4^{th} Form Physics Notes

4^{th} Form Edexcel PHYSICS IGCSE

Section 1: Forces and motion

Equations to Learn

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

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

$$a = \frac{(v - u)}{t}$$

$$\text{force} = \text{mass} \times \text{acceleration}$$

$$F = m \times a$$

$$\text{weight} = \text{mass} \times \text{gravitational field strength}$$

$$W = m \times g$$

moment = force × perpendicular distance from the pivot

Equations given in the exam

$$\text{orbital speed} = \frac{2 \times \pi \times \text{orbital radius}}{\text{time period}}$$

$$v = \frac{2 \times \pi \times r}{T}$$

Section 2: Electricity

Equations to Learn

$$\text{power} = \text{current} \times \text{voltage}$$

$$P = I \times V$$

$$\text{voltage} = \text{current} \times \text{resistance}$$

$$V = I \times R$$

$$\text{charge} = \text{current} \times \text{time}$$

$$Q = I \times t$$

Equations given in the exam

$$\text{energy transferred} = \text{current} \times \text{voltage} \times \text{time}$$

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

Section 3: Waves

Equations to Learn

$$\text{wave speed} = \text{frequency} \times \text{wavelength}$$

$$v = f \times \lambda$$

$$\text{refractive index,} \quad n = \frac{\sin i}{\sin r}$$

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

Equations given in the exam

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

$$f = \frac{1}{T}$$

Section 4: Energy Resources & Energy Transfer

Equations to Learn

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

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

$$W = F \times d$$

$$\text{gravitational potential energy} = \text{mass} \times g \times \text{height}$$

$$GPE = m \times g \times h$$

$$\text{kinetic energy} = \frac{1}{2} \times \text{mass} \times \text{speed}^2$$

$$KE = \frac{1}{2} \times m \times v^2$$

$$\text{energy transferred} = \text{work done}$$

Equations given in the exam

$$\text{Power} = \frac{\text{Work done}}{\text{time taken}} = \frac{\text{Energy Transferred}}{\text{time taken}}$$

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

Section 5: Solids, liquids and gases

Equations to Learn

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

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

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

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

$$\text{pressure difference} = \text{height} \times \text{density} \times g$$

$$p = h \times \rho \times g$$

Equations given in the exam

Section 6: Magnetism & Electromagnetism

Equations to Learn

Section 7: Radioactivity and particles

No equations in this section

Equations in **bold** are triple award only

Forces, Movement & Shape

Syllabus points:

1.9 describe the effects of forces between bodies such as changes in speed, shape or direction

1.10 identify different types of force such as gravitational or electrostatic

1.11 distinguish between vector and scalar quantities

1.12 understand that force is a vector quantity

1.13 find the resultant force of forces that act along a line

1.14 understand that friction is a force that opposes motion

1.15 know and use the relationship between unbalanced force, mass and acceleration:

force = mass × acceleration, $F = m \times a$

1.16 know and use the relationship between weight, mass and g:

weight = mass × g, $W = m \times g$

1.17 describe the forces acting on falling objects and explain why falling objects reach a terminal velocity

1.18 describe experiments to investigate the forces acting on falling objects, such as sycamore seeds or parachutes

1.19 describe the factors affecting vehicle stopping distance including speed, mass, road condition and reaction time

1.25 know and use the relationship between the moment of a force and its distance from the pivot:

moment = force × perpendicular distance from the pivot

1.26 recall that the weight of a body acts through its centre of gravity

1.27 know and use the principle of moments for a simple system of parallel forces acting in one plane

1.28 understand that the upward forces on a light beam, supported at its ends, vary with the position of a heavy object placed on the beam

1.29 describe experiments to investigate how extension varies with applied force for helical springs, metal wires and rubber bands

1.30 understand that the initial linear region of a force-extension graph is associated with Hooke's law

1.31 describe elastic behaviour as the ability of a material to recover its original shape after the forces causing deformation have been removed.

