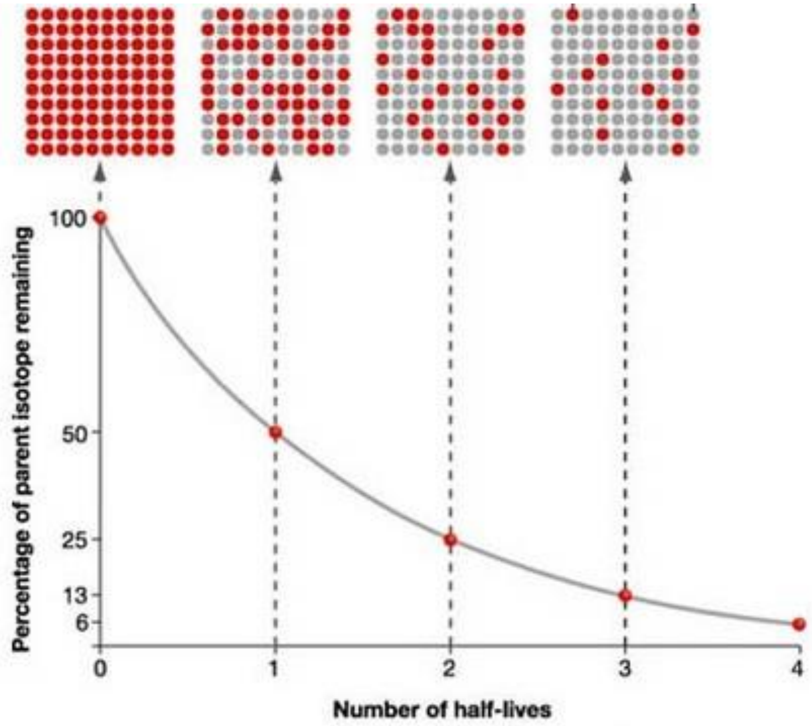
$${}^{99}_{43}\mathrm{Tc} \longrightarrow {}^{99}_{43}\mathrm{Tc} + \gamma$$

# Half life and the random nature of radioactive decay

Radioactive decay is a random process so the likelihood of a decay taking place is a probability problem. For this reason, the **half-life** of an isotope is given rather than saying how long it will take to fully decay.

The **half-life** of a radioactive isotope is the time it takes for the **number of nuclei** of the isotope in the sample to halve, or the time it takes for the **count rate** from a sample containing the isotope to fall to half its initial level.

The net decline of the isotope is the fraction remaining after a number of half lives.
E.g. 100 → 50 → 25
After 2 half lives net decline is 75/100 = **3/4**



# Half life and the random nature of radioactive decay

## Calculating the half life of a radioactive isotope.

If you know the start and finish count rate and the time taken, you can calculate the half life.

Example:

The count rate of an isotope is 1008 Bq. This falls to a count rate of 126 over a period of 21 days.

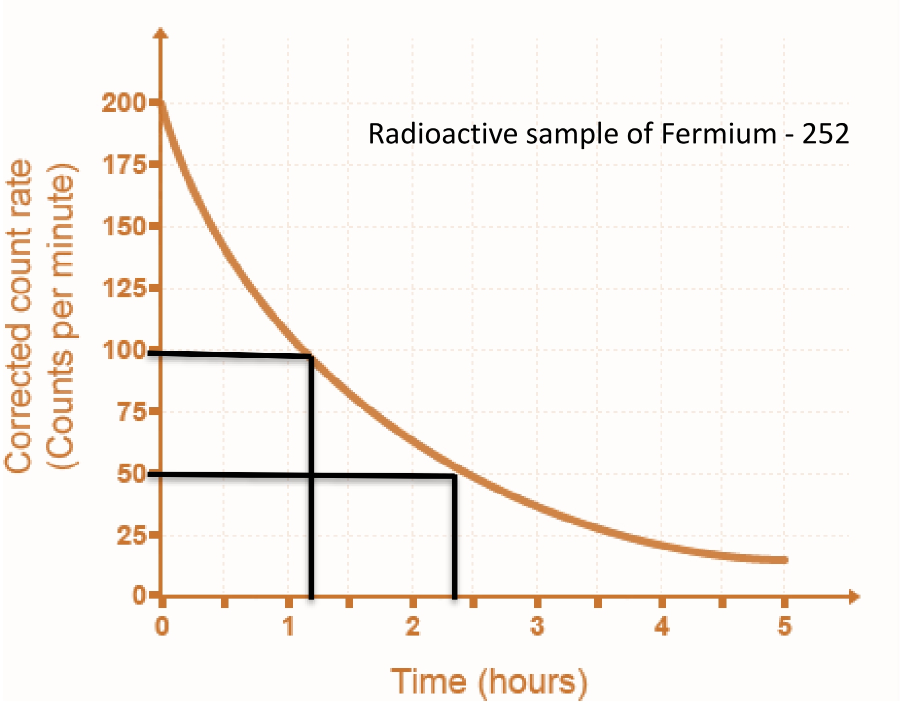
1008 → 504 → 252 → 126

1 2 3

3 half lives for count rate to fall to 126.

These 3 half lives took 21 days so each half life took 7 days.

**Half life if this isotope = 7 days**



**200 counts / min** at the beginning.

**100 counts/min** occurred after 1.2 hours.

**50 counts/min** occurred after 2.4 hours.

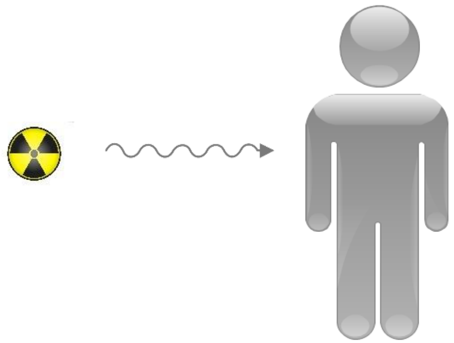
It always takes 1.2 hours for the count rate to halve.

**Half life of Fermium - 252 = 1.2 hours.**

# Radioactive contamination

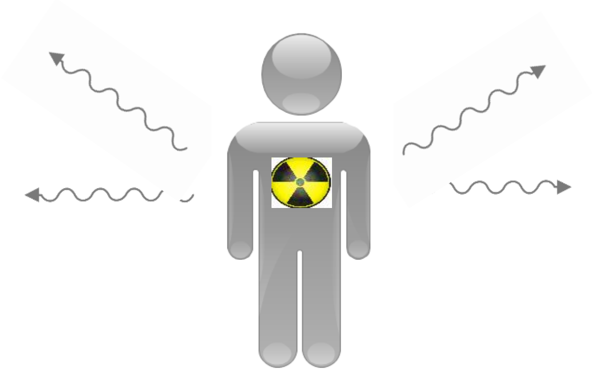
Radioactive substances can be hazardous by contamination or irradiation.

**Irradiation** is when an object or person is **exposed** to radiation. Protection from irradiation means stopping the radiation from reaching you.



Medical dressings are often irradiated but present no danger to the user.

**Contamination** is when a radioactive source is in **contact** with an object or person. The radioactive substance rather than the emissions are present.



The object remains radioactive until the contamination is removed or decays naturally.

# QuestionIT!

## Atoms and nuclear radiation

- Radioactive decay and nuclear radiation
- Nuclear equations
- Half life and the random nature of radioactive decay
- Radioactive contamination

# Atoms and nuclear radiation – QuestionIT

1. Which part of an atom is involved with radioactive decay?

2. Explain the meaning of the term activity, as applied to radioactive materials and state the units of activity.

3. What is meant by the term “count rate”?

4. Copy and complete the table to show the nature of alpha, beta and gamma radiations.

| **Radiation** | **Symbol** | **Composition** | **Electrical charge** |
|---|---|---|---|
| **Beta** | **β** | | |
| **Gamma** | | **Electromagnetic wave** | |
| **Alpha** | | | **+2** |

# Atoms and nuclear radiation – **QuestionIT**

5. A piece of radioactive rock shows a reading of 350 counts/min. When covered in aluminium foil, this drops down to 4 counts/min. Explain which type of radiation this rock is emitting.

6. Radioactive emissions are often described as ionising radiations. What does this mean?

7. Smoke detectors use americium-241 which is an alpha emitter. Explain why an alpha source is used in these detectors.

8. Why is an alpha particle often described as a helium nuclei?

9. Complete the nuclear equation for the beta decay of carbon.

$$^{14}\mathrm{C} \longrightarrow {}^{14}_{7}\mathrm{N} \;+$$

## Atoms and nuclear radiation – QuestionIT

10. Uranium-235 undergoes an alpha decay to produce thorium-231. (atomic number of uranium is 92). Complete the nuclear equation for this process.

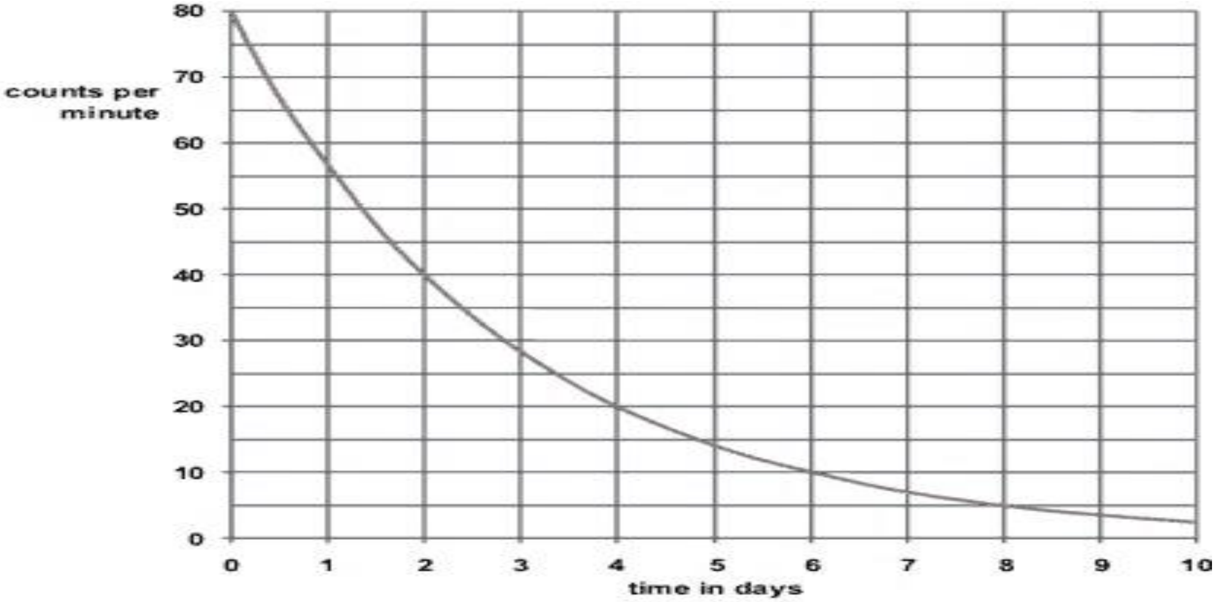
11. When iodine 131 decays, there is no mass change in the nucleus and no new products formed. What type of radioactive emission is this?

12. Explain what is meant by the term “half life”.

13. A radioactive sample reduces its count rate from 240 counts/min to 30 counts/min over a period of 60 hours what is its half life?

# Atoms and nuclear radiation – **QuestionIT**

14. Use the decay curve below to work out the half-life of the isotope.



15. (Physics only) Calculate the net decline of the above isotope expressed as a ratio, during radioactive emission after 3 half-lives.

# Atoms and nuclear radiation – QuestionIT

16. Explain the difference between radioactive irradiation and radioactive contamination.

17. Copy and complete the table below to suggest one way of preventing exposure to irradiation and contamination by radioactive materials.

| Type of exposure | Method of preventing exposure |
|---|---|
| **Irradiation** | |
| **Contamination** | |

# AnswerIT!

## Atoms and nuclear radiation

- Radioactive decay and nuclear radiation
- Nuclear equations
- Half life and the random nature of radioactive decay
- Radioactive contamination

# Atoms and nuclear radiation – AnswerIT

1. Which part of am atom is involved with radioactive decay?

   **The nucleus only.**

2. Explain the meaning of the term activity as applied to radioactive materials and state the units of activity.

   **The rate at which a source of unstable nuclei decays. Units Bq.**

3. What is meant by the term "count rate"?

   **The number of radioactive decays recorded in a given time.**

4. Copy and complete the table to show the nature of alpha, beta and gamma radiations.

| Radiation | Symbol | Composition | Electrical charge |
|---|---|---|---|
| **Beta** | **β** | **an electron** | **-1** |
| **Gamma** | **γ** | **Electromagnetic wave** | **0** |
| **Alpha** | **α** | **2 protons and 2 neutrons** | **+2** |

# Atoms and nuclear radiation – AnswerIT

5. A piece of radioactive rock shows a reading of 350 counts/min. When covered in aluminium foil, this drops down to 4 counts/min. Explain which type of radiation this rock is emitting.

   **Could be alpha or beta as both would be stopped by the foil and gamma would not be stopped by the foil.**

6. Radioactive emissions are often described as ionising radiations. What does this mean?

   **The emissions knock off electrons from atoms which then become ions.**

7. Smoke detectors use americium-241 which is an alpha emitter. Explain why an alpha source is used in these detectors.

   **Alpha particles are easily stopped by smoke.**

   **They do not travel far in air so are safe for the user.**

8. Why is an alpha particle often described as a helium nuclei?

   **It contains 2 protons and 2 neutrons, the same as the nucleus of a helium atom.**

9. Complete the nuclear equation for the beta decay of Carbon.

$${}^{14}_{6}\mathrm{C} \longrightarrow {}^{14}_{7}\mathrm{N} + {}^{0}_{-1}\mathrm{e}$$

# Atoms and nuclear radiation – AnswerIT

10. Uranium-235 undergoes an alpha decay to produce thorium-231. (atomic number of Uranium is 92). Complete the nuclear equation for this process.

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

11. When iodine 131 decays, there is no mass change in the nucleus and no new products formed. What type of radioactive emission is this?

**Gamma emission**

12. Explain what is meant by the term “half life”.

**The time it takes a radioactive sample to lose half its radioactivity (as measured by count rate).**

13. A radioactive sample reduces its count rate from 240 counts/min to 30 counts/min over a period of 60 hours what is its half life?

$$\boxed{240} \xrightarrow[1]{} \boxed{120} \xrightarrow[2]{} \boxed{60} \xrightarrow[3]{} \boxed{30}$$

**Three half lives in 60 hours = 20 hour half life**

# Atoms and nuclear radiation – QuestionIT

14. Use the decay curve below to work out the half-life of the isotope.

80 = 0 day; 40 = 2 days. Difference = 2 days. Half-life = 2 days

14. (Physics only) Calculate the net decline of the above isotope expressed as a ratio, during radioactive emission after 3 half-lives.

Counts/ min reduce from 80 to 10 in 3 half-lives.
Decline is 70/80 or 7/8ths

# Atoms and nuclear radiation – **AnswerIT**

16. Explain the difference between radioactive irradiation and radioactive contamination.
    **Irradiation is exposure to emissions from radioactive materials that are not in contact with an object. Contamination is when radioactive materials are in contact with the object.**
17. Copy and complete the table below to suggest one way of preventing exposure to irradiation and contamination by radioactive materials.

| Type of exposure | Method of preventing exposure |
|---|---|
| **Irradiation** | Wear protective clothing, e.g., lead apron, to shield from radiation.<br>Move away from the radiation.<br>Shield the radiation with appropriate material. |
| **Contamination** | Avoid contact with radioactive materials.<br>Prevent radioactive materials being released into the environment. |

# LearnIT!
# KnowIT!

## Hazards and uses of radioactive emissions and of background radiation

(Physics only)

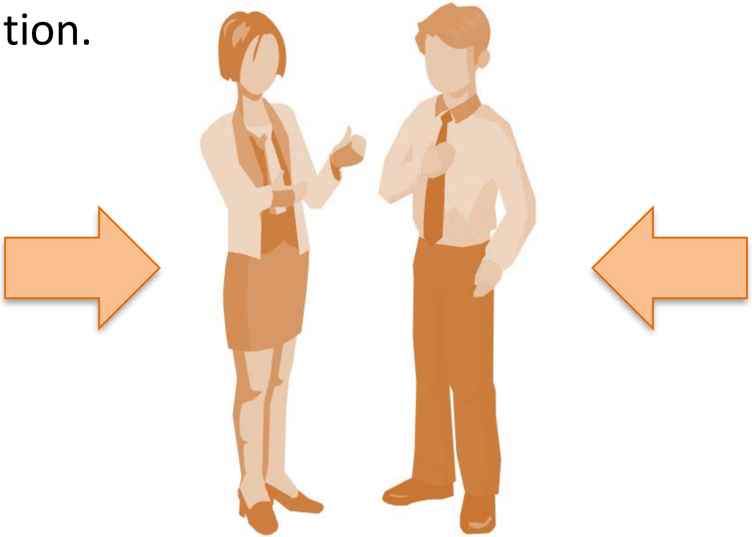
- Background radiation
- Different half lives of radioactive isotopes
- Uses of nuclear radiation

# Background radiation

**Background radiation** is the constant , low level radiation in the environment. This can be natural radiation from rocks, building materials, cosmic rays etc. **Radioactive pollution** from nuclear testing, nuclear power and industrial/medical waste also contributes to background radiation.

Sources of radioactive exposure and contamination.

- ● 14% Medicine
- ● 1% Nuclear Industry
- ● 42% Radon
- ● 18% Buildings/Soil
- ● 14% Cosmic
- ● 11% Food/Drinking Water
- ○ 85% Natural Radiation



Radiation dose is measured in: **sieverts (Sv)**

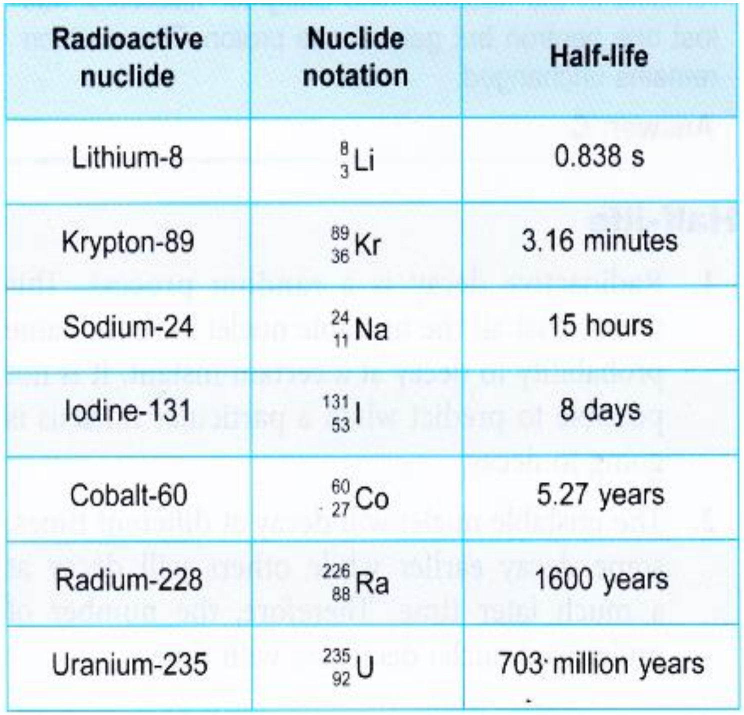
1 Sv = 1000 millisieverts

Everyone receives background radiation but people who **work or live** in locations with high levels of radiation **receive additional doses of radiation**.
Some nuclear workers, medical staff, military and industrial workers may have higher doses due to working with radioactive sources.

# Different half lives of isotopes

Radioactive isotopes have an enormous range of half-lives.

**Examples of the range of half-lives of radioactive materials**



| Radioactive nuclide | Nuclide notation | Half-life |
|---|---|---|
| Lithium-8 | $^{8}_{3}\mathrm{Li}$ | 0.838 s |
| Krypton-89 | $^{89}_{36}\mathrm{Kr}$ | 3.16 minutes |
| Sodium-24 | $^{24}_{11}\mathrm{Na}$ | 15 hours |
| Iodine-131 | $^{131}_{53}\mathrm{I}$ | 8 days |
| Cobalt-60 | $^{60}_{27}\mathrm{Co}$ | 5.27 years |
| Radium-228 | $^{226}_{88}\mathrm{Ra}$ | 1600 years |
| Uranium-235 | $^{235}_{92}\mathrm{U}$ | 703 million years |

**Half-life and hazard**

Radioactive isotopes with a **short half- life** often give **high doses** of radiation in a short period of time so are often dangerous.

**Long half-life** isotopes are **low dose** hazards but they are around for a very **long time**.

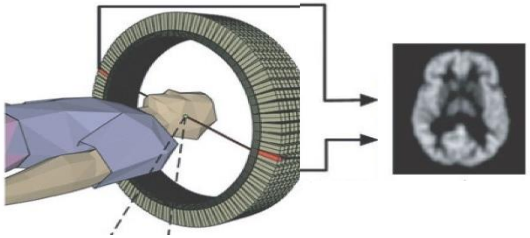
Uranium-238 is the main fuel producer for the nuclear industry but is so slow at emitting radiation it is often considered quite safe by scientists.

Products of the nuclear industry such as Iodine-131 are much more dangerous as they emit radiation at a much faster rate and are soluble so they get into the food chain much more easily.

# Uses of nuclear radiation (medical)

**Nuclear radiations** are used as **tracers** in the body to explore possible injury or disease of internal organs.

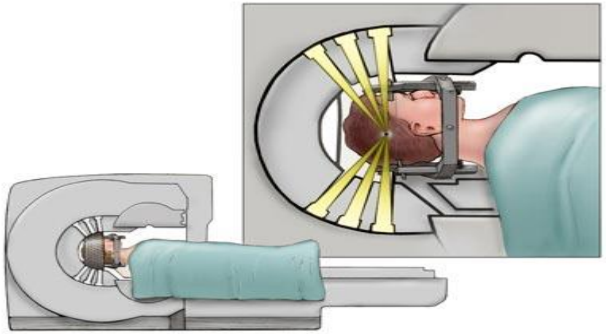
A **radioactive isotope** is either injected or ingested into the body, given time to circulate and **accumulate in damaged areas.** Then the emissions radiating out of the body are detected.



A camera such as a gamma detector or a PET scanner detects any accumulation of the tracer.

Tracers have to be **beta or gamma** emitters as alpha does not penetrate the body. The tracer must also have a **very short half-life** to minimise dosage.

**Radiation therapy** is used to treat illnesses such as cancer. **Cancer cells** are living cells and so are killed off by relatively high doses of **gamma rays**.



Here, the gamma rays are directed from the outside. The high dose required to kill the cancer cells will also kill healthy cells. The technique uses a 3 dimensional set of gamma ray guns all focussed on the cancer cells.

This **kills the cancer** cells while minimising the damage **healthy cells**.

# QuestionIT!

## Hazards and uses of radioactive emissions and of background radiation (Physics only)

- Background radiation
- Different half lives of radioactive isotopes
- Uses of nuclear radiation

# Hazards and uses of radioactive emissions and of background radiation (Physics only) – QuestionIT

1. Describe sources of background radiation, clearly identifying which are natural and which are man-made.

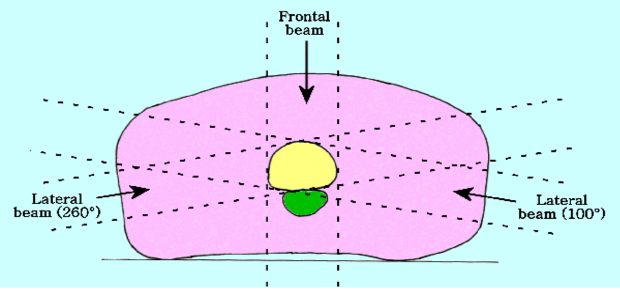
2. Describe **two** occupations where the radiation dose received by workers is likely to be higher than the background radiation.

3. Lithium-8 is a beta emitter with a half life of 0.8 s. What precautions would you take when working with this isotope?

# Hazards and uses of radioactive emissions and of background radiation (Physics only) – QuestionIT

4. Radium - 226 is an alpha emitter with a half-life of 1600 years. Explain how the way this material is stored is influenced by these properties.

5. The diagram shows how three separate gamma beams are used to treat a cancer tumour. Why is this preferred to using one powerful beam?



6. Alpha emitting radioisotopes cannot be used as tracers in the body to explore injured or diseased organs. Why?

# AnswerIT!

## Hazards and uses of radioactive emissions ar of background radiation (Physics only)

- Background radiation
- Different half lives of radioactive isotopes
- Uses of nuclear radiation

# Hazards and uses of radioactive emissions and of background radiation (Physics only) – AnswerIT

1. Describe sources of background radiation, clearly identifying which are natural and which are man made.

   **Natural – rocks, cosmic radiation, building materials**

   **Man made – fallout from nuclear weapons testing, nuclear power accidents, industrial and medical waste.**

2. Describe **two** occupations where the radiation dose received by workers is likely to be higher than the background radiation.

   **Working in the nuclear industry, as a radio-medical worker, working with radioisotopes in industry.**

3. Lithium-8 is a beta emitter with a half life of 0.8 s. What precautions would you take when working with this isotope?

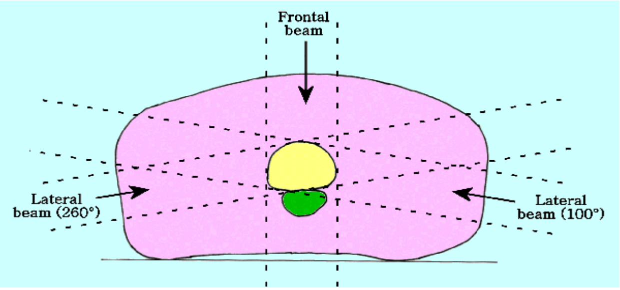
   **Take care not to ingest any material or come into contact with it (gloves, safety glasses, lab coat).**

   **Isolate the material for 24 hours to allow it to decay to a safe level.**

# Hazards and uses of radioactive emissions and of background radiation (Physics only) – AnswerIT

4. Radium - 226 is an alpha emitter with a half-life of 1600 years. Explain how the way this material is stored is influenced by these properties.

**Any sealed container will prevent radiation escaping as alpha particles are not very penetrating. Radioactive material will need to be placed in permanent storage, buried underground, as it will be radioactive for a very long time.**



5. The diagram shows how three separate gamma beams are used to treat a cancer tumour.

Why is this preferred to using one powerful beam?

**Single beam will damage both healthy or cancer cells but all three beams are focussed on the tumour so these cells receive a triple dose of radiation to kill them and reduces harm to healthy cells.**

6. Alpha emitting radioisotopes cannot be used as tracers in the body to explore injured or diseased organs. Why?

**Alpha particles are highly ionising so they will cause damage to bodily cells. They are also easily absorbed by body tissue so they will not escape the body to be detected.**

# LearnIT!
# KnowIT!

## Nuclear fusion and fission (physics only – Higher Tier)

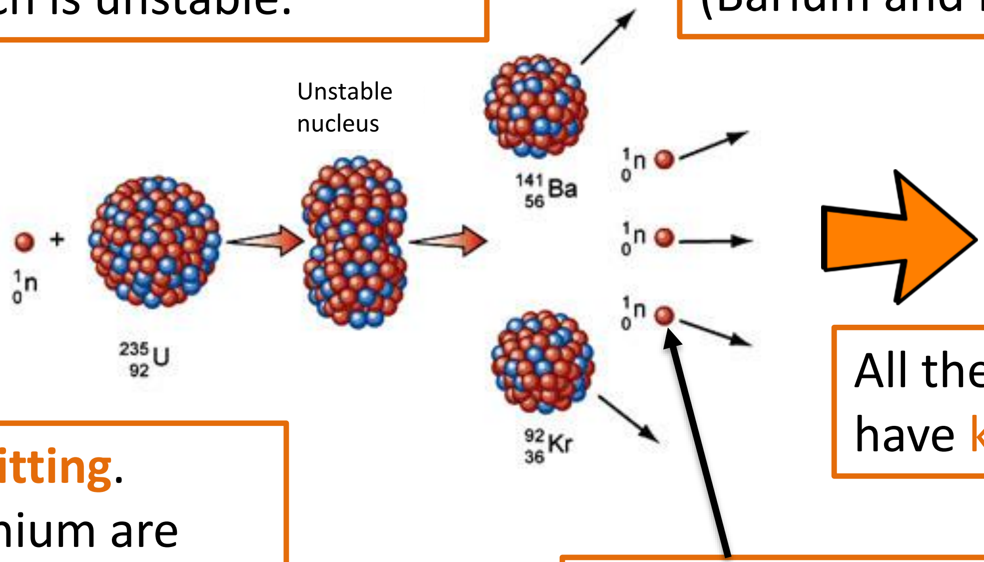
- Nuclear fission
- Nuclear fusion

# Nuclear fission and fusion (physics only HT) – Nuclear fission

Nuclear fission is the splitting of large, unstable atoms into two or more atoms along with the release of energy.

Here, a nucleus of Uranium - 235 is **bombarded with a neutron** to form Uranium 236 which is unstable.

Two **smaller elements** are produced in this fission process (Barium and Krypton).



**ENERGY**

All the fission products have kinetic energy

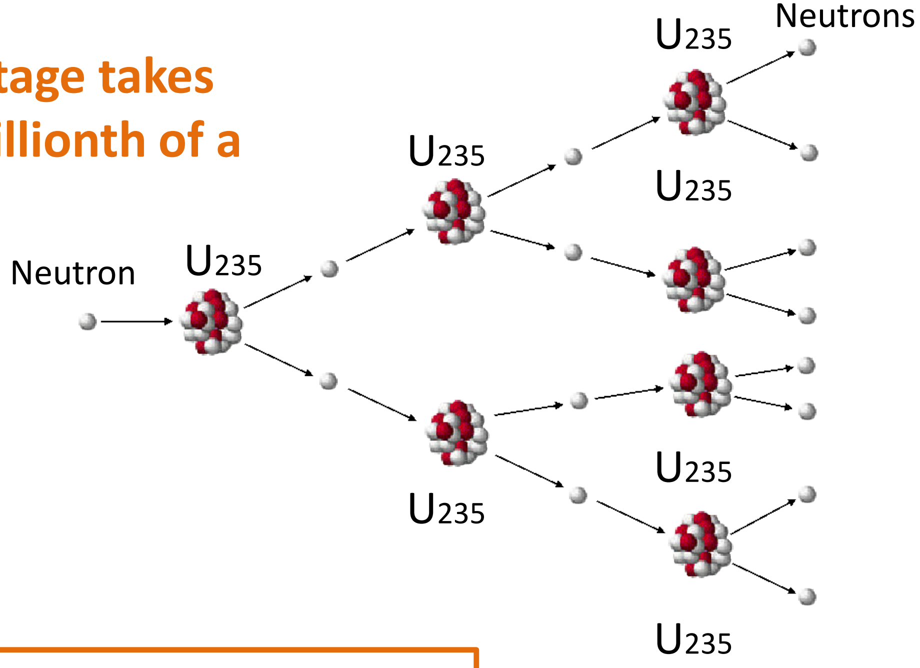
**Fission** means **splitting**. Uranium or Plutonium are often used in nuclear reactors to produce heat as their nuclei are easy to split.

These **neutrons** may go on to **split further Uranium atoms**.

