CP1a SP1a VECTORS AND SCALORS

Displacement versus Distance

In a 200m race, all runners cover a 200m distance

However, the track is curved so the distance in a straight line between the start and finish is less than this – this distance is called the 'displacement'.

Displacement is measured in a straight line so unlike distance (which only has a size), displacement has both a size and direction.

Speed -This is a SCALOR it has no direction

The speed of an object tells you how quickly it will take to travel a certain distance.

Speed can be calculated from the equation:

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

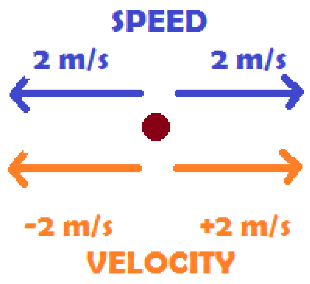
Like distance, speed only has a size (magnitude) but no direction.

Velocity- This is a VECTOR – it has a direction

Velocity tells you how quickly an object is moving, and it also tells you in which direction it's moving. If object is moving forwards – positive velocity. If object is moving backwards – negative velocity

Velocity, like speed, is measured in m/s

Quantities like displacement and velocity which have a size and direction are called **vector** quantities



CP1a SP1a Questions on Vectors and Velocity

- What is the difference between displacement and distance?
- What is the difference between speed and velocity?
- Write down the equation for speed.
- If a car travels 250 metres in 25 seconds what is its speed?

CP1b / SP1b **Distance-time graphs:**

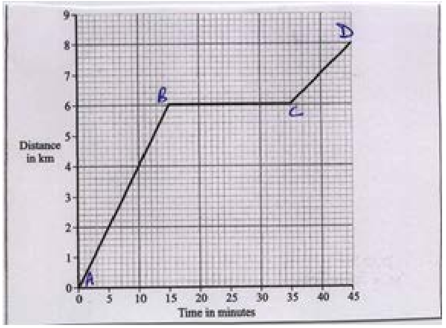
A graph in which distance is plotted against time is called a distance-time graph

Time and distance are used to calculate speed and from a distance-time graph, we can tell how fast an object is moving.

- *Horizontal lines mean object is stationary*
- *Straight, sloping lines mean the object is travelling at a constant speed*
- *The steeper the line, the faster the object is travelling*
- *The speed of the object can be calculated from the gradient of the line*
- speed = gradient = change in distance / change in time

e.g. Between A and B and between C and D, person is jogging at a steady speed

- The person is stationary (not moving) between points B and C
- Speed person is jogging at between points C and D:
    - Point C: 35 minutes, 6km
    - Point D: 45minutes, 8km
    - →speed = gradient = change distance / change in time
    - →speed = gradient = 2 / 10 = 0.2 km/min = 12 km/hour



CP1b/SP1b Questions on Distance-Time Graphs

- What is a distance- time graph?
- What does a straight line mean on a distance time graph?
- If a motorbike is racing a bike which vehicle will have the steepest line on a distance time graph?
- What feature of a distance time graph gives the speed?

CP1c/ SP1c ACCELERATION

Moving things speed up or slow down all the time and this change in velocity is called acceleration.

Acceleration has both a size and direction and is a vector quantity. Positive acceleration means the object is speeding up and negative acceleration means the object is slowing down

Acceleration can be calculated from the equation:

acceleration (m/s^2) = change in velocity (m/s) / time taken (s)

change in velocity = final velocity (v) - initial velocity (u)

$a = (v - u) / t$

e.g. a racing car starts from 0 m/s and reaches a velocity of 50 m/s in 5 seconds.
What is its acceleration?

Acceleration = $a = (v - u) / t$

$a = (50 - 0) / 5 = 10\ m/s^2$

$10\ m/s^2$ means that each second the velocity of the car increases by 10 m/s

e.g. during landing, a space shuttle slows down from 70 m/s to 20 m/s in 20s. Calculate its acceleration:

Acceleration = $(20 - 70) / 20 = -50/20 = -2.5\ m/s^2$

The minus sign shows that the space shuttle is slowing down (i.e negative acceleration)

CP1c/ SP1c Questions on Acceleration

- Is acceleration a vector or scalar?
- What is the unit for acceleration?
- Write down the equation for acceleration.
- What does acceleration =-0.5 m/s^2 mean?
- What does the gradient of a velocity time graph show?
- If a boat goes from rest to 60mph in 30 seconds calculate its acceleration.

CP1d/SP1d Velocity-Time Graphs

A velocity-time graph shows how the velocity of an object changes with time. A horizontal line means the object is travelling at a constant velocity. The higher the line, the higher the velocity

A straight sloping line shows the object is accelerating:

Steeper line = greater acceleration

Upwards slope = acceleration

Downwards = deceleration

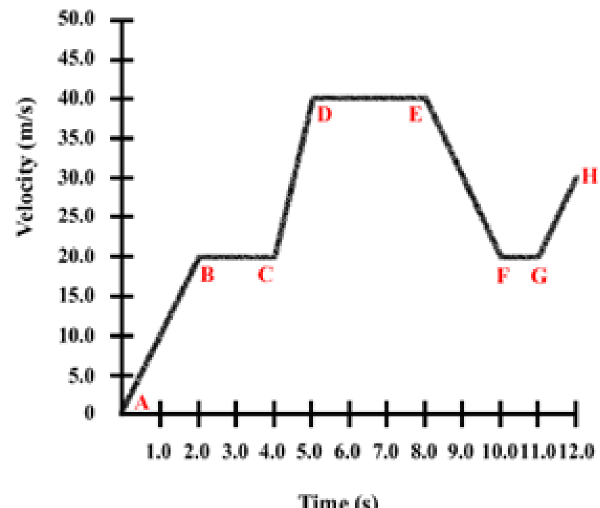
A: Stationary car

A&B, C&D, E&F, G&H: accelerating

E&F: deceleration, car slows

B&C, D&E, F&G: constant velocity

D&E: highest velocity



The acceleration of an object between two points can be calculated from a velocity-time graph, using the equation on the previous page

e.g. acceleration between points C and D (on diagram above):

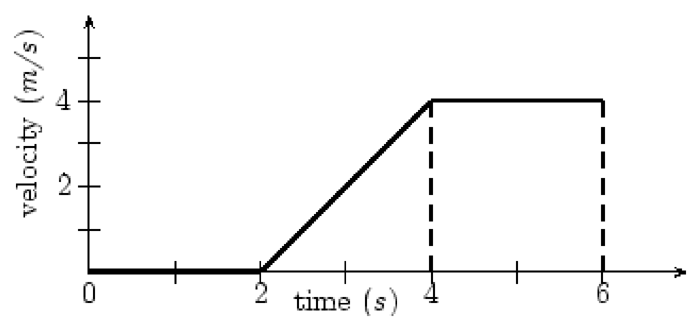
- final velocity = 40 m/s. Initial velocity = 20 m/s. Time = 1 second
- acceleration = 20 / 1 = 20 m/s^2

CP1d/SP1d Questions on VT Graphs

- Which axis does velocity go on?
- What does the gradient represent?
- If a line is flat, what does it mean?
- If a line is steeper, what does this mean?

CP1d/SP1d **Calculating distance from a VT graph**

- The area under a velocity-time graph tells us the distance the object has travelled
- To calculate the area under a velocity-time graph…
  - you split the area under the graph into shapes (squares and triangles), calculate each bit separately, and then add everything together
  - Area of triangle = ½ base x height…→ area = 1 x 4 = 4m
  - Area of square = base x height…→area = 2 x 4 = 8m
  - distance travelled = 8m + 4m = 12m



CP1d/SP1d Questions on VT Graphs

- Which axis does velocity go on?
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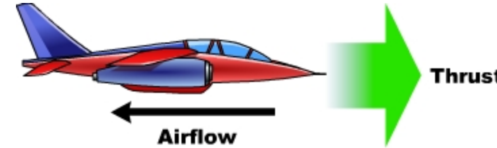
CP2a/SP2a RESULTANT FORCES



When more than one force acts on an object, the effect is the same as if they were combined into a single force – the 'resultant force'. To work out the resultant force, you add together all the forces acting in one direction, and then subtract them from all the forces acting in the opposite direction

Balanced forces: Forces that are equal but act in opposite directions are 'balanced'

- When all forces are balanced, the resultant force on an object is zero the object's movement, shape or direction will not change. If stationary, it will remain. If it was moving, it continues to move at the same velocity (same speed and same direction)

Unbalanced forces: if not equal, acting in opposite directions, forces are unbalanced

- When forces are unbalanced, the resultant force on an object is not zero. The object will accelerate in the direction of the resultant force. The thrust is the force produced by the plane's engines, moving the plane forwards. As the plane flies, air molecules push against the plane, producing an opposite force called air resistance. The thrust is greater than the air resistance (as thrust arrow is longer):
- If air resistance was greater than the thrust force, there would be a resultant force in the direction of air resistance. There would be a (negative) acceleration in the direction of the air resistance

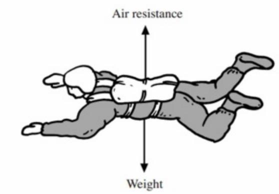
Note: remember when answering questions on forces that there are no air particles in space (space is a vacuum). There is no air resistance in space

CP2a/SP2a Resultant forces - Questions

- How do you work out the resultant force acting on an object?
- What will happen to a bus moving at 20mph with no net force?
- If the thrust on a rocket is greater than air resistance, what will happen to its velocity?
- Why does no air resistance act in space?

CP2a/SP2a Resultant Forces

- When a skydiver first starts to fall, the main force acting on the skydiver is their weight (downwards), there is very little air resistance acting in the opposite direction (upwards)
  - large resultant force downwards
  - skydiver accelerates quickly towards the ground



- As the skydiver gains velocity, the size of the air resistance force increases
  - the resultant force downwards is smaller
  - skydiver is still accelerating down towards the ground, but the size of the acceleration is smaller
- Eventually the weight and air resistance become balanced…
  - resultant force is now zero
  - skydiver stops accelerating, the skydiver continues to fall towards the ground, but now at a constant velocity
- This constant (maximum) velocity reached when the air resistance force balances the weight is called the ‘terminal velocity’

CP2a/SP2a Resultant Forces Questions

- What two forces act on a skydiver?
- Initially, what happens to the motion of a sky diver?
- What happens to the air resistance with a greater speed?
- Eventually, what happens to the forces?
- What Terminal Velocity?

CP2b/SP2b Newton's First Law of Motion

- Newton's First Law says that a stationary object will remain at rest unless an external force acts on it.
- So if the resultant force on a stationary object is zero, the object remains stationary. Things don't move on the own , there has to be a resultant force to get them started.
- If there is no resultant force on a moving object it will carry on moving at the same velocity. For an object to travel with a uniform (constant) velocity there must be zero resultant force.
- If there us a non zero resultant force then the object will accelerate in the direction of the force. This can take 5 forms: starting, stopping, speeding up, slowing down and changing direction.

CP2b/SP2b Newton's First Law of Motion

Questions

1. What is meant by a resultant force acting on an object ?
2. What will happen to an object that has a zero resultant force ?
3. What will happen to an object that will have a non zero resultant force ?

CP2c/SP2c Mass and Weight

Mass (measured in kg) is the quantity of matter there is in an object and does not change

Weight (measured in N) is a measure of the pull of gravity on an object. If gravity changes, weight also changes

- The strength of gravity is called the 'gravitational field strength' (N/kg)
- On earth, the gravitational field strength is 10N/kg. Each kilogram is pulled down with a force of 10N
- The weight of any object on earth can be calculated using the equation:
  - weight (N) = mass (kg) x gravitational field strength (N/kg). W = m x g

What is the weight of a 75kg person on Earth? weight = 75 x 10 = 750 N

What is the weight of a 75kg person on the moon? The moon's gravitational field strength is about 1.5N/kg. Weight = 75 x 1.5 = 112.5 N

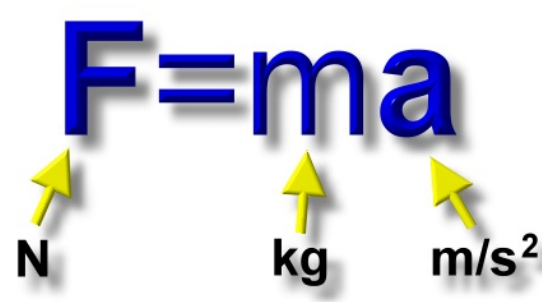
- Notice how person's mass (75kg) is the same on the moon as it is on Earth - mass never changes (it's not affected by gravitational field strength)
- Person's weight instead is much lower on the moon (112.5 N) than on Earth (750 N) because the gravitational field strength is much smaller on the moon than on the Earth

CP2c/SP2c Mass and Weight - Questions

- What is mass?
- What is weight?
- What is the strength of gravity, and its units?
- How do we calculate the weight of a person on Earth?

CP2d/ SP2d   Newton's Second Law

- The rate at which an object accelerates depends on:
  - the size of the (resultant) force – the greater the resultant force, the greater the acceleration of the object
  - the mass of the object – the greater the mass of the object, the smaller its acceleration
- equation linking acceleration, force and mass:
  - Force (N) = mass (kg) x acceleration (m/s^2)
  - F = m x a
  - 1 newton is the force needed to accelerate a mass of 1kg by $1 m/s^2$
- A car's acceleration is $3 m/s^2$. It weighs 1500kg. What is the force provided by the engine?
  - Force = 1500 x 3 = 4,500 N

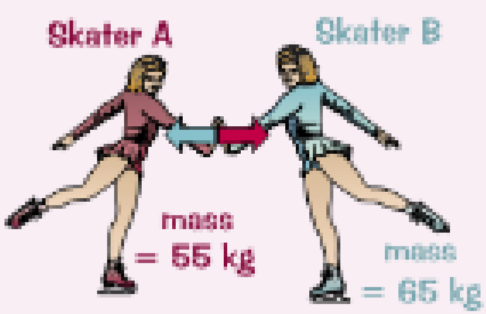


CP2d/ SP2d   Newton’s Second Law Questions

- What does the amount of acceleration depend on?
- If there is a bigger resultant force, what happens to the acceleration?
- What does a Newton represent?

CP2e/SP2e Newton's Third Law

- Newton's Third Law states that when two objects interact, the forces they exert on each other are equal and opposite.
- If you push a shopping trolley the trolley will push back against you just as hard. As soon as you stop pushing, so does the trolley.
- If the forces are always equal, how does anything ever go anywhere? Remember that the two forces are acting on different object. Think about a pair of ice skaters.