1.9 describe the effects of forces between bodies such as changes in speed, shape or direction

Forces can affect bodies in different ways. They can:

- increase or decrease the speed of an object so cause an acceleration/deceleration; if a ball is rolling along a table, friction acts in the opposite direction to the motion of the ball and causes the ball to slow down.
- squash or stretch and object which changes its shape; if you hang a weight from an elastic band you are applying a force to it. This causes the elastic band to stretch and its shape to change
- change the direction on object is moving; when you throw a ball in the air its weight is acting downwards and causes it to decelerate. Once it reaches the top of its flight it stops and then changes direction and starts to fall back towards the ground. In this case the force (the object's weight) caused a change in speed and a then a change in direction.

1.10 identify different types of force such as gravitational or electrostatic

Types of forces include:

Applied force;

E.g. a block is pulled with an applied force of 10N to the left.

Frictional Forces;

Friction always acts in the opposite direction to motion.

E.g. our sliding block might have a frictional force of 5N to the right.

Friction causes things to heat up and is often the reason why things stop moving.

Friction can be reduced with lubricants (e.g. oil in an engine) or by a cushion of air (e.g. hovercraft).

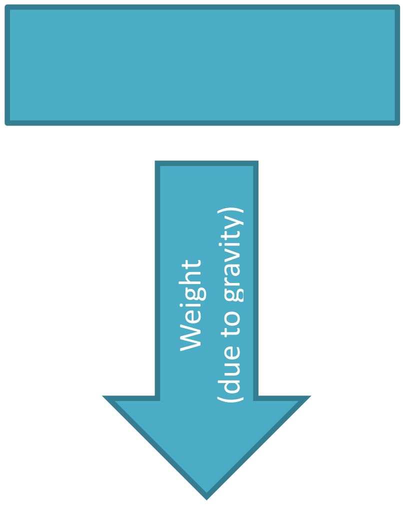
Gravitational Force

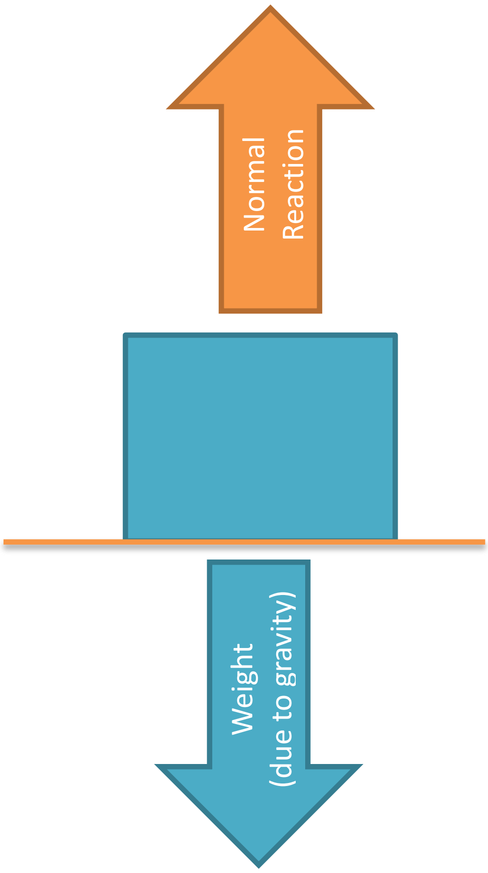
Masses attract other masses.

We are attracted to the Earth as it has a huge mass ($6\text{x}10^{24}$ kg).

The gravitational pull we feel when we are attracted to the large mass of the Earth is called our weight.

Gravitational forces also keep planets in orbits around the Sun and satellites in orbit around planets.