# Nuclear fission and fusion (physics only HT) – Nuclear fission

Nuclear **fission releases more neutrons** which can lead to further fission reactions.
If this is uncontrolled a **chain reaction** can occur which will release **vast amounts of energy**.

**Each fission stage takes less than a millionth of a second!**



If the chain reaction is **not controlled** a vast amount of energy is released almost instantly. This is how a **nuclear weapon** works.

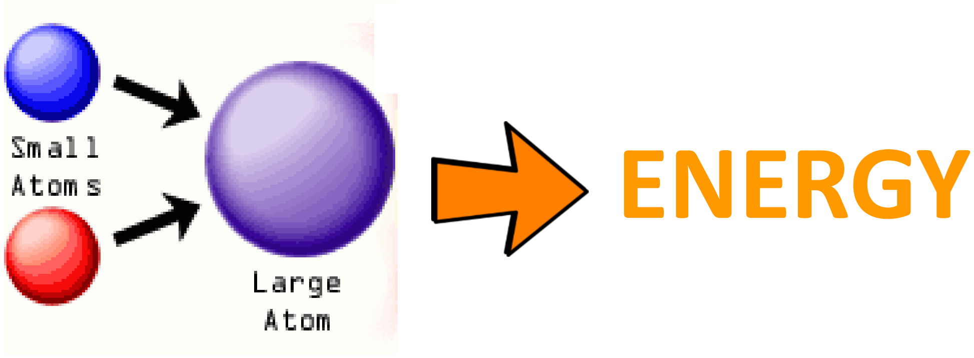
In a **nuclear reactor**, some of the **neutrons are absorbed** by boron rods to **control the reaction** and hence control the amount of energy released.

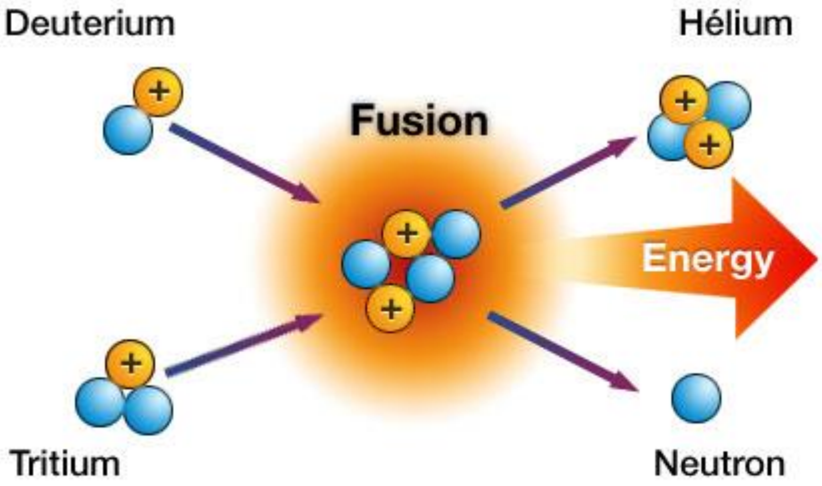
# Nuclear fission and fusion (physics only HT) – Nuclear fusion

Nuclear **fusion** is the **joining** of two small (light) nuclei to form a larger nucleus.

When two small nuclei join to form a larger nucleus, a small amount of **mass** is changed **into** a large amount of **energy**.

**Fusion** reactions take place in **stars** to release vast amounts of energy. Here, two types of hydrogen nuclei, deuterium and tritium, fuse to form helium and release a neutron plus energy.





# QuestionIT!

## Nuclear fusion and fission (physics only – Higher Tier)

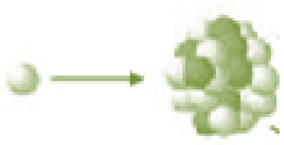
- Nuclear fission
- Nuclear fusion

# Nuclear fission and fusion (Physics only) – QuestionIT

1. Which particle is needed to begin the fission of a large, unstable nuclei?

2. During the fission of uranium, two smaller nuclei are produced and what else?

3. Copy and complete the diagram below to show the chain reaction of a sample of uranium



# Nuclear fission and fusion (Physics only) – **QuestionIT**

4. Explain what is meant by a controlled chain reaction.

5. What is nuclear fusion?

6. Where does nuclear fusion take place on a large scale?

7. Draw a diagram to show the process of fusion between deuterium and tritium to produce energy.

# AnswerIT!

## Nuclear fusion and fission (physics only – Higher Tier)

- Nuclear fission
- Nuclear fusion

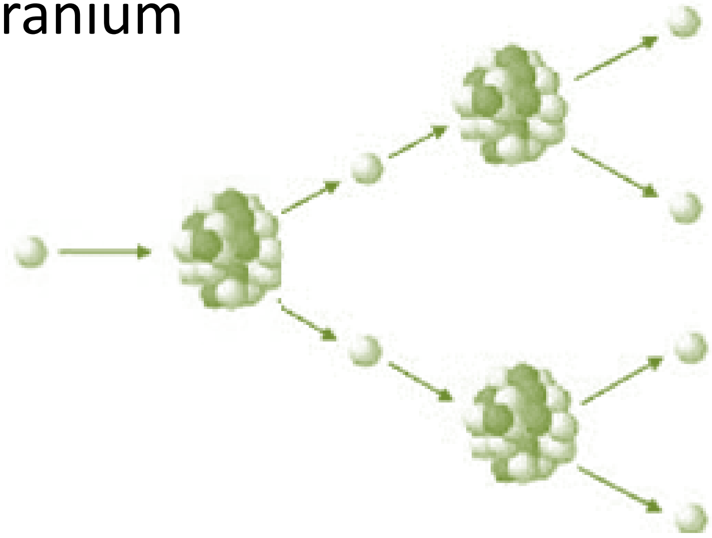
1. Which particle is needed to begin the fission of a large, unstable nuclei?

   A neutron

2. During the fission of uranium, two smaller nuclei are produced and what else?

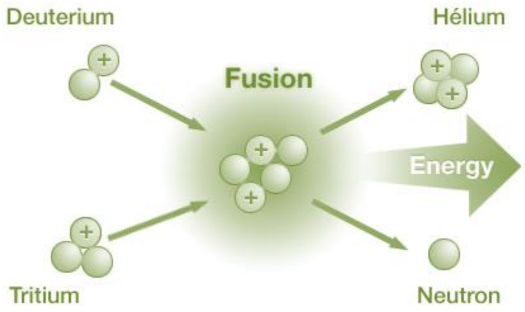
   A number of neutrons and large amounts of energy.

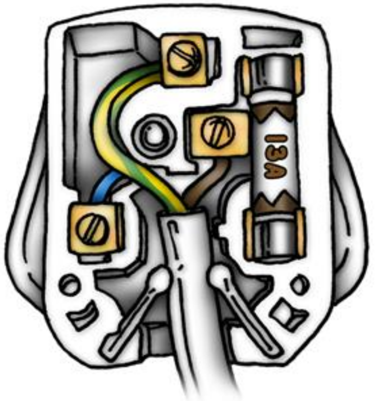
3. Copy and complete the diagram below to show the chain reaction of a sample of uranium

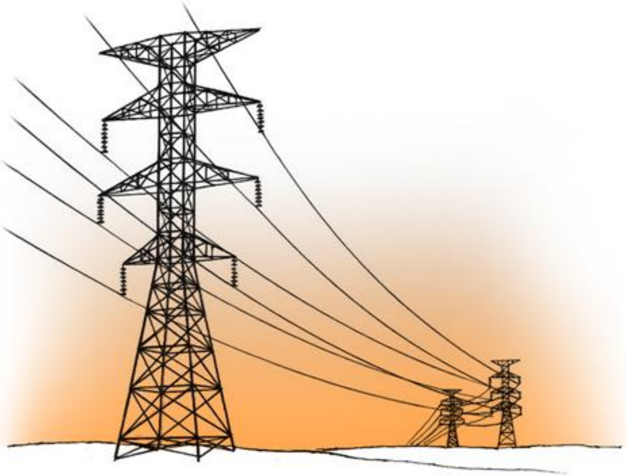


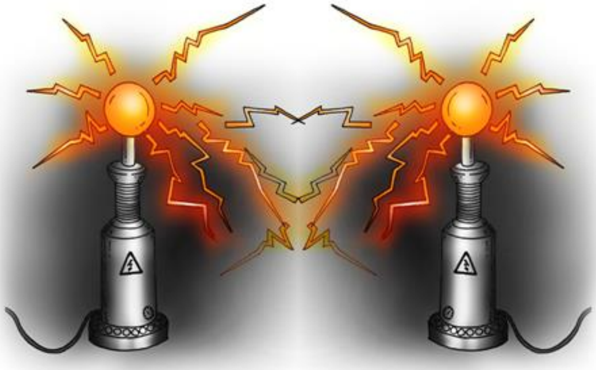
# Nuclear fission and fusion (Physics only) – QuestionIT

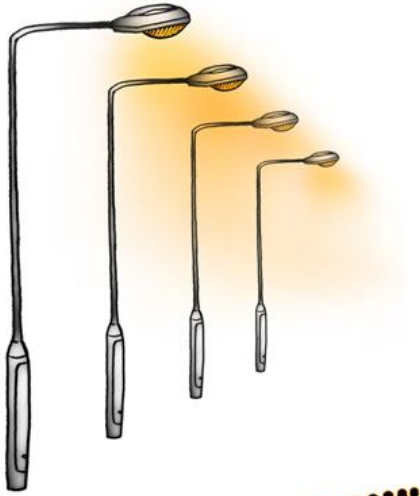
4. Explain what is meant by a controlled chain reaction.
   Nuclear fission reaction where some of the neutrons produced in the reaction are absorbed to prevent the reaction running out control.
5. What is nuclear fusion?
   The joining of two small nuclei to form a single larger nucleus.
6. Where does nuclear fusion take place on a large scale?
   In stars (sun)
7. Draw a diagram to show the process of fusion between deuterium and tritium to produce energy.



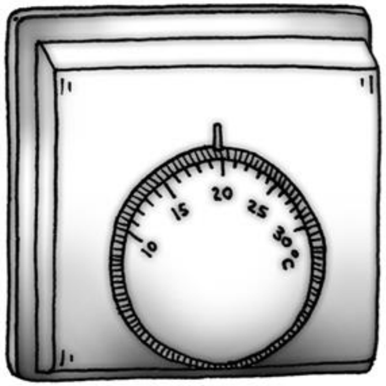


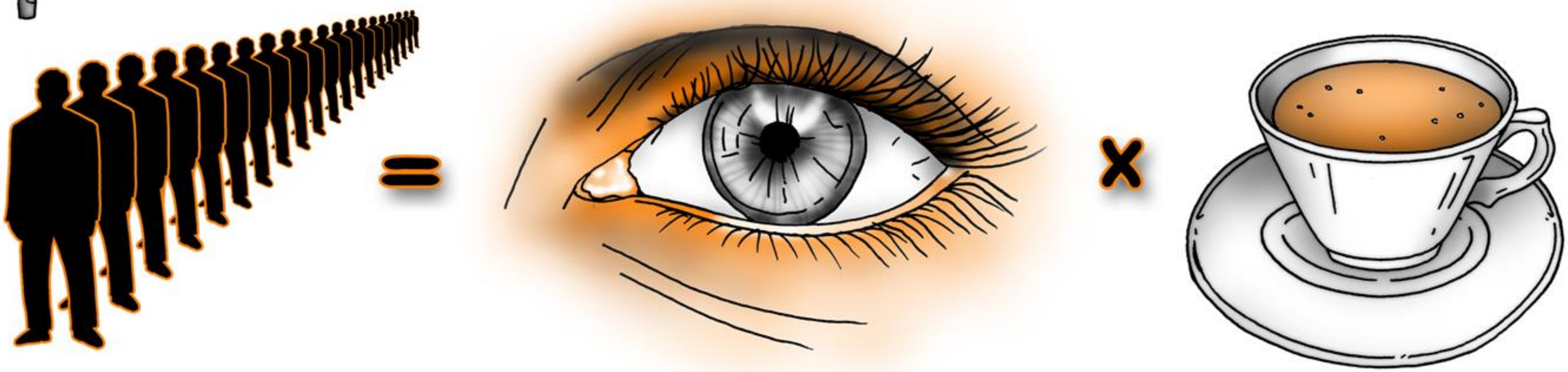






# Electricity

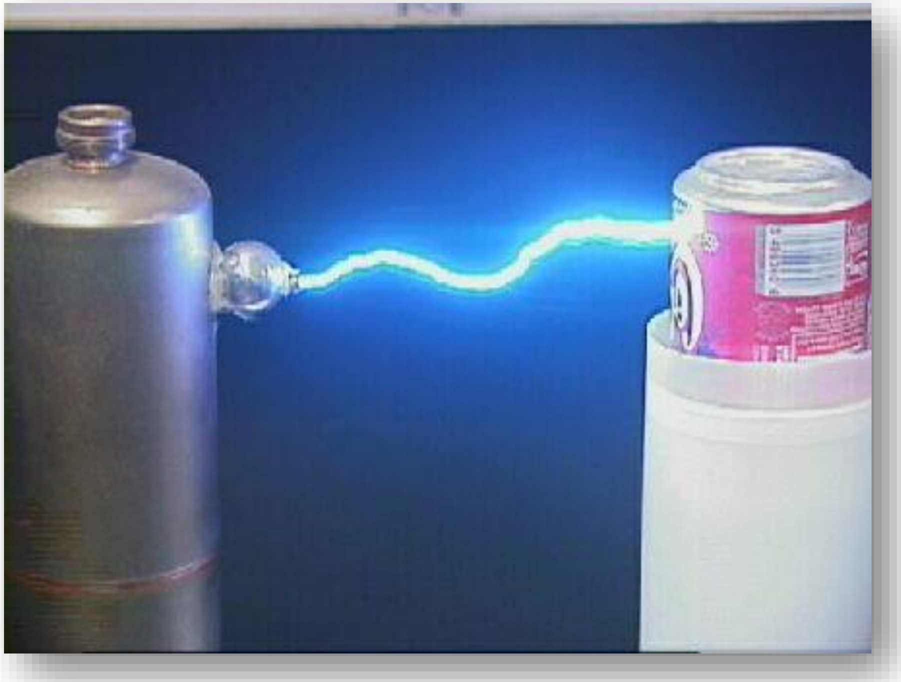




# Overview
# Magnetism and Electromagnetism

## Current, Potential Difference and Resistance

- Standard circuit diagram symbols
- Electrical charge and current
- Current, resistance and potential difference
- Resistors



## Series and Parallel Circuits

## Domestic Uses and Safety

- Direct and alternating potential difference
- Mains electricity

## Energy Transfers

- Power
- Energy transfers in everyday appliances
- The National Grid

## Static Electricity (Physics Only)

- Static charge
- Electric fields

# LearnIT!
# KnowIT!

## Current, Potential Difference and Resistance

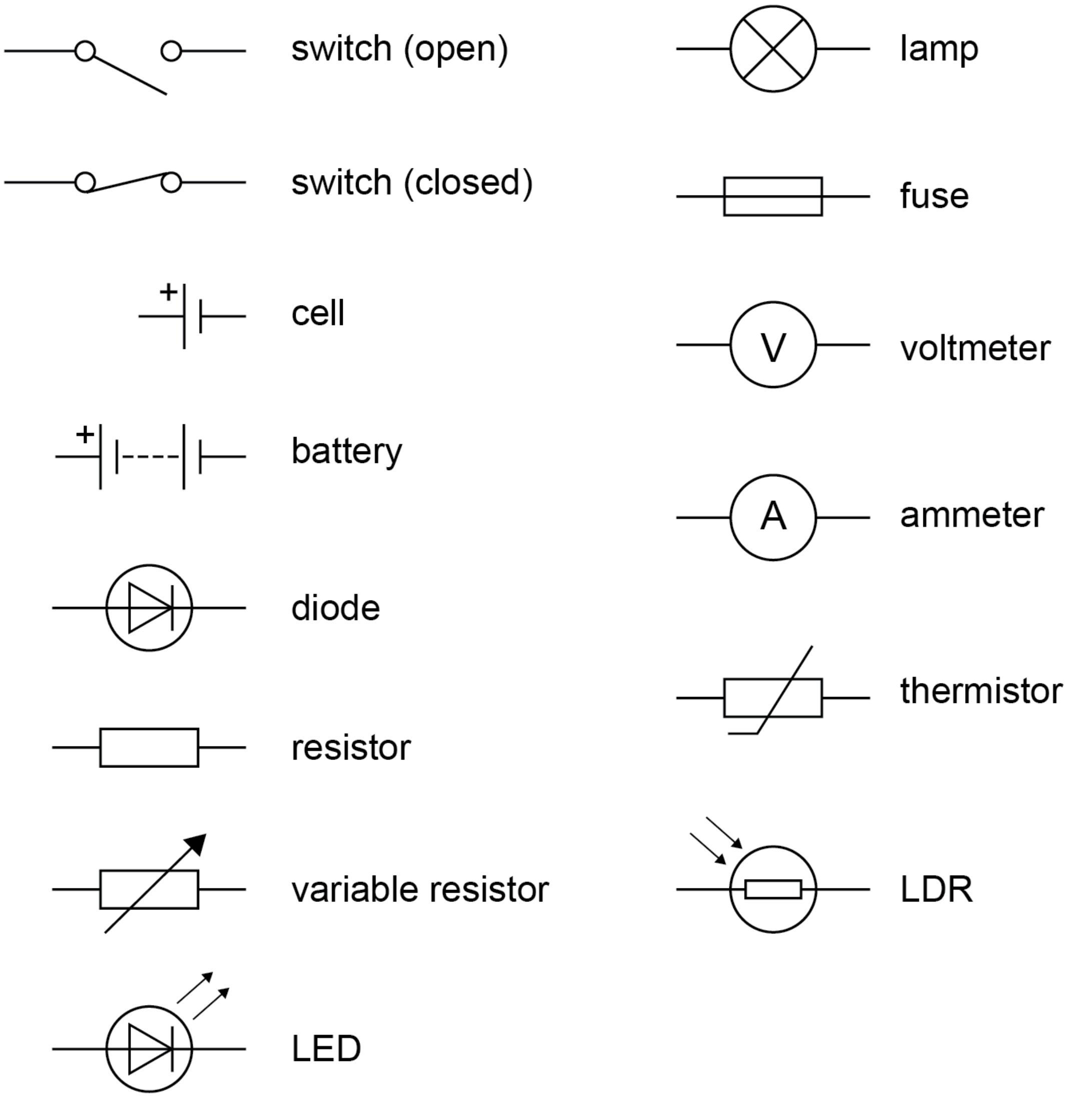
- Standard circuit diagram symbols
- Electrical charge and current
- Current, resistance and potential difference
- Resistors

Standard Circuit Diagram Symbols

# Circuit Symbols

Circuit symbols are used to clearly show components in a circuit and how they are connected.

These circuit symbols must be learnt so that you can draw them and interpret circuit diagrams that use them.



# Terminology

| Term | Definition |
|---|---|
| Current | The rate of flow of charge in a circuit. |
| Potential Difference | Also called voltage. The difference in potential between two points of a circuit. Causes a current to flow. |
| Charge | Charge is the amount of electricity travelling through a circuit. |
| Resistance | Anything that slows the flow of charge around a circuit. Resistance is usually caused by electrons colliding with ions in a material. |
| Series Circuit | A circuit with a single loop of wire. |
| Parallel Circuit | A circuit with two or more loops (branches) of wire. |

# Electrical charge and current

**For electrical charge to flow through a closed circuit, the circuit must include a source of potential difference.**

**An electric current is the flow of electrical charge, usually electrons, around a circuit. The size of the electric current is the rate of flow of electrical charge. In a series circuit (one with a single loop of wire) the current is the same at any point of the loop.**

***Intensité** de courant*

***'I' symbol** used by*

André-Marie **Ampère**

Charge flow, current and time are linked by the equation:

**Charge flow (C) = Current (A) × Time (s)**

$$Q = I\,t$$

| Name | Equation symbol | Unit | Unit Symbol |
|---|---|---|---|
| **Charge flow** | Q | Coulombs | C |
| **Current** | I | Amp | A |
| **Time** | t | Seconds | s |

# Electrical charge and current

**Example**

A current of 1.2 A flows through a wire for 5 minutes.

Work out the charge that has moved in the wire in the 5 minutes.

**Solution**

Convert time into standard units: 5 minutes = 300 seconds

State equation: $Q = I\ t$

Substitution: $Q = 1.2 \times 300$

Answer: $\underline{Q = 360\ \mathrm{C}}$

# Current, Resistance and Potential Difference

- The current (*I*) through a component depends on both the resistance (*R*) of the component and the potential difference (*V*) across the component.
- The greater the resistance of the component, the smaller the current for a given potential difference *(V)* across the component.

Current, potential difference or resistance can be calculated using the equation:

**Potential Difference *(V)* = Current *(A)* x Resistance *(Ω)***

$$V = I\,R$$

**The resistance in a circuit will depend on the components used in the circuit as well as the length of wire used in the circuit. The longer the wire, the greater the resistance.**

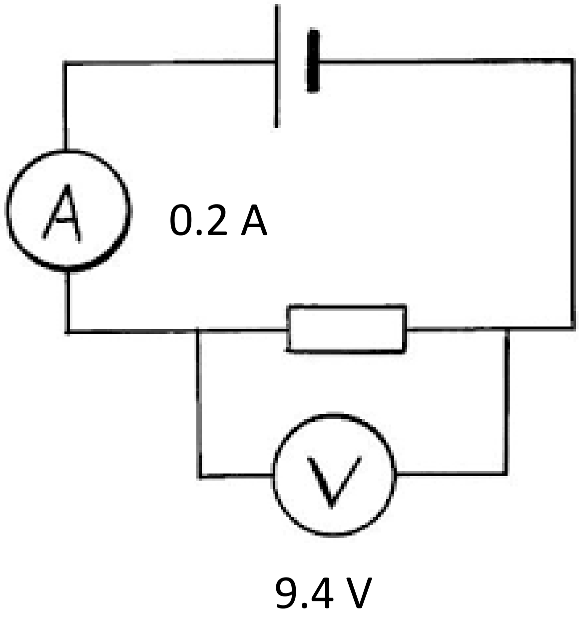
| Name | Equation symbol | Unit | Unit Symbol |
|---|---|---|---|
| **Potential difference** | V | Volts | V |
| **Current** | I | Amp | A |
| **Resisitance** | R | Ohms | Ω |

# Current, Resistance and Potential Difference

**Example**

**A resistor is placed into the circuit shown. The meter readings are shown next to each meter.**

**Work out the resistance.**



**Solution**

**State the equation:** **V = I x R**

**Rearrange:** **R = V / I**

**Substitution:** **R = 9.4 / 0.2**

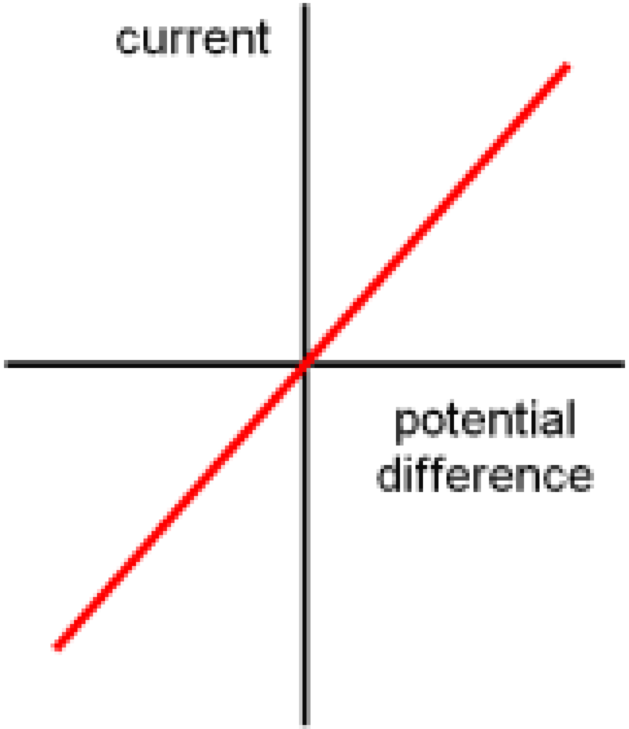
**Answer:** **R = 47 Ω**

# Ohmic Conductors

Some resistors have a fixed value that does not depend on the current flowing through the circuit. These are ohmic conductors.

Ohm’s Law states “the current through an ohmic conductor (at a constant temperature) is directly proportional to the potential difference across the resistor”.

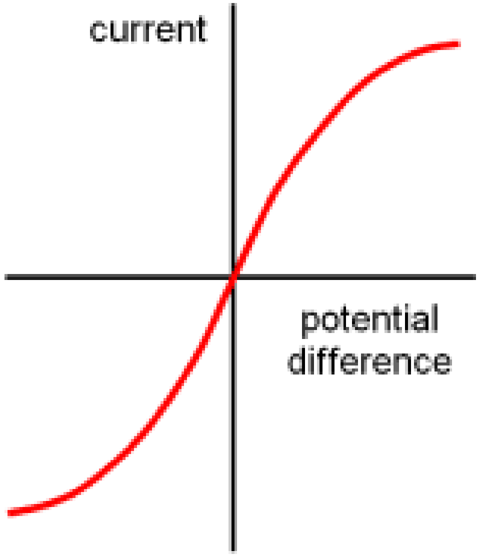
Ohmic conductors will produce a straight line I – V graph that goes through the origin.



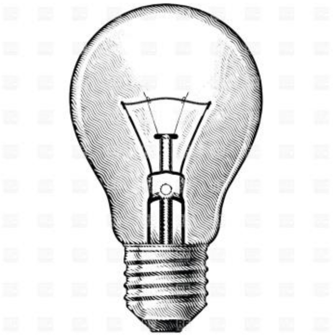
# Non-Ohmic Conductors: Filament Lamp

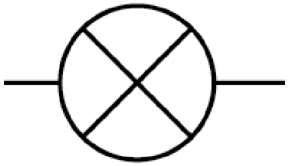
**The resistance of components such as lamps, diodes, thermistors and LDRs is not constant. It changes with the current through the component.**

**A filament lamp is often called a lamp or a lightbulb.**



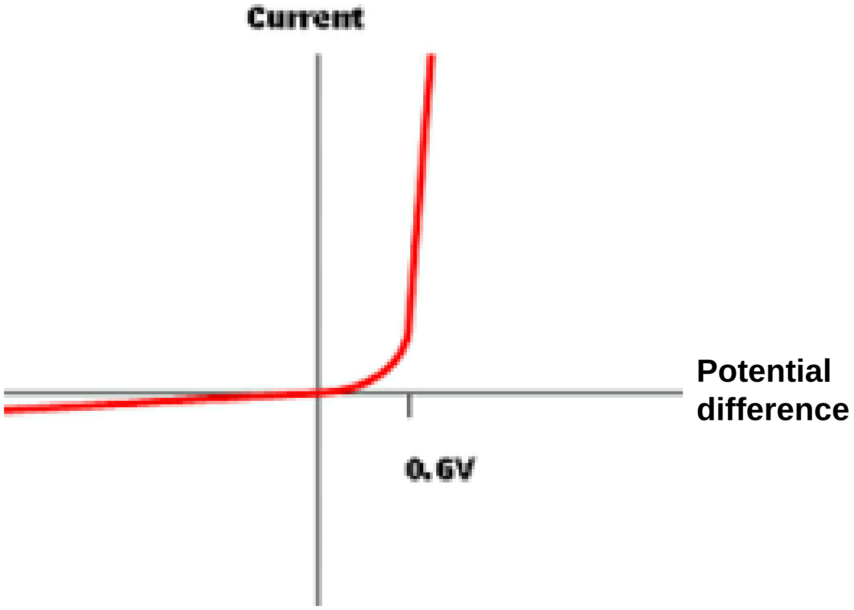
**As the current increases, the temperature of filament increases therefore the resistance of the filament lamp increases.**

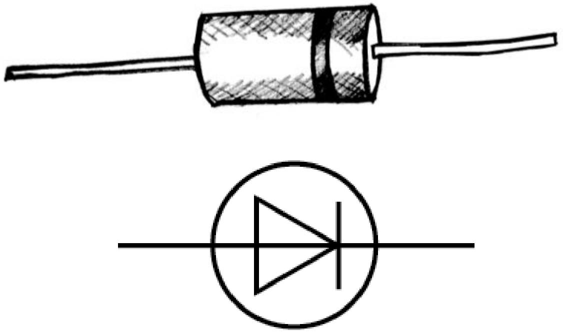




# Non-Ohmic Conductors: Diodes

**Diodes are electrical components that only allow a current to flow in one direction only.**

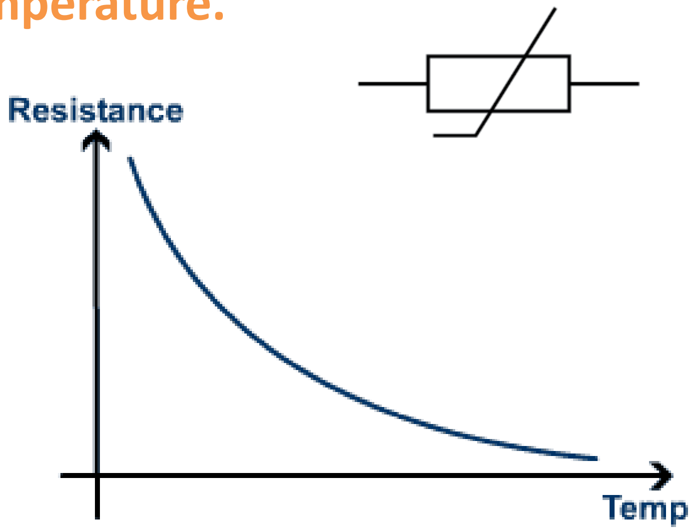




**Diodes have a low resistance in the forward direction but a high resistance in the reverse direction.**

# Thermistors and LDRs

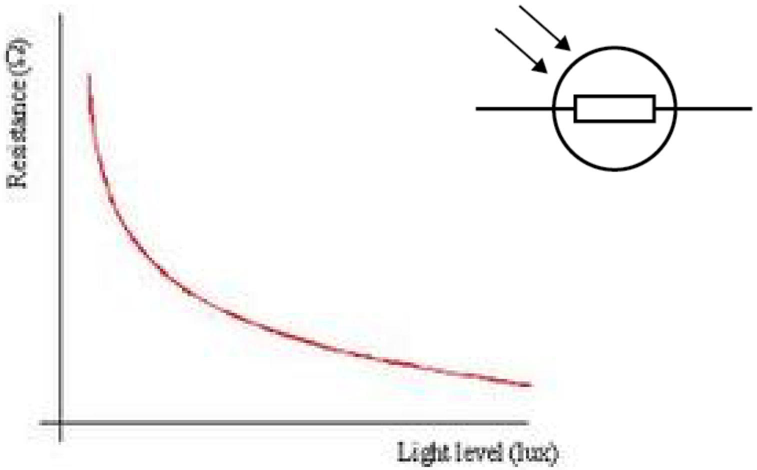
Thermistors are types of resistors where the resistance varies with temperature.



The resistance of a thermistor decreases as temperature increases.

Thermistors are used in thermostats to control temperature in the home.

Light Dependent Resistors - LDRs are types of resistors where the resistance varies with light intensity.