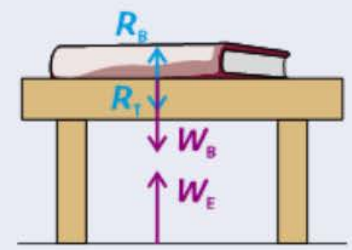
- When skater A pushes on skater B (the 'action' force), she feels an equal and opposite force from skater B's hand (the 'reaction' force).
- Both skaters feel the same sized force, in opposite directions, and so accelerate away from each other.
- Skater A will be accelerated more than skater B, though, because she has a smaller mass, so a smaller inertia — $a = F/m$ (from rearranging Newton's Second Law).

CP2e/SP2e Newton's Third Law

The weight of the book pulls it down, and the normal reaction force from the table pushes it up. This is NOT Newton's Third Law. These forces are different types and they're both acting on the book.

The pairs of forces due to Newton's Third Law in this case are:

- The weight of book is pulled down by gravity from Earth (W_B) and the book also pulls back up on the Earth (W_E).
- The normal contact force from the table pushing up on the book (R_B) and the normal contact force from the book pushing down on the table (R_T).



1. You are standing leaning on a wall, draw a sketch to show this (a stick man will do) and add arrows to show an action-reaction pair of forces acting in the vertical direction and then the horizontal direction.
2. A full shopping trolley and an empty one arte moving at the same speed . Why is it easier to stop the empty trolley than the full trolley over the same amount of time ?

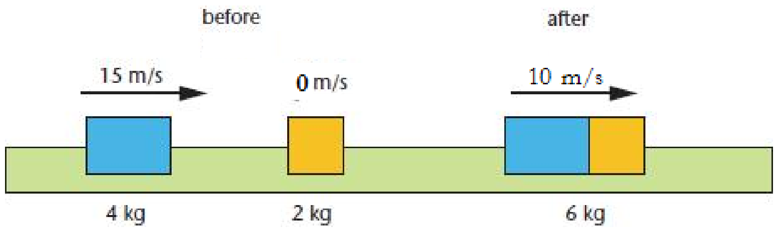
CP2f/SP2f Momentum

- Momentum is a measure of how strongly something is moving
  - Momentum (kg m/s) = mass (kg) x velocity (m/s)
  - The heavier the vehicle and the faster it is travelling, the greater its momentum
- What is the momentum of a monster truck (mass = 4500kg) when travelling at 12m/s, in an eastward direction? Momentum = 45000 x 12 = 54,000 kg m/s east
- Momentum has a size and direction so is a vector quantity (state a direction):

Conservation of momentum: when a moving object collides with another object:

  - their masses are added together, their combined speed will be slower
  - However, the total momentum of both objects is the same before the collision as it is after the collision - this is known as 'conservation of linear momentum'

- Before collision: Object on the left has a momentum = 15 x 4 = 60 kg m/s to the right. Object on the right has a momentum = 0 x 2 = 0 kg m/s
- After collision: Combined objects have a momentum = 10 x 6 = 60 kg m/s to the right
- The combined momentum of the objects before and after the collision is the same
- This demonstrates that when objects collide, momentum is conserved (i.e it is transferred to the other object without any being lost)



CP2f/SP2f Momentum Questions

- What is momentum?
- What are the units of momentum?
- Is momentum scalar or vector?
- Is momentum conserved or lost?

CP2g/SP2g Stopping Distances

Thinking Distance - when a driver sees a problem, the car travels some distance before the driver reacts and applies brakes

Braking distance - Once the brakes are applied, the car will travel some distance before it comes to a stop

- Overall 'stopping distance' for a car = thinking distance + braking distance

Factors affecting stopping distances:

1. Person's reaction time :

- The slower a person's reaction time, the longer the thinking distance. Tiredness, illness, or taking drugs or alcohol can all slow down reaction times

2. Speed of the vehicle:

- The faster the vehicle is travelling, more distance covered

3. State of the car's brakes and road conditions:

- For a car to come to a stop there must be friction created between the car's tyres and the road
  - More friction, smaller braking distance
  - Friction depends on condition of car brakes (better brakes, more friction), condition of road (if lose gravel or wet, less friction). Due to longer braking distances in wet conditions, drivers should leave more of a gap before the car in front

4. Mass of the vehicle:

- More mass, more force is needed to make it slow down, longer braking distance

CP2g/SP2g Stopping Distances Questions

- What is the thinking distance?
- What is the braking distance?
- What is stopping distance?
- What 4 factors affect stopping distance?
- How does alcohol affect the stopping distance?
- How does friction affect stopping distances?

CP2h/SP2i MOMENTUM AND SAFETY

When travelling in a car, passengers are going at the same speed as the car. If a car brakes suddenly, there's a rapid change in momentum, and a strong force is applied to the passengers - this can result in serious injury (passengers can smash their heads against the windscreen)

The 'rate of change of momentum' is equal to the force applied to the object - The rate of change of momentum = Force (N) = change in momentum (kg m/s) ÷ time taken for that change (s). Force $F = (mv – mu) \div t$

Vehicle safety measures:

1. Seat belts:
   - In an accident, seat belts stretch, passenger's velocity is slowed down more gradually
   - it takes longer for passenger's momentum to be slowed to zero. The force applied to the passengers is less and there is reduced chance of injury

However, in high speed accidents, the force is so great that the seat belt by itself could still cause injury

2. So cars are fitted with airbags, which also reduce the rate of change of momentum

3. Cars also have crumple zones. In an accident, the material in these crumple zones squashes and folds. This crumpling and folding reduces the momentum of the car over a longer period of time (i.e reduces the rate of change of momentum).So the impact forces on the passengers are less and there is reduced chance of serious injury

CP2h/ SP2i Questions on Momentum and Safety

- What is the formula for force in terms of momentum?
- How do seat belts work?
- How do crumple zones work?

CP3/ SP3a ENERGY TRANSFERS

There are 9 forms of energy:

- Thermal (heat energy)
- Light
- Electrical
- Kinetic (movement energy)
- Sound
- Chemical potential (e.g. energy stored in batteries, muscles and fuels)
- Nuclear potential (energy stored in nuclei of atoms)
- Elastic potential (energy stored by things that have been stretched or squashed and can spring back)
- Gravitational potential (energy stored in things that can fall)

Energy cannot be created or destroyed it is simply changed from one form to another.
e.g a battery-powered torch has the energy transfers shown below:
chemical energy → electrical energy →light and heat energy

Conservation of Energy

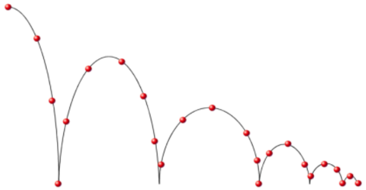
If you add up all the energy that has been transferred by a system (the output energy) and compare it with the energy put into the system (the input energy), the amounts are the same

output energy = input energy

This means energy can't be created or destroyed (it's 'conserved') and can only be transformed from one form to another: this is the law of conservation of energy.

Although energy is conserved, it's not always transferred into forms that can be used.

e.g. after a bouncy ball has bounced it gains thermal energy and loses kinetic energy which means on the second bounce the ball doesn't reach the height it was initially dropped from.



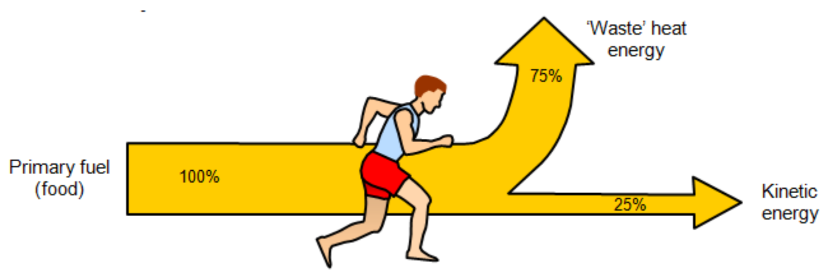
CP3a/SP3a Questions on Energy Transfers

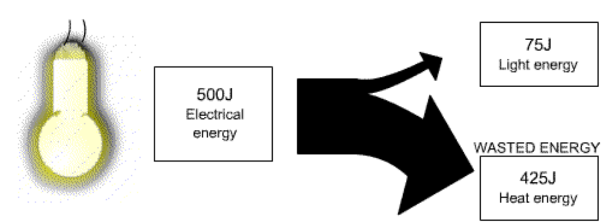
- What is the correct name for heat energy?
- Which type of energy implies movement?
- What is the name for stored energy?
- How many different types of stored energy are there?
- State the law of conservation of energy.
- Draw the energy transfer diagram for a) a washing machine b) a light bulb c) a wind up toy car

CP3a/SP3a Energy Conservation Diagrams (Sankey diagrams)

- These show the amount of energy converted or transferred.
- The width of the arrows represents the amount of energy in joules.

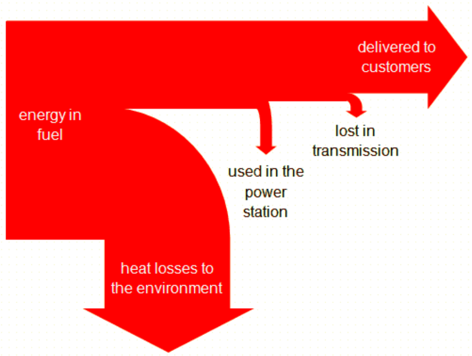
e.g. energy conservation diagram for a runner and for a light bulb





CP3a/SP3a Questions on Sankey Diagrams

- Explain this Sankey Diagram for the energy released from a power station.
- Is this an efficient process?



- Construct a Sankey diagram for a washing machine that takes in 200,000 Joules of electrical energy, puts 100,000 Joules into kinetic energy, 50,000 Joules into thermal energy, 25,000 Joules into sound energy and the remaining energy is wasted. How much energy is left unaccounted for? Can you suggest what happens to it?

CP3b/SP3b ENERGY EFFICIENCY

The efficiency of a device is the percentage (%) of energy transferred into useful forms.

e.g. When a light bulb is switched on, most of the electrical energy supplied to it is converted into wasted thermal energy that spreads to the surroundings.

Old-style: 100 J light bulbs give out 9 J of useful light energy, 91 J is wasted thermal energy.

New :100 J light bulbs give out 45 J useful light energy, 55 J wasted heat energy.

Therefore new light bulbs transform more of the input electrical energy into light energy than older-style bulbs and are more efficient.

Equation to calculate the efficiency of a device

$$\text{Efficiency (\%)} = \frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}} \times 100$$

e.g. for 200 J input energy, a jet pack produces 80 J of kinetic energy, 10 J of sound and 110 J of thermal energy.

Calculate its efficiency:

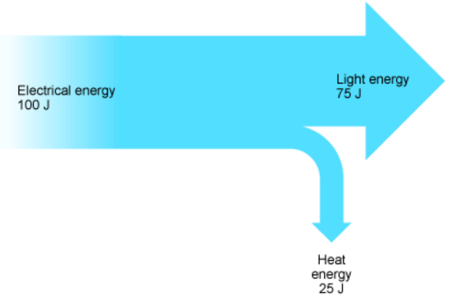
Wasted energy = sound and thermal energy = 120 J
useful energy transferred into kinetic energy = 80 J
Efficiency = 80/200 x 100 = 40%

CP3b/ SP3b

Questions on Energy Efficiency

- Define efficiency of a device.
- Write down the equation for efficiency.
- How do you know which is useful energy and which is wasted energy?

- What is the energy efficiency of the light bulb shown in this Sankey diagram?



- What is the percentage efficiency of the washing machine described on the last card?

CP3c/ SP3c Keeping Warm

- Energy is transferred by heating in three different ways
- **Conduction** occurs mainly in solids. Conduction is the process where vibrating particles pas extra energy in their kinetic energy stores to the kinetic energy stores of neighbouring particles.

- **Convection** occurs in fluids(liquids and gases.) Convection occurs when the particles with more energy in their kinetic energy stores move from the hotter region to the cooler region and take their kinetic energy stores with them
- **Radiation** can travel through a vacuum. For energy to be transferred by conduction or convection you need particles. Energy can also be transferred by radiation which can travel through a vacuum. When energy is transferred by heating by radiation the energy is carried by infra red waves .

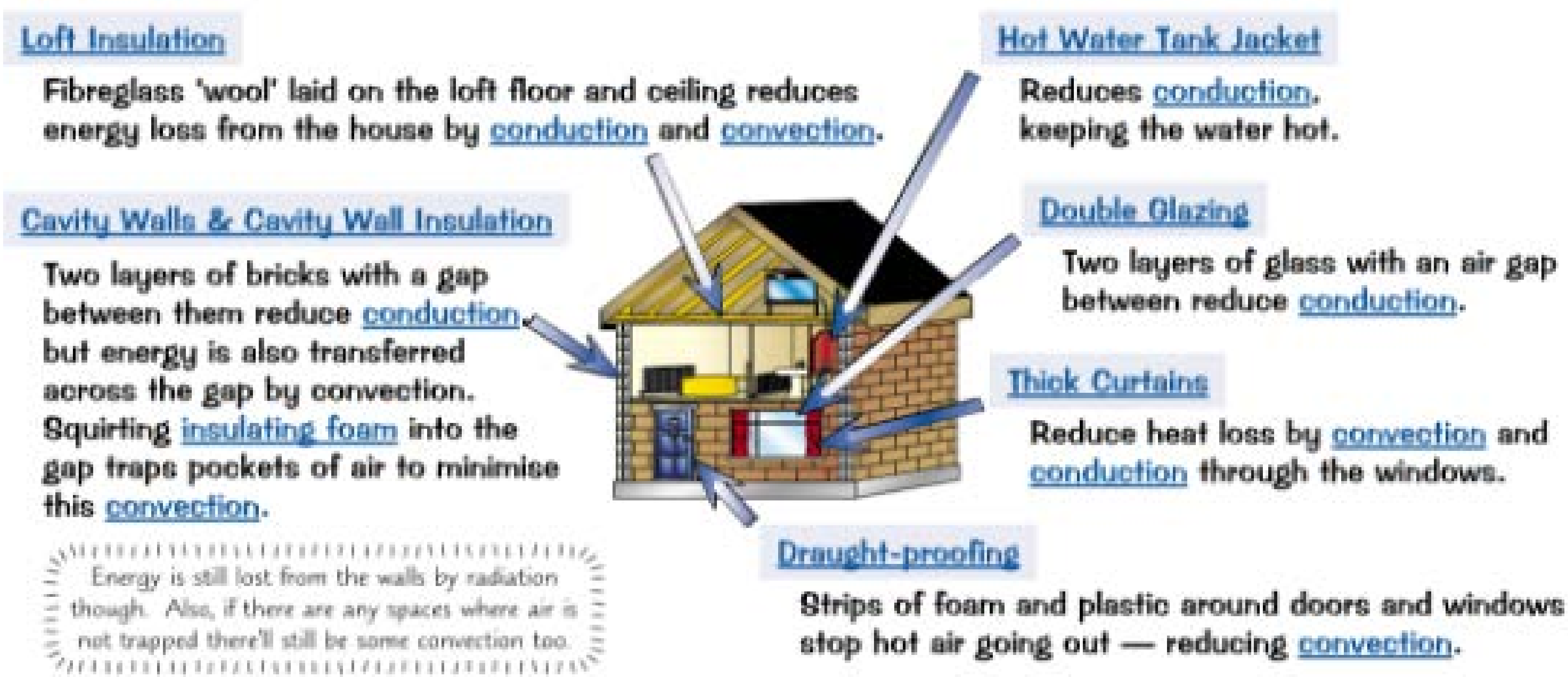
CP3c/ SP3c Keeping Warm

Questions

1. A pan of water is heated on a cooker, describe how energy is transferred from the cooker to the water and how the energy spreads out through the water.
2. Explain why bubble wrapping is a good insulation material.