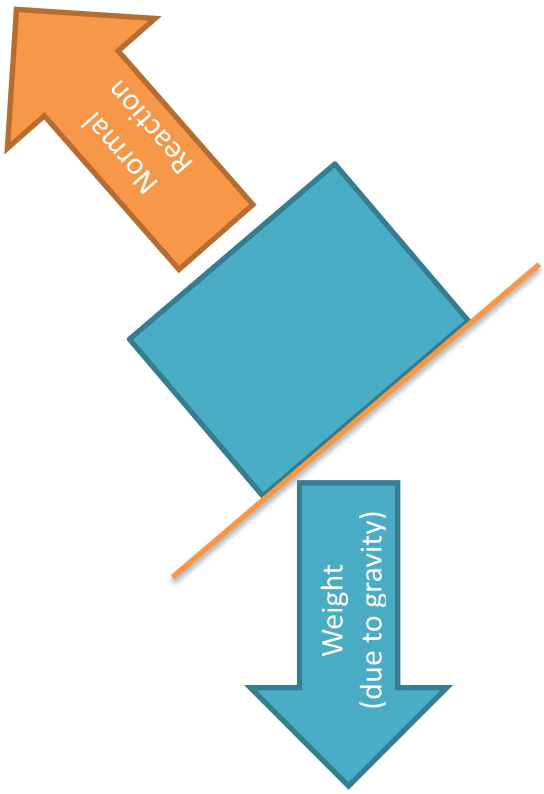




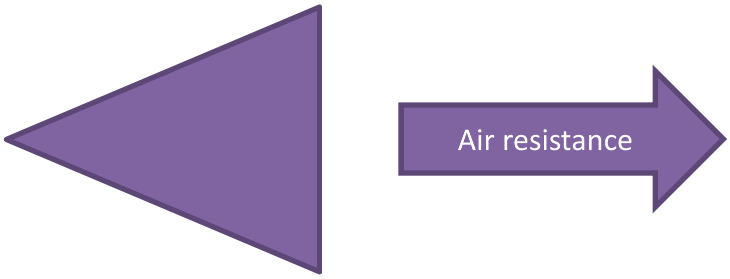
Normal Reaction Force

When an object rests on a solid it feels a reaction force at 90° *to the surface.*

This is equal and opposite to the force of the object pushing on the surface.



Air Resistance (Drag)

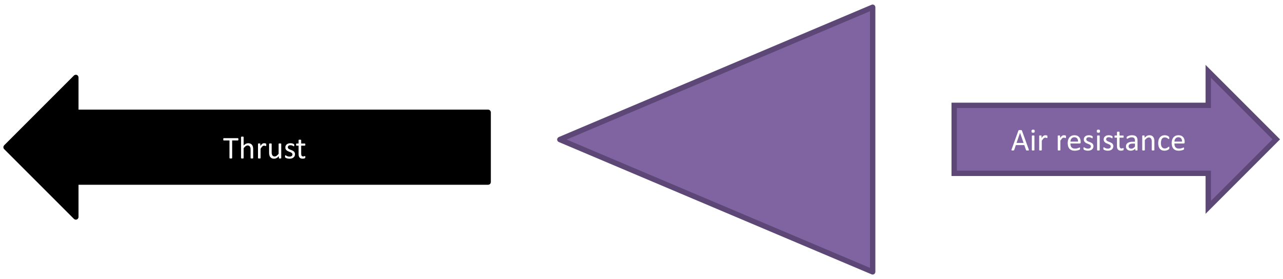


Drag occurs when an object moves through a fluid (called air resistance in air etc.).

Drag is affected by an object's shape, the fluid it travels in and its speed.

Like friction, drag opposes motion.

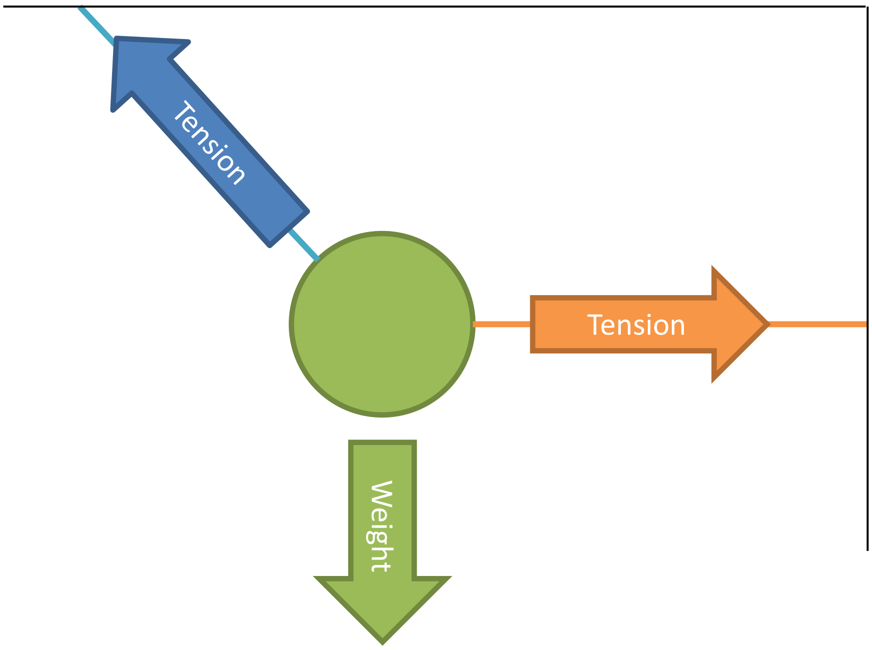
Thrust



Thrust is a reaction force.