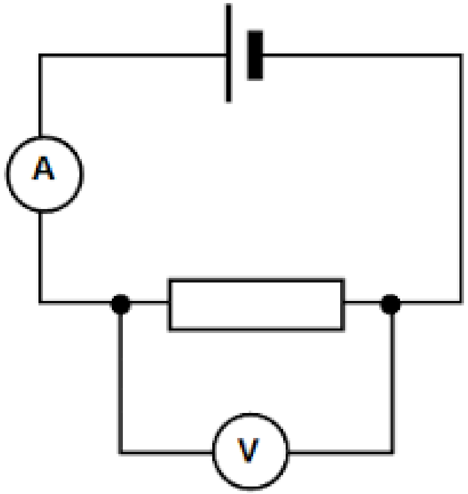


The resistance of a LDR decreases as light intensity increases.

LDRs are used as switches to turn on street lights when it gets dark.

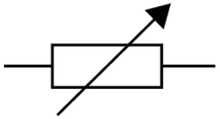
## Measuring Resisitance:

**To measure the resistance of an electrical component the following circuit needs to be set up…**



**By measuring the current, using the ammeter, and the potential difference, using a voltmeter, the resistance can be found from…**

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



**The electrical component tested can be changed from the resistor shown to any other electrical component.**

**To get a range of potential differences and currents a variable resistor can be added into the circuit or the input potential difference changed.**

| Name | Equation symbol | Unit | Unit Symbol |
|---|---|---|---|
| **Potential difference** | V | Volts | V |
| **Current** | I | Amp | A |
| **Resisitance** | R | Ohms | Ω |

# QuestionIT!

## Current, Potential Difference and Resistance

- Standard circuit diagram symbols
- Electrical charge and current
- Current, resistance and potential difference
- Resistors

# Current, Potential Difference and Resistance - QuestionIT

1. **Draw the circuit symbols for the following components…**
    a. A switch open and a switch closed
    b. A cell
    c. A battery
    d. A diode
    e. A resistor
    f. A variable resistor
    g. An LED (light emitting diode)
    h. A lamp
    i. A fuse
    j. A voltmeter
    k. An ammeter
    l. A thermistor
    m. An LDR (light dependent resistor)

**2. Describe the difference between a series circuit and a parallel circuit.**

**3. What is an electric current?**

# Current, Potential Difference and Resistance – QuestionIT

4. State the equation that links charge flow, current and time.

5. Calculate the current in a circuit if a charge of 4 C flows in 20 seconds.

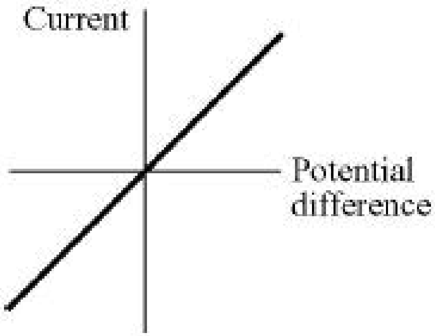
6. In a lightning bolt, a charge of 15 C flows and there is a current of 30,000 A.

   Calculate the duration of the lightning strike.

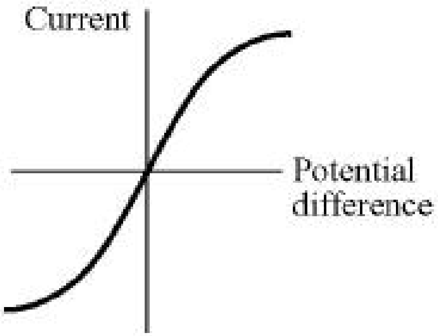
7. What is an ohmic conductor?

8. Which of the following current – potential difference graphs is for an ohmic conductor? Explain your answer.

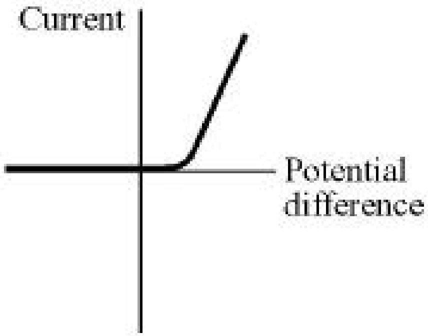
A resistor at constant temperature



A filament lamp



A diode



# Current, Potential Difference and Resistance – QuestionIT

9a) A student wants to draw a current – potential difference graph for a filament lamp.
Draw a circuit that the student will need to set up to obtain the data needed to be able to draw the graph.

9b) Sketch the current– potential difference graph the student should obtain and say why the graph has the shape you have drawn.

# AnswerIT!

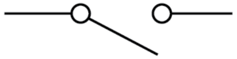
## Current, Potential Difference and Resistance

- Standard circuit diagram symbols
- Electrical charge and current
- Current, resistance and potential difference
- Resistors

# Current, Potential Difference and Resistance – AnswerIT

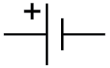
## 1. Draw the circuit symbols for the following components…

**a.**


switch (open)

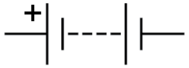

switch (closed)

**b.**



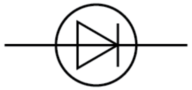
cell

**c.**

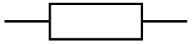


battery

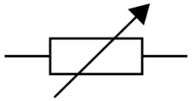
**d.**


diode

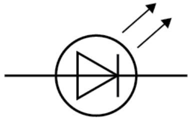
**e.**


resistor

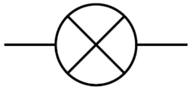
**f.**


variable resistor

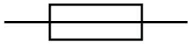
**g.**


LED

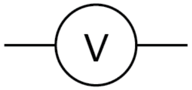
**h.**


lamp

**i.**

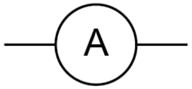

fuse

**j.**



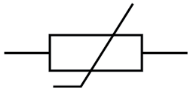
voltmeter

**k.**

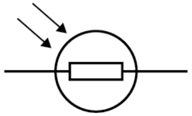


ammeter

**l.**


thermistor

**m.**


LDR

# Current, Potential Difference and Resistance - AnswerIT

**2. Describe the difference between a series circuit and a parallel circuit.**

- A series circuit contains only one loop of wire.
- A parallel circuit contains two or more loops (branches) of wire.

**3. What is an electric current?**

- An electric current is the flow of charge, usually electrons.

**4. State the equation that links charge flow, current and time.**

$$Q = I\,t$$

**5. Calculate the current in a circuit if a charge of 4 C flows in 20 seconds.**

- $Q = I\,t$
- $I = Q / t$ or $I = 4 / 20$
- $I = 0.2$ A

**6. In a lightning bolt, a charge of 15 C flows and there is a current of 30,000 A. Calculate the duration of the lightning strike.**

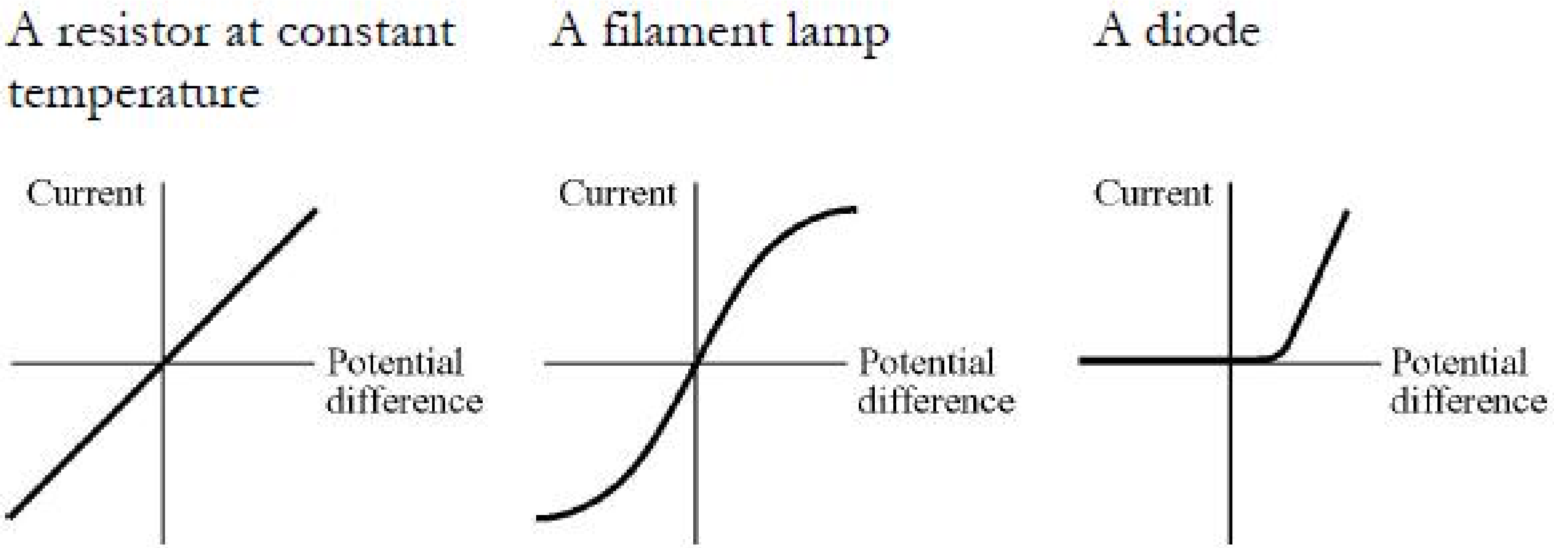
- $t = Q / I$
- $t = 15 / 30\,000$
- $t = 0.0005$ s or 0.5 ms

# Current, Potential Difference and Resistance - AnswerIT

**7. What is an ohmic conductor?**

- A material where the current through the material is proportional to the potential difference applied across its ends.

**8. Which of the following current – potential difference graphs is for an ohmic conductor? Explain your answer.**



A resistor at constant temperature

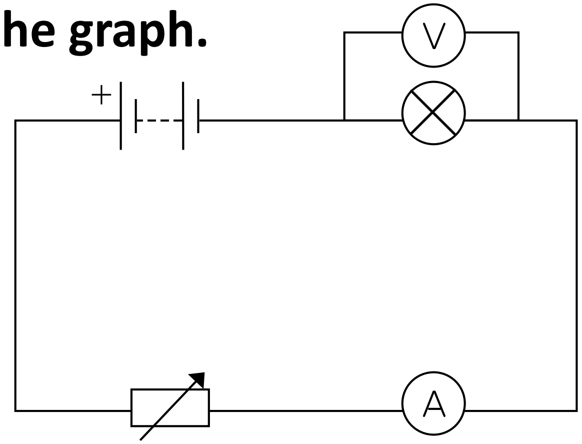
A filament lamp

A diode

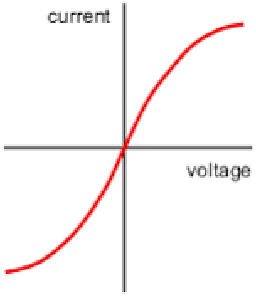
- The resistor is the ohmic conductor, as the graph produced is a straight line through the origin.

# Current, Potential Difference and Resistance – AnswerIT

9a) A student wants to draw a <u>current – potential difference graph</u> for a filament lamp.
Draw a circuit that the student will need to set up to obtain the data needed to be able to draw the graph.



9b) Draw the current– potential difference graph the student should obtain and explain why the graph has the shape you have drawn.



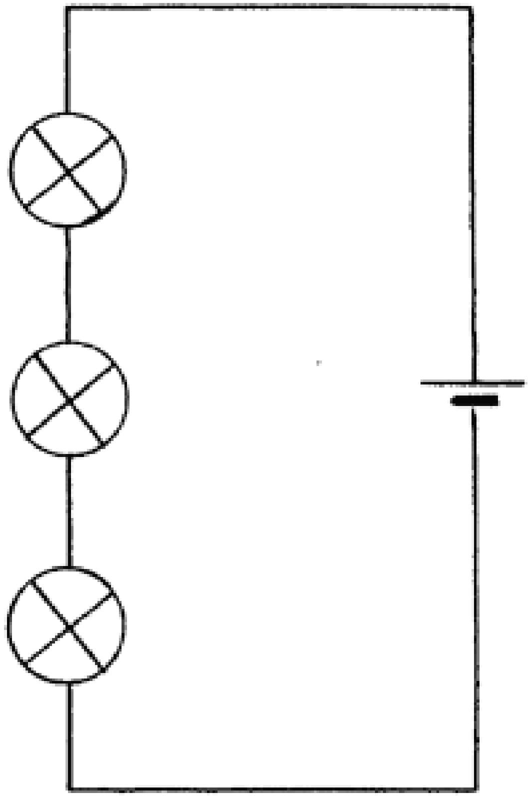
- As the current increases the temperature of the filament increases thus increasing the resistance of the filament lamp.

# LearnIT!
# KnowIT!

## Series and Parallel Circuits

# Series Circuits

Series circuits consist of one loop of wire.



For components connected in series:

- there is the same current through each component
- the total potential difference of the power supply is shared between the components
- the total resistance of two components is the sum of the resistance of each component.

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

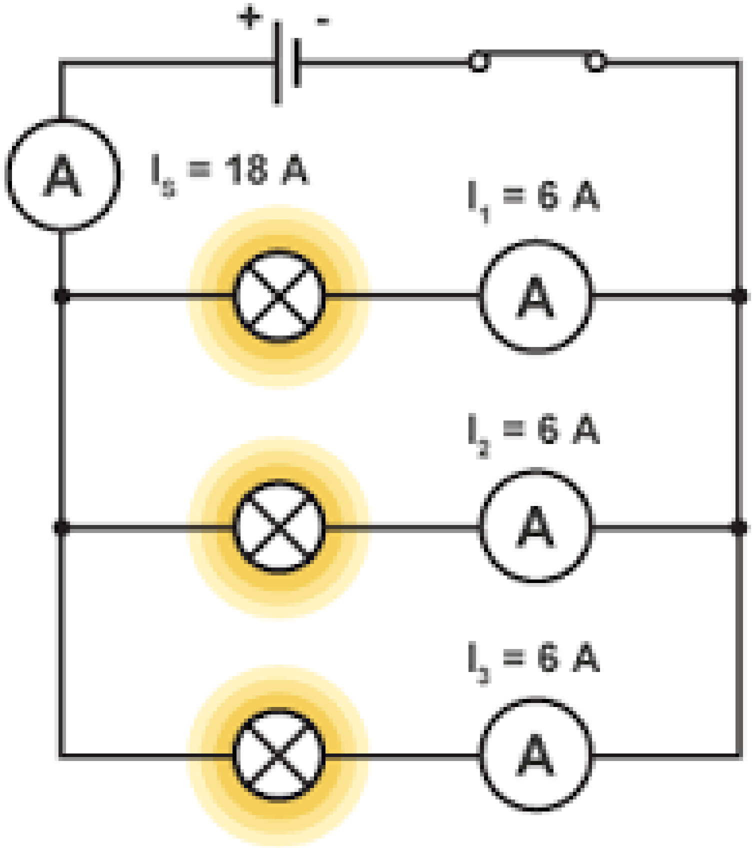
resistance, *R*, in ohms, Ω

# Parallel Circuits

Parallel Circuits consist of two or more loops (branches) of wire.

For components connected in parallel:

- the potential difference across each component is the same
- the total current through the whole circuit is the sum of the currents through the separate components on each loop (branch)
- the total resistance of two resistors is less than the resistance of the smallest individual resistor.

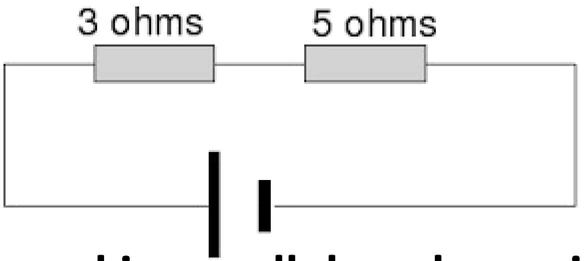


# QuestionIT!

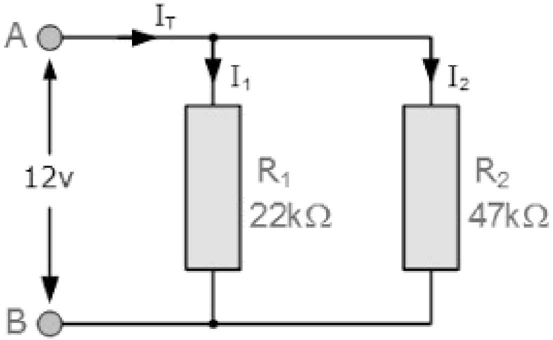
## Series and Parallel Circuits

# Series and Parallel Circuits - QuestionIT

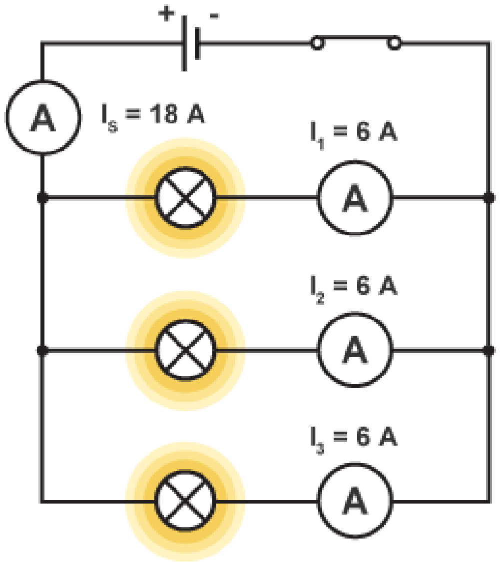
1. Describe how the currents in a series circuit and a parallel circuit differ.
2. Draw a fully labelled series circuit that contains a switch, a battery and two lamps.
3. Calculate the resistance of the resistors in series shown in the diagram below.



4. Two resistors are placed in parallel as shown in the diagram below. What will the maximum resistance of the circuit be?



5a) What is the current in the main branch ($I_s$) of the circuit shown?



5b) The cell in the circuit above supplies a potential difference of 9 V to the circuit.

What is the potential difference across each lamp?
Explain your answer.

# AnswerIT!

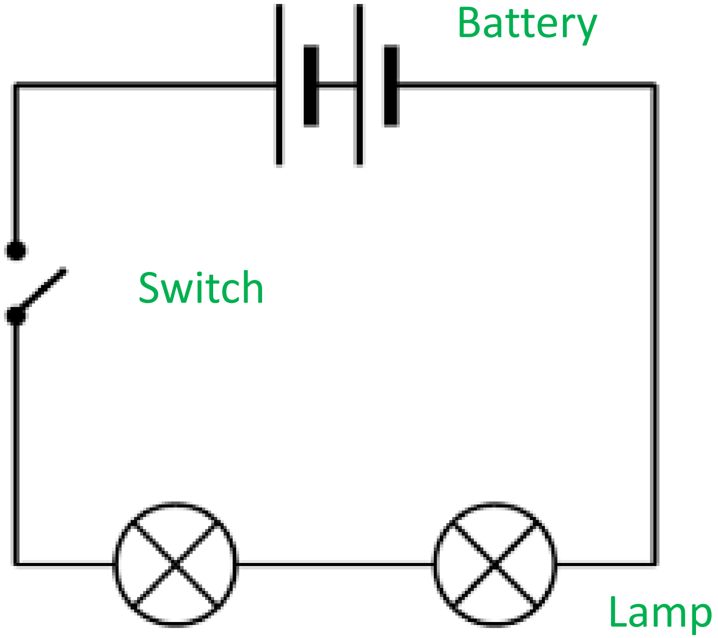
## Series and Parallel Circuits

## Series and Parallel Circuits - AnswerIT

1. **Describe how the currents in a series circuit and a parallel circuit differ.**

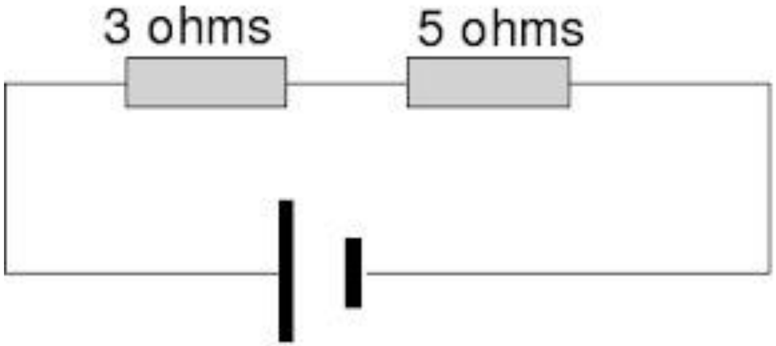
- **Series circuit – same current at any point of the loop.**
- **Parallel circuit – the total current through the whole circuit is the sum of the currents in each loop.**

2. **Draw a fully labelled series circuit that contains a switch, a battery and two lamps.**



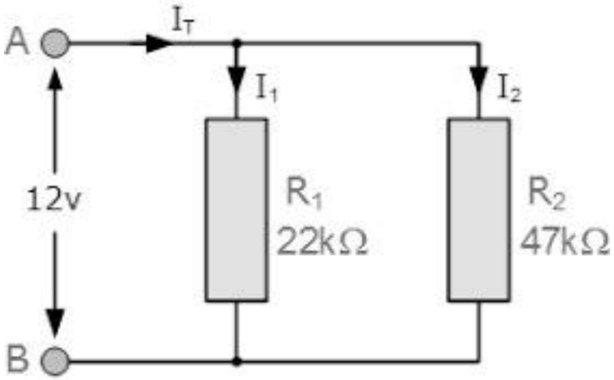
# Series and Parallel Circuits - AnswerIT

3. **Calculate the resistance of the resistors in series shown in the diagram below.**



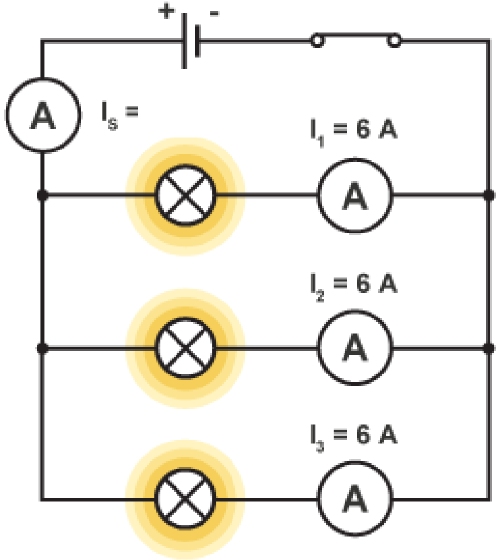
- $R_{total} = R_1 + R_2$
- 8 Ω

4. **Two resistors are placed in parallel as shown in the diagram below. Why will the maximum resistance of the circuit be less than 22 kΩ?**



- It will be *<u>less than</u>* 22 kΩ because the total resistance of two resistors in parallel is less than the resistance of the smallest individual resistor.
- The smallest individual resistor is 22 kΩ.

5a) What is the current in the main branch ($I_s$) of the circuit shown?



- 18 A
- As 6 + 6 + 6 = 18

5b) The cell in the circuit above supplies a potential difference of 9 V to the circuit.
What is the potential difference across each lamp? Explain your answer.

- 9 V
- As the potential difference across each lamp is the same in a parallel circuit.

# LearnIT!
# KnowIT!

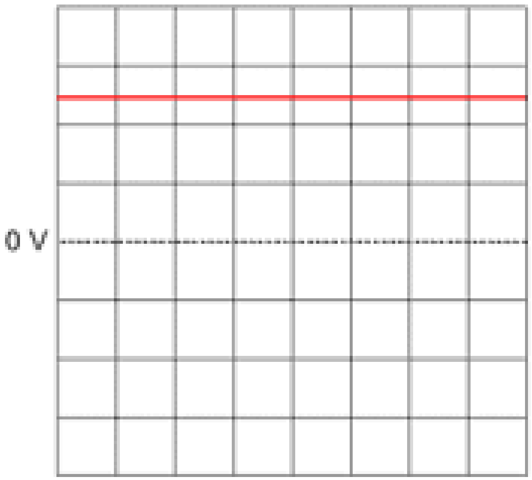
## Domestic Uses and Safety

- Direct and alternating potential difference
- Mains electricity

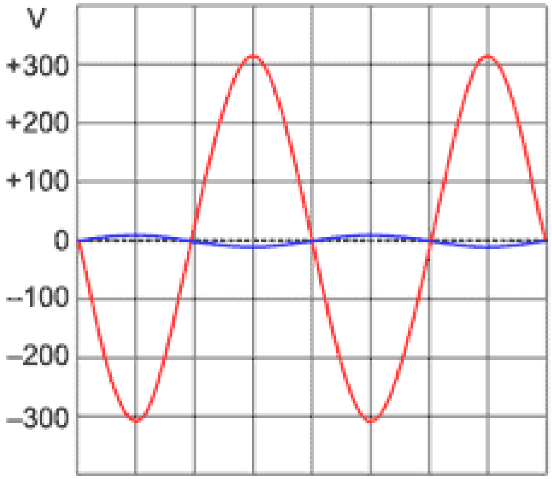
# Direct and Alternating Potential Difference

**A direct potential difference will produce a direct current (dc) (a current in which the charge carriers move in one direction only). Batteries are dc.**

**An alternating potential difference will produce an alternating current (ac) (a current in which the charge carriers move backwards and forwards). Mains electricity is ac.**



**A direct pd does not go below 0 V**



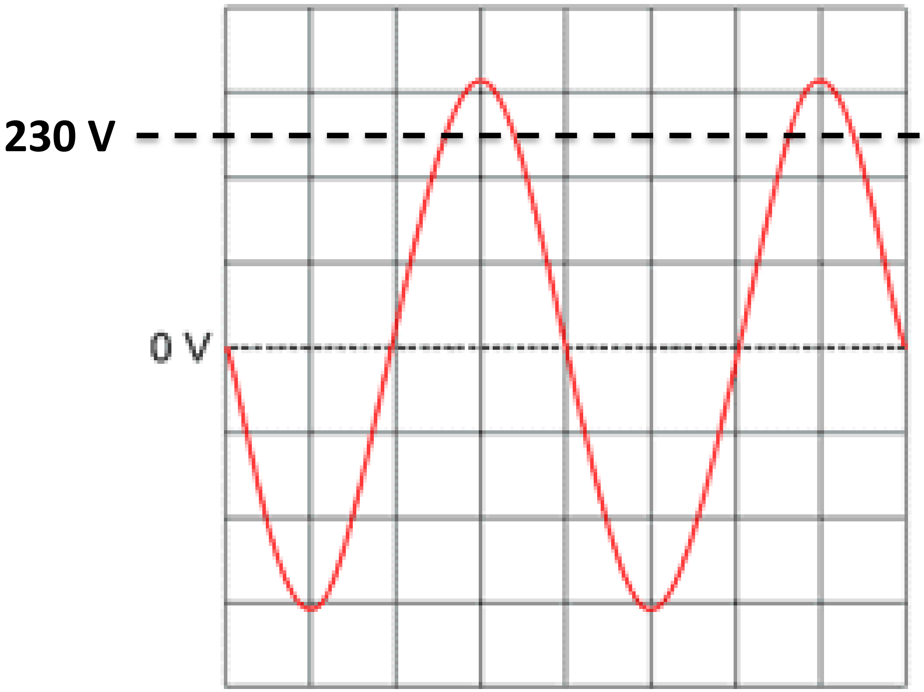
**An alternating pd goes below 0 V**

# Mains Electricity Supply

In the UK, mains electricity is supplied at approximately 230 V, 50 Hz ac.

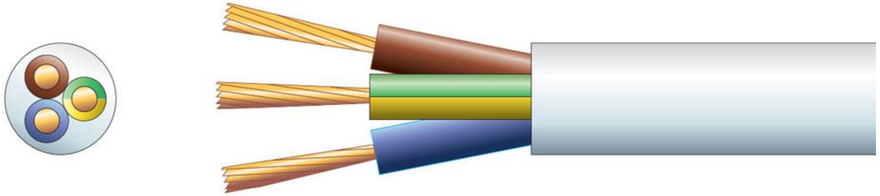
- The mains supply does change slightly, which is why your lights at home may get a bit brighter or dimmer at various times.

- Lights usually dim when a commercial starts on TV during a big show, as lots of people get up to put the kettle on and so demand increases.



# Wiring in the Home

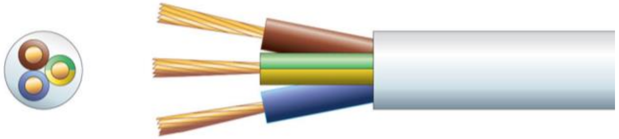
**Most electrical appliances are connected to the mains using three-core electrical cable.**



| Name | Colour | Function |
|---|---|---|
| Live | Brown | Carries alternating potential difference from the supply. |
| Neutral | Blue | Completes the circuit. |
| Earth | Yellow/Green | Safety wire to stop appliance becoming live. |

# Wiring in the Home… continued

- The potential difference between the live wire and earth (0 V) is about 230 V.
- The neutral wire is at, or close to, earth potential (0 V).
- The earth wire is at 0 V,
- The earth wire only carries a current if there is a fault.



The live wire may be dangerous when a switch in the mains circuit is open as a person could complete the circuit to ground (0 V) themselves and therefore get electrocuted as the current will flow through them.

Any connection between the live wire and earth can cause a current to flow. This can potentially cause:

- electrical fires, if the current is too high
- or electrocution, if a person is making the connection.

# QuestionIT!

## Domestic Uses and Safety

- Direct and alternating potential difference
- Mains electricity

# Domestic Uses and Safety - QuestionIT

1. What does a.c stand for?
2. What does d.c stand for?
3. Give an example of where a.c is used.
4. Give an example of where d.c is used.
5. Describe the difference between alternating potential difference and direct potential difference. You may draw a sketch graph to help answer the question.
6. What is the frequency and potential difference of mains electricity in the U.K?
7. Copy and complete the table below for the wire in three core electrical cable.

| Name | Colour | Function |
|---|---|---|
| | | |
| | | |
| | | |

8. Explain why a live wire may be dangerous even when a switch in the mains circuit is open.

# AnswerIT!

## Domestic Uses and Safety

- Direct and alternating potential difference
- Mains electricity

# Domestic Uses and Safety - AnswerIT

**1. What does a.c stand for?**

Alternating current

**2. What does d.c stand for?**

Direct current

**3. Give an example of where a.c is used.**

Mains electricity

**4. Give an example of where d.c is used.**

Batteries

**5. Describe the difference between an alternating potential difference and direct potential difference. You may draw a sketch graph to help answer the question.**

- An alternating potential difference will go from positive to negative repeatedly
- Producing an alternating current in a circuit.
- A direct potential difference will stay either positive or negative, but not change sign
- Producing a direct current in a circuit.

# Domestic Uses and Safety - AnswerIT

6. What is the frequency and potential difference of mains electricity in the U.K?

Frequency 50Hz

Potential difference 230V

7. Copy and complete the table below for the wire in three core electrical cable.

| Name | Colour | Function |
|---|---|---|
| Live | Brown | Carries alternating potential difference from the supply. |
| Neutral | Blue | Completes the circuit. |
| Earth | Yellow/Green | Safety wire to stop appliance becoming live. |

8. Explain why a live wire may be dangerous even when a switch in the mains circuit is open.

A person could complete the circuit to ground getting electrocuted.