CP3c/ SP3c Keeping Warm 2

- Insulating your house reduces energy loss



CP3c/ SP3c Keeping Warm 2

Questions

1. State 3 ways you could reduce the amount of energy loss from a house.
2. State two properties that affect how quickly energy is transferred through a wall.
3. Give two reasons why a cavity wall keeps a house warmer than a single wall.
4. Suggest why modern buildings have the cavity filled with foam or a similar material >

CP3d/SP3d STORED ENERGIES

Gravitational potential energy is energy that is stored because of an object's position in a gravitational field.

On Earth, if something can fall (e.g a person on a diving board) it has gravitational potential energy

Gravitational potential energy (J) = mass (kg) x gravitational field strength (N/kg) x vertical height from ground (m). GPE = m x g x h

Kinetic energy is another name for movement energy

kinetic energy (J) = ½ x mass (kg) x (velocity)^2 (m/s^2) KE = ½ x m x v^2

Conservation of energy:

When energy is transferred from one form to another, energy is conserved (i.e total amount always remains the same…none is lost)

As an object falls, its gravitational potential energy is converted into kinetic energy. When an object with gravitational potential energy falls down, the amount of kinetic energy it has just before it hits the ground is equal to its initial gravitational potential energy (as all the GPE has been converted to KE).

CP3d/SP3d Stored Energies Questions

- Define gravitational potential energy.
- What is the formula for gravitational potential energy?
- Calculate the gravitational potential energy for an object of mass 5kg, at a height of 100m, when the value of g= $10 m/s^2$

- What is the formula for kinetic energy?
- What is the conservation of energy principle?
- What is the relationship between gravitational potential energy and kinetic energy, as an object falls

CP3e/SP3e Non-Renewable Resources

Most of our electricity is generated using non-renewable resources (e.g. fossil fuels such as oil, coal, natural gas) which will eventually run out.

Fossil fuelled power stations produce waste gases:

Carbon dioxide - contributes to climate change

Sulphur dioxide and nitrogen oxides - can cause acid rain

Nuclear power

Nuclear power stations use radioactive metals such as uranium or plutonium as their energy source. These metals will also run out one day so nuclear power is also non-renewable.

Nuclear power stations don't emit any carbon dioxide or other gases however, the waste they produce is radioactive and it must be sealed into concrete or glass and buried safely so that the radioactivity cannot damage the environment.

A nuclear power station also needs to be dismantled carefully when closing down so that no radioactive materials escape into the environment. These safety considerations make nuclear power stations more expensive to build and dismantle than fossil-fuelled power stations.

There aren't many accidents as the stations are designed to contain any radioactive leaks however, when major accidents occur, they have very serious consequences (e.g. Chernobyl, 1986).

Advantages of fossil fuels and nuclear power (compared to renewable resources)

At the moment there is still good supply of both fossil fuels and nuclear fuel and they produce electricity more cheaply.

They don't depend on the weather or the tides and electricity is available all the time.

CP3e/SP3e Questions on Non- Renewable Resources

- Define non-renewable.
- What is a fossil fuel and give 3 examples?
- Fossil fuelled power stations emit gases. Name them and the problems that they can cause.
- Can nuclear power run out?
- Give one advantage and one disadvantage of a nuclear power station.
- Are there any advantages to using non-renewable energy resources?

CP3f/SP3f Renewable Resources

Renewable energy resources are resources that will not run out and most don't cause pollution or produce greenhouse gases.
Using renewable sources of energy also reduces reliance on fossil fuels so we can conserve stocks of fossil fuels .

Solar energy

Solar cells can convert solar energy directly into electrical energy. Solar energy is dependent on sunlight and isn't available all the time.

Hydroelectricity

Hydroelectricity is generated by falling water. Water is trapped in high reservoirs and as long as the reservoir doesn't dry up, hydroelectricity is available all the time.

Wind turbines

With the right wind speed (not too high or too low), wind turbines can generate electricity however if it's not windy then no energy is produced. Many turbines are needed to produce the same amount of energy as fossil-fuelled power stations and some people think they spoil the landscape.

Geothermal energy

In some places, rocks are hot enough to turn underground water into steam so the steam can turn turbines in power stations to generate electricity. Some gases in the steam can cause pollution.

Tidal power

Turbines can generate electricity from tidal currents and although not available all the time, tidal power is available at predictable times. Unfortunately, not many places are suitable for installing turbines, and they may affect birds and other wildlife that live or feed on tidal mudflats.

Wave power

Wave power can generate electricity when floating electrical generators move up and down. In coastal power stations, ocean waves can force air up pipes in the power station, and the moving air turns turbines to generate electricity

CP3f.SP3f Renewable Energy Questions

- Define renewable energy.
- State a disadvantage of solar energy.
- How is hydroelectricity generated?
- Give an advantage and disadvantage of wind turbines.
- What is geothermal energy?
- Explain the difference between tidal power and wave power.

CP4a/SP4a WAVES

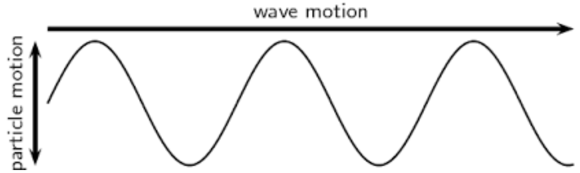
Luminous objects in space give out visible light that travels as waves of energy. Many objects in space don't give out much visible light but give out other types of energy-carrying waves, like radio waves and microwaves.

Transverse waves – e.g electromagnetic waves, sea waves

Waves in which particles vibrate at right angles to the direction that the wave is going are called transverse waves.

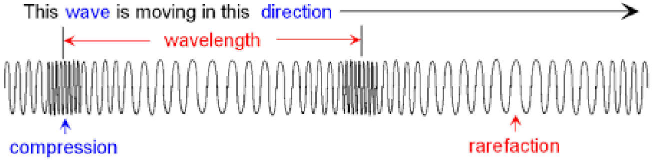
Transverse waves do not need a medium in which to travel (so can travel through space) – e.g. electromagnetic waves (visible light, radio waves, microwaves).

Sea waves are also examples of transverse waves. When waves hit a cliff/shore, energy is transferred and wears the cliff away. This happens without transferring matter (i.e water particles move up and down as the wave passes abd they aren't carried to the shore). Note: this is true for longitudinal waves as well



Longitudinal waves - e.g sound waves

Sound waves are not transverse – they are longitudinal. In a sound wave, the particles vibrate back and forth in parallel with the direction that the wave is going, forming areas where air particles are spread out and areas where they are pushed together. Longitudinal waves need a medium in which to travel, which is why sound cannot travel through a vacuum (i.e can't travel in space).

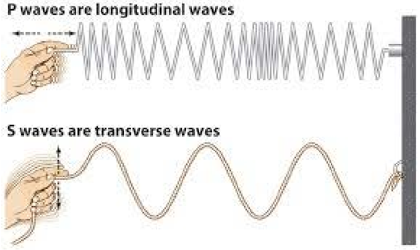


Seismic waves

Earthquakes and explosions produce seismic waves that travel through the earth.

Seismic waves can be either longitudinal or transverse.

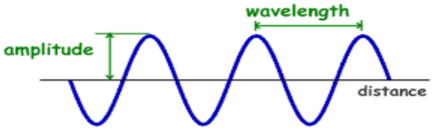
- Longitudinal - rock material is pushed and pulled
- Transverse - rock material is moved up and down or side to side



CP4a/SP4a Questions on Waves

- What is a transverse wave?
- Give an example of a transverse wave.
- Can a transverse wave travel through space? Why?
- What type of wave is a sound wave? What does this mean?
- Describe what will happen to rock if longitudinal and transverse waves occur during an earthquake.

CP4a/b – SP4a/b Properties of Waves



Frequency - is the number of waves passing a point each second and is measured in Hertz (Hz). 1 Hz means 1 wave passing per second.

Wavelength - distance from a point on one wave to the same point on the next wave (measured in metres).

Amplitude -maximum distance of a point on the wave from its rest position (measured in metres). The top of the wave is called the crest, the bottom the trough.

Wave speed

The wave speed refers to how fast the energy in a wave travels.

1. Wave speed (metre/second, m/s) = $\frac{\text{distance (metre, m)}}{\text{time (second, s)}}$

   e.g. a wave carries a surfer 52 metres in 8 seconds

   wave speed =52/8 = 6.5 m/s

2. Wave speed is also linked to the wave frequency and wavelength.

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

e.g. if waves of 13m wavelength have a frequency of 0.5 Hz

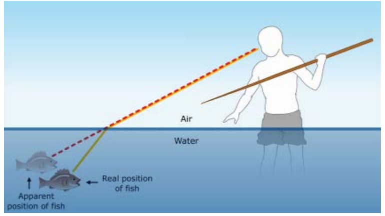
Wave speed = 0.5 x 13 = 6.5 m/s

CP4a/b- SP4a/b Questions on Properties of Waves

- Draw a wave and label the amplitude and wavelength on it.
- Define wavelength and amplitude.
- Draw a wave with twice the amplitude of the first one and then draw a wave with half the wavelength.
- Define frequency of a wave. What unit is frequency measured in?
- Calculate the speed of a wave if its frequency is 50Hz and its wavelength is 10m. Which equation did you use?

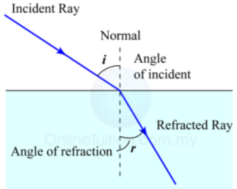
CP4c/SP4c REFRACTION

Light travels in straight lines, however it can change direction when it moves into a different material (e.g from air into water). This is called refraction and happens at the boundary ('interface') between two materials ('mediums').The 'normal' line is at a right angle to the interface



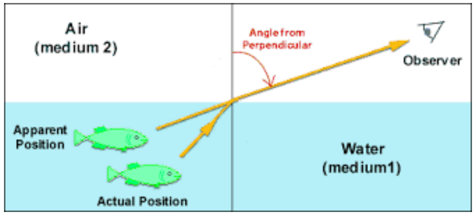
Why does refraction occur?

Refraction occurs because light travels at different speeds in different mediums – fastest through air, slower through glass and water. When moving from air to water/glass (or from deep water to shallow water), light slows down and refracts towards the normal. The wavelength of the wave also decreases.



Note: the amplitude and frequency of the light wave does not change.

When moving from water/glass to air (or from shallow water to deep water), light speeds up and refracts away from the normal. The wavelength of the wave also increases.



Note: the amplitude and frequency of the light wave does not change.

CP4c/SP4c Questions on Refraction

- Define refraction.
- Why does refraction occur?
- What is meant by ‘medium’?
- What is the normal?
- When light goes from a less dense to more dense medium what happens?
- When light goes from water to air what happens?
- What happens to the frequency and amplitude of the wave in the above?

CP5a-b/SP5d-e Electromagnetic waves

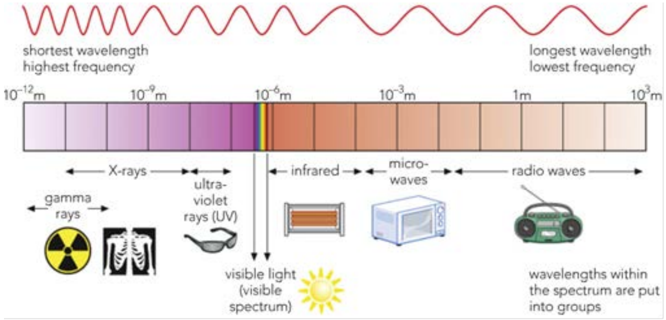
Visible light, IR and UV are all types of electromagnetic radiation. The electromagnetic vibrations are at right angles to the direction in which the energy is being transferred by the wave as they are transverse waves.

THE ELECTROMAGNETIC SPECTRUM

Electromagnetic waves can travel without any particles to vibrate so can travel through a vacuum, such as space. All electromagnetic waves travel at 300,000,000 m/s (3×10^8 m/s)in a vacuum which is the fastest speed anything can move.

Since v=f ʎ and V, the speed of waves is always the same, if frequency goes up the wavelength, ʎ, must decrease. The full range of electromagnetic waves is called the electromagnetic spectrum. Although continuous, the spectrum is conveniently divided into 7 major according to the wavelength and frequency of the waves.

Gamma rays (shortest wavelength, highest frequency)→x-rays→UV→ visible light (violet, indigo, blue, green, yellow, orange, red)→IR→ microwaves→radio waves (longest wavelength, lowest frequency). So, compared to visible light UV has a shorter wavelength and higher frequency waves. IR has a longer wavelength and lower frequency waves. Visible light waves are the only ones visible to the human eye.



Modern astronomy tries to observe stars and galaxies by detecting various parts of the electromagnetic spectrum they give off - the Hubble Space telescope can detect visible light, UV and IR.

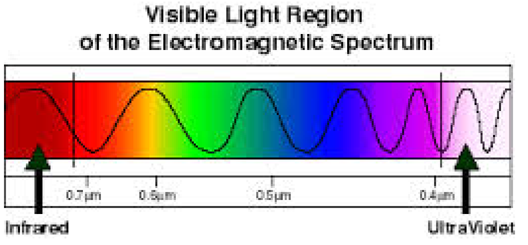
CP5a-b/SP5d-e Questions on Electromagnetic Waves

- Electromagnetic waves are transverse waves – explain what this means.
- What speed do all electromagnetic waves travel at?
- Write down the equation that links speed to frequency and wavelength.
- If the wavelength increases what must happen to the frequency – why?
- Calculate the frequency of a wave in the electromagnetic spectrum that has a wavelength of 500m.