It occurs when mass is pushed out the back of something, causing the object to move forwards e.g. rockets, letting go of a balloon and jet engines.

Tension



In the diagram above a ball is being suspended from the ceiling by one rope and stopped from swinging by a second rope.

Tension acts in strings, chains and cables when they are stretched.

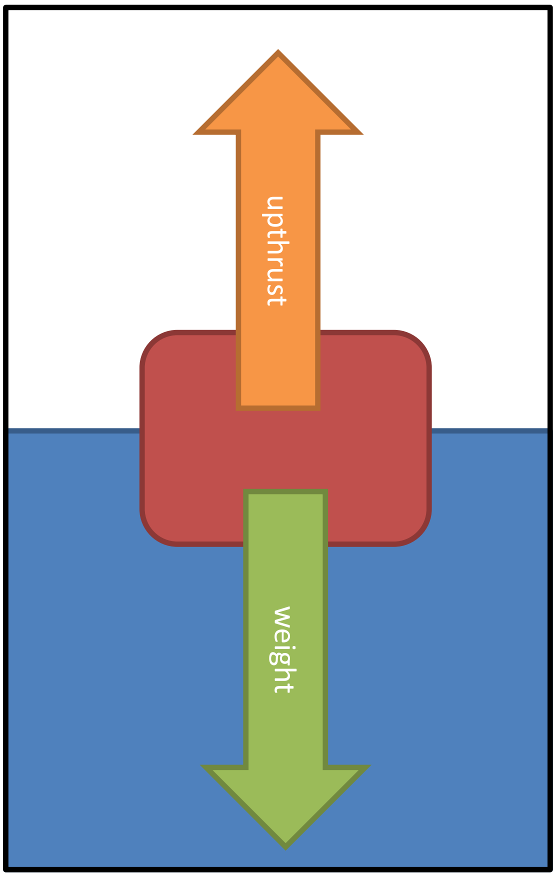
The force always acts parallel to (i.e. along) the string.

The opposite of tension is compression.

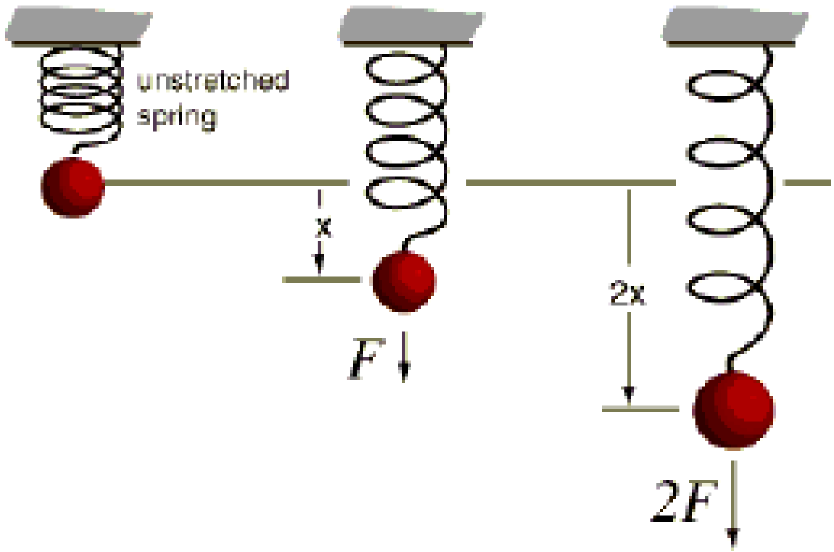
Upthrust

Upthrust can only occur in fluids (gases or liquids) and is the reason things float (also known as buoyancy)

IT IS NOT THE SAME AS NORMAL REACTION FORCE.