# LearnIT!
# KnowIT!

## Energy Transfers

- Power
- Energy transfers in everyday appliances
- The National Grid

# Power

**Power:** **When electrical appliances are connected into a circuit energy is transferred to the appliance. The rate at which energy is transferred to the appliance is the power rating of the appliance.**

**To calculate the power of an electrical component:**

**Power (W)= Potential Difference (V) x Current (A)**

$$P = V I$$

**An alternative equation for calculating power is:**

**Power = $(\text{current})^2$ x Resistance**

$$P = I^2 R$$

| Name | Equation symbol | Unit | Unit Symbol |
|---|---|---|---|
| **Power** | P | Watts | W |
| **Potential difference** | V | Volts | V |
| **Current** | I | Amp | A |
| **Resisitance** | R | Ohms | Ω |

# Power Equations

**Example**

A microwave oven is powered by mains electricity at 230 V. The microwave oven has a power rating of 800 W.

Calculate the current flowing in the microwave oven.

**Solution:**

**State the equation:** $P= VI$

**Rearrange:** $I = P/ V$

**Substitution:** $I= 800 / 230$

**Answer:** $I= 3.5$ A (to 1 decimal place)

# Power Equations… continued

**Example:**

**An overhead powerline is 100 miles long and carries a current of 400 A. The powerline has a resistance of 27.5 Ω.**

**Calculate the power loss in the 100 mile length of powerline.**

**Solution:**

**State the equation:** $P = (I)^2 \times R$

**Substitution:** $P = (400)^2 \times 27.5$

**Answer:** P = 4.4 MW or 4 400 000 W

**Therefore the power loss in the overhead powerline is 4.4 MW per 100 miles of cable.**

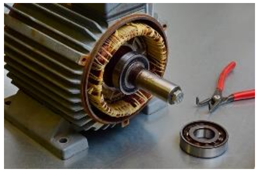
# Energy Transfers in Everyday Appliances

**Everyday electrical appliances are designed to bring about energy transfers.**

**The amount of energy an appliance transfers depends on how long the appliance is switched on for and the power of the appliance.**

**Electrical appliances convert electrical energy from ac mains, or from batteries into more useful forms.**

**Some common energy transfers from electrical energy include…**



- **motors** converting electrical energy into kinetic energy

- **lightbulbs** converting electrical energy into light energy

- **electric heaters** converting electrical energy into heat energy.

**As with any energy transfer, some energy will be transferred usefully and some energy will be wasted (converted into forms that are not useful).**

# Energy Transfers in Everyday Appliances

**Work Done in Electrical Circuits**

**Work is done when charge flows in a circuit.**

**The amount of energy transferred by electrical work can be calculated using the equation:**

Energy transferred (J) = Power (W) × Time (s)

$$E = P\,t$$

**Also:** Energy transferred = Charge flow (C) x Potential difference (V)

$$E = Q\,V$$

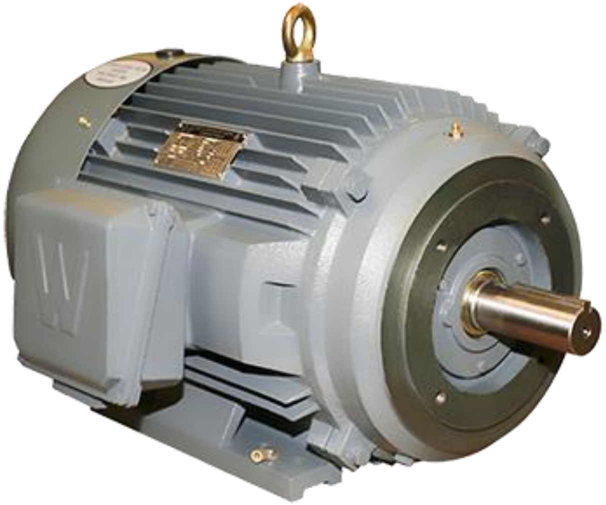
| Name | Equation symbol | Unit | Unit Symbol |
|---|---|---|---|
| **Energy transferred** | E | Joules | J |
| **Power** | P | Watts | W |
| **Time** | t | Seconds | s |
| **Charge flow** | Q | Coulombs | C |
| **Potential difference** | V | Volts | V |

# Using Equations for Energy Transferred

**Example:**

**An electric motor with a power rating of 5 kW is switched on for 2 minutes.**

**Work out the energy transferred by the electric motor.**



**Solution:**

**Conversion into standard units:** 5000 W for power and 120 s for time.

**State the equation:** $E = P\,t$

**Substitution:** E= 5000 x 120

**Answer:** E= 600 000 J or 600 kJ

# Using Equations for Energy Transferred…continued

**Example:**

**A different electric motor has a power rating of 8 kW. This electric motor runs off mains electricity at 230 V, 50 Hz ac.**
**Calculate the charge flow if this electric motor is left on for 1.5 minutes.**

**Solution:**

***Conversion into standard units:*** **8 kW = 8000 W and 1.5 minutes = 90 seconds**

**Calculate the energy transferred:**

**State the equation:** $E = P\,t$
**Substitution:** E = 8000 x 90
**Answer:** E = 720 000 J

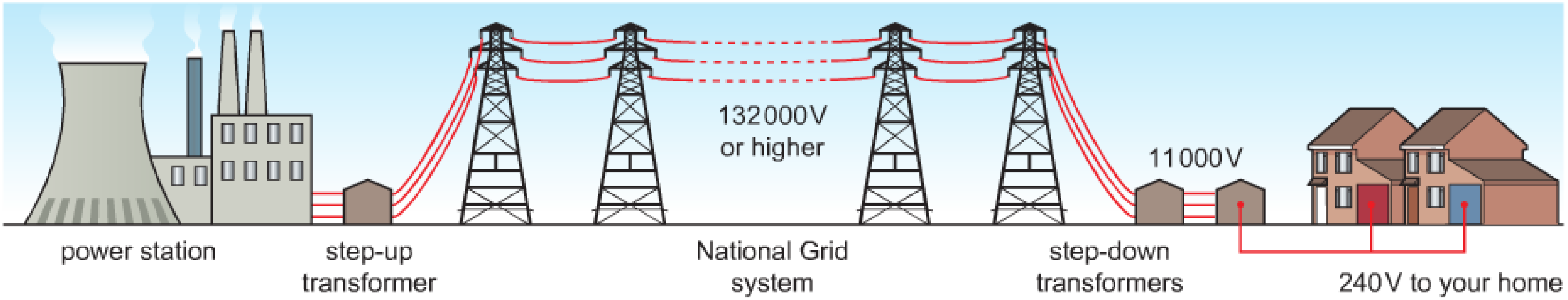
**State the equation:** $E = Q\,V$
**Rearrange:** $Q = E/V$
**Substitution:** Q = 720 000/ 230
**Answer:** Q= <u>3130 C</u>

# The National Grid

**The National Grid is a system of cables and transformers linking power stations to consumers e.g. homes, shops, factories an.**

**Electrical power is transferred from power stations to consumers using:**

## The National Grid



- **Step-up transformers are used to increase the potential difference from the power station to the transmission cables.**
- **Step-down transformers are used to decrease, to a much lower value, the potential difference for domestic use in homes.**

# Why are Transformers used in The National Grid?

Electric current generates heat as it moves through electrical wires.

If electricity is transmitted at a very high potential difference and low current this means less energy is wasted as heat making the whole system more efficient.

- Step up transformers – Increase the potential difference and decrease the current.
- Step down transformers - Decrease the potential difference and Increase the current.

A lower potential differences is used in the home as it is safer, so a step-down transformer is used near homes and offices.

Pylons carry overhead power cables

# QuestionIT!

## Energy Transfers

- Power
- Energy transfers in everyday appliances
- The National Grid

Energy Transfers - QuestionIT

1. State the equation that links power, potential difference and current. Include equation symbols and units.

2. State the equation that links power, current and resistance. Include equation symbols and units.

3. Recall the two equations for energy transferred. Include equation symbols and units.

4a) A kettle has a power rating of 1.2 kW.
The kettle runs on mains electricity at 230 V.
Calculate the current flowing through the kettle when in use.

4b) The kettle takes 1 minute and 20 seconds to boil some water.
Calculate the energy transferred by the kettle in this time.

5. Describe fully how electricity is transmitted from power stations to our homes.

6. Explain why a step-up transformer is used when transmitting electricity long distances across the UK.

# AnswerIT!

## Energy Transfers

- Power
- Energy transfers in everyday appliances
- The National Grid

1. **State the equation that links power, potential difference and current. Include equation symbols and units.**

- Power = Potential Difference x Current
- $P = V I$

2. **State the equation that links power, current and resistance. Include equation symbols and units.**

- Power = $(\text{current})^2$ x Resistance
- $P = I^2 R$

| Name | Unit | Unit Symbol |
|---|---|---|
| **Power** | Watts | W |
| **Potential difference** | Volts | V |
| **Current** | Amp | A |
| **Resisitance** | Ohms | Ω |

**3. Recall the two equations for energy transferred. Include equation symbols and units.**

- Energy transferred = Power × Time
- E = P t

- Energy transferred = Charge flow x Potential difference
- E = Q V

| Name | Unit | Unit Symbol |
|---|---|---|
| Energy transferred | Joules | J |
| Power | Watts | W |
| Time | Seconds | s |
| Charge flow | Coulombs | C |
| Potential difference | Volts | V |

4a) A kettle has a power rating of 1.2 kW.
The kettle runs on mains electricity at 230 V.
Work out the current flowing through the kettle when in use.

- 5.2 A
- 1.2 kW = 1200 W
- Power = Potential difference x Current
- Current = power / potential difference or current = 1200 / 230

4b) The kettle takes 1 minute and 20 seconds to boil some water.
Work out the energy transferred by the kettle in this time.

- 96 000 J
- Energy transferred = Power x Time
- Energy transferred = 1200 x 80

5. Describe fully how electricity is transmitted from power stations to our homes.
   - A step-up transformer is used to increase potential difference / decrease current
   - Electricity transmitted along power cables (at high potential difference)
   - Step-down transformers used to decrease the potential difference before the electricity enters homes.

6. Explain why a step-up transformer is used when transmitting electricity long distances across the UK.
   - Increasing the potential difference will decrease the current
   - Lower currents mean less heating of the power cables
   - So, less electrical energy wasted as heat
   - Making the transmission process more efficient.

# LearnIT!
# KnowIT!

## Static Electricity (Physics Only)

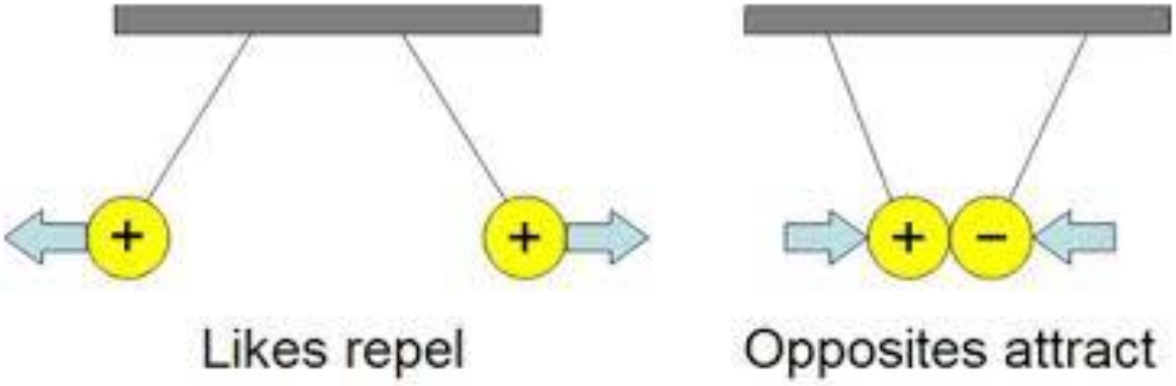
- Static charge
- Electric fields

# Static Charges

There are two types of electrical charge.

These are positive (+) and negative (-).

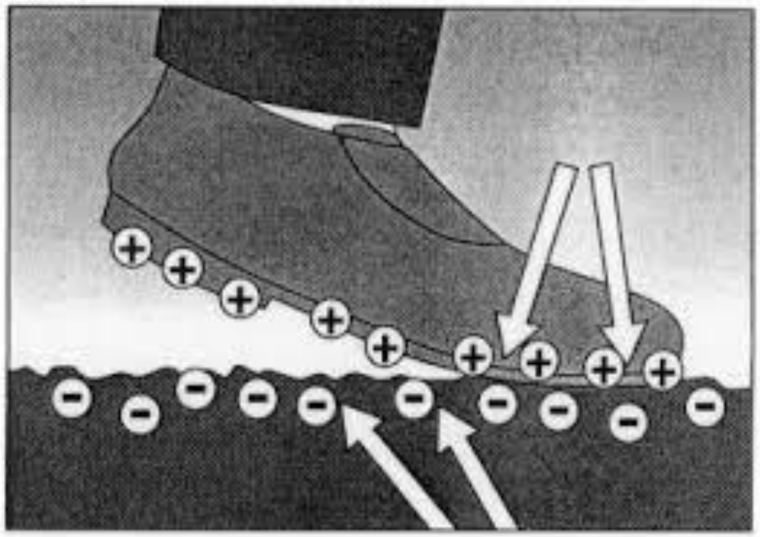
When two electrical charges are placed near each other they exert a force on one another. The direction of the force depends on the electrical charges involved. Electrostatic forces are an example of non-contact forces.



# Producing a Static Charge

**When certain insulating materials are rubbed against each other they become electrically charged. Negatively charged electrons are rubbed off one material and on to the other. The material that gains electrons becomes negatively charged. The material that loses electrons is left with an equal positive charge.**

**When you walk across a carpet in socks, the friction between the carpet and the socks can cause a build up of charge. This is noticeable when you touch something that is earthed afterwards and you get a small spark and an electric shock. The cause of the shock is electrons moving through you to ground.**



# Demonstration of Static

**There are two common examples of static phenomena.**

**Rubbing a balloon on your head:**

**When you rub a balloon on your head electrons are transferred, causing a build up of negative charge on the balloon.**

**Placing a charged balloon over some dust will cause the dust to be attracted to the balloon.**

**Placing the charged balloon onto a wall can get the balloon to stick.**

# Demonstration of Static

There are two common examples of static phenomena.

Rubbing a plastic rod, a comb for example, on some material will cause a transfer of electrons.

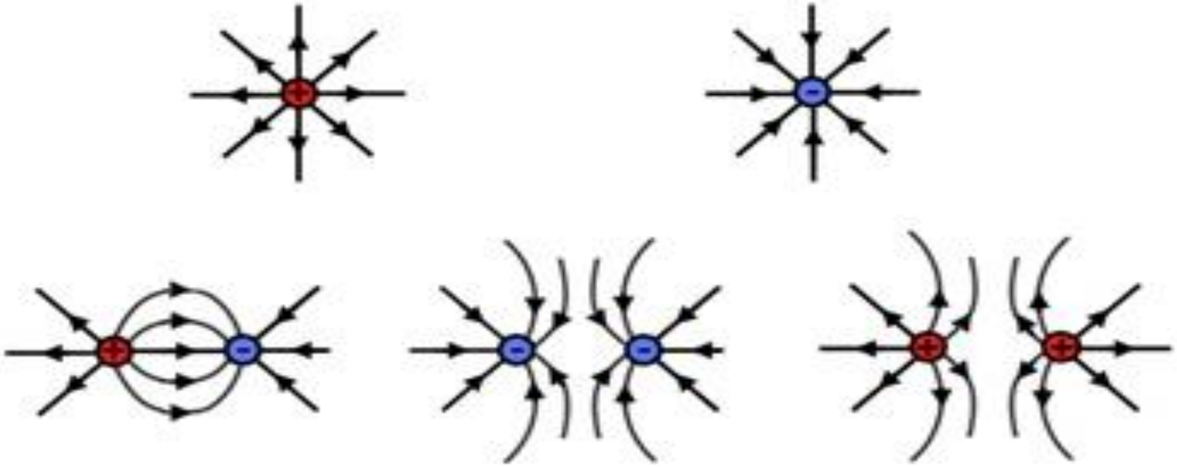
Placing the charged rod above bits of paper will get the paper to attract to the rod.
The oppositely charged particles in the paper will be attracted to the rod.

Placing the charged rod next to running water will get the water to attract towards the rod.

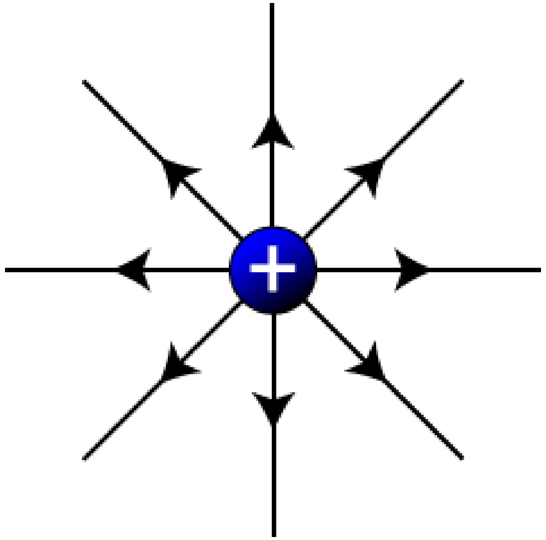
# Electric Fields

**A charged object creates an electric field around itself. The electric field is strongest close to the charged object. The further away from the charged object, the weaker the field.**

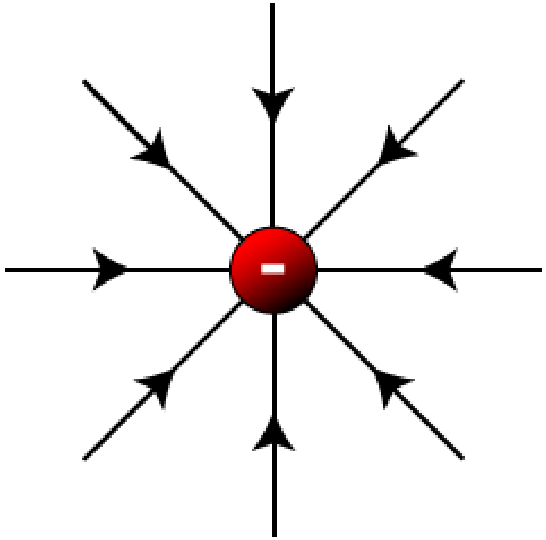
**A second charged object placed in the field experiences a force. The force gets stronger as the distance between the objects decreases.**



# Electric Field Patterns



A positive isolated charge



A negative isolated charge

**An electric field is the region around a charged particle within which a force would be exerted on another charged particle.**

# The Effects of an Electric Field

**Sparking:**

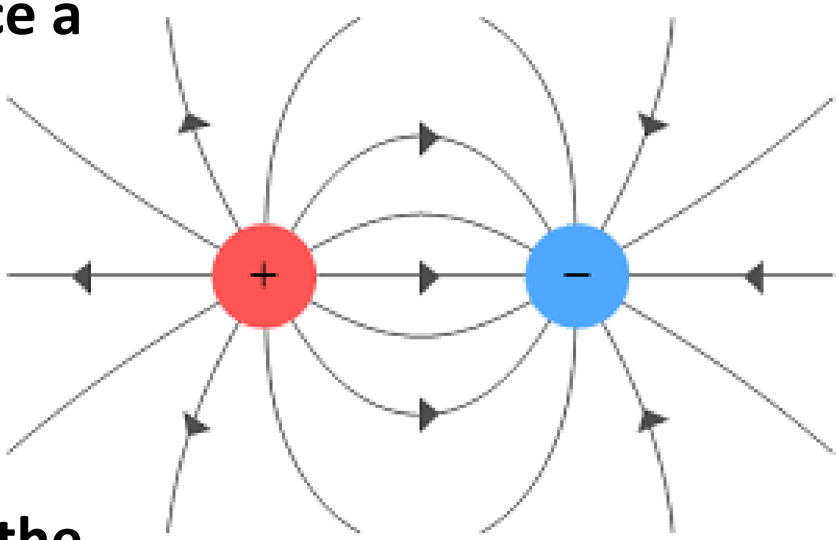
When the electric field strength of a charged object is greater than the dielectric field strength a spark can occur. The dielectric field strength is the maximum electric field strength a material (usually air) can have without breaking down.

When the dielectric field strength is exceeded there is an increase in the number of free electrons in the air. This allows the air to conduct electricity and a spark is produced.

# The Effects of an Electric Field… continued

## Electrostatic Attraction:

When a charged particle is placed in an electric field the particle will experience a force.



The electric field acts like a force at a distance and the lines are considered the lines of force.

A positively charged particle placed in the electric field will move in the direction of the field lines. Negatively charged particles will move in the opposite direction.

# QuestionIT!

## Static Electricity (Physics Only)

- Static charge
- Electric fields

# Static Electricity - QuestionIT

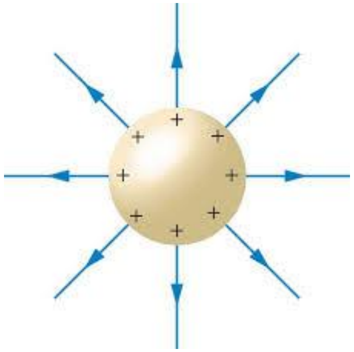
1. Draw the electric field pattern of a positively charged particle.
2. State the two types of electrical charge.
3. Describe what would happen if two like charged particles were placed near each other.
4. A balloon is rubbed on a jumper.
   The balloon becomes positively charged.
   Explain why the balloon gains a negative charge.
5. Describe what would happen if a charged rod was placed above a pile of dust.
6. What is an electric field?
7. Mike gets off a trampoline and gets an electric shock. Mike sees a spark pass between himself and the trampoline.
   Explain why a spark formed in the air between Mike and the trampoline.

# AnswerIT!

## Static Electricity (Physics Only)

- Static charge
- Electric fields

1. Draw the electric field pattern of a positively charged particle.



2. State the two types of electrical charge.
- Positive and negative
3. Describe what would happen if two like charged particles were placed near each other.
- Two like charges would repel away from each other.
4. A balloon is rubbed on a jumper.
The balloon becomes positively charged.
Explain why the balloon gains a negative charge.
- Electrons move from the jumper to the balloon
- So there are more negative charges on the balloon than positive charges.

5. Describe what would happen if a charged rod was placed above a pile of dust.

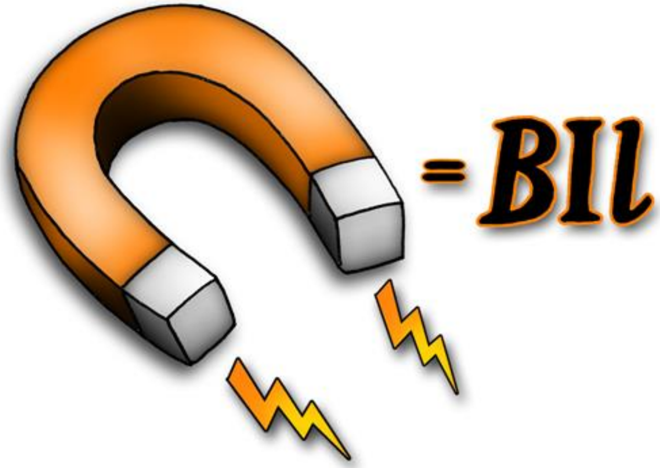
- The dust will attract to the rod
- Note: The dust will stick to the rod is not an acceptable answer.

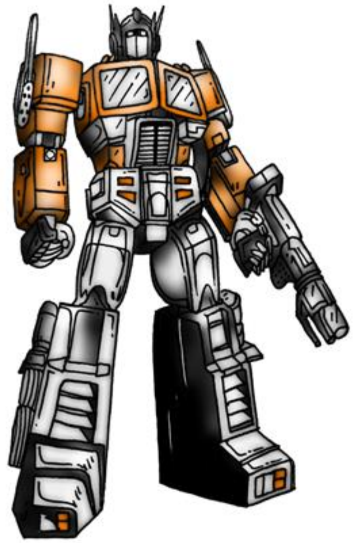
6. What is an electric field?

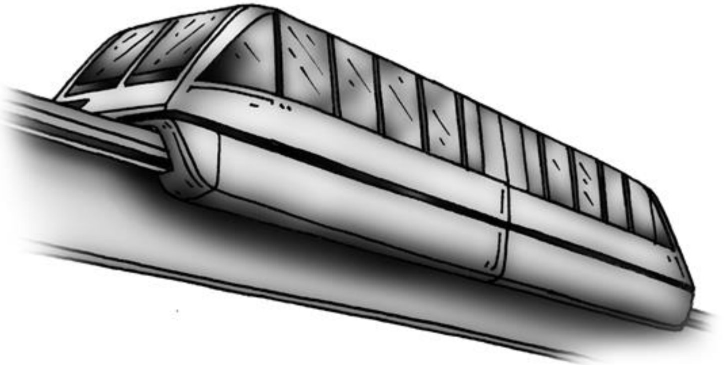
- An electric field is the space around a charged object that will exert a force upon another charged object that is placed there.

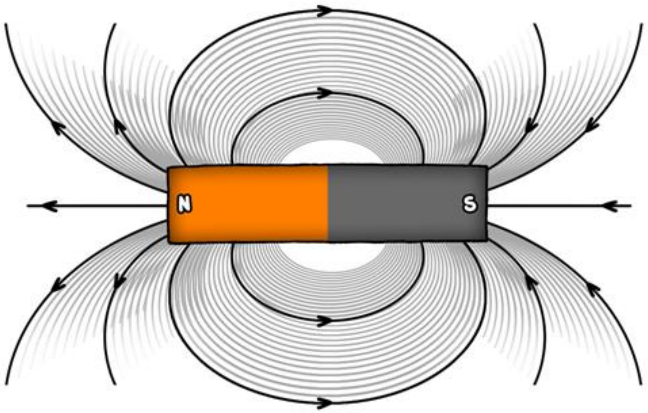
7. Mike gets off a trampoline and gets an electric shock. Mike sees a spark pass between himself and the trampoline.
   Explain why the spark formed in the air between Mike and the trampoline.

- The electric field strength of Mike as a charged object
- Is greater than the dielectric field strength of air
- Causing an increase in the number of free electrons in the air
- Allowing the air to conduct
- And a spark to form.

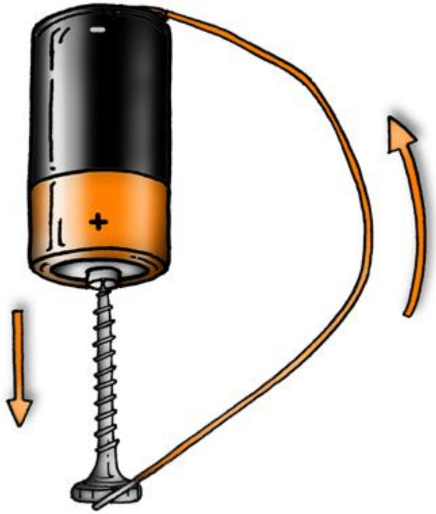


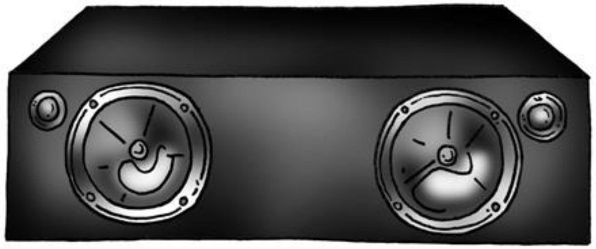


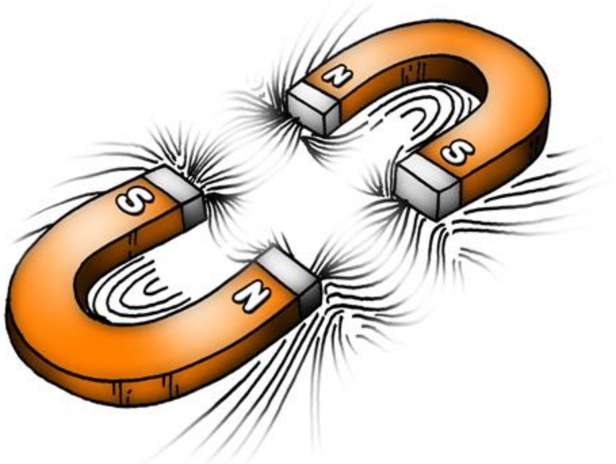




# Magnetism & Electromagnetism







# Overview
# Magnetism and Electromagnetism

## Permanent and Induced Magnetism, Magnetic Forces and Fields

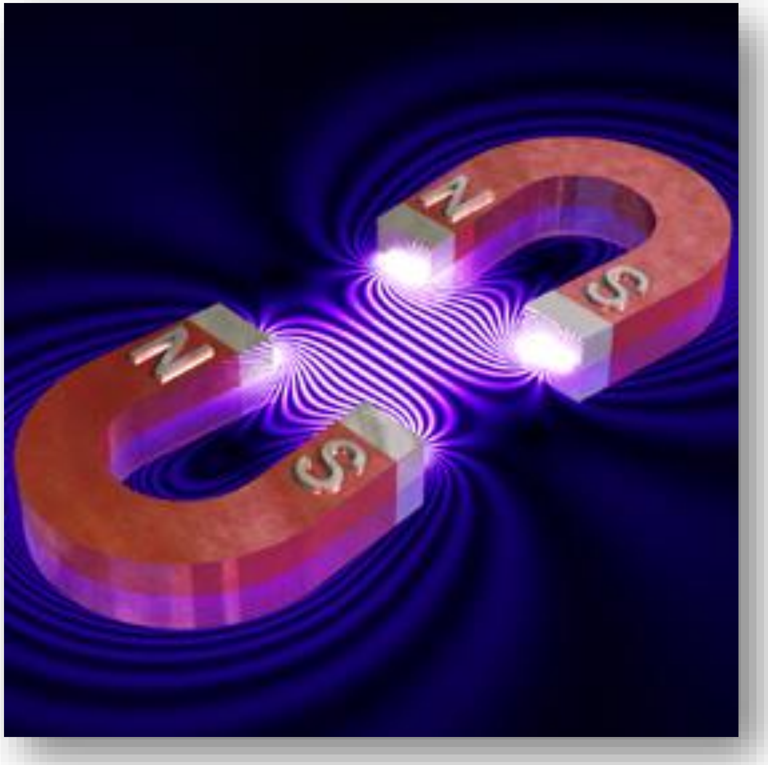
- Poles of a Magnet
- Magnetic Fields

## The Motor Effect

- Electromagnetism
- Fleming’s Left-hand Rule (HT)
- Electric Motors (HT)
- Loudspeakers (HT)(Physics)

## Induced Potential, Transformers and the National Grid (HT)(Physics)

- Induced Potential (HT)
- Uses of the Generator Effect (HT)
- Microphones (HT)
- Transformers (HT)



# LearnIT!
# KnowIT!

## Permanent and Induced Magnetism, Magnetic Forces and Fields

- Poles of a Magnet
- Magnetic Fields

# Poles of a Magnet

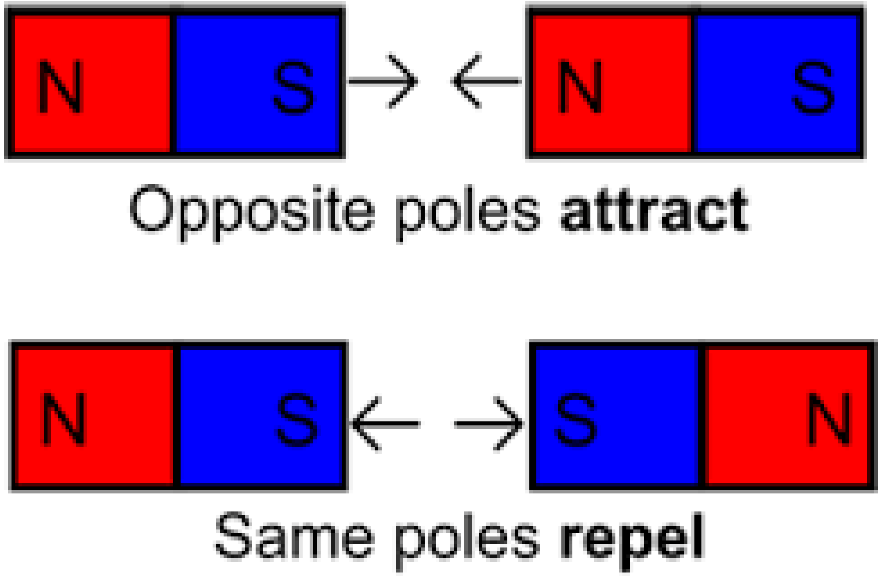
| Object | Definition |
|---|---|
| Poles | Places where the magnetic forces are strongest. |
| Permanent Magnets | Produce their own magnetic fields. Permanent magnets can attract and repel. |
| Induced Magnets | Material that becomes magnetic when placed in a magnetic field. Induced magnets can only attract. When the magnetic field is removed an induced magnet will lose most/all of its magnetism quickly. |

When two magnets are brought together they exert a force on each other. Two like poles repel each other, two unlike poles attract each other.