CP5a-b/SP5d-e Infra Red and Ultra Violet

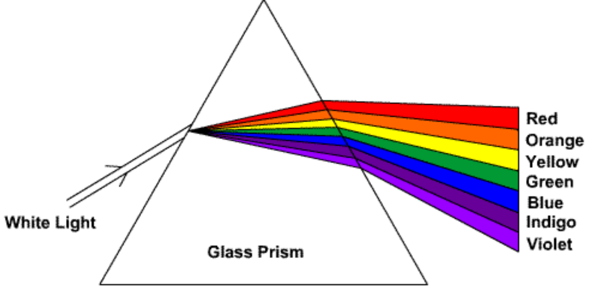
Spectrum of visible light in order

Red →orange→yellow→green →blue→indigo→violet (shortest wavelength, highest frequency). Use 'Richard Of York Gave Battle In Vain' to remember the order.



The discovery of infrared

The astronomer William Herschel put coloured filters on his telescope to observe the Sun safely and he noticed that different coloured filters heated up his telescope to different extents hence he wondered whether different colours of light contained different amounts of heat. To test this, Herschel used a prism to split sunlight into a spectrum and then put a thermometer in each of the colours. He found that as he changed the colour from violet→indigo→blue→ green→yellow→orange→red, the temperature increased. Herschel then measured the temperature just beyond the red end of the spectrum, where there was no visible light, and found this gave the highest temperature. This band of invisible light beyond the red spectrum is called infrared radiation (IR).



Going beyond violet

Johann Ritter found out about Herschel's work and set about trying to find 'invisible rays' at the other end of the spectrum (i.e violet end). He used silver chloride, a chemical that breaks down to give a black colour when exposed to light and it was already known that silver chloride turned black more quickly in <u>violet</u> light than in <u>red</u> light.

Ritter showed that silver chloride turned black even faster when exposed to 'invisible rays' just beyond violet and these 'invisible rays' were later called ultraviolet waves (ultraviolet radiation, UV).

CP5a-b/SP5d-e Questions on Infra Red and Ultra Violet

- List the colours of light in the visible spectrum starting with Red – the longest wavelength.
- Which of these has the highest frequency?
- Why does the wave with the longest wavelength have the shortest frequency?
- How did Herschel discover Infra red light?
- How did Ritter discover Ultra Violet?

Cp5c-d/Sp5f&h Using long and short wavelengths

Illumination, vision and photography: Visible light is necessary for illumination, vision and photography e.g .the EURion pattern on banknotes (prevents digital copying) can be seen when illuminated because it reflects certain wavelengths of visible light.

Security UV: Some materials absorb UV radiation and re-emit it as visible light – this is called fluorescence which is used to check banknotes – real banknotes fluoresce when UV light is shone onto them.

Some security lights use fluorescent lamps – these produce UV waves and use a fluorescent material on the inside of the bulb glass.

X-ray: X-ray scanners are used in airports to detect objects hidden on the body as well as in luggage. Both x-rays and gamma rays can penetrate the body, but x-rays transfer less energy than gamma rays so are safer. X-rays are used in hospitals to detect broken bones.

IR radiation: All warm objects give off some heat as IR radiation so CCTV cameras that detect IR are used to watch people at night – this is called thermal imaging. IR radiation can pass through fog so it's useful in daytime too

Communications: Both radio waves and microwaves carry TV signals. Wi-fi wireless connections for computers use radio waves and mobile phone signals use microwaves.

IR radiation carry signals a short distance from remote controls to devices like TVs and are also sent down optical fibre cables for telephone and internet communications.

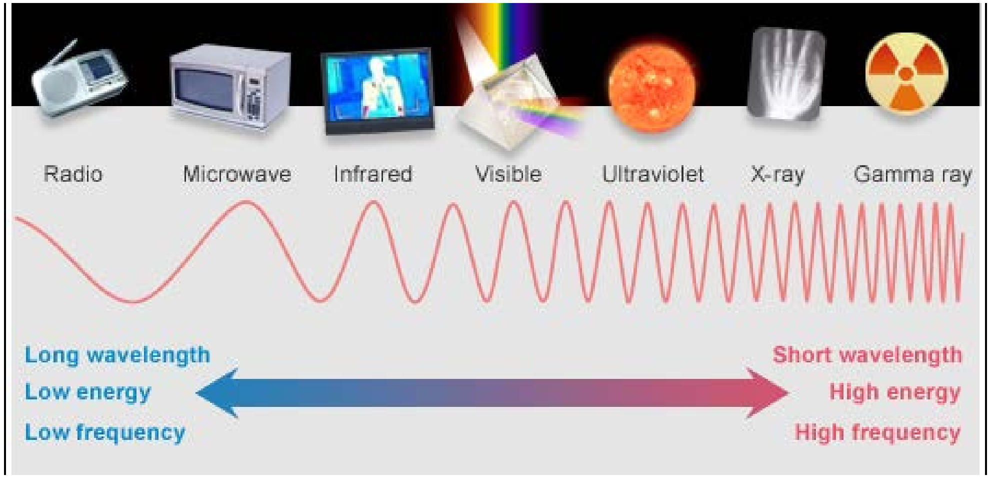
Food and medicine: Gamma rays transfer a lot of energy which can kill cells (including those of bacteria/ microorganisms) so are used to sterilise food and surgical instruments. They are also used also to kill cancer cells in radiotherapy (gamma rays are <u>aimed</u> at the cancer cells so damage to normal cells is limited). They can also detect cancer: A chemical that emits gamma rays is injected into the blood. The chemical is designed to collect inside cancer cell so a scanner then locates the cancer by finding the source of the gamma rays

UV radiation: UV radiation can kill bacteria so is used to disinfect water and sewage.

Ionising Radiation: Gamma rays are ionising radiation – i.e. they can remove electrons from atoms to form ions which are very reactive so if atoms in the cell are ionised, the reactions that follow can damage DNA (this is how gamma rays can cause cancer). Some elements naturally emit gamma radiation all the time (e.g radium) – such elements are said to be radioactive

Alpha and Beta particles : Not all substances emit gamma (ɤ) waves. Others emit alpha (α) and beta (β) particles. Some e.g plutonium give off all three types. Alpha and beta are particles of matter with a lot of kinetic energy which can ionise atoms so alpha and beta particles are also types of ionising radiation. Gamma rays, alpha and beta particles can damage DNA inside cells however, unlike gamma rays, they are not electromagnetic radiation.

Cp5c-d/Sp5f&h Questions Using long and short wavelengths (EM Waves)



Give a use of each part of the electromagnetic spectrum of waves:

Radio Waves

Microwaves

Infrared

Visible

Ultraviolet

Xrays

Gamma rays

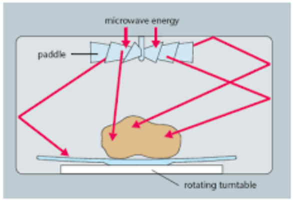
Which wave has the longest wavelength?

Which wave has the highest frequency?

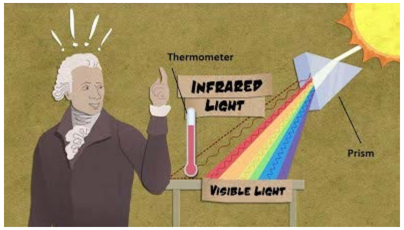
Which wave has the highest energy?

Cp5e/SP5i DANGERS OF ELECTROMAGNETIC WAVES

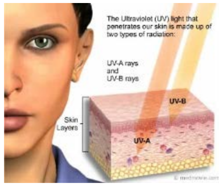
Microwaves: The microwave frequency that can heat water is used in microwave ovens. Humans are mostly water so microwaves can cause internal heating of body cells which is potentially dangerous. This is why microwave ovens have shields in them to stop the waves escaping. Mobile phones signal using microwaves, but use different frequencies so do not pose a health risk.



IR radiation: Our skin absorbs IR, which we feel as heat (remember from Herschel's experiment that IR had higher temperature than visible spectrum). Too much IR can damage or destroy cells and cause burns to skin. All waves transfer energy however, higher frequency waves transfer more energy (have greater penetration) so are potentially more dangerous.



UV radiation: Sunlight contains UV, which carries more energy than visible radiation and the energy transferred by UV to our cells can damage their DNA. Too much exposure to sunlight (UV) can cause skin cancer. UV in sunlight can also damage eyes leading to cataracts which cloud the lens, reducing vision. To protect yourself from UV radiation, you should put sun cream on and wear sunglasses.



X-rays and gamma rays: These waves have higher frequency than UV, carrying even more energy and excessive exposure to x-rays or gamma rays may cause genetic mutations in DNA leading to cancer.

Cp5e/SP5i

Questions on Dangers of Electromagnetic Waves

- What molecule is heated by microwave radiation?
- Why is this dangerous to humans?
- Where does IR radiation come from? What damage could it cause to humans?
- If the skin is exposed to too much UV what may happen? What can you do to protect yourself from UV rays?
- What dangers are associated with X-rays and Gamma rays? Why are these rays so dangerous?

Cp6a+b/SP6a+b Atomic models

- The particle theory is a model used to explain the properties of solids, liquids and gases. Particles are usually represented as spheres.
- We can explain some of the properties of different elements by thinking about the particles that each contains. These particles are ATOMS. Chemical reactions occur when the different atoms in substances become joined in different ways.
-

The Atom is Made Up of Protons, Neutrons and Electrons

Protons, neutrons and electrons are all subatomic particles — particles that are smaller than atoms.

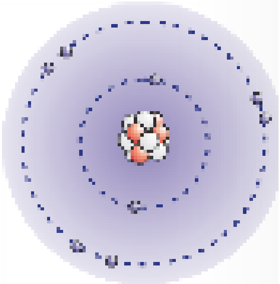
The quantities to do with atoms are really tiny, so they're written in standard form:

$A \times 10^n$

A is always a number between 1 and 10.

n is the number of places the decimal point would move if you wrote the number out in decimal form. It's negative for numbers less than 1, and positive for numbers greater than 1.

1) The nucleus contains protons (which are positively charged) and neutrons (which are neutral) — which gives it an overall positive charge. The nucleus is tiny — the nuclear radius is about 1×10^{-15} m. Almost the whole mass of the atom (about 1×10^{-23} g, depending on the element) is concentrated in the nucleus.



2) The rest of the atom is mostly empty space. The negative electrons whizz round outside the nucleus really quickly, in electron shells. They give the atom its overall size — the diameter of an atom is around 1×10^{-10} m — so the nuclear radius is around 10 000 times smaller than the atomic radius.

3) Atoms can join together to form molecules — e.g. molecules in oxygen gas are made up of two atoms of oxygen bonded together. Small molecules like this have a typical size of 10^{-10} m — they're roughly the same size as an atom.

Particle	Relative mass	Relative charge
Proton	1	+1
Neutron	1	0
Electron	0.0005	-1

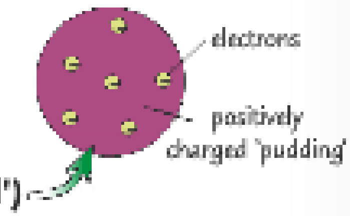
Cp6a+b/SP6a+b Atomic models

- Describe the current model of the structure of an atom.
- What are the relative masses and charges of the particles that make up an atom ?
- How does particle theory explain how solids have a fixed shape?

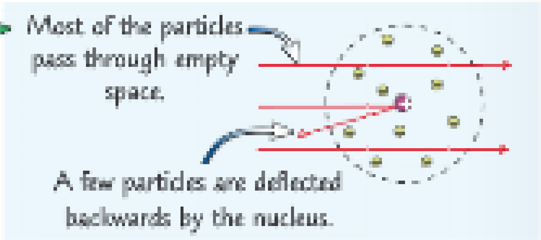
Cp6a+b/SP6a+b History of Atomic models

Atoms are the tiny particles of matter (stuff that has a mass) which make up everything. We used to think they were solid little spheres (like mini ball-bearings), then some clever clogs did some experiments...

The Theory of Atomic Structure Has Changed Over Time



1) In 1897 J J Thomson figured out that atoms weren't solid spheres. His measurements of charge and mass showed that an atom must contain smaller, negatively charged particles — electrons. From his results, he made a model of the atom known as the 'plum pudding model' (or the 'Thomson model') where negative electrons were spread through the positive 'pudding' that made up most of the atom.
2) In 1909 Ernest Rutherford, working with Hans Geiger and Ernest Marsden, conducted the famous gold foil experiment. They fired positively charged alpha particles at an extremely thin sheet of gold.
3) From the plum pudding model, they expected the particles to pass straight through the gold sheet, or only be slightly deflected. But although most of the particles did go straight through the sheet, some were deflected more than they had expected, and a few were deflected back the way they had come — something the plum-pudding model couldn't explain.



4) Rutherford came up with the theory of the nuclear atom to explain this new evidence. In his model, most of the mass of an atom is concentrated in a tiny, positively charged nucleus at the centre, surrounded by a 'cloud' of negative electrons — most of the atom is empty space.
5) Scientists realised that electrons in a 'cloud' around the nucleus of an atom like this would be attracted to the nucleus, causing the atom to collapse.
6) Niels Bohr got round this a few years later by proposing a new model where the electrons are in shells. He suggested that electrons can only exist in these shells (or fixed orbits), and not anywhere in-between. Each shell has a fixed energy. His theory was pretty close to the model of the atom shown below.

Cp6a+b/SP6a+b History of Atomic models Questions

- Describe the Thomson model of the atom.
- Describe Rutherford's model of the atom including the words charge, electron, mass and nucleus in your description.

Cp6b/SP6b Isotopes

Isotopes are *Different Forms* of the *Same Element*

1) Atoms consist of a nucleus (made up of protons and neutrons), surrounded by electrons.
2) The atomic/proton number is the number of protons in an atom.
   The number of protons defines what the element is (e.g. a carbon atom always has 6 protons).
3) Since protons are positively charged and neutrons are neutral,
   the nucleus of each element has a particular overall positive charge.
4) The mass number is the number of protons plus the number of neutrons
   in an atom — it tells you the mass of the nucleus.
5) You can represent atoms using this notation:

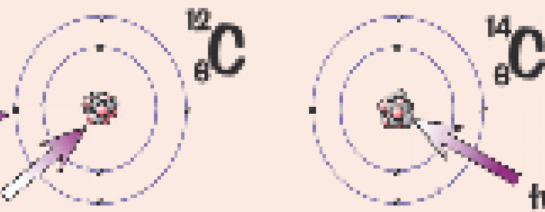
6) Isotopes are atoms of the same element — they have
   the same number of protons but a different number of neutrons.
   So isotopes have a different nuclear mass but the same nuclear charge.

So isotopes have the same atomic number, but different mass numbers.