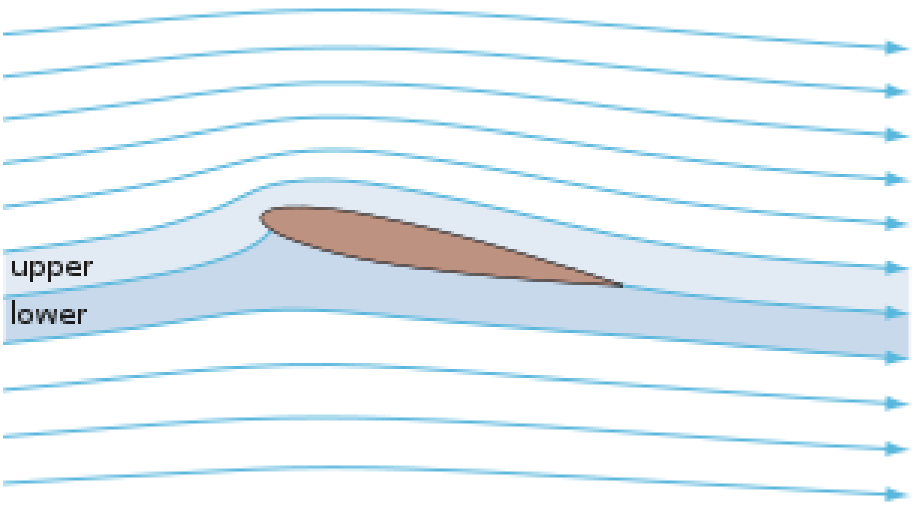
Spring Force



A force is required to stretch or compress a spring.

The extension is directly proportional to the stretching force (Hooke's Law).

Lift

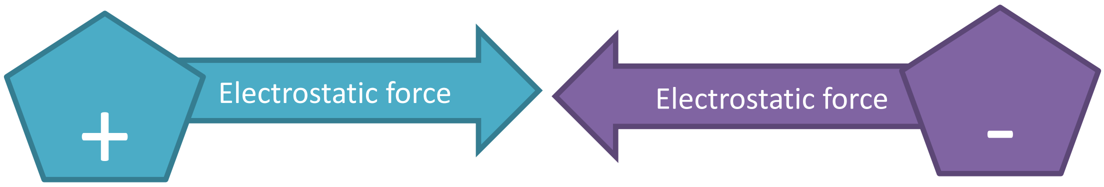


Lift is the force produced due to the flow of a fluid over an aerodynamic surface.

In aircraft it acts against weight (i.e. against the force due to gravity).

On a high-speed F1 car it acts downwards (as the rear wing is upside down) and is known as downforce.

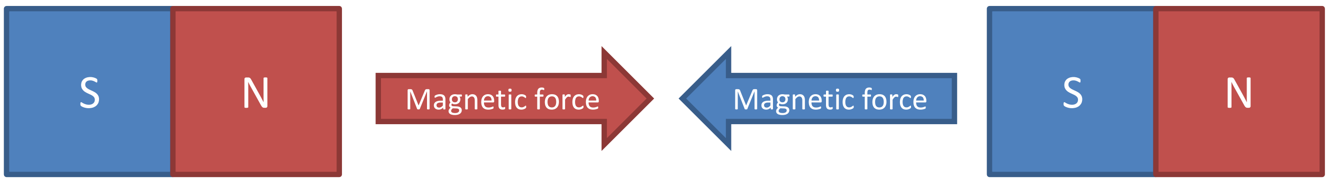
Electrostatic Force



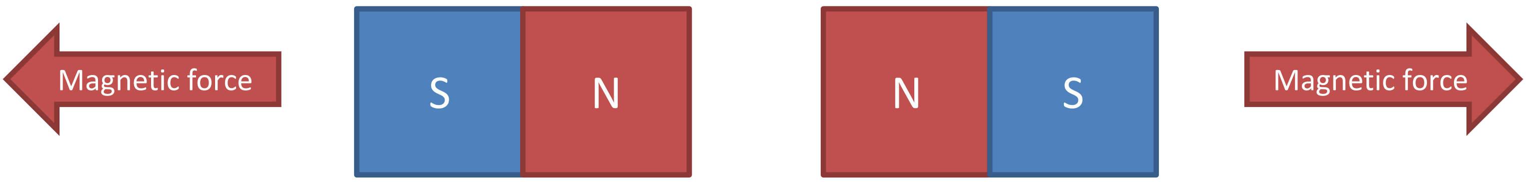
The diagram above shows electrostatic attraction (two opposite charges).