Attraction and repulsion are examples of non-contact force.

# Magnetic Forces

**When two poles of two magnets are placed near each other they can either attract or repel each other. The combination of north and south poles determines whether they attract or repel.**

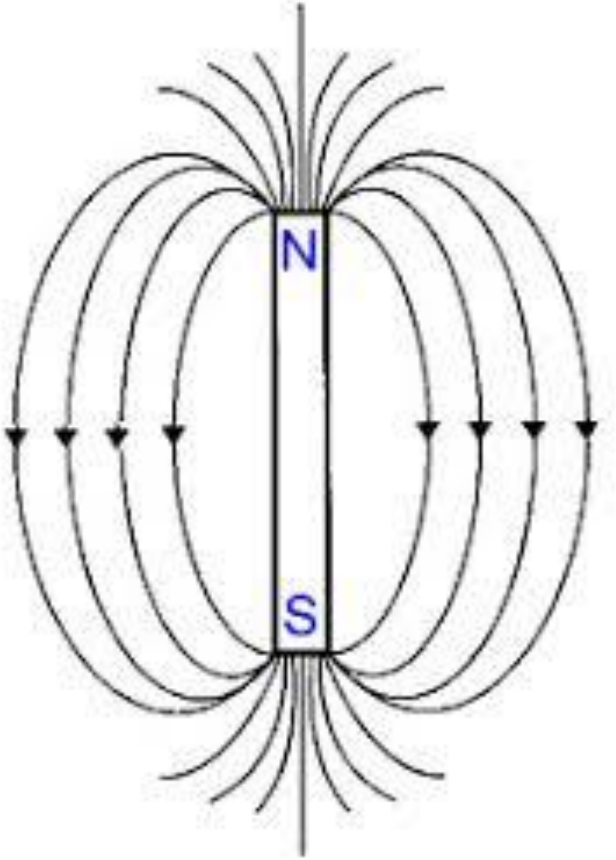


# Magnetic Fields

There are four main magnetic materials that you need to know: **iron**, **steel** (because it is made from iron), **nickel** and **cobalt**. There is always a force of **attraction** between magnets and magnetic materials.

**Magnetic field** = The region around a magnet where a force acts on another magnet (or magnetic material).

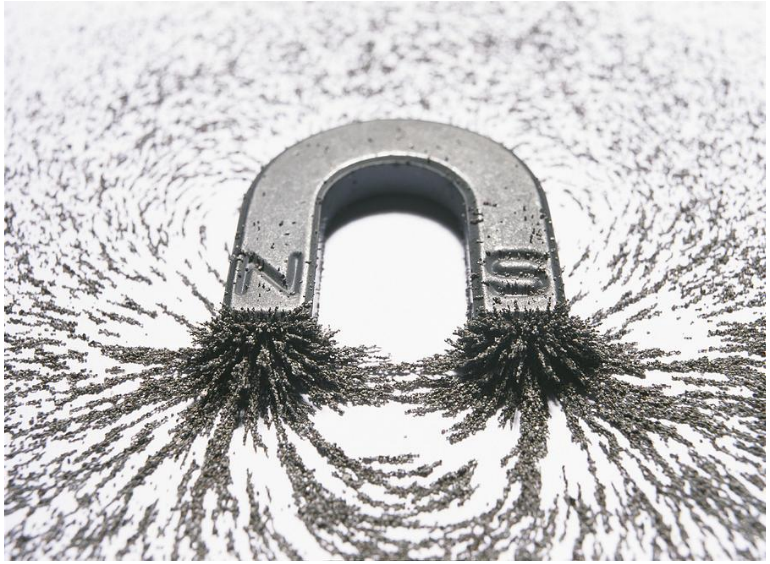
The **strength** of a magnetic field depends on the **distance from the magnet**.
The field is **strongest at the poles**.



# Direction of a Magnetic Field

**The direction of the magnetic field at any point is given by the direction of the force that would act on another north pole placed at that point.**

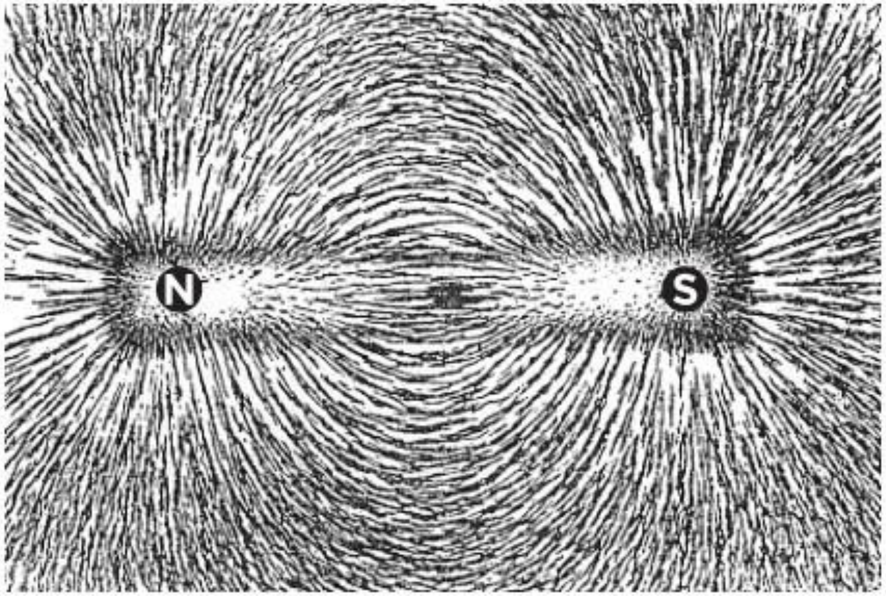
**The direction of a magnetic field line is always from north (seeking) pole to south (seeking) pole.**



# Magnetic Field Shapes

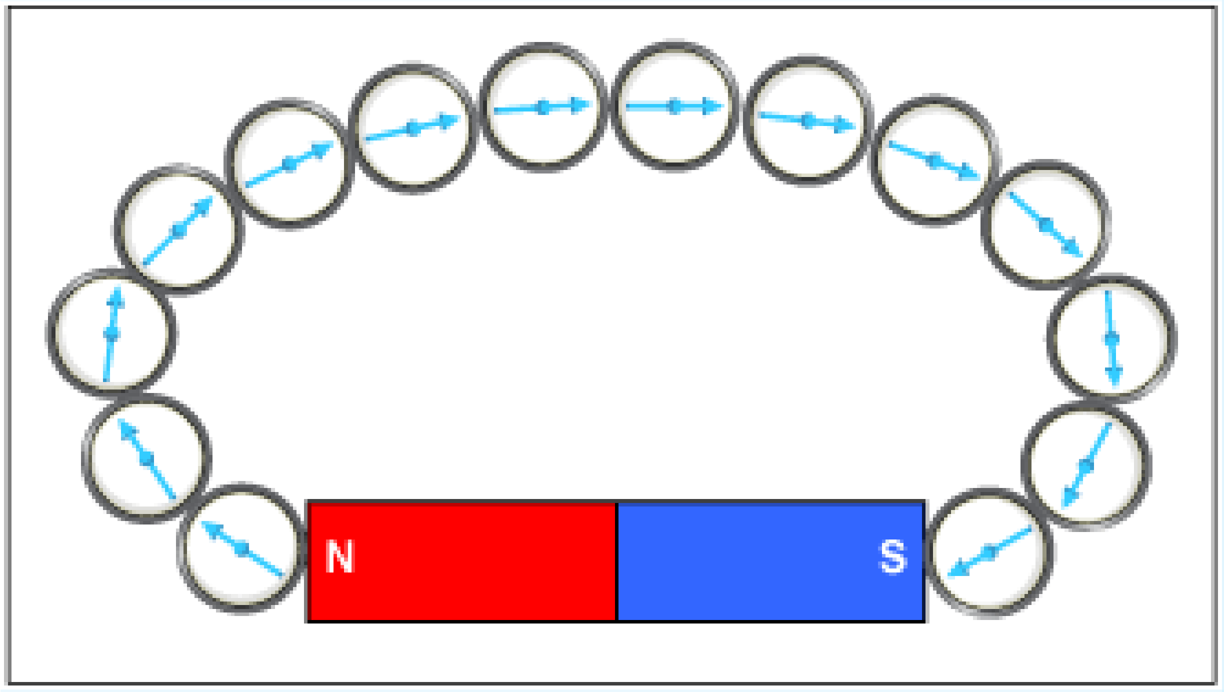
To find the direction of the magnetic field of a bar magnet there are two main techniques.

1. Place the bar magnet under a piece of paper and sprinkle **iron filings** over the paper. Tapping the paper will produce the magnetic field pattern of the bar magnet.



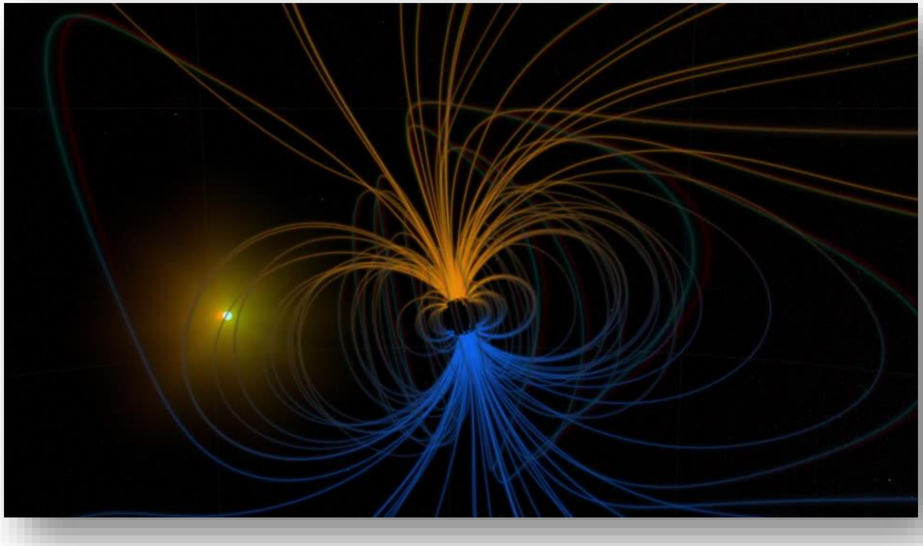
# Magnetic Field Shapes…continued

2. Placing a **magnetic compass** (which contains a small bar magnet) in the magnetic field of a bar magnet causes the compass needle to point in the direction of the magnetic field.



# Earth's Magnetic Field

A **magnetic compass** contains a small **bar magnet**. The Earth has a magnetic field. The compass points in the **direction of the Earth's magnetic field**.



The magnetic field pattern produced by compass needles leads us to conclude that the **Earth's core is magnetic**. The origin of the Earth's magnetic field is thought to be the movement of **molten iron** in the core.

# QuestionIT!

## Permanent and induced magnetism, magnetic forces and fields

- **Poles of a Magnet**
- **Magnetic Fields**

## Permanent and Induced Magnetism, Magnetic Forces and Fields - **QuestionIT**

1. What are the poles of a magnet?
2. When two magnets are brought together what do they do?
3. When a magnet and a magnetic material are brought together what do they do?
4. What is a permanent magnet?
5. What is an induced magnet?

## Permanent and Induced Magnetism, Magnetic Forces and Fields - **QuestionIT**

6. Describe the difference between permanent and induced magnets.

7. Which part of a magnet has the strongest magnetic field?

8. Two magnets are placed close together, north seeking pole to north seeking pole. Describe the forces acting on the two magnets.

9. Name three magnetic elements.

## Permanent and Induced Magnetism, Magnetic Forces and Fields - QuestionIT

10. Describe two methods for finding the magnetic field pattern of a bar magnet.

11. Draw the magnetic field pattern of a bar magnet.

12. How would you describe the direction of a magnetic field line?

13. What does a magnetic compass contain?

14. Which way does the compass needle point?

15. What do scientists think is the cause of the Earth’s magnetic field?

# AnswerIT!

## Permanent and induced magnetism, magnetic forces and fields

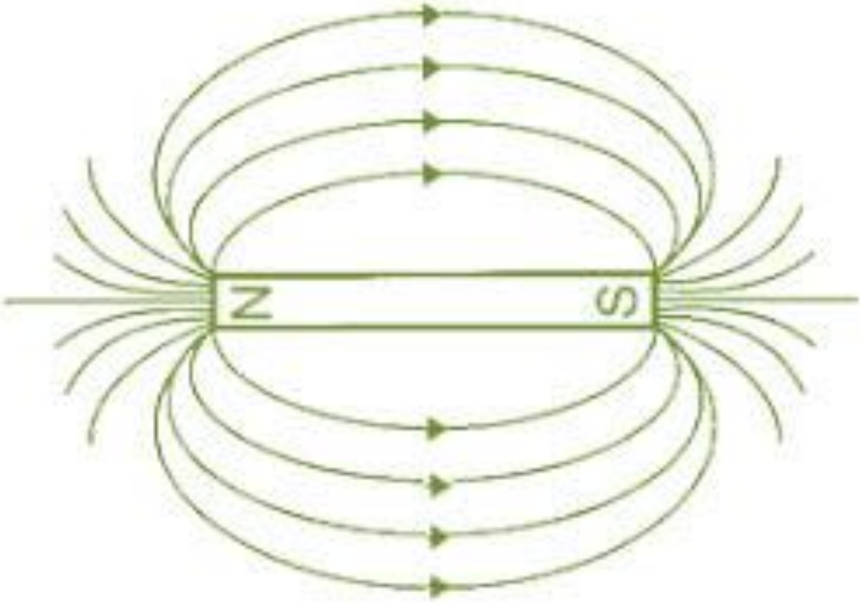
- **Poles of a Magnet**
- **Magnetic Fields**

Permanent and Induced Magnetism, Magnetic Forces and Fields - **QuestionIT**

1. What are the poles of a magnet?
   Places where the magnetic forces are strongest.
2. When two magnets are brought together what do they do?
   Exert a force on each other; attraction or repulsion.
3. When a magnet and a magnetic material are brought together what do they do?
   Attract.
4. What is a permanent magnet?
   Material that produces its own magnetic field.
5. What is an induced magnet?
   Material that becomes a magnet when it is placed in a magnetic field.

6. Describe the difference between permanent and induced magnets.
   Permanent produces its own field/ induced becomes magnetic when placed in a field.
   Permanent can attract or repel/ induced always attracts.
   Induced magnet loses most/all of its magnetism quickly when removed from magnetic field.
7. Which part of a magnet has the strongest magnetic field?
   Poles.
8. Two magnets are placed close together, north seeking pole to north seeking pole. Describe the forces acting on the two magnets.
   Repulsion.
9. Name three magnetic elements.
   Iron, steel, cobalt, nickel.

10. Describe two methods for finding the magnetic field pattern of a bar magnet.
    Sprinkle iron filings onto paper, tap paper. Use small compasses to follow field from poles; mark paper at the compass needle end.
11. Draw the magnetic field pattern of a bar magnet.



12. How would you describe the direction of a magnetic field line?
    Given by the direction of the force that would act on another north pole placed at that point/ from the north (seeking) pole to the south (seeking) pole.
13. What does a magnetic compass contain?
    Small bar magnet.
14. Which way does the compass needle point?
    In the direction of the Earth’s magnetic field.
15. What do scientists think is the cause of the Earth’s magnetic field?
    Molten iron core.

# LearnIT!
# KnowIT!

## The Motor Effect

- Electromagnetism
- Fleming’s Left-hand Rule (HT)
- Electric Motors (HT)
- Loudspeakers (HT)(Physics)

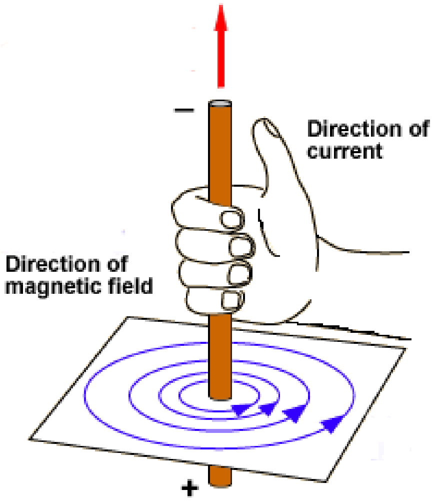
# Electromagnetism

**When a current flows through a conducting wire a magnetic field is produced around the wire.**

**The strength of the magnetic field depends on the current through the wire and the distance from the wire.**

**Increasing the current through the wire increases the strength of the magnetic field.**

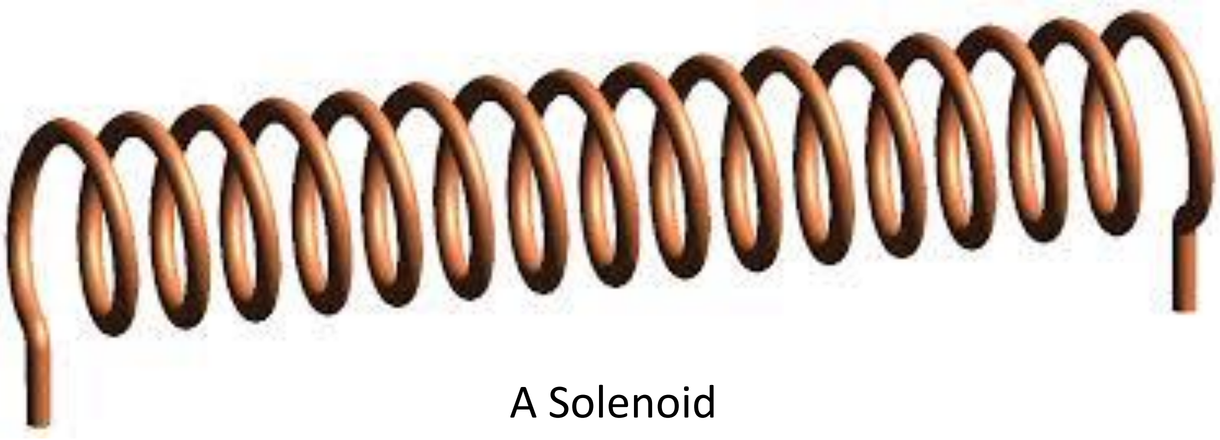
**Increasing the distance from the wire decreases the strength of the magnetic field.**



# Solenoids

A solenoid is a **coil of wire** used to produce a **magnetic field**.

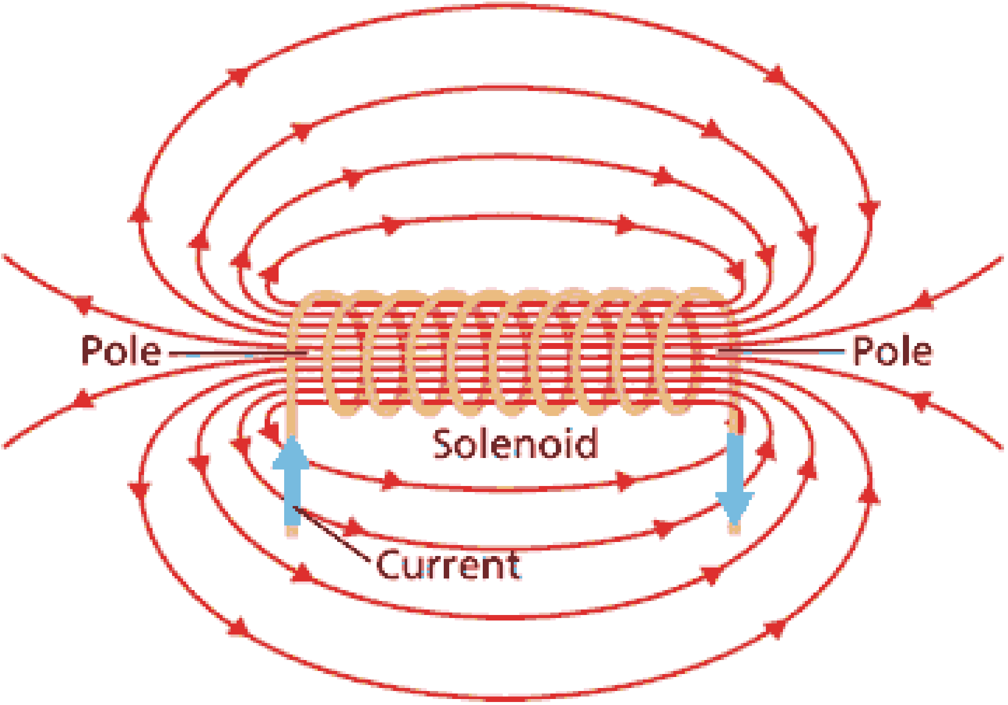
Shaping a wire to make a solenoid **increases the strength** of the magnetic field created by the current through the wire.



A Solenoid

# Solenoids… continued

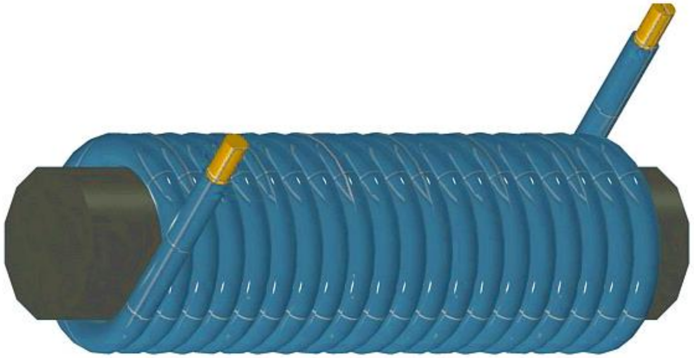
The magnetic field of a solenoid has a **similar shape to that of a bar magnet** – though the magnetic field extends inside the solenoid and is **strong and uniform**.



# Making the Magnetic Field of a Solenoid Stronger

It is possible to increase the strength of a solenoid's magnetic field by…

1. Adding **an iron core** to a solenoid.
2. **Increasing the current** though the solenoid.
3. **Increasing the number of turns of wire** on the solenoid.

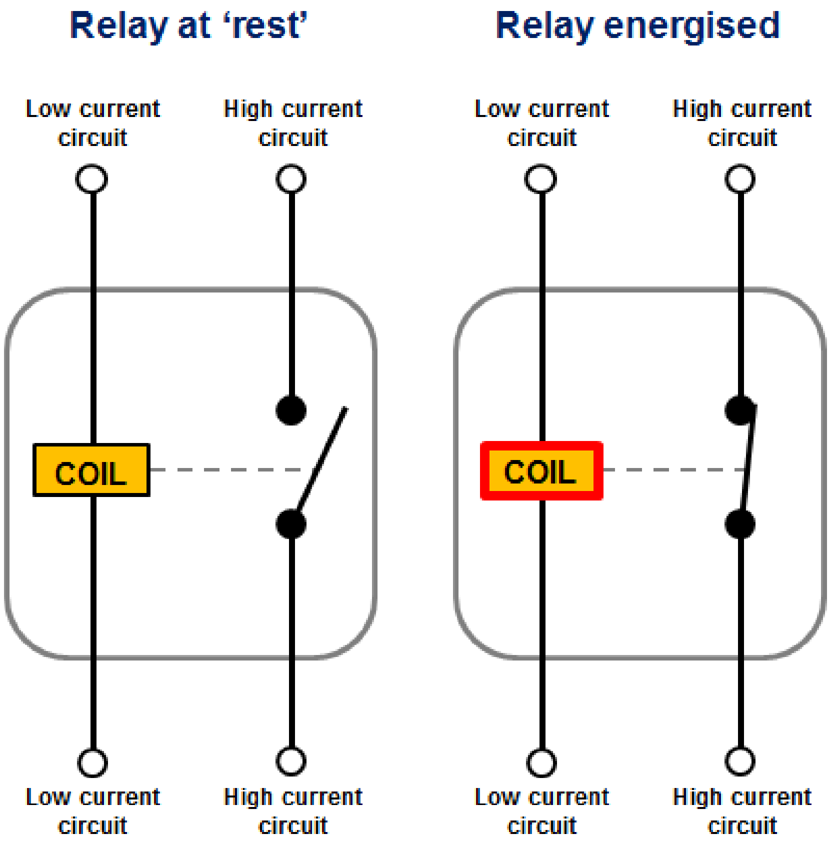


A **solenoid** with an **iron core** is an **electromagnet.**

# (Physics only) Electromagnetic Device: Relay

A **relay is a switch**. It uses a **solenoid** (shown as a coil in the diagram opposite) to attract an iron armature.

Relays are used so that a **small current can turn on a larger current in an isolated circuit**. This reduces the amount of thicker, more expensive, wires needed.

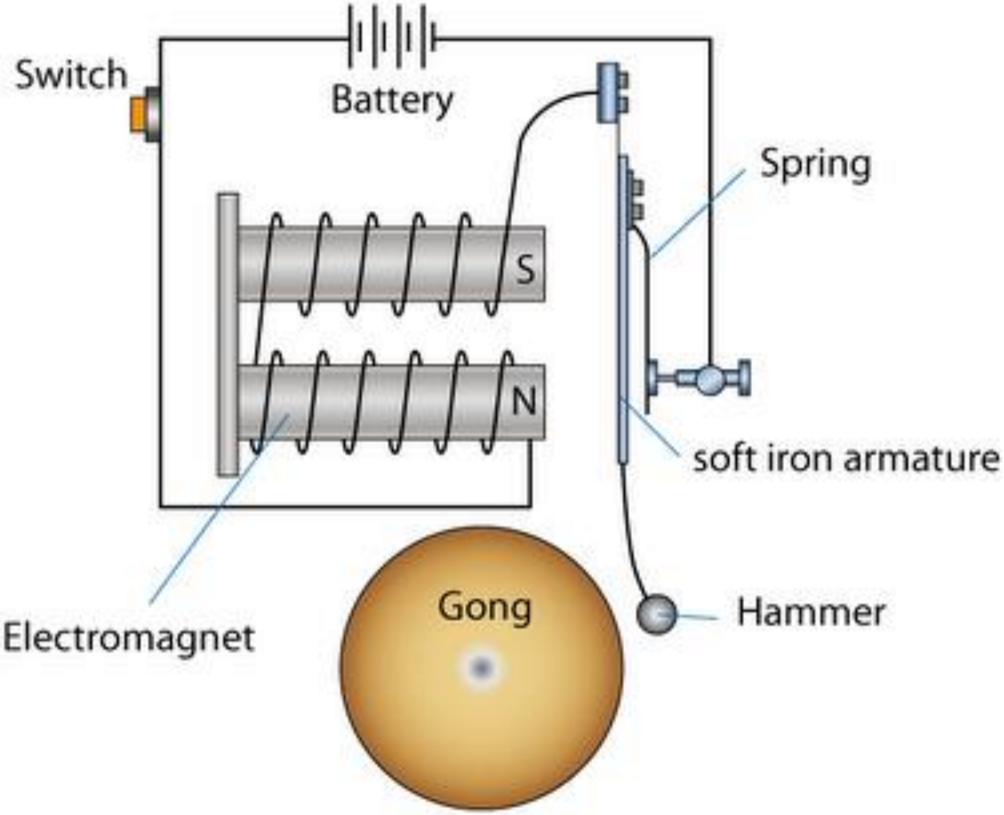


# (Physics only) Electromagnetic Device: Electric Bell

An electric bell uses a **solenoid** to **attract a soft iron armature**.

This makes the hammer hit the bell making a single ring. The movement of the soft iron armature breaks the circuit demagnetising the soft iron armature which returns to its original position.

The whole process then repeats - as long at the switch is pressed.



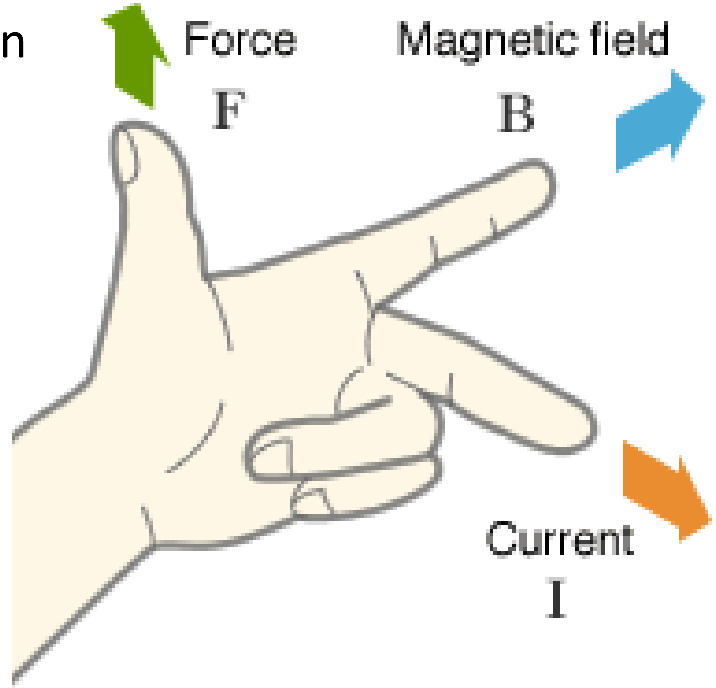
# Fleming's Left-Hand Rule

When a **conductor carrying a current** is **placed in a magnetic field** the **magnet** producing the field **and the conductor** exert a **force** on each other. This is called the **motor effect**.

The direction of the force can be found if the direction of the current flow and the direction of the magnetic field are known.

In the diagram the thumb, first finger and second finger are held at right angles to each other.