Carbon-12 and carbon-14
are examples of isotopes:

electrons surround the nucleus

nucleus containing protons and neutrons



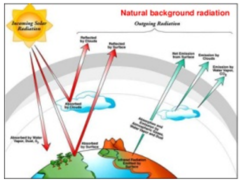
two extra neutrons

Cp6b/SP6b Isotopes Questions

- Write a glossary definition for the term isotope.
- The symbol for an isotope of beryllium is $^{9}_{4}Be$. How many protons and how many neutrons does it contain?
- How many neutrons are there in the nucleus of an atom of oxygen -18.

CP6d/SP6d Background Radiation Questions

- We are constantly exposed to low levels of ionising radiation from space and from naturally radioactive substances in the environment - this is called 'background radiation'
- When scientists measure the activity of a source:
  - They first need to measure the background radiation
  - The background radiation is then subtracted from measurements to give the corrected reading of the source's activity



Sources of background radiation:

1. Radon gas is the main source of background radiation:
   - When uranium in rocks decays, it produces other radioactive isotopes that also decay – one of these is radon
   - Radon diffuses into the air from rocks and soil and can build up in houses, especially if there is poor ventilation
   - The amount of radon in the air depends on the type of rock and its uranium content and the radon content (and therefore the background radiation) varies according to where you are in the UK
2. X-ray scans, gamma ray scans and radiotherapy treatment for cancer contribute to background radiation
3. Some foods naturally contain small amounts of radioactive substances. Some background radiation comes from space
4. High energy charged particles come out of stars, supernovae, neutron stars and black holes:
   - They are known as 'cosmic rays' and are a form of ionising radiation
   - Many cosmic rays are stopped by the upper atmosphere but some still reach the Earth's surface

CP6d/SP6d Background Radiation

- Describe the meaning of the phrase ‘background radiation’
- Why is it important to measure the background radiation and how is it used in experiments?
- Is the background radiation a constant – explain your answer?
- Name as many sources of background radiation as you can.

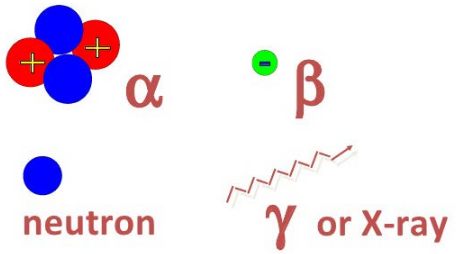
CP6e/SP6e Types of Radiation

Radioactive substances have unstable nuclei that emit ionising radiation (randomly). They release energy and decay to become more stable. Ionising radiation - enough energy to cause atoms to lose electrons and become ions. Three main types of ionising radiation:

Alpha particles: (2 protons, 2 neutrons (helium nucleus, no electrons, +2 charge))

- Very ionising (i.e they easily make atoms lose electrons and become ions)
- Each time ionising particles ionise an atom, they lose some energy, so alpha particles lose energy quickly so don't travel far into matter - 'short penetration distance'.
- Alpha particles can be stopped by a few centimetres of air or a few mm of paper

Beta particles: (Electrons, negatively charged)



- Moderately ionising
- Lose energy slower than alpha particles, so they can penetrate further into matter than alpha particles can
- Beta particles can be stopped by a few millimetres of aluminium

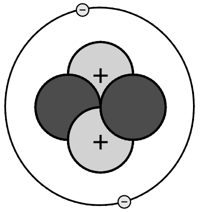
Gamma rays: (High-frequency electromagnetic waves – speed of light, no charge)

- Weakly ionising (much less than both alpha and beta particles)
- Lose energy very slowly, so can penetrate further into matter than both alpha and beta particles can.
- Gamma rays need thick lead to stop them

CP6e/SP6e Types of Radiation Questions

- What is an alpha particle made of?
- What is a beta particle made of?
- What is gamma radiation?
- Which is the most penetrating?
- Which is the most ionising?
- What is gamma radiation stopped by?

CP6f/SP6f Beta and Positron radiation

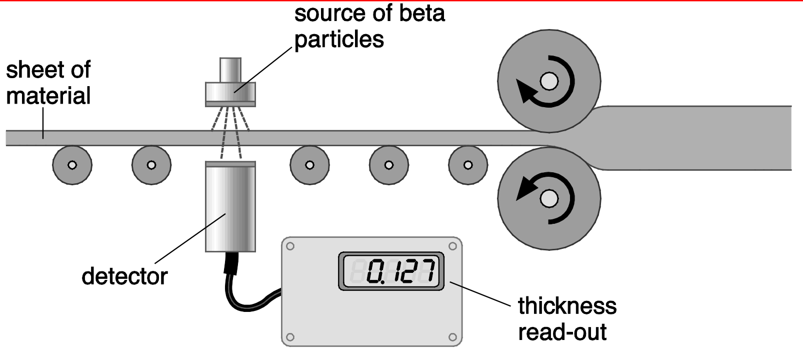


What is beta decay?

- **Atom –** an atom consists of a small nucleus containing protons and neutrons and with electrons around it.
- **Nucleons** – protons and neutrons are known as nucleons.
- **Atomic number** – same as proton number which is the number of protons in the atom
- **Mass number** – same as nucleon number, which is the number of protons and neutrons in an atom.
- **Beta particles** – electrons (Beta-minus) or positrons (Beta-plus)

Beta minus decay – In beta minus decay, a neutron becomes a proton plus an electron. Beta minus radiation is made up of a stream of high energy electrons. They can penetrate paper but not thin sheets of metal. The particles are ionising. Beta-minus decay increases the atomic number by 1 but mass number is unaffected.

Beta plus decay – In positron or beta-plus decay, a proton becomes a neutron plus a positron. Positron decay decreases the atomic number by 1 but mass number remains unchanged.



The diagram shows how ionising radiation can be used as part of the system for controlling the thickness of paper produced in a paper mill.

CP6f/SP6f Beta and Positron radiation

1. Describe two properties of beta radiation.
2. Describe two properties of positron radiation.
3. Describe the process of ß+ decay and ß- decay.
4. What happens to the proton number and mass number during each type of ß decay?

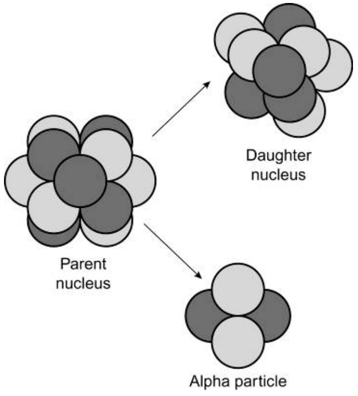
CP6f/SP6f Alpha and gamma radiation

Radioactive emissions – there are three types, alpha, beta and gamma.

- **Alpha radiation –** alpha particles are each made up of 2 protons and 2 neutrons. They are not very penetrating but are very ionising.
- **Alpha decay –** results in the atomic number decreasing by 2 and mass number decreasing by 4.

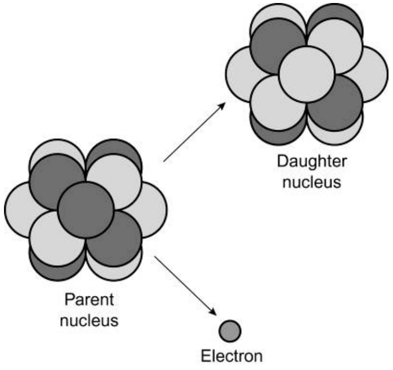
- **Gamma radiation** – are a type of electromagnetic radiation, it has no mass and causes no change to the atomic number or mass number. Gamma rays are very penetrating but not very ionising.

- **Neutron radiation** – sometimes in radioactive decay, a neutron is emitted. Neutrons have no charge, but they are as penetrating as gamma rays.
- **Nuclear Reactions** – Shows the reactants and products in a nuclear reaction. This reaction has to be balanced in terms of the total atomic mass number and total mass number which must be the same on both sides.

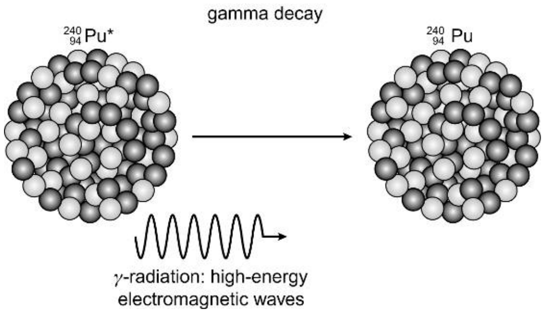


Alpha decay

Beta decay



Gamma decay



CP6f/SP6f Alpha and gamma radiation questions

1. What happens to nuclei that have undergone radioactive decay?

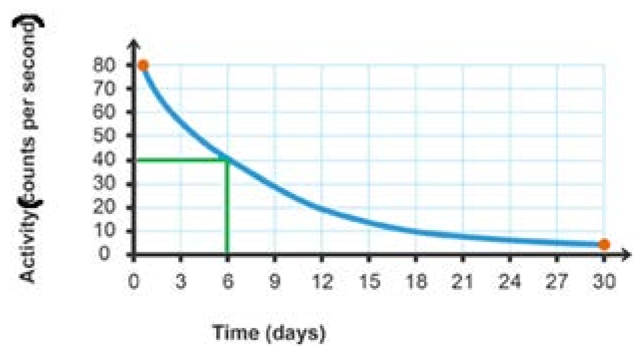
2. Radium 226 emits an alpha particle. Complete the equation to show the products formed.

$$^{226}_{88}Ra \Rightarrow$$

3. What effect does gamma radiation have on the mass number? Explain your answer.

CP6g/SP6g HALF LIFE

- Radioactive substances have unstable nuclei that emit ionising radiation (alpha particles, beta particles and gamma rays) – this is a random process
  - As unstable nuclei emit ionising radiation, they lose (release) energy and decay to become more stable
- The 'activity' of any radioactive substance is the number of nuclear decays (i.e. the number of unstable nuclei that emit ionising radiation and then become more stable) per second – it is measured in Becquerel (Bq)
  - 1 Bq is equal to one nuclear decay per second - the more unstable nuclei in a sample, the faster its rate of decay→the higher its 'activity'
- The 'half-life' is the time taken for the 'activity' for a radioactive substance to decrease by half (i.e it's the time taken for half of the nuclei in a sample of a radioactive isotope to decay and become more stable)
  - The shorter the half-life, the quicker the isotope decays
- The half-life of a radioactive sample is found by recording its activity over a period of time - this is done using a Geiger-Muller (GM) tube:
  - A GM tube is connected to a counter – every time ionising radiation is detected, it gives out a click
  - The 'count rate' is the number of clicks per second
  - The time it takes for the count rate to halve is the half-life
- The half-life can be calculated from a graph:
  - Activity of radioactive substance is initially 80 counts per second
  - It takes 6 days for its activity to reduce to 40 - its half-life is 6 days



CP6g/SP6g Half Life - Questions

- When an atom decays, what ionising radiation particles/rays are emitted?
- Describe the measurement of radiation and indicate the unit of measure.
- What instrument would you use to measure radiation?
- Define the term ‘half life’ of a substance.
- Name a good method of determining the half life

CP6h/Sp6i Dangers of ionising radiation

What are the dangers of ionising radiation?

- **Mutations –** changes in the structure of the DNA, which may then copied over to new cells.
- **Dosage** – in radiation exposure, it is the total amount of radiation absorbed by the person exposed to it.
- **Dosimeter –** is a film badge, developing the film reveals the dose of radiation received by the wearer.

Increase in radiation levels can:

- Kill healthy cells – risk of damage to their DNA.
- Stimulate the growth of cancers
- Cause mutations – the structure of the DNA in cells can cause cancers or harmful changes to the function of genes, which are passed down to the next generation.
- Cause radiation burns – beta burns are mainly surface burns, gamma burns go deeper into the tissue and organs inside the body.

Protecting people from over-exposure

- Increase the distance that medical staff work from the source.
- Shielding the containment of the radioactive source
- Minimise the time spent in the presence of sources
- Controlling the dosage of the radioactive material used in patients for diagnosis or treatments
- Wear a dosimeter to monitor the levels of exposure and dose received by the wearer

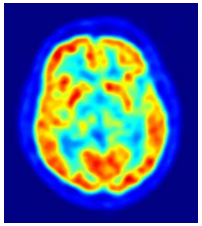
CP6h/SP6i Dangers of ionising radiation

1. Describe two dangers of ionising radiation.

2. How is the safety of the patient and radiographer protected from over-exposure?

CP6h/SP6i Radiation in hospitals

How are radioactive substances used in hospitals?



- **Radiotherapy** – Use of ionising radiation to treat cancer by killing cancer cells or to reduce the size of a tumour with
- **Internal radiotherapy** – where the radioactive source is placed inside the body, e.g. placing iodine-131 next to the tumour in the patient
- **External radiotherapy** – where a gamma source or X-ray tube is used to apply a dose to the patient.
- **Palliative care** = a condition that cannot be cured, but allows the patient to be in less pain to enjoy a better quality of life.
- **Tracer** – a radioactive substance that is injected into the body and emits gamma rays that can be detected outside of the body to monitor how a part of the body is functioning.
- **PET Scans** – Positron emission tomography – uses principle of positron-electron annihilation shows the active areas of parts of the body that take up more of the injected tracer (more detail found in Topic 4: PET Scans slide).

Radiotherapy is used to treat cancers by killing cancer cells. It may also be used in palliative care. Cancers can be diagnosed using a tracer. **Tracers** will concentrate in particular organs or diseased or cancerous tissues and tumours. They usually have a **short half-life**, i.e. it will lose its **radioactivity** very quickly so other parts of the body are affected minimally.
In a **PET scan**, the tracer emits a **positron**, this then interacts with an **electron** (annihilates) releasing **two gamma rays** in opposite directions. The **PET camera** then **detects** the gamma rays.

CP6h/SP6i Radiation in hospitals

1. Describe what is meant by palliative care.
2. Why do isotopes used in PET scanners have to be produced nearby?
3. Give two uses of radioactive substances in diagnosis of medical conditions.

CP7a/SP8a WORK AND POWER

‘Work’ is done when energy is transferred from one form to another. Car brakes ‘do work’ by transferring kinetic energy to thermal energy

The amount of ‘work’ done is equal to the amount of energy transferred

Energy and work are measured in joules (J)

Work done (joules, J) = force (newtons, N) x distance moved in the direction of the force (metres, m). $E = F \times d$

Power is the rate of doing work – measured in watts (W)

Power (watt, W) = work done (joule, J) / time taken (second, s). $P = E / t$

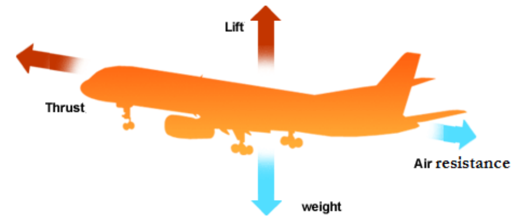
- 1 watt = 1 joule of work done per second
- i.e the more work done per second, the more power generated

CP7a/SP8a Questions on Work and Power

- What units do we use to measure work?
- What is the formula for work done?
- What units do we use to measure power?
- What is the formula for power?