The diagram above shows electrostatic repulsion (two similar charges)

Magnetic Force



The diagram above shows magnetic attraction (two opposite poles).



The diagram above shows magnetic repulsion (two similar poles).

1.11 distinguish between vector and scalar quantities

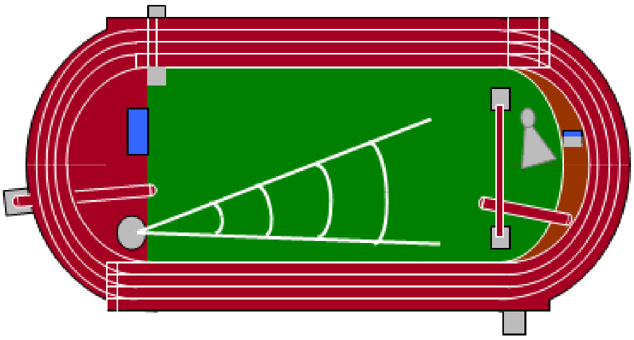
Scalar quantities, such as mass, only have a magnitude (e.g. a carrot has a mass of 1kg).

Vector quantities have a magnitude AND a direction (e.g. I walked 10m north and then 5m east).

Distance (scalar) is a measure of how far an object has travelled. This is used to calculate speed.

Displacement (vector) is a measure of how far and in which direction an object has travelled. This is used to calculate velocity.

Consider a 400m race.



The distance travelled by a runner is 400 m. If they take 60 s then their speed is 400 m/60 s = 6.7 m/s. However, their displacement is zero; this is because they have returned to their starting position. This makes their velocity zero too as 0m/60s = 0m/s.

Speed (scalar) is a measure of how quickly an object is moving.

Speed = distance/time

Velocity (vector) is a measure of how quickly an object is moving *and* in which direction.

Velocity = displacement/time

Both are measured in metres per second (m/s).

Acceleration is another vector.

An object can be travelling at a constant speed but can still be accelerating; if you travel at a constant speed of 10 m/s but in a circle then your direction is continually changing and so too is your velocity. Because your velocity is changing, you are accelerating.

Here is a list of scalar quantities and vector quantities:

Scalar	Vector
Speed	Velocity
Distance	Displacement
Time	Acceleration
Mass	Force
Energy	Momentum
Temperature	Moment
Area	Current
Volume	
Density	
Frequency	
Charge	
Power	
Resistance	
Activity	
Pressure	

It's easy to remember the first two; speed/scalar and velocity/vector based on their first letters. As there are so many scalar quantities, it's easier to remember the 7 vector quantities and remember that the rest are scalar.

Examples which confuse people are:

Temperature; as you can have negative temperatures, people assume temperature is a vector. However, if you work in Kelvin, the lowest temperature is 0 K so there are no negative values.

Charge; as there are positive and negative charges people assume charge is a vector; however, it's just that there are two types of charge (positive and negative), they could have had any other name. They don't have a direction, so they aren't vectors.

Current; while charge doesn't have a direction, current does because it is to do with which direction the charges are moving in.

1.12 understand that force is a vector quantity

Force is on the vector list. Force is a vector quantity.

This should be obvious; when drawing free body force diagrams we use arrows which indicate the direction of the force. We know that weight always acts towards the centre of the Earth so we always draw weight as an arrow pointing downwards.

When describing a force always include a direction; this can be with an arrow or by stating "5 N *to the right*."

1.13 find the resultant force of forces that act along a line

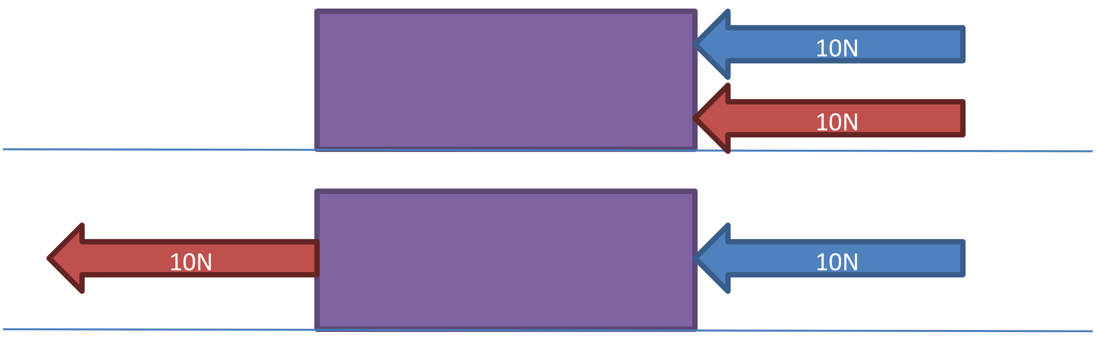
If forces are acting in the same direction then you get a larger total force.