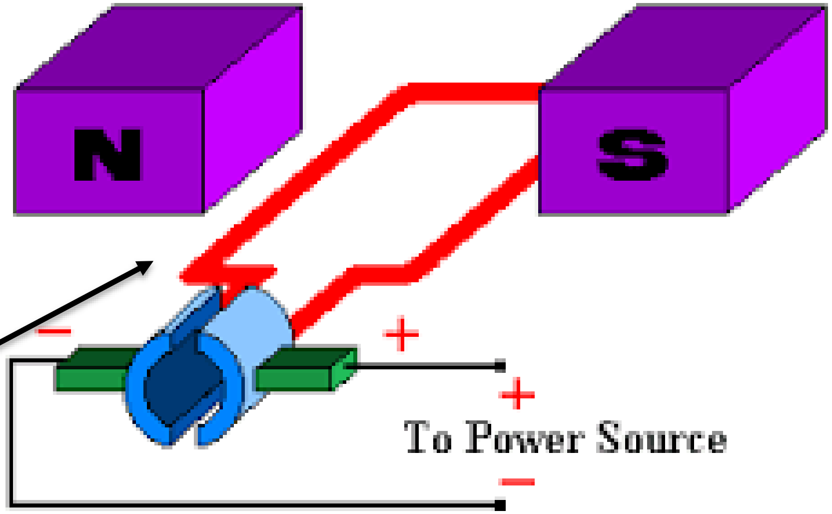
First Finger – Field (magnetic N to S)
Second Finger – Direction of current flow
Thumb – Direction of Force (motion)



# Motors

Example:

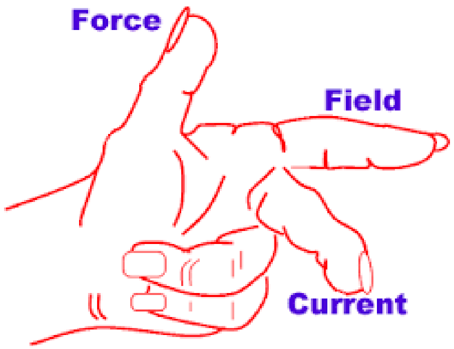
Determine the direction that the motor will spin using Fleming's Left-Hand Rule.



Solution:

Looking at the wire **next to the North seeking pole** of the magnet…

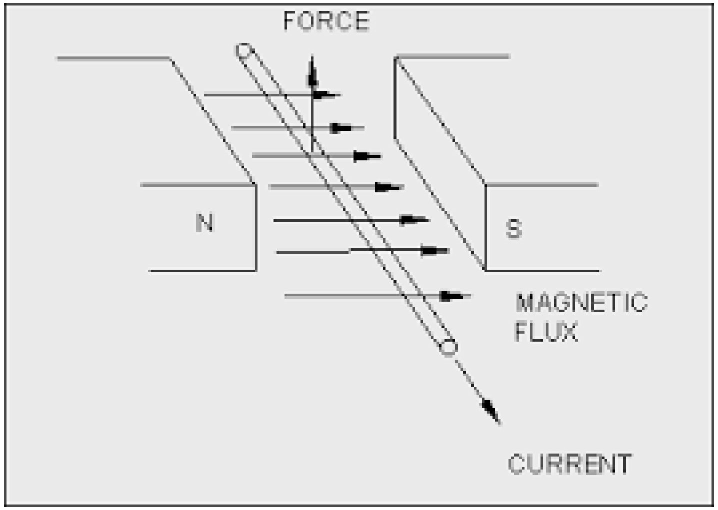
- **Magnetic field** (first finger) is pointing to the **right** (North to south).
- **Current flow** (second finger) is pointing **towards you**.
- (Remember, conventional flow is + to -)
- **Force/Motion** of the wire will be **upwards** (so the motor will spin clockwise.



# Force on a Conductor

The factors that affect the force on a conductor are:

- **Magnetic Flux Density (B) in tesla**
- **Current (I) in amperes**
- **Length of Conductor (ℓ) in metres**



These quantities are linked by the equation:

**Force (N) = Magnetic flux density (T) x Current (A) x Length (m)**

$$F = BI\ell$$

# Force on a Conductor… continued

Example:

A 6 cm wire placed in a magnetic field carries a current of 50 mA.

Work out the force on the current carrying wire if the magnetic field strength of the magnetic field is 0.25 T.

Solution:
First step is convert the units: 6 cm = 0.06 m and 50 mA = 0.05 A

Then:

$$\boldsymbol{F = BI\ell}$$

$$F = 0.25 \times 0.05 \times 0.06$$

$$F = 7.5 \times 10^{-4}\ N$$

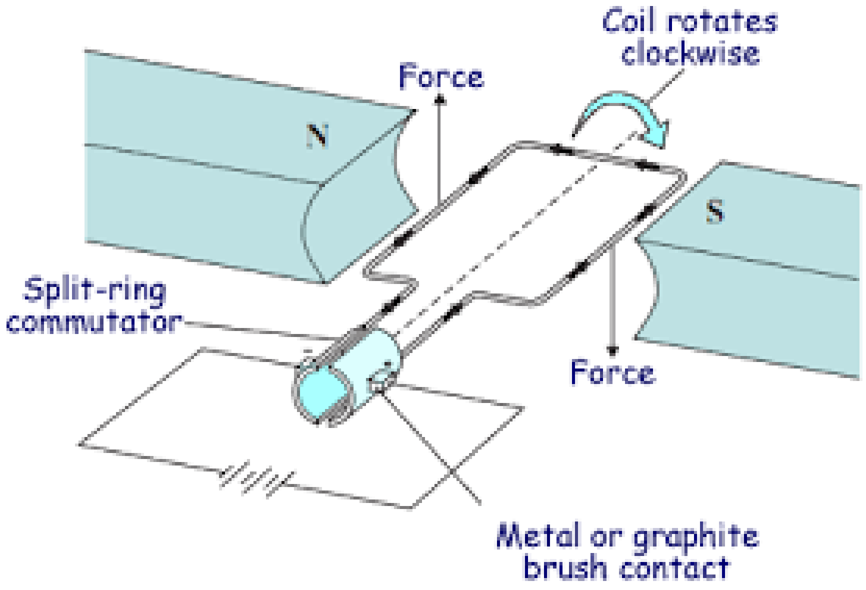
# Electric Motors

A **coil of wire carrying a current in a magnetic field** tends to **rotate**. This is the basis of an **electric motor**.

As the coil of wire carrying a current is in a magnetic field, the coil will experience a **force** (the direction of which can be found from **Fleming's left-hand rule**).

The coil of wire shown will experience an **upwards force on the left-hand side** of the coil and a **downwards force on the right-hand side of the coil**.

As the coil will be **fixed** to an axle the coil of wire will **rotate in a clockwise direction**.

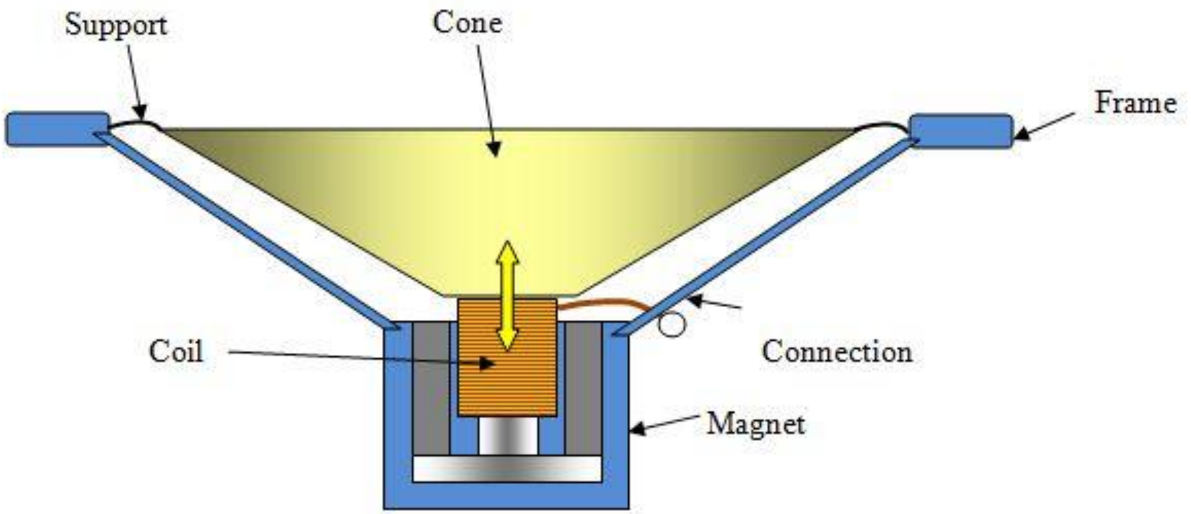


# Loudspeakers

Loudspeakers and headphones use the **motor effect** to convert **variations in current** in electrical circuits to the **pressure variations in sound waves**.

Modern loudspeakers can be wired or wireless.

# Loudspeakers… continued



- A **fluctuating electric current** flows through the **coil of wire**. The coil of wire then becomes an **electromagnet of variable strength**.
- The **electromagnet is then attracted or repelled** away from the **permanent magnet**.
- This **causes the cone to move** – producing a sound.

# Headphones

Headphones are **miniature loudspeakers**. As the headphones only have to move the air inside the ear canal they can be a lot smaller than typical loudspeakers.

# QuestionIT!

## The Motor Effect

- Electromagnetism
- Fleming’s Left-hand Rule (HT)
- Electric Motors (HT)
- Loudspeakers (HT)(Physics)

1. What is produced when a current flows through a conducting wire?

2. Name two factors which will impact on your answer to question 1.

3. What is a solenoid?

4. Describe the magnetic field inside a solenoid.

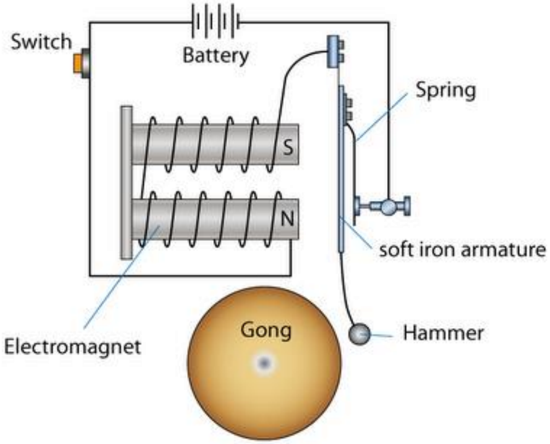
5. State three ways of increasing the strength of the magnetic field produced by a solenoid.

6. Draw the magnetic field pattern produced by a solenoid.

7. What is an electromagnet?

8. (Physics only) Describe how a relay works.

9. (Physics only) An electric bell uses a solenoid. Use the diagram below, and your own knowledge, to explain how an electric bell works.



**The Motor Effect - QuestionIT**

10. (HT) Describe the motor effect.

11. (HT) What 3 factors does Fleming’s left hand-rule represent?

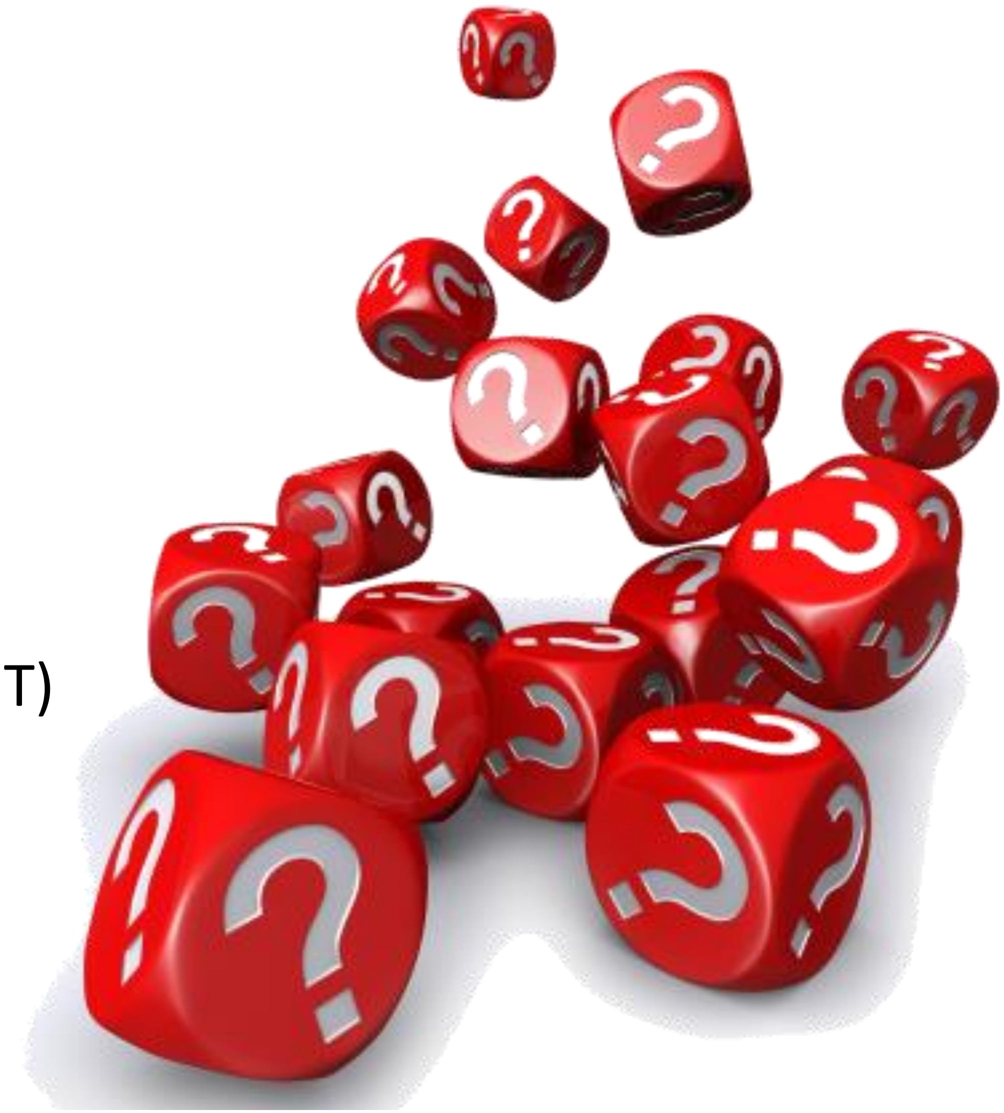
12. (HT) Give three ways of making the electric motor spin faster.

13. (HT) A 40 cm piece of wire is placed in a magnetic field of strength 0.4 T. The wire carries a current of 60 mA. Work out the force on the wire using the equation: Force = magnetic flux density x current x length.

14. (Physics HT only) Explain how a loudspeaker works.

# AnswerIT!

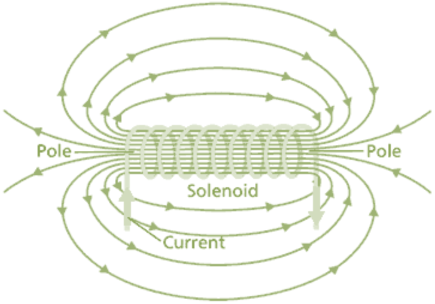
## The Motor Effect



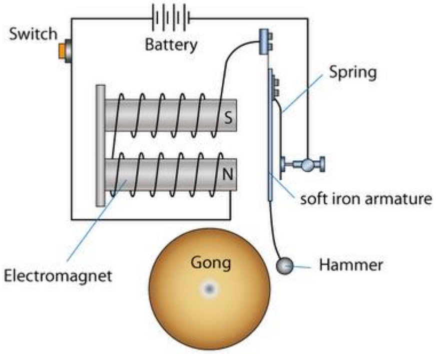
- Electromagnetism
- Fleming’s Left-hand Rule (HT)
- Electric Motors (HT)
- Loudspeakers (HT)(Physics)

1. What is produced when a current flows through a conducting wire?
   Magnetic field.
2. Name two factors which will impact on your answer to question 1.
   Current flowing through the wire, distance from the wire.
3. What is a solenoid?
   Coil of wire in which a magnetic field is created by passing a current though it.
4. Describe the magnetic field inside a solenoid.
   Strong and uniform.
5. State three ways of increasing the strength of the magnetic field produced by a solenoid.
   Increase the current

6. Draw the magnetic field pattern produced by a solenoid.



7. What is an electromagnet?
   Solenoid with an iron core.
8. (Physics only) Describe how a relay works.
   A switch; uses a solenoid to attract an iron armature; small current turns on a larger current.
9. (Physics only) An electric bell uses a solenoid. Use the diagram below, and your own knowledge, to explain how an electric bell works.
   Solenoid attracts an iron armature,
   breaking the circuit.
   Demagnetises, armature springs back.
   Circuit reformed. Repeat.



**The Motor Effect - QuestionIT**

9. (HT) Describe the motor effect.
   Conductor carrying current placed in magnetic field; magnet and conductor exert a force on each other; this force = motor effect.
10. (HT) What 3 factors does Fleming’s left hand-rule represent?
    The force, the current in the conductor, the magnetic field.
11. (HT) Give three ways of making the electric motor spin faster.
    Increase the current; increase the number of turns on the coil; increase the strength of the magnets.

12. (HT) A 40 cm piece of wire is placed in a magnetic field of strength 0.4 T. The wire carries a current of 60 mA. Work out the force on the wire using the equation: Force = magnetic flux density x current x length.

    0.0096 N

    40 cm = 0.4 m

    60 mA = 0.06 A

    $F = Bil$ $\qquad$ $F = 0.4 \times 0.06 \times 0.4\ N$

13. (Physics HT only) Explain how a loudspeaker works.

    A fluctuating electric current flows through the coil of wire.

    The coil of wire then becomes an electromagnet.

    The electromagnet is then attracted or repelled away from the magnet.

    This causes the cone to move – producing a sound.

# LearnIT!
# KnowIT!

## Induced Potential, Transformers and The National Grid (Physics HT only)

- Induced Potential
- Uses of the Generator Effect
- Microphones
- Transformers

# The Generator Effect

If an electrical conductor moves relative to a magnetic field or if there is a change in the magnetic field around a conductor, a **potential difference** is **induced** across the ends of the conductor. If the conductor is part of a complete circuit, a current is **induced** in the conductor. This is called **the generator effect**.

Induced **means to bring about, produce or cause. An induced current is one that is produced by moving a conductor relative to a magnetic field.**

An **induced current generates a magnetic field** that **opposes the original change**, either the movement of the conductor or the change in magnetic field.

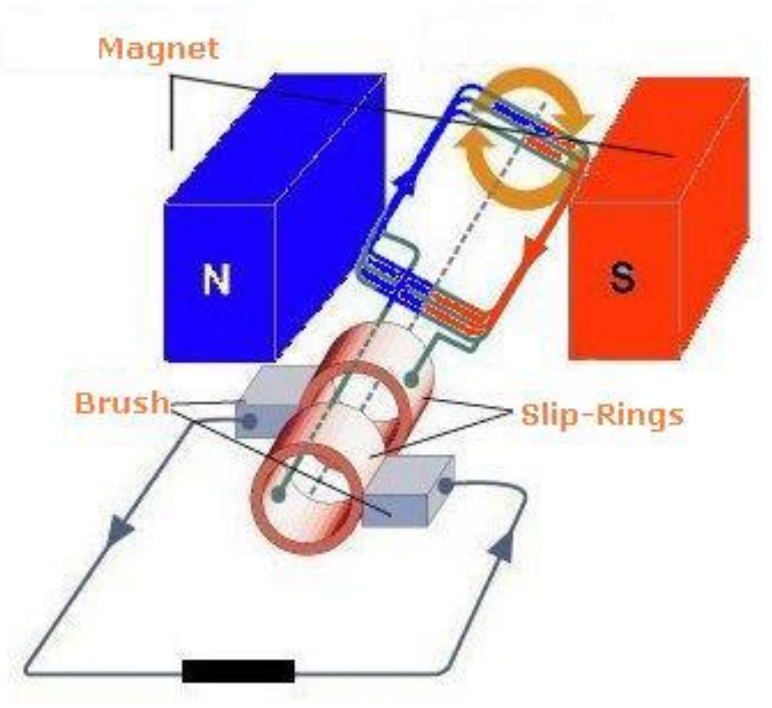
# Generators

A simple generator will have a **coil of wire** that **moves** in a **magnetic field**.

A potential difference is induced across the ends of the conductor – and as there is a complete circuit a current is induced in the coil of wire.

To **increase** the **size** of the induced potential difference/current…

- The coil of wire should be **rotated faster**;
- The **magnetic field** should be made **stronger**;
- The **number of turns** of wire on the coil should be **increased**.



# Direction of Induced Potential

The **direction** of the induced potential difference/induced current are **dependent on the direction of rotation** of the coil and the orientation of the magnetic field.

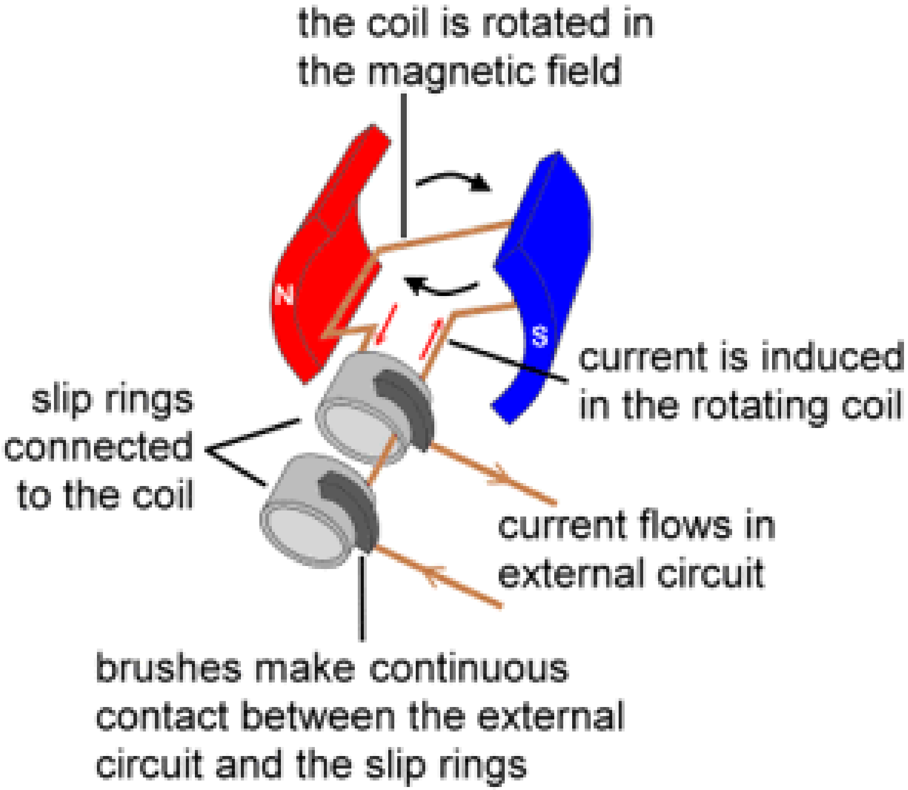
- **Reversing the direction** of rotation of the coil will reverse the direction of the induced potential difference/induced current.
- **Swapping the polarity** of both magnets will also reverse the direction of the induced potential difference/induced current.
- **Swapping the direction of rotation** of the coil **AND swapping the polarity** of each magnet will give **no change to the direction** of the induced potential difference/induced current (as it would have been reversed and reversed again).

# Alternators

**Alternators** use the **generator effect** to generate an **alternating current** (ac).

As a coil of wire moves relative to a magnetic field there is an induced potential difference / induced current.

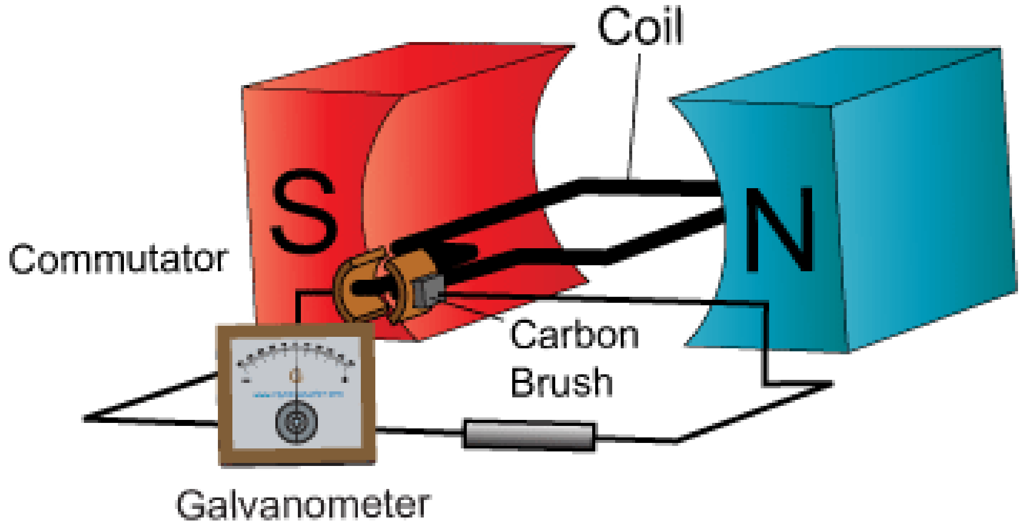
Since the direction of movement of one side of the coil of wire changes, so does the direction of the induced current – so giving ac.



# Dynamos

**Dynamos** use the **generator effect** to generate a **direct current** (dc).

With a dynamo the coil of wire is connected to **split ring commutators** rather than **slip ring commutators**. This means that every half rotation one side of the coil of wire attaches to a different side of the circuit, but as the direction of motion of the coil on the left and right-hand side remain the same the current in the external circuit only moves one way – a dc output.



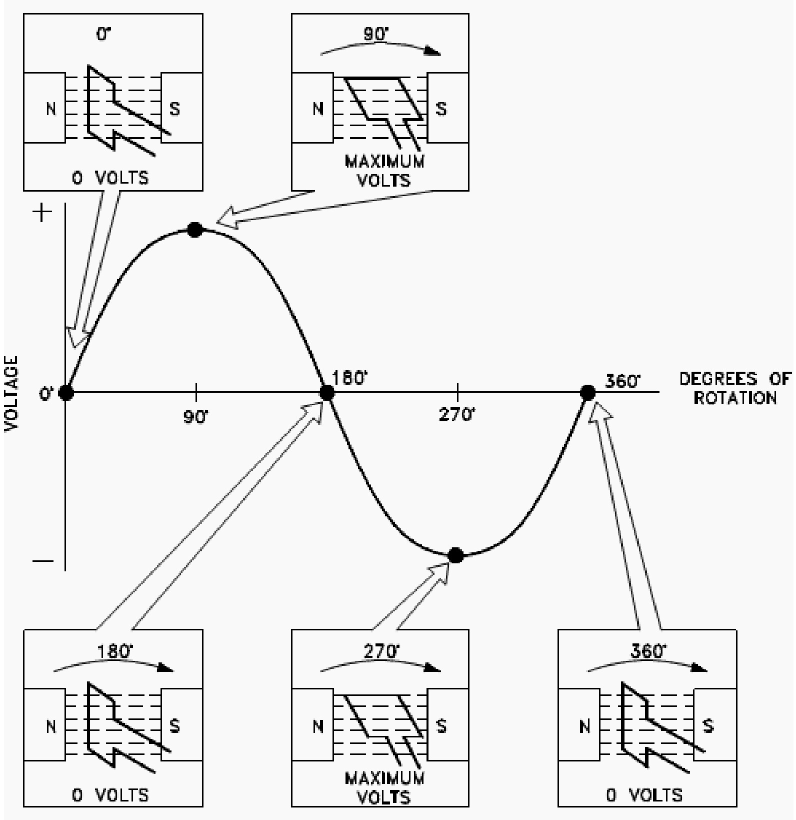
# The Output of a Generator

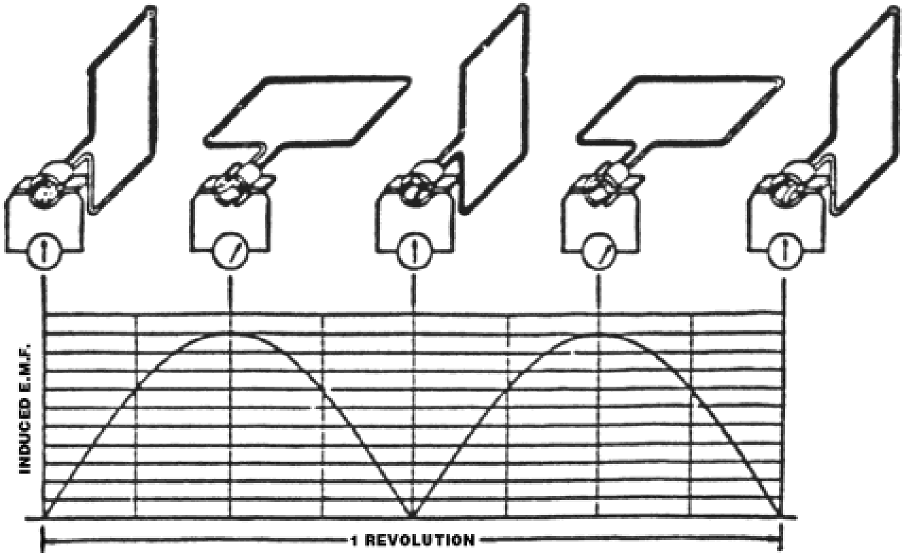
The output of a generator is greatest when the magnetic field lines of the magnets used are being broken at the fastest rate.

For a coil of wire rotating between two magnets the magnetic field lines are being broken fastest when the **coil is moving vertically upwards** – this occurs when the coil of wire and the magnetic field are horizontal.

**No current is induced when the coil moves parallel to the magnetic field lines** – as no field lines are being broken. The output is zero when the coil of wire is vertical.

# The Output of a Generator… continued





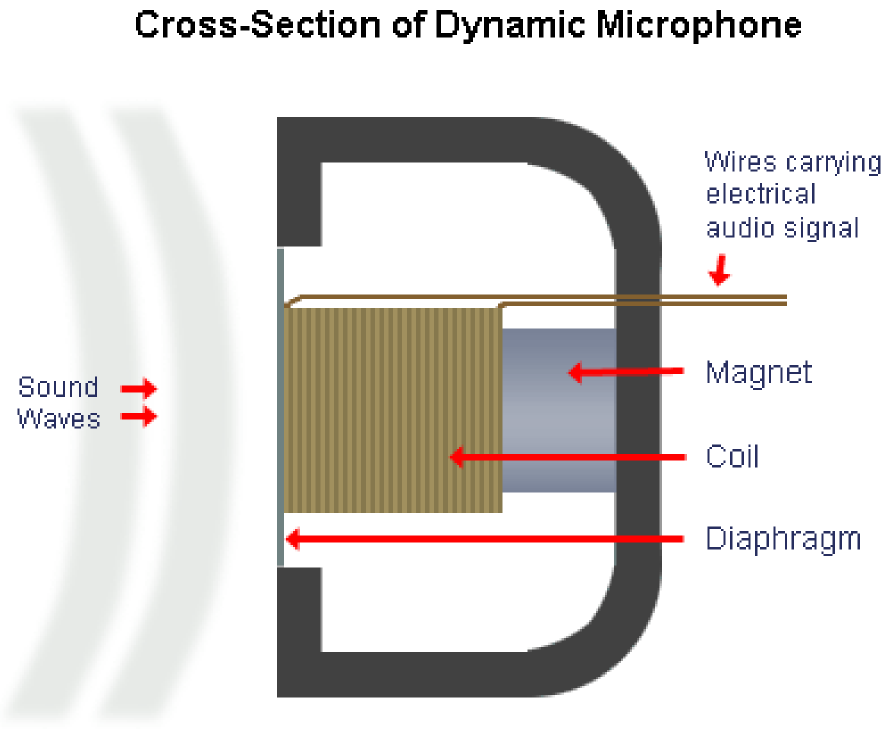
Dynamo Output

Alternator Output

# Microphones

**Microphones** use the **generator effect** to covert the **pressure variations** in sound waves into **variations in current** in electrical circuits.

Microphones contain a diaphragm that moves when sound waves hit it. The movement of the **diaphragm** makes the **coil of wire** move relative to the **magnet**, which induces a current in the wires (the generator effect).