CP8a/SP9a Forces

Forces make objects change speed, shape or direction. A force (N – Newtons) is a vector quantity (it has both a size and direction)



Different types of forces:

- Upthrust/lift – these act upwards (in air). Weight (gravity)
- Friction/air resistance/drag – against the direction of movement
- Thrust/driving force – these act in the direction of movement. They are forces produced by engines that push vehicles forwards
- Push/pull – these are forces that also act in the direction of movement, but are generated by direct contact between objects (not by engine power)

Action and reaction forces - whenever two objects touch, they interact with each other.

- the forces they exert on each other are equal in size and opposite in direction
- These forces are known as 'action' and 'reaction' forces, an 'action-reaction' pair

A book resting on a table: the weight of the book exerts a downward force on the table – this is the 'action force'. The table exerts an equal and opposite (i.e upward) pushing force on the book - this is the 'reaction force'. Without this reaction force, the book would fall through the table

Action and reaction forces are used to propel rockets: Gases are pushed out from the rear of the rocket – this is the action force. The reaction force from the gases pushes the rocket forwards.

Free-body force diagrams: shows the different forces acting on an object

- The arrows show the direction in which the forces act
- The length of the arrows shows the size of the forces (the longer the arrow, the bigger the size of the force)

CP8a/SP9a Forces - Questions

- What is a force?
- In which direction does friction or drag work?
- What is an action-reaction force?
- Where is the action-reaction on a book resting on the table?
- What does a larger arrow represent on a free-body diagram?

CP8b/SP9b Vector Diagrams

- Vector Diagrams are also known as Scale Diagrams

Use Scale Drawings to Find the Resultant Force

Resultant force can also be called the net force.

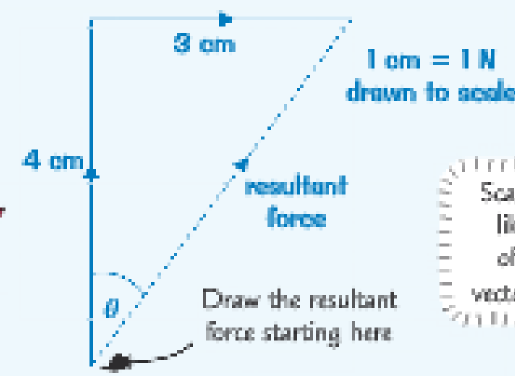
You can find the size and direction of the resultant force on an object using scale drawings. Draw the forces acting on the object to scale and 'tip-to-tail', then measure the length of the resultant force on the diagram. This is the line drawn from the start of the first force to the end of the last force.

EXAMPLE:

A man is on an electric bicycle that pushes him with a force of 4 N north. However, the wind is pushing him with a force of 3 N east. Find the magnitude of the resultant force.

1) Start by drawing a scale diagram to illustrate the forces acting on the man. *Make sure you choose a sensible scale* (e.g. 1 cm = 1 N).
2) Then just measure the missing side with a ruler.

If you were asked to find direction as well, you would just measure the angle θ with a protractor.



Scale drawings like this are often called vector diagrams.

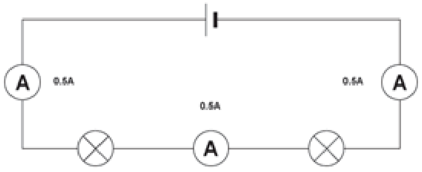
Resultant force vector is 5 cm long, so the resultant force is 5 N.

CP8b/SP9b Vector Questions

- A boat is being pushed by its propeller with a driving force of 600N south and by the wind with a force of 450N east. Use a vector diagram to find the size of the resulting force acting on the boat.

CP9a&b/SP10a&b **Current in Series and Parallel Circuits**

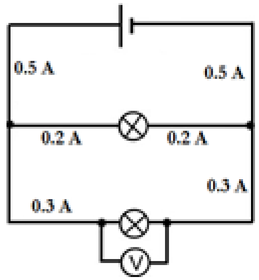
Series circuits consist of just one continuous loop – they have no junctions.



Parallel circuits have different branches, which form separate loops

In a parallel circuit, when current reaches a junction, the current splits into two. In diagram when the 0.5 A current reaches the junction, it splits into 0.2 A and 0.3 A

Note: current is conserved - none is lost.



Measuring current

The size of a current (in amps) is measured using an ammeter.

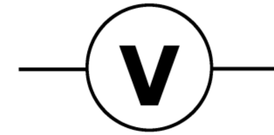
Ammeters are always placed in 'series' with other components in a circuit. Ammeters have low resistance and so the electrons aren't used up and the current leaving the cell is the same as the current that flows back into the cell.

An ammeter can be placed anywhere in a series circuit as it will always give the same reading.

CP9a&b/SP10a&b Questions on Series and Parallel Circuits

- What is the difference between series and parallel circuits?
- What does an ammeter do?
- Where would you place an ammeter in a circuit?
- What property does an ammeter have that makes it useful?
- In a series circuit what can you say about the current all the way round?

CP9b/SP10b Measuring voltage



Potential difference (the voltage) is measured using a voltmeter.

Voltmeters measure the **difference** in energy between the electrons going into the component and those coming out so they're always placed in parallel with the component (on a separate branch).

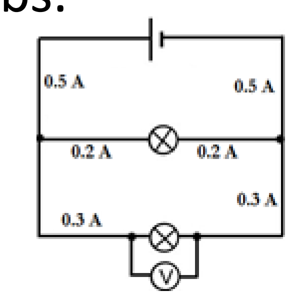
e.g in the diagram, the voltmeter is measuring the potential difference (i.e the difference in energy between electrons going in and those coming out) across the light bulb.

The higher the potential difference, the more energy emitted from the cell so the bigger the current and the brighter the bulb.

The potential difference is the energy transferred (to a component) for each unit of charge that passes through that component.

Energy is measured in joules, charge is measured in coulombs.

1 volt = 1 joule per coulomb



CP9b/SP10b Questions on Measuring Voltage

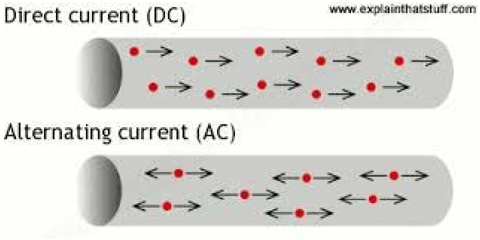
- Name the piece of apparatus used to measure the voltage or potential difference.
- Why is this piece of equipment placed in parallel?
- What are the units for energy and charge?
- What is 1 volt?

CP9a-c/SP10a-c ELECTRIC CURRENTS

In conducting materials (e.g. metals), some of the electrons from each atom are free to move about producing an electric current. In a piece of metal, the free electrons all move round in different directions.

When a metal wire is placed in a complete electrical circuit the cell (battery) pushes the free electrons in one direction around the circuit. Cells and batteries supply current that flows in only one direction called 'direct current'

Generators produce 'alternating current' – i.e electrons change direction many times each second. An electric current is the rate of flow of charged particles



Units of Charge – measured in coulombs (C)

Units of Current – measured in amperes (or amps, A)

The size of the electric current depends on how much charge is passing a point in a circuit each second. 1 ampere is a flow of 1 coulomb of charge per second

The equation linking charge and current:

charge (coulombs, C) = current (amps, A) x time (seconds, s)

$$Q = I \times t$$

i.e the more charge that passes a point in a circuit per second, the greater the current

e.G a current of 5A flows for 10s-how much charge has flowed through the circuit?

Charge = 5 x 10 = 50 C

CP9a-c/SP10a-c Questions on Electric Current

- What makes the electrons all flow in the same direction in a circuit?
- Describe the direction of electron flow in a generator?
- Name the units for charge and current.
- What is the equation that links charge and current?
- How much charge flows when a current of 10A flows for 2 minutes?

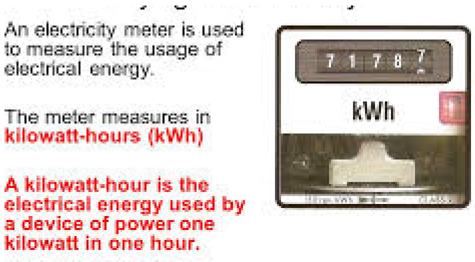
CP9c/SP10c PAYING FOR ELECTRICITY

- Energy is measured in Joules (J)
- Power is the amount of energy that is used by a working appliance each second.
- Unit of measurement for power is joule/second (J/s) or Watt (W)

2 equations

Power = $\frac{\text{Energy}}{\text{time}}$ $P=\frac{E}{t}$

(watt, W) = (joule, J) / (second,s)



Power = current x voltage $P=I\times V$

(watt,W) = (Amps, A) x Volts (v)

Many electrical appliances need a lot of power and usually their 'power rating' (showed on the appliance) is given in kilowatts (kW)

1 kW = 1000W

- Electricity companies charge for electrical energy by the kilowatt-hour (kWh).

1 KwH is the amount of energy that's transferred by a 1 kW device in 1 hour.

- The cost of electricity is worked out using the formula:

Cost (pence, p) = power (kilowatt, kW) x time (hour, h) x cost of 1 kWh (p/kWh)

e.g an electric heater has a power rating of 2kW. What is the cost of using the fire for 3 hours if 1 kWh of electricity costs 12 p?

Cost = 2 x 3 x 12 = 72 p

CP9c/SP10c Questions on Paying for Electricity

- Complete this table

Device	Power (in kW)	Time of use (in hours)	Energy transferred (in kW h)
Computer	0.4	3.0	1.2
Heater	2.0	2.0	
Kettle	3.0	0.2	
Lamp	0.1	5.0	
Microwave oven	1.0	2×0.2	
Television	0.2	2.0	

- Calculate the cost of each appliance running for the time stated if a unit of electricity costs 12p.
- Calculate the power of a kettle that transfers 240,000 Joules in 120 seconds.

CP9d&e/SP10d&e RESISTANCE

Resistance is a way of measuring how hard it is for electricity to flow measured in ohms (Ω).The higher the total resistance in a circuit, the smaller the current and the current flowing in a circuit can be changed by changing the resistance which can be done by using a variable resistor (or by putting a different resistor into the circuit).

The size of the current flowing in an electric circuit depends on the potential difference of the cell/power supply and the resistance of the circuit.

Relationship between resistance, current and voltage:

Potential difference (volts, V) = current (amps, A) x resistance (ohms, Ω)

$$V = I \times R$$

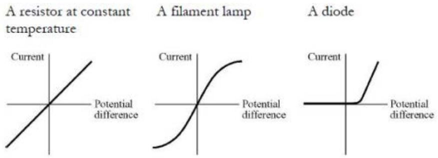
I.e the bigger the voltage and the smaller the resistance, the bigger the current

Question: What potential difference is needed to make a 2A current flow through a 10 Ω resistor? Potential difference = 10 x 2 = 20 V

Some electrical components change their resistance depending on the potential difference

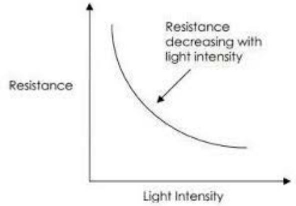
1. *Filament lamps* :As the potential difference increases, the filament lamp gets hotter and its resistance increases so the current vs voltage graph flattens off at high voltages

2. *Diodes*: Conduct electricity in one direction only if a potential difference is applied in the other direction, no current will flow. The resistance of fixed resistors isn't affected by the potential difference in the presence of a fixed resistor there's a directly proportional relationship (i.e straight line graph) between current and voltage

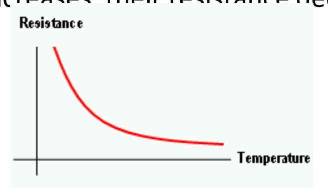


Some electrical components change their resistance depending on the conditions surrounding them...

Light-dependent resistor (LDR): Its resistance is large in the dark and decreases when light is shone on it. The greater the light intensity, the smaller its resistance.



Thermistors- as the temperature increases, their resistance decreases or increases.



CP9d&e/SP10d&E Questions on Resistance

- Define resistance.
- What is the unit of resistance?
- Write down the equation that links V, I and R.
- What is the resistance in a circuit if the voltage is 230V and the current flowing is 11 Amps?
- Draw the current:voltage graphs for a diode, filament lamp, an LDR and a negative temperature coefficient thermistor.

CP9f-h/SP10f-h TRANSFERRING ENERGY

When current flows through a resistor, energy is transferred to the resistor and it becomes warm e.g. in a motor, the main energy transfer is from electrical energy to kinetic (movement) energy. However, some energy is lost/wasted as heat energy.

Explanation for this transfer of heat energy. A current in a wire is a flow of electrons and as the electrons move in a metal, they collide with the ions in the lattice, transferring (heat) energy to them. This transfer of heat energy can be beneficial e.g in electric fires and kettles

However, this heating effect of an electric current can cause problems in some electrical appliances can produce so much waste heat energy that they could cause burns if touched. Wires can catch fire if too much current flows and for this reason, plugs are fitted with fuses which melt and break the circuit if current gets too high.

Calculating Power and Energy

Power is the energy transferred every second. The unit of power is joules per second, or watts (W).

For electrical appliances, the power can be worked out from the current and the potential difference.

electrical power (watts, W) = current (amps, A) x potential difference (volts, V)

$$P = I \times V$$

e.g. a kettle uses the mains electricity supply at 230V. The current is 13 A. What is the power of the kettle?

Power = 13 x 230 = 2990 W

The total energy transferred by an appliance depends on its power and for how long it's switched on for . The energy transferred can be calculated using the equation.

Energy transferred (joules, J) = current (amps, A) x potential difference (volts, V) x time (seconds, s)

$$E = I \times V \times t$$

e.g the kettle in the above example takes 2 minutes to boil some water. How much energy does it transfer?