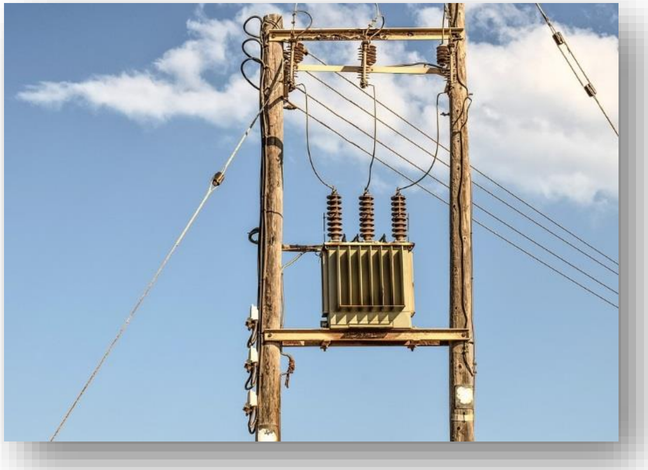
# Transformers

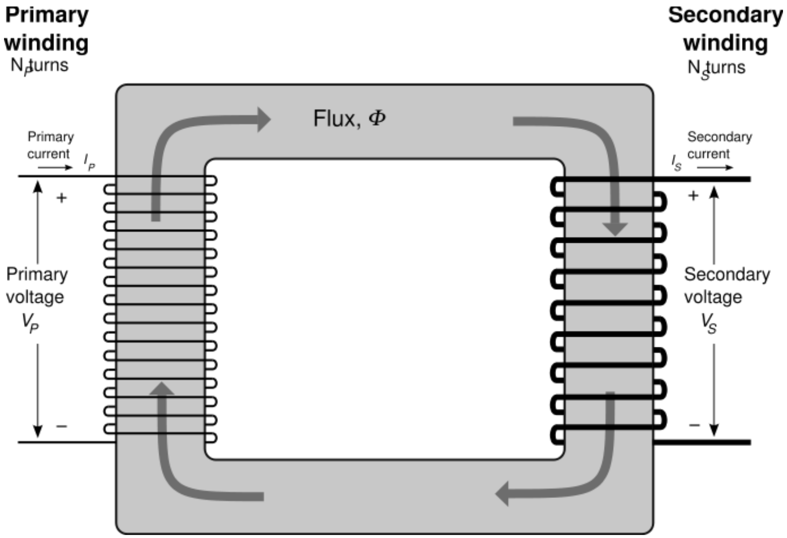
A **basic transformer** consists of a **primary and a secondary coil** wound on an **iron core**.

Iron is used as it is **easily magnetised**.

You need to know about two types of transformer:

- **Step-up transformer**
- **Step-down transformer.**





# Transformer Equations

The ratio of the **potential differences (in Volts, V)** across the primary and secondary coils of a transformer $V_p$ and $V_s$ depends on the ratio of the number of **turns on each coil**, **Np** and **Ns**.

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

If transformers were **100% efficient**, the **electrical power output ($V_s$ x $I_s$)** would equal the **electrical power input ($V_p$ x $I_p$)**.

$$V_s \text{ x } I_s = V_p \text{ x } I_p$$

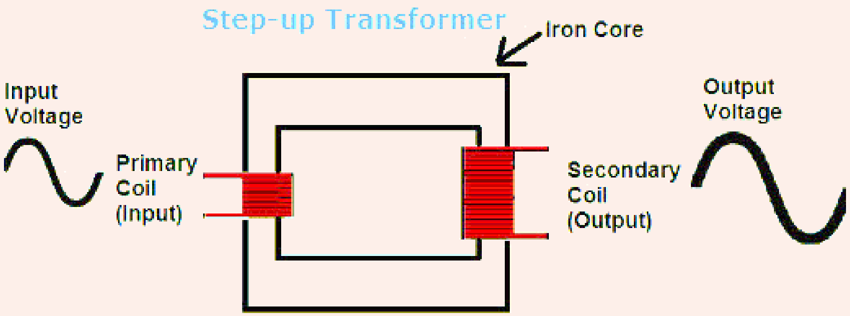
**The output can also be calculated using ratios**.

- If there are 3 times the number of turns of wire on the secondary coil then the output potential difference will be 3 times greater.
- If there are 10 times fewer turns of wire on the secondary coil the output potential difference will be 10 times less.

# Induced Potential, Transformers and The National Grid
## Part 4: Transformers

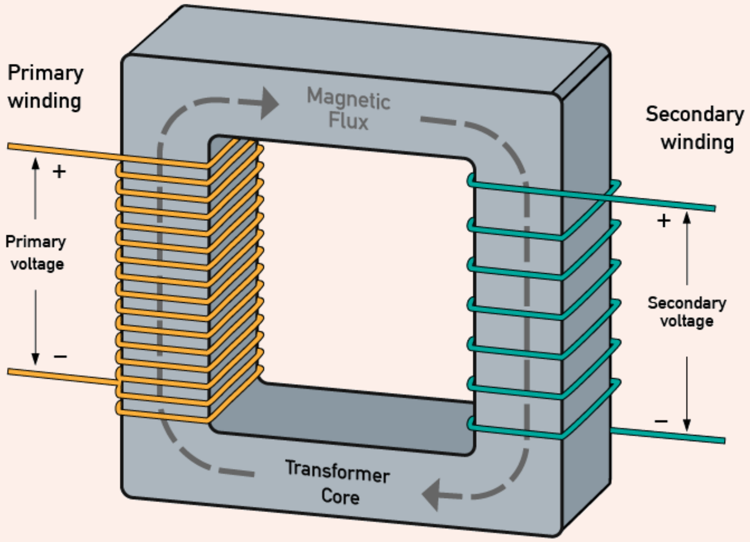
## Step-up transformers

- Increase the potential difference so $V_s > V_p$
- More turns on the secondary coil



## Step-down transformers

- Decrease the potential difference so $V_s < V_p$
- More turns on the primary coil



# How Transformers Work.

- Transformers have a **primary coil of wire** with an **alternating current (ac)** flowing.

- This produces an **alternating magnetic field** in the **iron core**.

- On the **secondary side** of the transformer there is a **coil of wire** and an **alternating magnetic field**.

- So the **magnetic field is moving relative to the coil of wire**.

- This **induces** a potential difference (and **induces** a current if there is a complete circuit). This is the **generator effect**.

# Advantages of power transmission at higher voltages

Transformers are used in **The National Grid** to make the transmission of electricity more **efficient**.

**Increasing** the potential difference will **decrease** the current in the overhead powerlines. Assuming that the transformers are 100 % efficient, the power input and power output would be the same, so:

$$V_s \text{ x } I_s = V_p \text{ x } I_p$$

Where $V_s \times I_s$ is the power output (secondary coil) and $V_p \times I_p$ is the power input (primary coil).

**Potential difference** and **current** are **inversely proportional**. A lower current means that the powerlines will heat up less, less energy will be ‘lost’ as heat.

# Using the Transformer Equations

Example 1

A step-up transformer has 100 turns of wire on the primary coil and 400 turns of wire on the secondary coil.

The input potential difference on the primary coil is 12 V. Work out the output potential difference of the transformer.

**Using** $V_p / V_s = N_p / N_s$

**Substituting gives** $12 / V_s = 100 / 400$

**Rearranging gives** $V_s = \frac{12 \times 400}{100}$

$V_s = 48\ \mathrm{V}$

Alternatively, there are four times as many turns of wire on the secondary coil the output potential difference is four times greater.

# Using the Transformer Equations…continued

Example 2

A step-down transformer has an input potential difference of 230 V. The output potential difference is 12 V and the current in the secondary coil is 30 mA.

Work out the current in the primary coil.

**Assuming no power losses in the transformer…**

$$V_s \times I_s = V_p \times I_p$$

**Substituting gives** $12 \times 0.03 = 230 \times I_p$

**Rearranging gives** $\frac{12 \times 0.03}{230} = I_p$

$$I_p = 0.0016 \text{ A} \quad \text{or } 1.6 \text{ mA}$$

# QuestionIT!

## Induced Potential, Transformers and The National Grid

- Induced Potential
- Uses of the Generator Effect
- Microphones
- Transformers

# Induced Potential, Transformers and The National Grid – **QuestionIT**

1. What does the term ‘induced current’ mean?
2. What is a simple generator made of?
3. How can the size of the induced potential difference/ current in a generator be increased?
4. What factors affect the direction of the induced potential difference/ current?
5. What type of current is induced by an alternator?
6. What type of current is produced by a dynamo?

## Induced Potential, Transformers and The National Grid – **QuestionIT**

7. Describe two ways of reversing the direction of current flow on a dynamo.

8. At which point of the rotation does a dynamo induce the greatest potential difference?

9. How do microphones use the generator effect?

10. What does a basic transformer contain?

11. Why are cores made of iron?

## Induced Potential, Transformers and The National Grid – **QuestionIT**

12. What can be said about the potential difference in the primary and secondary coils of a step-down transformer?

13. How do transformers work?

14. A step-up transformer is used in a power station to increase the potential difference output from 25,000 V to 400,000 V. The current through the overhead power lines is 25 A. Work out the current in the primary coil.

$$Vs \times Is = Vp \times Ip$$

15. Why are transformers used when sending electricity through the National Grid?

# AnswerIT!

## Induced Potential, Transformers and The National Grid

- Induced Potential
- Uses of the Generator Effect
- Microphones
- Transformers

## Induced Potential, Transformers and The National Grid – **QuestionIT**

1. What does the term ‘induced current’ mean?
   Current made by moving a conductor relative to a magnetic field.
2. What is a simple generator made of?
   Coil of wire; magnetic field, movement.
3. How can the size of the induced potential difference/ current in a generator be increased?
   More turns, stronger magnetic field, increase sped of movement.
4. What factors affect the direction of the induced potential difference/ current?
   Direction of movement/ rotation; reversing the polarity.
5. What type of current is induced by an alternator? ac

6. What type of current is produced by a dynamo? dc

## Induced Potential, Transformers and The National Grid – **QuestionIT**

7. Describe two ways of reversing the direction of current flow on a dynamo.
   Swap the polarity of both magnets.
   Spin the coil of wire in the opposite direction.
8. At which point of the rotation does a dynamo induce the greatest potential difference?
   When the coil of wire is perpendicular to the magnetic field; it is at this point that the magnetic field lines are being cut at the greatest rate.
9. How do microphones use the generator effect?
   Convert the pressure variations in sound waves into variations in current.
10. What does a basic transformer contain?
    Primary coil, secondary coil, iron core.
11. Why are cores made of iron? Easily magnetised.

12. What can be said about the potential difference in the primary and secondary coils of a step-down transformer?
    $V_s < V_p$
13. How do transformers work?
    - Transformers have a **primary coil of wire** with an **alternating current (ac)** flowing.
    - This produces an **alternating magnetic field** in the **iron core**.
    - On the **secondary side** of the transformer there is a **coil of wire** and an **alternating magnetic field**.
    - So the **magnetic field is moving relative to the coil of wire**.
    - This **induces** a potential difference (and **induces** a current if there is a complete circuit). This is the **generator effect**.

14. A step-up transformer is used in a power station to increase the potential difference output from 25,000 V to 400,000 V. The current through the overhead power lines is 25 A. Work out the current in the primary coil.

    $$V\text{s} \times I\text{s} = V\text{p} \times I\text{p}$$

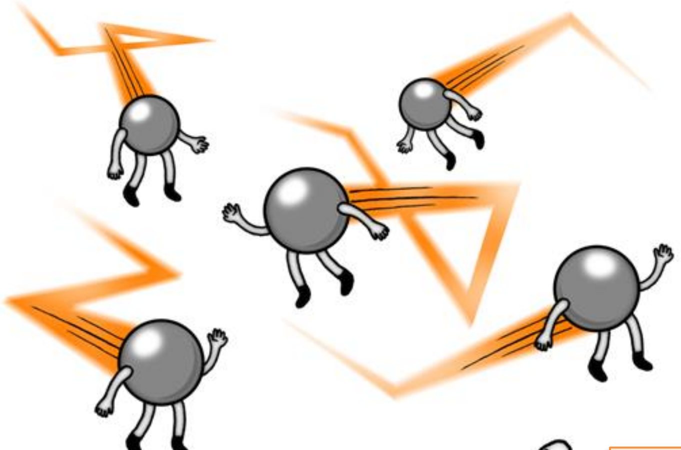
    **400 A**

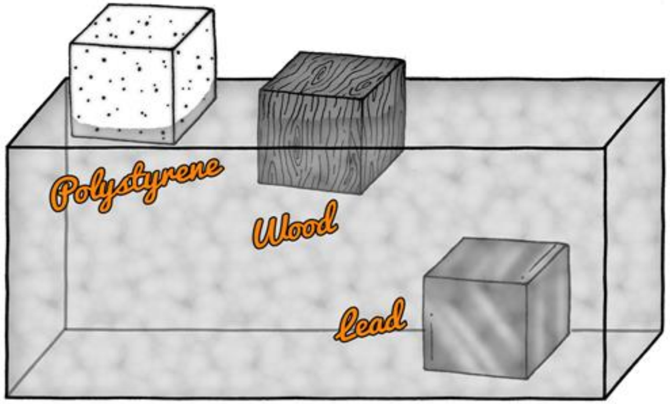
    **16 times more potential difference so 16 times less current.**

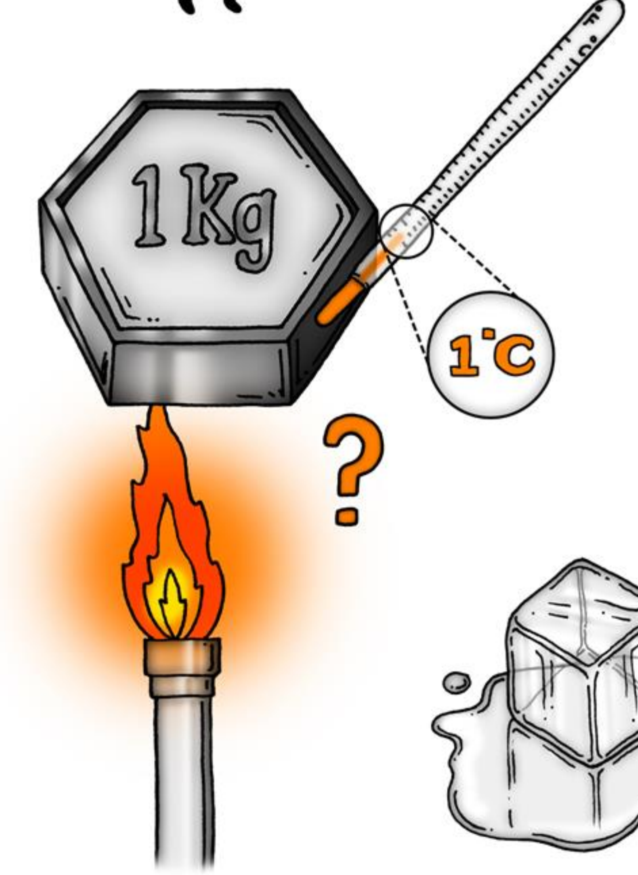
    **$V\text{s} \times I\text{s} = V\text{p} \times I\text{p}$ or correct substitution.**

15. Why are transformers used when sending electricity through the National Grid?

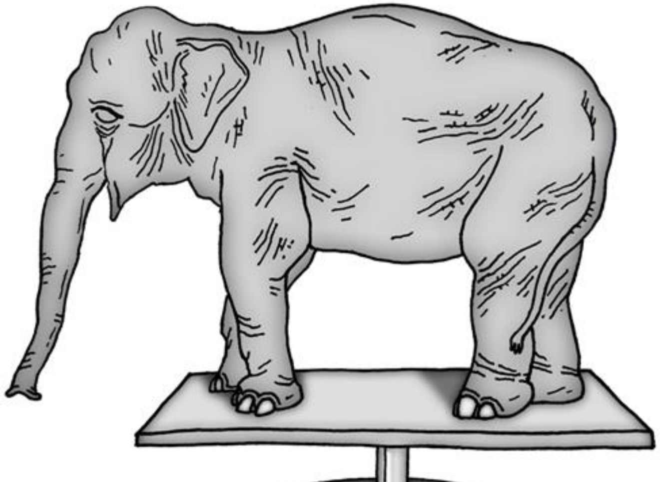
    Increases potential difference; decreases current; decreases loss of energy through heat.

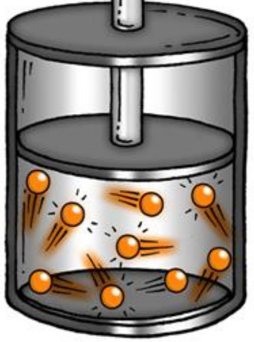


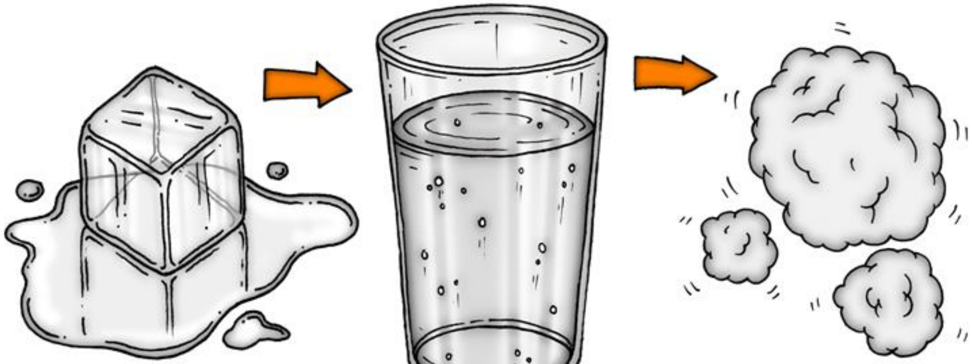




# Particle Model of Matter







# Overview
# Particle Model of Matter

## Changes of state and the particle model

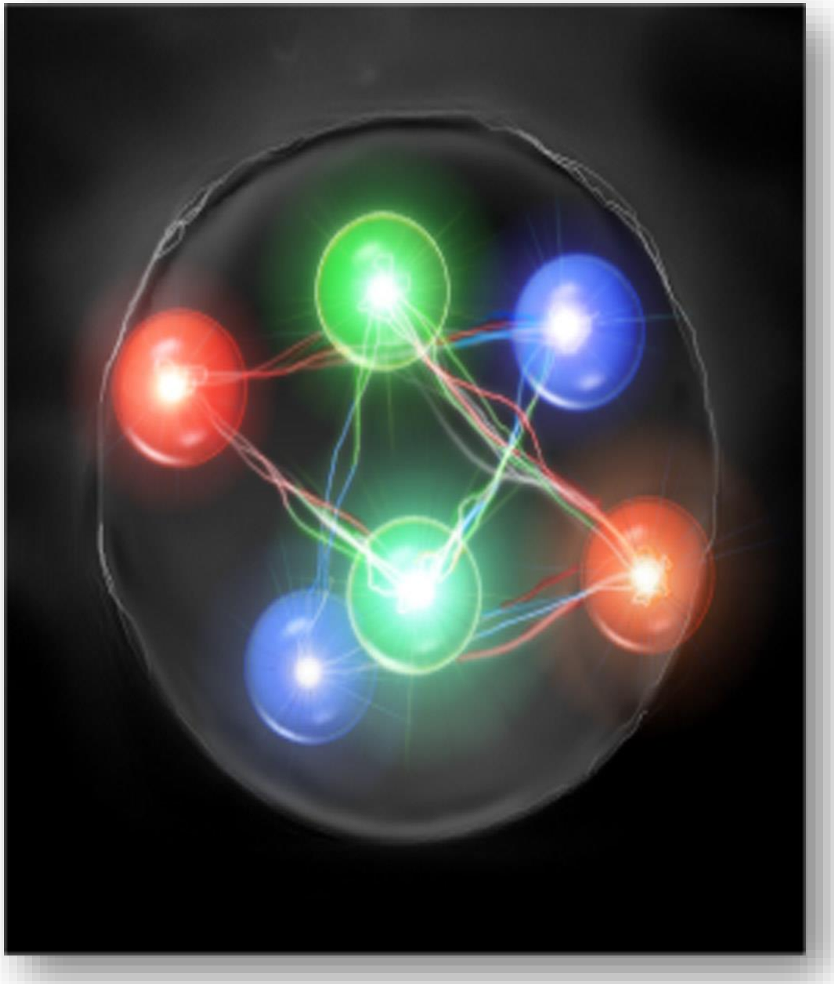
- Density of materials
- Changes of state

## Internal energy and energy transfers

- Internal energy
- Temperature changes in a system and specific heat capacity
- Changes of heat and specific latent heat

## Particle model and pressure

- Particle motion in gases
- Pressure in gases (physics only)
- Increasing the pressure of a gas (physics only – Higher Tier)



# LearnIT!
# KnowIT!

## Changes of state and the particle model

- Density of materials
- Changes of state

# Changes of state and the particle model – Density of materials

## Density is the mass of a given volume of a substance

The density of a substance is determined by the mass of the atoms it is made from and how closely these atoms are packed together.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

mass in kg

volume in $m^3$

What is the density of a bar of gold if its volume is 350 cm³ (0.00035 m³) and its mass is 6.76 kg?

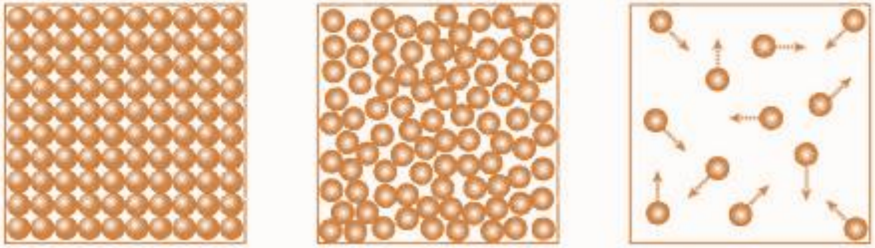
$$\text{Density } \rho = \frac{\text{mass (kg)}}{\text{volume (m}^3\text{)}} = \frac{6.76}{0.00035}$$

Density of gold = 19 314 $kg/m^3$

| Substance | Density ($kg/m^3$) |
|---|---|
| Water (l) | 1 000 |
| Glass (s) | 3 140 |
| Iron (s) | 7 700 |
| Aluminium (s) | 2 800 |
| Hydrogen (g) | 0.085 |

# Changes of state and the particle model – Density of materials

Density also depends on the **state** of a substance.



In **solids** the particles are packed close together.

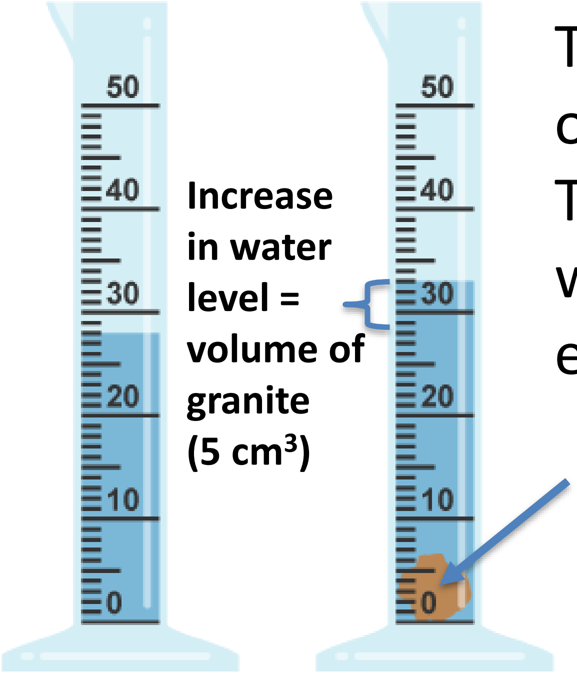
In **liquids** the particles are free to move so the same mass takes up more space.

In **gases** the particles take up a much greater volume than in liquids and solids.

For any particular substance, a solid is usually denser than its liquid and the liquid is usually denser than the gas.

However, there are exceptions to this. Solid water (ice) is less dense than liquid water. This is why ice floats on water.

# Finding the density of an irregular object



**Increase in water level = volume of granite (5 $cm^3$)**

To find the density of an **irregular** shaped object, you need to determine its volume. To do this, it is placed in a known volume of water and the amount of water **displaced** equals the volume of the object.

Piece of **granite** stone with a mass of 13.5 g (0.0135 kg)

Volume = 0.000005 $m^3$

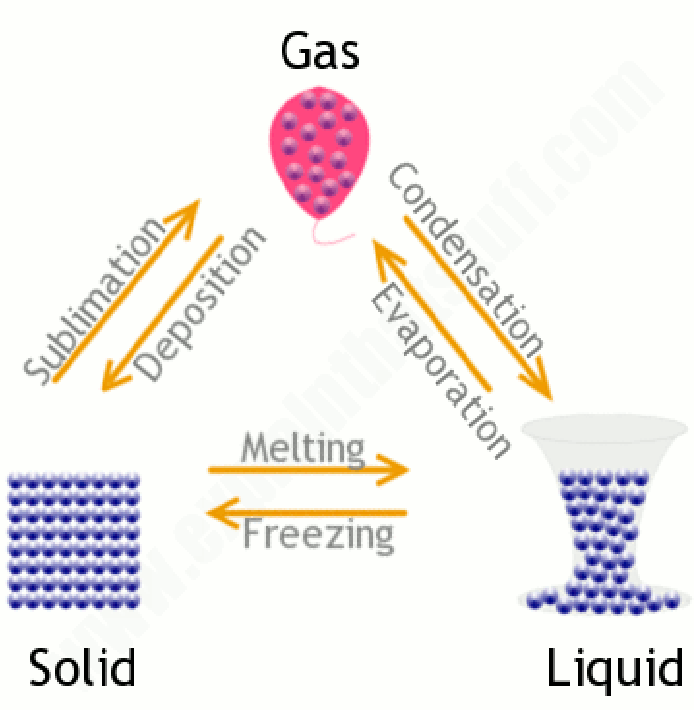
$$\text{Density of granite} = \frac{0.0135\text{ kg}}{0.000005\text{ m}^3} = 2\,690\text{ kg/m}^3$$

# Changes of state and the particle model – Changes of state

A change of state can be brought about by changing the **temperature** or **pressure** of a material.

If the solid shown has a mass of 1kg, then the liquid and gas will both have a mass of 1 kg.

**Mass is conserved when a substance changes state, only the volume changes.**



**The arrows show the direction in change of state.**

Changes of state are **physical changes** **not** chemical changes. The change can be **reversed** in a physical change so the material recovers its **original properties**. This does not happen with a chemical change.

# QuestionIT!

## Changes of state and the particle model

- Density of materials
- Changes of state

# Changes of state and the particle model – AnswerIT

1. Why is it incorrect to say iron is heavier than wood?

2. Water has a density of 1000 kg/m³. A piece of rubber has a density of 1024 kg/m³. Explain what would happen if the rubber was put in a pool of water?

3. This "ready-mix" concrete waggon contains 9600 kg of concrete. If the density of the concrete is 2400 kg/m³, what volume of concrete does the waggon contain?

# Changes of state and the particle model – **AnswerIT**

4. a. A sheet of insulating foam measures 3 m x 1 m x 0.08 m. It has a mass of 9.6 kg. Calculate the density of the insulating foam.

   b. High density foam is made of the same material and can be used to give better insulation for the same thickness of foam. Describe how the arrangement of particles would differ in these two types of foam (you may draw diagrams to help your answer).

5. When copper metal is heated to 1100 °C it melts.

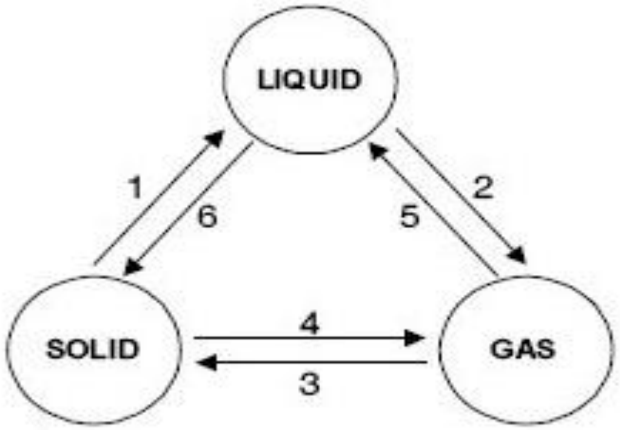
   a. Is this a chemical or physical change? Explain your answer.

   b. What will happen to the mass of the sample of copper after it has melted? Explain your answer.

# Changes of state and the particle model – AnswerIT

6. Explain the difference between a physical and a chemical change.

7. Name the changes in state given in the diagram by the arrows 1 to 6.



8. If you wanted to find the density of a brass key, you first need to measure its volume. Describe how to determine the volume of a brass key.

# AnswerIT!

## Changes of state and the particle model

- Density of materials
- Changes of state

# Changes of state and the particle model – **AnswerIT**

1. Why is it incorrect to say iron is heavier than wood?

   It depends how much iron and wood you have. You should say iron is denser than wood.

2. Water has a density of 1000 kg/m³. A piece of rubber has a density of 1024 kg/m³. Explain what would happen if the rubber was put in a pool of water?

   **Rubber has a higher density than water so the rubber would sink in water.**

3. This "ready-mix" concrete waggon contains 9600 kg of concrete. If the density of the concrete is 2400 kg/m³, what volume of concrete does the waggon contain?

$$\text{Density} = \frac{m}{v} \qquad v = \frac{\text{mass}}{\text{density}} \qquad = \frac{9600\ \text{kg}}{2400\ \text{kg/m}^3} = 4$$

**volume of concrete in the waggon = 4 m³**

# Changes of state and the particle model – AnswerIT

4. a. A sheet of insulating foam measures 3 m x 1 m x 0.08 m. It has a mass of 9.6 kg. Calculate the density of the insulating foam.

**$V = 3 \times 1 \times 0.08 = 0.24\ m^3$**　　**$Density = 9.6 / 0.24 = 40\ kg/m^3$**

b. High density foam is made of the same material and can be used to give better insulation for the same thickness of foam. Describe how the arrangement of particles would differ in these two types of foam (you may draw diagrams to help your answer).

**Particles in the high density foam will be closer together so there are more particles in a given volume, making it denser.**

5. When copper metal is heated to 1100 °C it melts.

a. Is this a chemical or physical change? Explain your answer.

**Physical change. No new products have been formed.**

b. What will happen to the mass of the sample of copper after it has melted? Explain your answer.

**It will stay the same. Mass is conserved when state changes.**

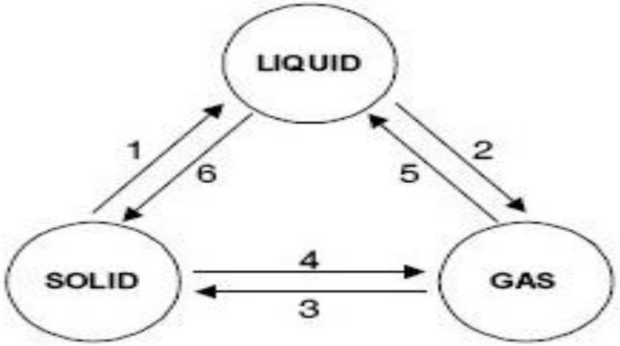
# Changes of state and the particle model – AnswerIT

6. Explain the difference between a physical and a chemical change.

**In a physical change no new products are formed and it can be easily reversed.**

**In a chemical change a new substance is formed which can not easily be changed back .**

7. Name the changes in state given in the diagram by the arrows 1 to 6.



**1. melting 2. evaporating 3. deposition**
**4. subliming 5. condensing 6. freezing**

8. If you wanted to find the density of a brass key, you first need to measure its volume. Describe how to determine the volume of a brass key.