2 minutes = 120 seconds

energy transferred by kettle = = I x V x t = 13 x 230 x 120 = 358,800J or 358.8 KJ

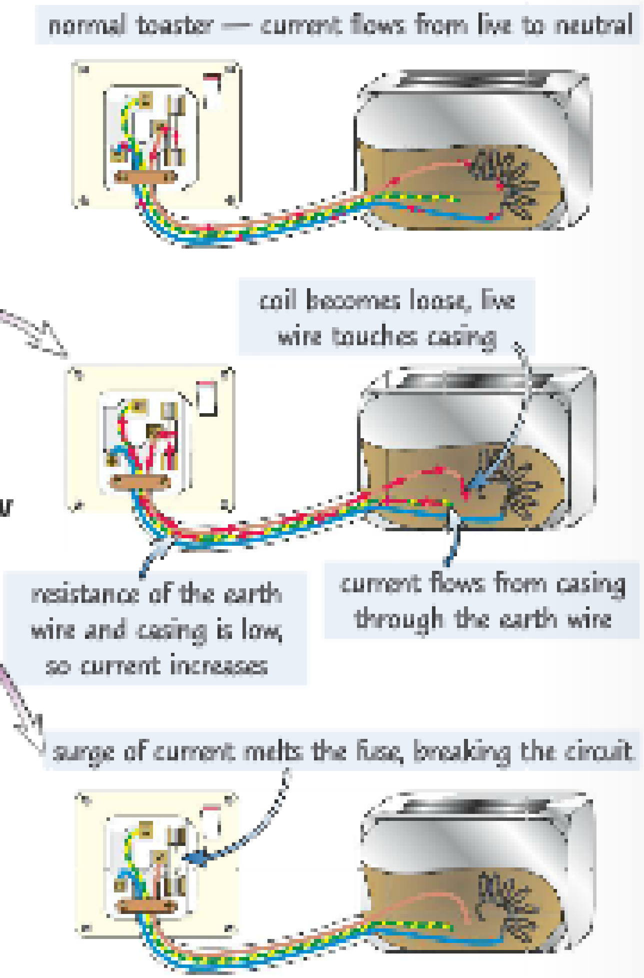
CP9f-h/SP10f-h Questions on Transferring Energy

- What happens to a resistor when current flows through it?
- Explain in terms of electrons and ions why the above happens.
- What happens to a fuse wire if too much current flows?
- What is the unit of Power?
- Write down the equation that links Power to current and voltage.
- If a washing machine has a power of 30KW and runs off mains electricity of 230V, how much energy is used during its shortest wash cycle of 45 minutes?

Cp9i/Sp10i Electrical Safety

Earthing and Fuses Prevent Fires and Shocks

1) Electricity will flow through anything that conducts. So if the live wire accidentally connects with something metal (e.g. the case of an appliance) current will flow. This could cause serious electric shocks and fires.
2) All appliances with metal cases must be "earthed" for safety. This means the case must be attached to an earth wire.
3) If a fault develops so the live wire touches the metal case, then a current will flow down the earth wire.
4) The earth wire is very thick, to give it a low resistance. This means the total resistance of the circuit decreases. Current = p.d. ÷ resistance, so this causes a big current to flow through the live wire, the case, and out down the earth wire.
5) This surge in current melts the fuse, breaking the circuit and cutting off the live supply. This isolates the appliance, so it's impossible to get an electric shock from the case. It also prevents fires caused by the heating effect of a large current.
6) Fuses and earthing also protect the circuits and wiring in your appliances from getting fried if there is a current surge.
7) If the appliance has a casing that's non-conductive (e.g. plastic) then it's double insulated. Anything with double insulation doesn't need an earth wire as it can't become live.



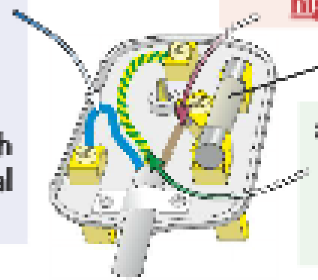
Cp9i/Sp10i Electrical Safety

Plugs Contain Three Wires

Appliances usually contain three wires.
You need to know what each of them is for:

1) LIVE WIRE — brown.
The live wire carries the voltage (potential difference, p.d.). It alternates between a high +ve and –ve voltage of about 230 V.

2) NEUTRAL WIRE — blue.
The neutral wire completes the circuit — electricity normally flows in through the live wire and out through the neutral wire. The neutral wire is always at 0 V.



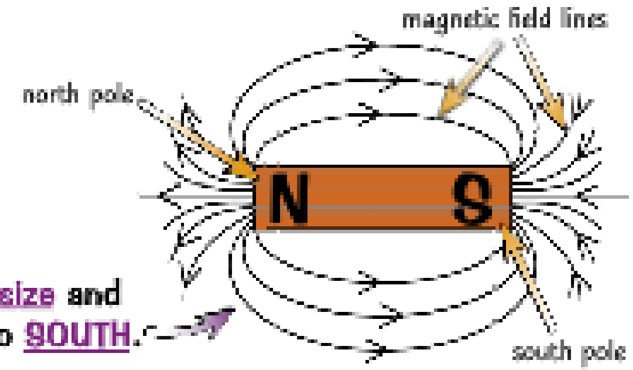
3) EARTH WIRE — green and yellow.
The earth wire is for safety. It carries the current away if something goes wrong. It's also at 0 V.

1) The p.d. between the live wire and the neutral wire equals the supply p.d. (230 V for the mains).
2) The p.d. between the live wire and the earth wire is also 230 V for a mains-connected appliance.
3) There is no p.d. between the neutral wire and the earth wire — they're both at 0 V.
4) Your body is also at 0 V. This means if you touched the live wire, there'd be a large p.d. across your body and a current would flow through you. This large electric shock could injure or even kill you.
5) Even if a plug socket is off (i.e. the switch is open) there is still a danger of an electric shock. A current isn't flowing, but there is still a p.d. in the live part of the socket, so your body could provide a link between the supply and the earth if you made contact with it.

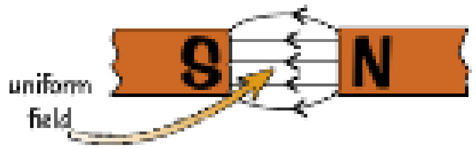
- A metal kettle is plugged into the mains electricity supply(230V,50Hz) Explain why the kettle needs an earth wire and how it works.

CP10a/SP12a Magnets and Magnetic Fields

Magnets **Have** *Magnetic Fields*



1) All magnets have two poles — north and south.
2) A magnetic field is a region where a magnetic material (iron, nickel or cobalt) experiences a force.
3) Magnetic field lines (or "lines of force") are used to show the size and direction of magnetic fields. They always point from NORTH to SOUTH.
4) The closer the field lines are to each other, the stronger the magnetic field at that point.



5) The strength of the magnetic field is called the magnetic flux density and is measured in teslas (T).
6) Placing the north and south poles of two permanent bar magnets near each other creates a uniform field between these two poles.

The Earth's magnetic field has a similar shape to the magnetic field of a bar magnet.

When a piece of magnetic material is in a magnetic fields it becomes a magnet itself, this is called an induced magnet

CP10a/SP12a Magnets and Magnetic Fields Questions

- Magnets are used to separate steel food cans from aluminium cans in recycling plants. Why can magnets be used for this purpose?
- Describe the difference between a permanent magnet and an induced magnet.

CP10b / SP12b Electromagnetism

A Current-Carrying Wire has a Magnetic Effect

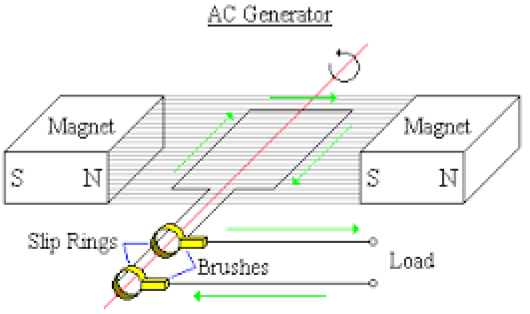
1) An electric current in a material produces a magnetic field around it.
2) The larger the electric current, the stronger the magnetic field.

Induced current

If you move a piece of wire in a magnetic field, an electric current will flow in the wire and this process is called electromagnetic induction and the current produced is called an induced current.

The size of the induced current can be increased by:

- Putting more turns on the coil of wire
- Using an iron core inside the coil of wire
- Using stronger magnets
- Moving the wire faster



The direction of the current can be changed by:

Changing the direction of movement of the wire

Changing the direction of the magnetic field (i.e by swapping the poles of the magnet)

To create a continuous induced current, you must keep the magnet moving relative to the coil of wire.

CP10b / SP12b Electromagnetism Questions

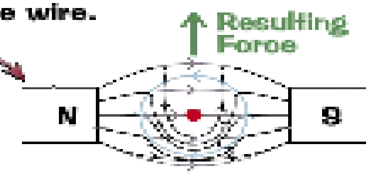
- Define current.
- Define voltage.
- If a wire is moved in a magnetic field what is created inside the wire?
- State 4 ways you can increase the induced current.
- How could you change the direction of current flow?

CP10c / SP12c Magnetic Forces

A Current in a Magnetic Field Experiences a Force

When a current-carrying conductor (e.g. a wire) is put between magnetic poles, the two magnetic fields affect one another. The result is a force on the wire.

This is an aerial view. The red dot represents a wire carrying current "out of the page" (towards you). (If it was a cross (×) then that would mean the current was going into the page.)

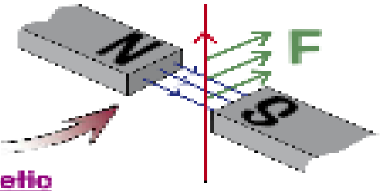


1) To experience the full force, the wire has to be at 90° (right angles) to the magnetic field. If the wire runs along the magnetic field, it won't experience any force at all. At angles in between, it'll feel some force.

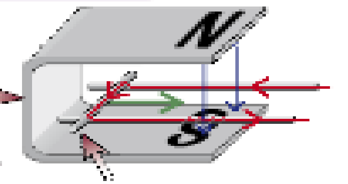
The wire also exerts an equal and opposite force on the magnet, but here we're just looking at the force on the wire.

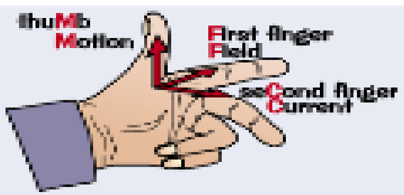
2) The force gets stronger if either the current or the magnetic field is made stronger.

3) The force always acts in the same direction relative to the magnetic field of the magnets and the direction of the current in the wire. So changing the direction of either the magnetic field or the current will change the direction of the force.



4) A good way of showing the direction of the force is to apply a current to a set of rails inside a horseshoe magnet (as shown). A bar is placed on the rails, which completes the circuit. This generates a force that rolls the bar along the rails.





1) Fleming's left-hand rule is used to find the direction of the force on a current-carrying conductor.
2) Using your left hand, point your First finger in the direction of the magnetic Field and your seCond finger in the direction of the Current.
3) Your thuMb will then point in the direction of the force (Motion).

CP10c / SP12c Magnetic Forces

You can Calculate the Force Acting on a Current-Carrying Conductor

The equation used to calculate the force on a current-carrying conductor (e.g. a wire) when it's at right-angles to a magnetic field is:

Force on a conductor carrying a current (N) = magnetic flux density (T) × current (A) × length (m)   or $F = B \times I \times L$

Remember — 'magnetic flux density' is just a fancy term for magnetic field strength.

EXAMPLE: An iron bar of length 0.20 m is connected in a circuit so a current of 15 A flows through it. If an external magnetic field of 0.18 T is placed at right angles to the direction of the current in the bar, calculate the force acting on the iron bar due to the presence of the magnetic field.

Force on the bar = magnetic flux density × current × bar length = 0.18 × 15 × 0.20 = 0.54 N

- State what the thumb, first finger and second finger each represent in Flemings Left Hand Rule.
- Describe 3 factors that affect the force experienced by a current carrying conductor in a magnetic field. Include the effect of each factor in your answer

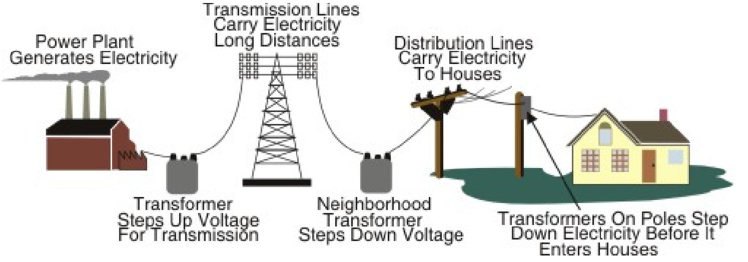
CP11a&b/ SP13b&c Transformers and the National Grid

Electricity is sent from power stations to homes, schools and factories by a system of wires and cables called the National Grid.

The National Grid

1. Power stations produce alternating currents with voltages around 25,000V
2. Before the electricity is sent around the country, step-up transformers are used to increase the voltage to 400,000V. Why?
   - When electricity passes through wires (along transmission lines), energy is lost as heat
   - Increasing the voltage of the electricity passing along transmission lines reduces the current (current = power / voltage) hence less energy is wasted as heat and efficiency is improved.

3. After passing along transmission lines, step-down transformers in local sub-stations reduce the voltage to about 230V for homes and schools – this is necessary for safety reasons



Transformer calculations

Transformers consist of two coils of insulated wire wound onto an iron core and the voltage produced or the number of turns required by a transformer can be calculated by:

$$\frac{\text{Voltage (primary coil)}}{\text{Voltage (secondary coil)}} = \frac{\text{turns (primary coil)}}{\text{turns (secondary coil)}}$$

e.g radio runs off mains supply (230V) but only needs 23V supply. If the transformer has 100 turns of wire on primary coil, how many turns are needed on the secondary coil?

- 230V – voltage (primary coil) and 23V – voltage (secondary coil) =230/23 =10
- 100 turns (primary coil) / 10 turns (secondary coil) =10
- Both sides equal

CP11a&b/ SP13b&c Transformers and the National Grid

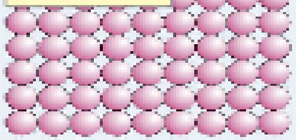
- What is the National grid?
- What is the voltage of the electricity produced by the power stations?
- Why is this voltage increased to 400,000 volts before it is sent around the country?
- What needs to happen to this voltage before it comes into our homes?
- How many turns are needed on a secondary coil if there are 40 on the first and the voltage needs to come down by a factor of 5?

Cp12a / SP14a Particles

- The Particle or Kinetic Theory is a way of explaining matter and depends on the forces between particles

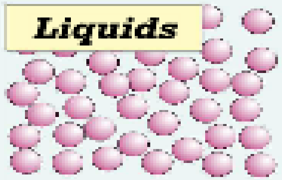
States of Matter **Depend on the** *Forces Between Particles*

Solids



1) There are strong forces of attraction between particles, which hold them in fixed positions in a very regular lattice arrangement.
2) The particles don't move from their positions, so all solids keep a definite shape and volume, and don't flow like liquids.
3) The particles vibrate about their positions — the hotter the solid becomes, the more they vibrate (causing solids to expand slightly when heated).
4) If you heat the solid (give the particles more energy), eventually the solid will melt and become liquid.