**Drop the key into a known volume of water and measure the amount of water displaced by the key. This will be the volume of the key.**

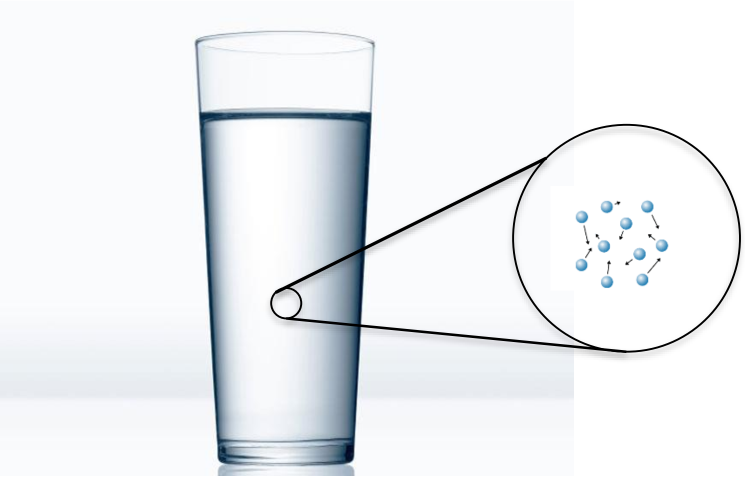
# LearnIT!
# KnowIT!

## Internal energy and energy transfers

- Internal energy
- Temperature change in a system and specific heat capacity
- Changes of heat and specific latent heat

# Internal energy and energy transfers – Internal energy

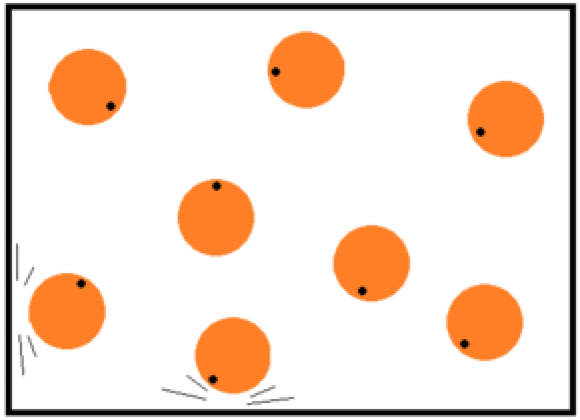
Internal energy is the energy stored in a system by the atoms and molecules that make up that system.



The molecules of water have kinetic (movement) energy and some potential energy. The total **kinetic ($E_k$)** and **potential ($E_p$)** energy in the system make up the **internal energy (U).**

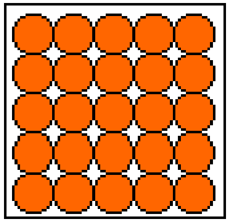
The particles inside a **liquid** or a **gas** are in **constant motion**, colliding with each other and the walls of any container they are in.

In a **solid** the particles are **vibrating** around a fixed point.

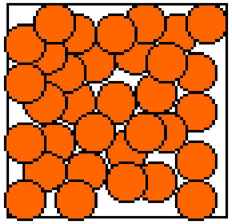


# Internal energy and energy transfers – Internal energy

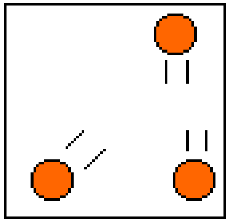
When heat is added to a system the **internal energy** of the particles increases. This can result in the material **changing state**.



In a **solid**, particles can only **vibrate** so they cannot move relative to each other. When the solid is heated the particles gain kinetic energy and vibrate faster and faster.



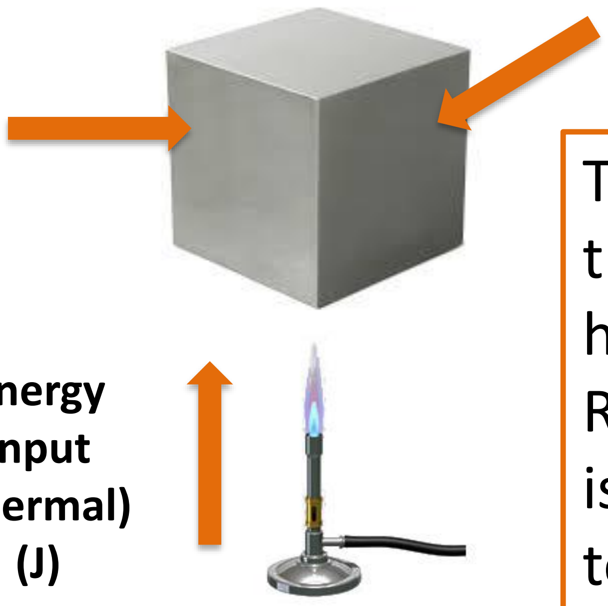
In a **liquid**, the particles are **moving** fast enough to break free from the solid. They are free to move relative to each other but are held within a container.



In a **gas**, the particles have sufficient energy to **break free** from their container. Gas particles can move away from their container and away from other gas particles.

# Internal energy and energy transfers –
# Temperature change in a system and specific heat capacity

The temperature increase of an object depends on what it is made of, the mass of the object and the amount of energy put into it.



**Mass of system (kg)**

**Type of material (specific heat capacity) (J/kg °C)**

**Energy input (thermal) (J)**

To calculate the temperature change, the formula for **specific heat capacity** has to be re-arranged.
Remember, specific heat capacity (***c***) is the energy required to raise the temperature of 1 kg of a substance by 1°C.

$$\text{Temperature change } (\boldsymbol{\Delta\theta}) = \frac{\text{change in thermal energy } (\boldsymbol{\Delta E})}{\text{mass } (\mathbf{m}) \times \text{specific heat capacity } (\boldsymbol{C})}$$

# Internal energy and energy transfers – Temperature change in a system and specific heat capacity

## Calculating temperature change

A kettle contains 1400 g of water at 12 ºC.
If 400 kJ of heat energy is supplied to the water, how much will the temperature rise?

Temperature change (**Δθ**) = $\dfrac{\text{change in thermal energy } (\mathbf{\Delta E})}{\text{mass } (\mathbf{m}) \text{ x specific heat capacity } (\mathbf{\mathit{C}})}$

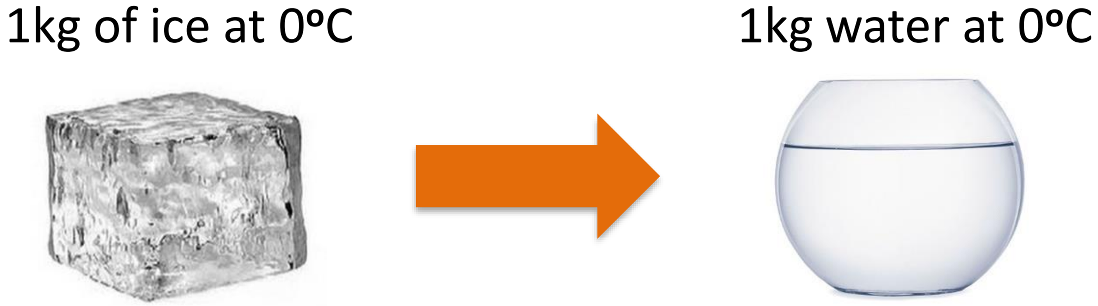
$$\mathbf{\Delta\theta} = \frac{\mathbf{\Delta E}}{\mathbf{m \times \mathit{C}}} = \frac{400\,000}{1.4 \times 4200} = \mathbf{68\ ^{o}C}$$

The temperature rise will be 68 ºC.
The new temperature of the water will be 68 + 12 = 80 ºC.

# Internal energy and energy transfers – Changes of heat and specific latent heat

**Latent heat** is the energy needed to **change the state** of a substance without a change in temperature.
The energy supplied is used to change the **internal energy store** of the substance.

Latent heat for melting is called **specific latent heat of fusion** ($L_f$)
Latent heat for evaporating is called **specific latent heat of vaporisation** ($L_v$)



1kg of ice at 0ºC

1kg water at 0ºC

**Specific latent heat of fusion for water = 336 000 J/kg**
**This means 336 000 J of energy are needed to turn 1 kg of ice into 1 kg of water with no temperature change.**

# Internal energy and energy transfers – Changes of heat and specific latent heat

5 g of gold is being melted to make a ring.
Once the gold reaches its melting temperature, how much heat energy is needed to melt the gold?

**Specific latent heat of fusion for gold = 64 400 J/kg**

**Energy to change state (J) = mass (kg) x specific latent heat (J/kg)**

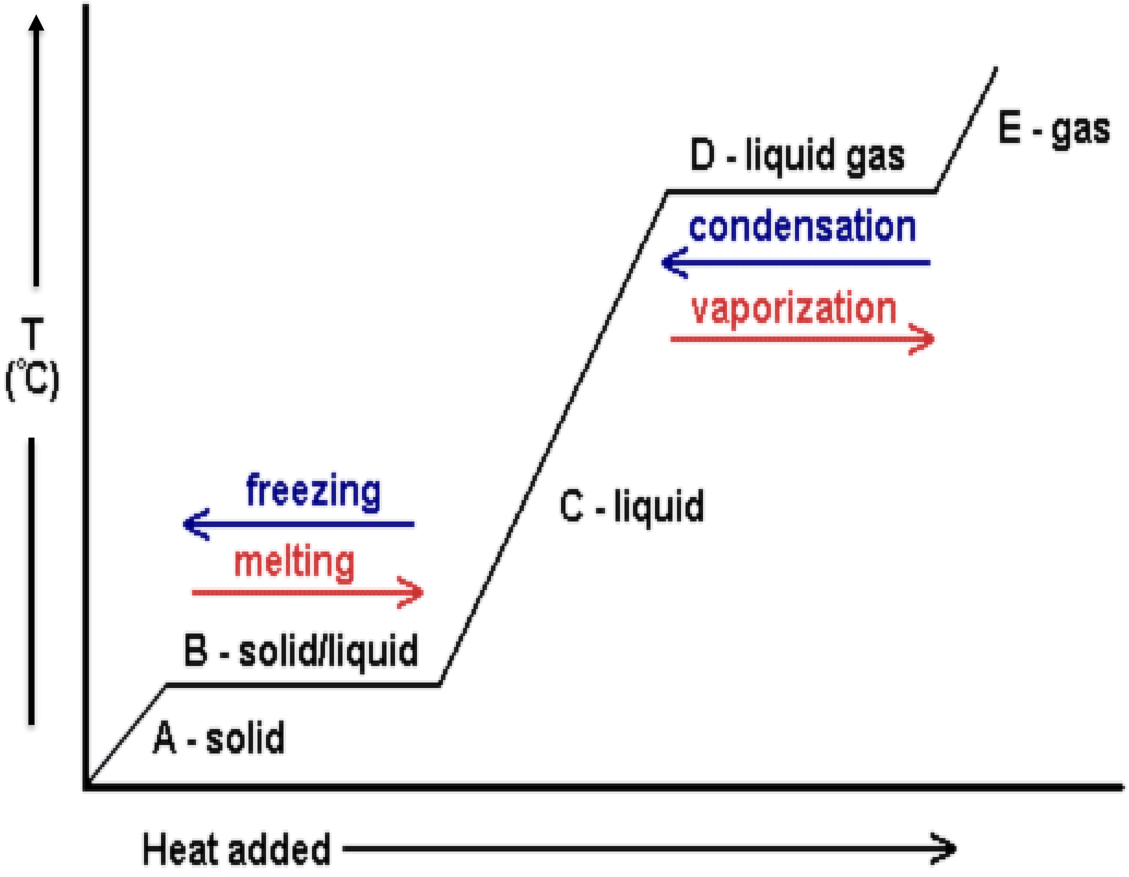
**Remember there are two latent heats for each substance – fusion and vaporisation.**
**Fusion – melting and freezing  Vaporisation – evaporating and condensing**

Energy = 0.0005 kg x 64,400 J/kg = 322 J

322 J of heat energy is needed to melt 5 g of gold

# Internal energy and energy transfers –
# Changes of heat and specific latent heat

## Heating and cooling graphs



As heat energy is added to a solid, the temperature rises until it reaches its **melting point.**
As the substance melts, all the heat energy added is used to **change the state** of the substance with no temperature change.
When all the substance is melted, the temperature will then rise until the **boiling point** is reached.
Again, heat energy is now required to **change the state** to a gas with no temperature change.

# QuestionIT!

## Internal energy and energy transfers

- Internal energy
- Temperature change in a system and specific heat capacity
- Changes of heat and specific latent heat

# Internal energy and energy transfers – AnswerIT

1. Define internal energy.

2. Which of the following will change the internal energy of a stone?
    A. Lifting it to the top of a building.
    B. Heating it.
    C. Firing it from a catapult.

3. Water and the chemical isooctane both boil at 100 ºC. When the same mass of each substance is placed on a heater, the isooctane boils first. Explain why this happens.

# Internal energy and energy transfers – AnswerIT

4. A hot stone is placed into a glass of water containing 200 g of cold water. The stone transfers 25 200 J of energy to the water. How much will the temperature of the water rise?

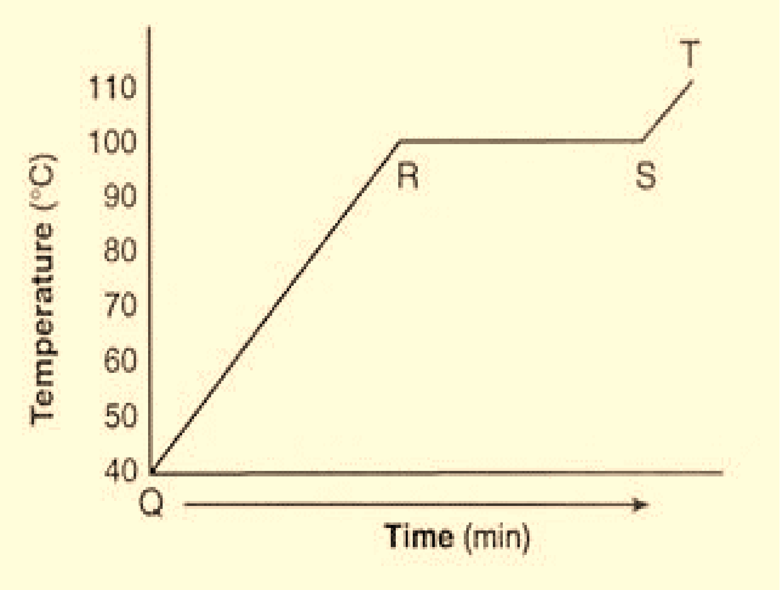
**Specific heat capacity of water = 4200 J/kg °C** **$\Delta E = m\, c\, \Delta\theta$**

5. What is specific latent heat?

6. Explain the difference between latent heat of fusion and latent heat of vaporisation.

# Internal energy and energy transfers – AnswerIT

7. A boiler is being used to heat water. The graph shows the temperature of the water every 5 minutes.



a. What state is the water in between points Q and R?

b. At which point does the water begin to boil?

c. What state is the water in at 110 °C?

8. Candle wax has a latent heat of fusion of 200 000 J/kg. If the candle is at its melting temperature, how much heat energy is needed to melt a 250 g candle?

$$E = m L_f$$

# AnswerIT!

## Internal energy and energy transfers

- Internal energy
- Temperature change in a system and specific heat capacity
- Changes of heat and specific latent heat

# Internal energy and energy transfers – AnswerIT

1. Define internal energy?

**The total kinetic and potential energy of all the particles within a system**

2. Which of the following will change the internal energy of a stone?

A. Lifting it to the top of a building
B. Heating it
C. Firing it from a catapult

**Heating it.**

3. Water and the chemical isooctane both boil at 100 ºC. When the same amount of each substance is placed on a heater, the isooctane boils first. Explain why this happens.

**Isooctane has a lower specific heat capacity than water so less heat energy is needed to raise its temperature to its boiling point.**

# Internal energy and energy transfers – AnswerIT

4. A hot stone is placed into a glass of water containing 200 g of cold water. If the stone transfers 25 200 J of energy to the water, what will the temperature rise of the water be?

**specific heat capacity of water = 4200 J/kg °C** **$\Delta E = m\,c\,\Delta\theta$**

$$\Delta\theta = \frac{\Delta E}{m \times c} = \frac{25\ 200}{0.2 \times 4200} = 30\ ^{o}\mathrm{C}$$

**Temperature rise of the water = 30 °C**

5. What is latent heat?

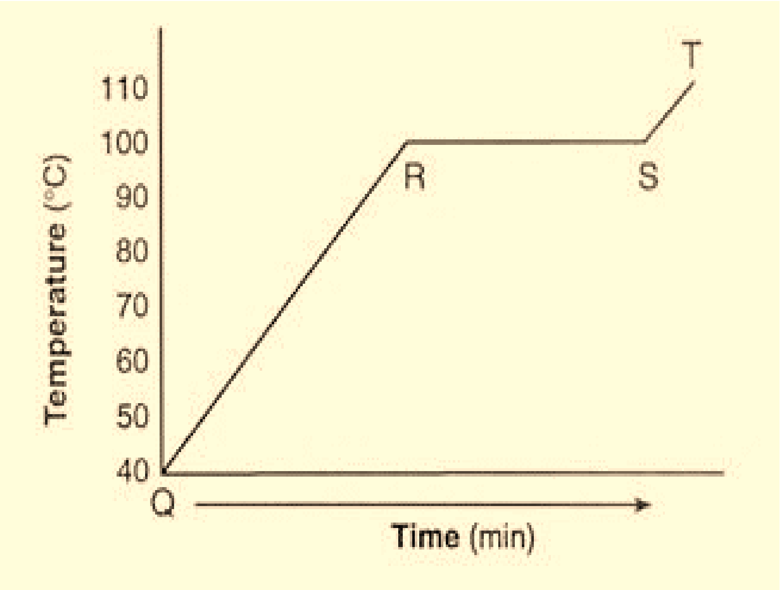
**The energy needed to change the state of a substance without changing the temperature.**

6. Explain the difference between latent heat of fusion and latent heat of vaporisation.

**Latent heat of fusion is the energy needed to change between solid and liquid. Latent heat of vaporisation is the energy needed to change state between liquid and gas.**

# Internal energy and energy transfers – AnswerIT

7. A boiler is being used to heat water. The graph shows the temperature of the water every 5 minutes.



a. What state is the water in between points Q and R?

**Liquid**

b. At which point does the water begin to boil?

**R**

c. What state is the water in at 110 ºC?

**Gas**

8. Candle wax has a latent heat of fusion of 200 000 J/kg. If the candle is at its melting temperature, how much heat energy is needed to melt a 250 g candle?

$$\mathbf{E = m\, L_f}$$

$$E = 0.25 \times 200\,000 \quad = 50\,000\ J$$

# LearnIT!
# KnowIT!

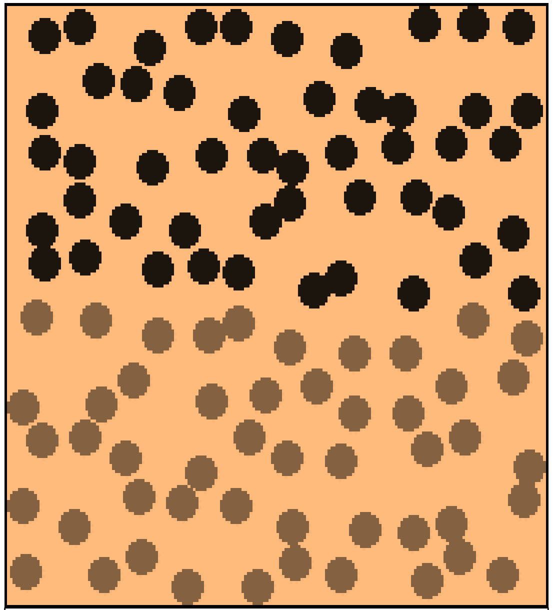
## Particle model and pressure

- Particle motion in gases
- Pressure in gases (physics only)
- Increasing the pressure of a gas

  (physics only – Higher Tier)

# Particle model and pressure- particle motion in gases

Molecules in a gas are in constant random motion (called Brownian motion)



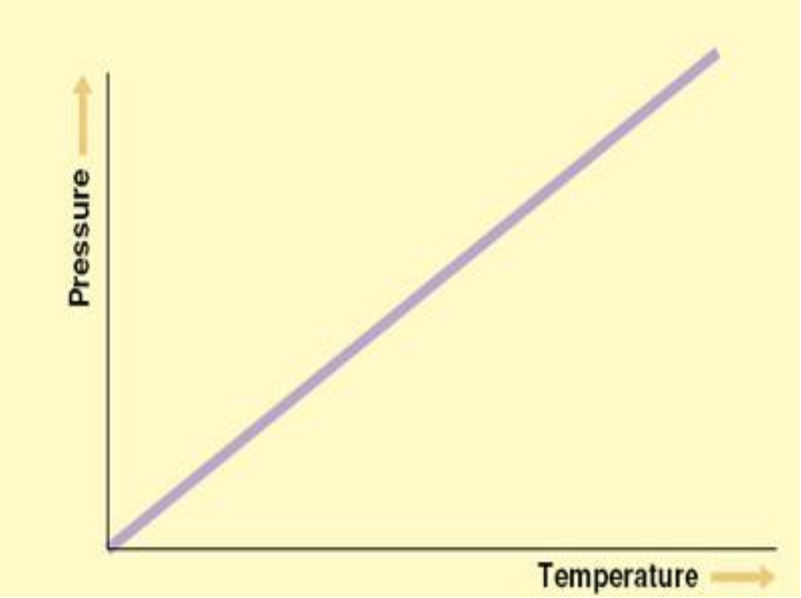
**Particles of a gas inside a container have kinetic energy**

- The **temperature** of this gas is related to the average **kinetic energy** of all the particles.
- If the temperature of the gas is increased, the particles will **move faster**.
- Faster moving particles exert a **greater force** on the walls of the container.
- This will either cause the container to **expand** (balloon) or **increase the pressure** of the gas (gas cylinder).

# Particle model and pressure- particle motion in gases

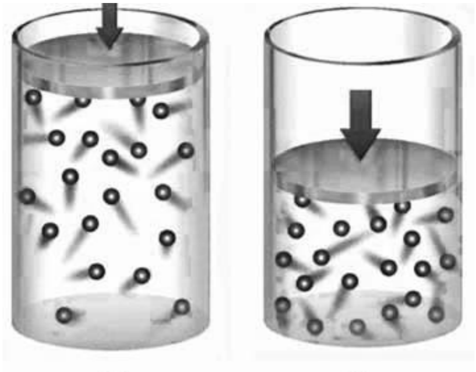
If a sealed can of air (gas) is heated, the molecules of air move faster and faster.
The collisions of these molecules on the inside walls of the container create a pressure. The hotter the molecules, the faster they move and the more pressure they exert on the wall of the can.

If the can continues to be heated, the pressure will keep rising steadily.
The graph opposite shows that **gas pressure is directly related to its temperature**, if the volume remains constant.



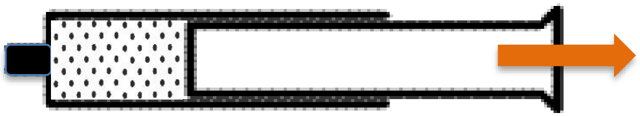
# Particle model and pressure- pressure in gases (physics only)

When a gas is **compressed** inside a fixed container, there are more particles in a given volume to **strike the walls** of the container, therefore the **pressure on the container walls increases.**



The pressure produces a net force at right angles to the wall which means the pressure will act evenly in all directions.

Think about a sealed syringe with a fixed amount of gas inside. The particles will be colliding with the syringe walls creating a pressure.



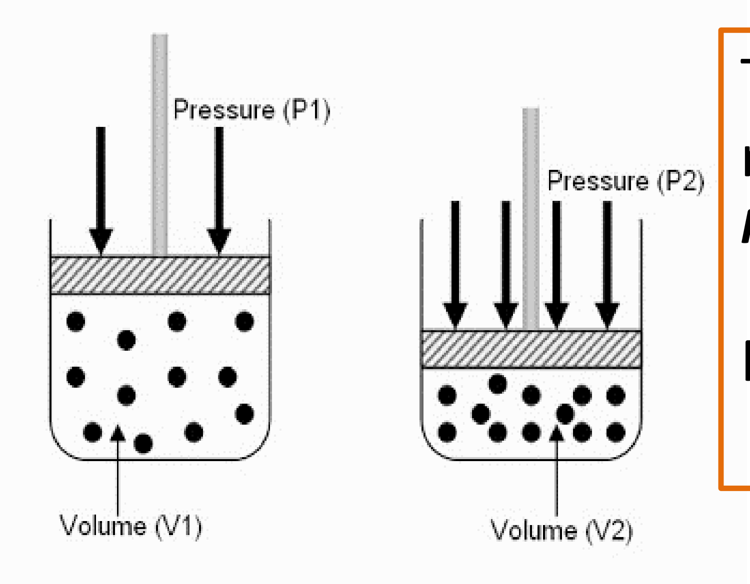
If the plunger is pulled out, the same amount (mass) of gas will be occupying a greater volume.
This will result in fewer collisions over a given area of the syringe wall.

**Gas pressure will be reduced**

# Particle model and pressure - pressure in gases (physics only)

When a fixed mass of gas is compressed the volume decreases

In the example shown, if the pressure applied to the gas doubles, the volume halves.



This is an inverse relationship:

$P = \frac{1}{V}$ or $pV$ = constant

For calculations:

$$p_1V_1 = p_2V_2$$

If the container has a volume of 0.04 m³ and a pressure of 100 000 Pa, calculate the new volume if the pressure is increased to 320 000 Pa.

$p_1V_1 = p_2V_2$ $V_2 = \frac{p_1V_1}{p_2} = \frac{100\,000 \times 0.04}{320\,000}$ New volume = 0.0125 m³

# Particle model and pressure- Increasing the pressure of a gas (physics only – Higher Tier)

When work is done on a gas, energy is transferred to the gas by a force. This transfer of energy to the gas increases its temperature.

When a foot pump is used to inflate a tyre, **work is done** by the piston on the **vibrating air particles** inside the pump. There is therefore a **transfer of energy** between the piston and the particles and this results in an increase in **kinetic energy** of the air particles.

If the kinetic energy of the air particles increases then there will be more collisions between gas particles. This will cause the temperature of the gas to rise

# QuestionIT!

## Particle model and pressure

- Particle motion in gases
- Pressure in gases (physics only)
- Increasing the pressure of a gas

  (physics only – Higher Tier)

# Particle model and pressure – AnswerIT

1. What happens to the temperature of a gas if the average kinetic energy of the particles of the gas increases?

2. The sealed gas syringe is filled with air.

Explain what will happen to the syringe if the air inside is gently heated.

3. As a weather balloon rises high in the atmosphere its volume increases. Explain why this happens.

# Particle model and pressure – AnswerIT

4. A cylinder of oxygen is left in the sunshine for an hour.

   a. Explain what will happen to the oxygen molecules in the cylinder as they warm up.

   b. Explain why these heated molecules cause a greater pressure inside the cylinder.

5. When air is blown into a balloon, it expands equally in all directions. The best explanation for this is:

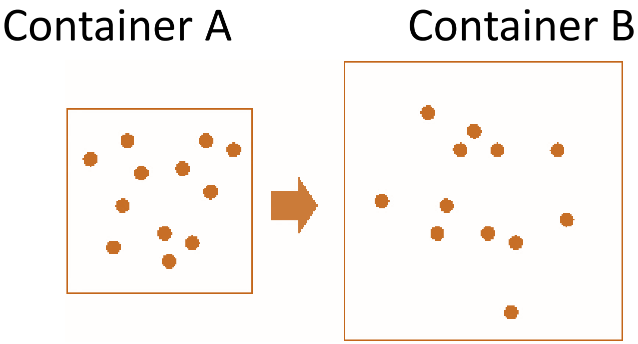
   A - The gas molecules in the balloon are expanding

   B - Internal air pressure acts at right angles to the balloon surface.

   C - As more air is blown in, the temperature increases causing the balloon to expand.

# Particle model and pressure – AnswerIT

6. Container A is filled with a gas represented by the dots. The container size is increased but the mass of gas remains the same.



a. Explain, using the particle model, why the pressure will be less inside container B.

b. Container A has a volume of 2 m³ and a pressure of 100 000 Pa. If the expanded container has a volume of 5 m³, what will the pressure be in container B?

# AnswerIT!

## Particle model and pressure

- Particle motion in gases
- Pressure in gases (physics only)
- Increasing the pressure of a gas (physics only – Higher Tier)

# Particle model and pressure – AnswerIT

1. What happens to the temperature of a gas if the average kinetic energy of the particles of the gas increases?

   **The temperature will increase.**

2. The sealed gas syringe is filled with air.

   Explain what will happen to the syringe if the air inside is gently heated.

   **The air molecules will gain kinetic energy. This will create a greater force inside the syringe so the piston will move outwards.**

3. As a weather balloon rises high in the atmosphere its volume increases. Explain why this happens.

   **As the weather balloon gets higher the pressure on the outside of the balloon decreases, making the balloon expand. The temperature decreases as you get higher, but the effect of pressure decreasing is greater.**

# Particle model and pressure – AnswerIT

4. A cylinder of oxygen is left in the sunshine for an hour.

   a. Explain what will happen to the oxygen molecules in the cylinder as they warm up.

   **They will gain kinetic energy, so move faster.**

   b. Explain why these heated molecules cause a greater pressure inside the cylinder.

   **The higher kinetic energy causes the molecules to hit the surface of the cylinder more often and with greater force.**

5. When air is blown into a balloon, it expands equally in all directions. The best explanation for this is:

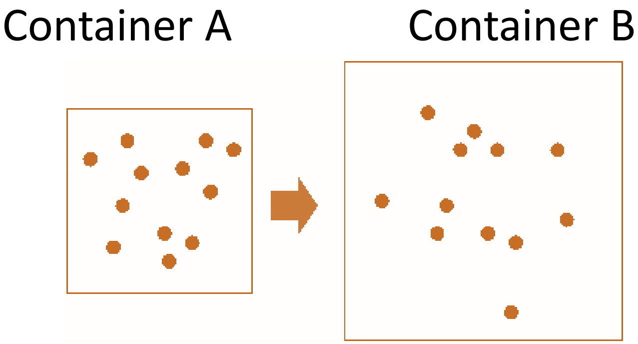
   A - The gas molecules in the balloon are expanding

   **B - Internal air pressure acts at right angles to the balloon surface.**

   C - As more air is blown in, the temperature increases causing the balloon to expand.

# Particle model and pressure – AnswerIT

6. Container A is filled with a gas represented by the dots. The container size is increased but the mass of gas remains the same.



a. Explain, using the particle model, why the pressure will be less inside container B.

**Over a given area there will be fewer gas molecule collisions so the pressure will be less.**

b. Container A has a volume of 2 m³ and a pressure of 100 000 Pa. If the expanded container has a volume of 5 m³, what will the pressure be in container B?

$p_1V_1 = p_2V_2$  $\frac{100\,000 \times 2}{5} = p_2$  **New pressure = 40 000Pa**