Liquids



1) There is some force of attraction between the particles. They're free to move past each other, but they do tend to stick together.
2) Liquids don't keep a definite shape and will flow to fill the bottom of a container. But they do keep the same volume.
3) The particles are constantly moving with random motion. The hotter the liquid gets, the faster they move. This causes liquids to expand slightly when heated.
4) If you cool a liquid, it will freeze and become solid. If you heat a liquid enough, it evaporates (or boils) and becomes a gas.

Gases

1) There's next to no force of attraction between the particles — they're free to move. They travel in straight lines and only interact when they collide.
2) Gases don't keep a definite shape or volume and will always fill any container. When particles bounce off the walls of a container, they exert a pressure on the walls.
3) The particles move constantly with random motion. The hotter the gas gets, the faster they move. Gases either expand when heated, or their pressure increases.
4) If you cool a gas, it will condense and become a liquid.

Particle theory is a great model for explaining the three states of matter, but it isn't perfect. In reality, the particles aren't solid and they aren't spheres — they're atoms, ions or molecules. The model doesn't give you any idea of the size of the particles, or the space between them. Also, the model doesn't show any of the forces between the particles, so there's no way of knowing just how strong they are.

Cp12a / SP14a Particles

- Describe two properties of a) solids

  b) Liquids

  c) Gases

- Explain why a) Liquids and gases can flow but solids can't.

  b) Gases can be compressed but solids and liquids can't.

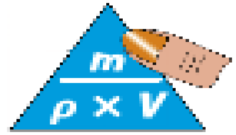
CP12a /SP14a Density

Density is Mass per Unit Volume

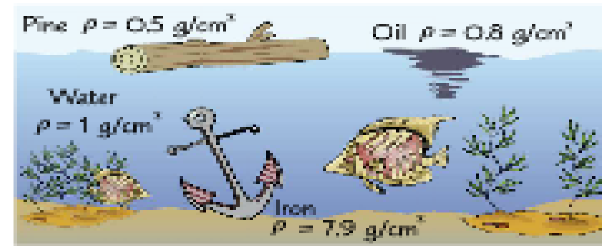
The symbol for density is a Greek letter rho (ρ) — it looks like a p but it isn't.

Density is a measure of the 'compactness' (for want of a better word) of a substance. It relates the mass of a substance to how much space it takes up.

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$



The units of density are g/cm^3 or kg/m^3.



1) The density of an object depends on what it's made of. Density doesn't vary with size or shape.
2) The average density of an object determines whether it floats or sinks — a solid object will float on a fluid if it has a lower average density than the fluid.

You Can Measure the Density of Solids and Liquids

PRACTICAL

1) To measure the density of a substance, measure the mass and volume of a sample of the substance and use the formula above.
2) You can measure the mass of a solid or liquid using a mass balance.
3) To measure the volume of a liquid, you can just pour it into a measuring cylinder.
4) $1\ ml = 1\ cm^3$. If you need to convert a volume into other units, e.g. m^3, remember you need to cube the scaling factor for converting distance units to get the scaling factor for converting volume units. For example, to convert $50\ cm^3$ into m^3, you need to divide by $100^3 = 1\,000\,000$ (as there are 100 cm in 1 m). So $50\ cm^3 = 50 \div 1\,000\,000 = 5 \times 10^{-5}\ m^3$.
5) If you want to measure the volume of a solid cuboid, measure its length, width, and height, then multiply them together. To find the volume of a solid cylinder, measure the diameter of one of the circles at the base, then halve this to give a radius. Then measure the cylinder's height, and use the formula $\text{volume} = \pi \times \text{radius}^2 \times \text{height}$.
6) An object submerged in water will displace a volume of water equal to its own volume. You can use this to find the volume of any object, for example using a eureka (Archimedes) can:

The volume of any prism is the area of its base multiplied by its height.

CP12a /SP14a Density

- Describe an experiment to calculate the density of an irregular solid object .
- An object has a mass of 4.5×10^{-2} kg and a volume of 75cm^3 Calculate its density in kg/m^3

CP12b/SP14b Energy and Changes of State

- Heating a substance increases the energy in its thermal energy store.

In kinetic theory, temperature is a way of measuring the average internal energy of a substance. However, it takes more energy to increase the temperature of some materials than others. E.g. you need 4200 J to warm 1 kg of water by 1 °C, but only 139 J to warm 1 kg of mercury by 1 °C. Materials which need to gain lots of energy to warm up also release loads of energy when they cool down again. They store a lot of energy for a given change in temperature.

The change in the energy stored in a substance when you heat it is related to the change in its temperature by its specific heat capacity. The specific heat capacity of a substance is the change in energy in the substance's thermal store needed to raise the temperature of 1 kg of that substance by 1 °C. E.g. water has a specific heat capacity of 4200 J/kg°C (that's pretty high).

You need to know how to use the equation relating temperature, energy, mass and specific heat capacity:

Change in Thermal Energy (J) = Mass (kg) × Specific Heat Capacity (J/kg°C) × Change in Temperature (°C)

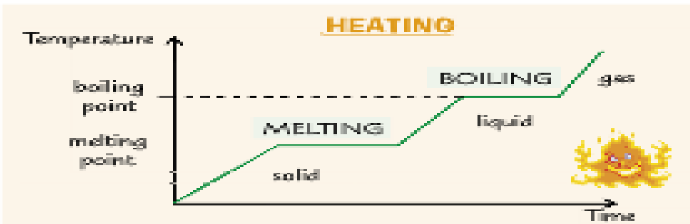
If a metal has a specific heat capacity of 420J/kg° C, calculate how much the temperature of a 0.20kg block of the metal will increase by if 1680J of energy are supplied to it.

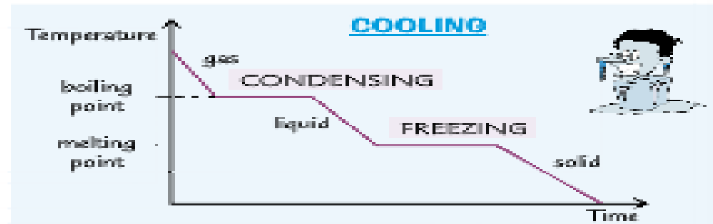
CP12b/SP14b Energy and Changes of State

If you heat up a pan of water on the stove, the water never gets any hotter than 100 °C. You can carry on heating it up, but the temperature won't rise. How come, you say? It's all to do with latent heat...

You Need to Put In Energy to Break Intermolecular Bonds

1) Remember, when you heat a solid or liquid, you're transferring energy to the kinetic energy stores of the particles in the substance, making the particles vibrate or move faster.
2) When a substance is melting or boiling, you're still putting in energy, but the energy's used for breaking intermolecular bonds rather than raising the temperature — there are flat spots on the heating graph.





3) When a substance is condensing or freezing, bonds are forming between particles, which releases energy. This means the temperature doesn't go down until all the substance has turned into a liquid (condensing) or a solid (freezing).

Specific Latent Heat is the Energy Needed to Change State

1) The specific latent heat of a change of state for a substance is the change of energy in its thermal energy store when 1 kg of the substance changes state without changing its temperature (i.e. the substance has got to be at the right temperature already).
2) Specific latent heat is different for different materials, and for different changes of state.
3) The specific latent heat for changing between a solid and a liquid (melting or freezing) is called the specific latent heat of fusion. The specific latent heat for changing between a liquid and a gas (boiling or condensing) is called the specific latent heat of vaporisation.
4) There's a formula to help you with all the calculations. And here it is:

Thermal Energy for a Change in State (J) = Mass (kg) × Specific Latent Heat (J/kg)

Energy / Mass × SLH (this is specific latent heat)

Sketch a graph showing how the temperature of water will change over time as its constantly heated from -5° C to 105°C.

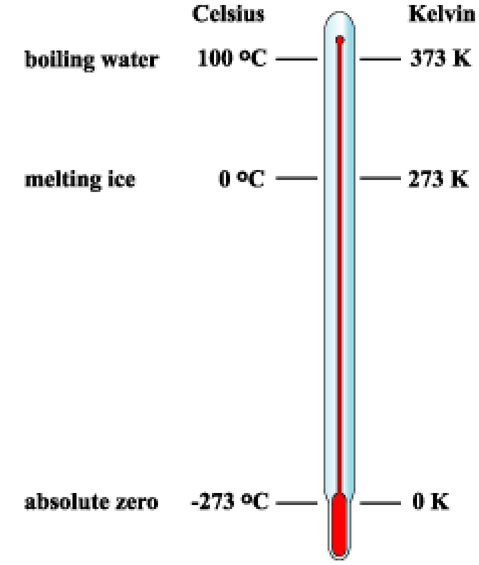
Explain the shape of your graph.

CP12d/Sp14d Gas Temperature and Pressure

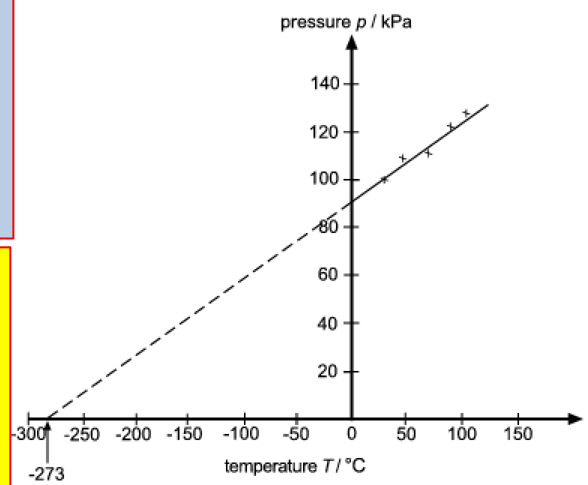
What is Absolute Zero?

Absolute zero = 0K = -273°C

- **Kinetic theory** – states that everything is made up of tiny particles that are atoms or molecules.
- **Kinetic energy** – the energy a particle has due to its movement. Calculated using the equation K.E. = $1/2mv^2$, unit of K.E. is Joules (J).
- **Pressure** – is force per unit area and is measured in Pascals (Pa) where 1 Pa = 1 N/m^2.
- **Absolute zero** – is a temperature of -273°C which is the temperature at which the pressure of a gas would be zero and the particles would NOT be moving.
- **Kelvin temperature scale** – measures the temperatures relative to absolute zero. The units are kelvin (K) and 1K is the same temperature interval as 1°C.



- **A graph to show how the pressure of a fixed volume of gas changes with temperature.**
- **Temperatures are easily converted:**
  - From **K**elvin to **C**elsius – **subtract 273** degrees
  - From **C**elsius to **K**elvin – **add 273** degrees



CP12d/Sp14d Gas Temperature and Pressure Questions

1. What is absolute 0?

2. What is 100^{o} **C**elsius in **K**elvin?

3. How does the pressure of a fixed volume of gas change with temperature?

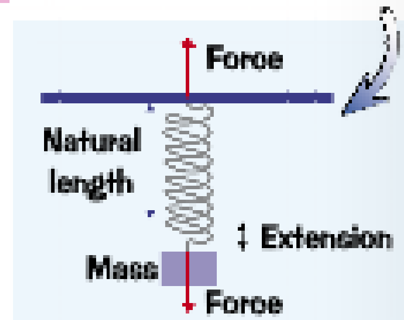
CP13a&b/SP15a&b Bending and Stretching

A Deformation can be Elastic or Plastic

1) When you apply forces to an object it can be stretched, compressed or bent — this is deformation.
2) To deform an object, you need at least two forces. Think of a spring — if you just pull one end of it, and there's no force at the other end, you'll just pull the spring along rather than stretching it.
3) If an object returns to its original shape after the forces are removed, it's an elastic deformation.
4) If the object doesn't return to its original shape when you remove the forces, it's a plastic deformation.

Extension is Directly Proportional to Force for an Elastic Deformation...

1) Imagine you have a vertical spring that is fixed at the top end and has a mass attached to the bottom.
2) When the spring and mass are in equilibrium (i.e. the spring isn't stretching any further), the downwards force on the mass (its weight) is equal in size to the upwards force that the spring exerts on the mass.
3) The extension of a spring (or any object that's deforming elastically) is directly proportional to the force that the spring exerts on the mass (up to a point, see below).
4) How much an elastically deforming object stretches for a given force depends on its spring constant. The spring constant depends on the material that you're stretching — the stiffer the material, the larger the spring constant.



5) The relationship between the extension of a spring and the force is called Hooke's law:

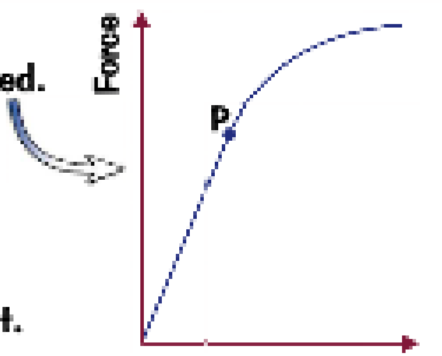
force exerted by a spring (N) = extension (m) × spring constant (N/m) or $F = x \times k$

This equation can be applied to any elastic

CP13a&b/SP15a&b Bending and Stretching

...but this *Stops Working* when the *Force* is *Great Enough*

1) There's a limit to the amount of force you can apply to an object for the extension to keep on increasing proportionally.
2) The graph shows force against extension for an object being stretched.
3) For small forces, force and extension have a linear relationship. So the first part of the graph shows a straight-line (up to point P). This is where Hooke's law (see above) applies to the object.
4) The gradient of the straight line is equal to the spring constant of the object — the larger the spring constant, the steeper the gradient.
5) Beyond point P, the object no longer obeys Hooke's law.



6) Most objects still deform elastically for a little bit after you reach the limit of proportionality. But if you continue to increase the deforming force, you'll reach a point where its elasticity 'runs out' and it starts to deform plastically — the object won't spring back to its original shape after the stretching force has been removed.
7) The maximum force that can be applied to a material before this happens is called its elastic limit. For the graph here it'll be somewhere after point P (P is just where a material stops obeying Hooke's law).
8) For some objects, the elastic limit is so low that you'll never normally see them deforming elastically — you might see these called plastic materials. The relationship between force and extension for these materials is non-linear, so the force-extension graphs of these materials are curved.

energy transferred in stretching = 0.5 × spring constant × (extension)²
(J) (N/m) (m)²