The total or resultant force in this case would be:

If forces are acting in different directions you get a smaller total force.

Here the total or resultant force would be:

Think of it this way; if you want to help someone move a heavy object you either both push in the same direction, or one pushes and the other pulls in the same direction.



Both will give a resultant force of 20 N to the left.

1.14 understand that friction is a force that opposes motion

Friction is a force which always opposes motion. So if an object is moving to the left then friction will be acting to the right. If an object is falling downwards through the air then friction from the air (air resistance/drag) will be acting upwards.

Friction is the reason things come to a stop in everyday life. If you push a ball it will roll for a bit and then stop; this is because there is a resultant force which is causing the ball to decelerate (see 1.15 below)

Similarly to drive at a constant speed, the engine of a car has to produce a driving force equal and opposite to the friction caused by the road on the tyres and by the air on the car's body.

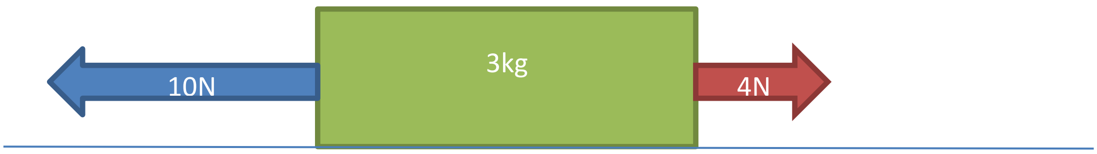
If you know the direction of the frictional force you know that the object is moving in the opposite direction.

Friction is often the reason energy transfers are not 100% efficient, as energy is transferred into thermal energy due by friction.

1.15 know and use the relationship between unbalanced force, mass and acceleration:

resultant force = mass × acceleration, $F = m \times a$

Force is measured in newtons (N). The force in this equation is the resultant/total/unbalanced force. Whatever you call it, you need to take into account all of the forces acting in the direction of movement.



The driving force is 10 N to the left and the frictional force is 4 N to the right. This means the resultant force is 6 N to the left. So the acceleration is 6 N/3 kg = 2 m/s^2 to the left (don't forget, acceleration is a vector).

This equation is often quoted as Newton's Second Law. It tells us that if there is no resultant force acting there will be no acceleration. This means either;

- a stationary object remains stationary
- a moving object will continue to move at the same velocity in a straight line

The second of those often causes confusion. People often assume you need a driving force to keep moving; this Aristotelian view is incorrect. You only need a driving force if there is a frictional force acting. If you throw an object in space where there are no particles in the way it will continue to move in a straight line at a constant speed. When you throw a ball in the air the only force acting on it is the gravitational pull of the Earth. This is why it slows down on the way up, stops, then falls, accelerating downwards.

For a constant mass (i.e. for a given object), the acceleration of it will be directly proportional to the resultant force applied. So if you double the force you double the acceleration.

1.16 know and use the relationship between weight, mass and g:

weight = mass × g, $W = m \times g$

A person's weight is caused by the force of attraction between their mass and the mass of the planet.

Mass is fixed and is determined by the number of, and types of, atoms in an object. It is measured in kilograms (kg).

Weight can change if you go to different parts of the solar system; this is because the gravitational field strength (g) on different planets is different to the gravitational field strength on Earth. On Earth g = 10N/kg. This means each 1 kg of mass has a weight of 10 N. Weight is measured in newtons (N), as it is a force.

Elsewhere things are different; for example, on the moon g = 1.6 N/kg. Here things would feel around 6 times lighter. However, on Jupiter g = 25 N/kg so things would feel 2.5 times heavier.

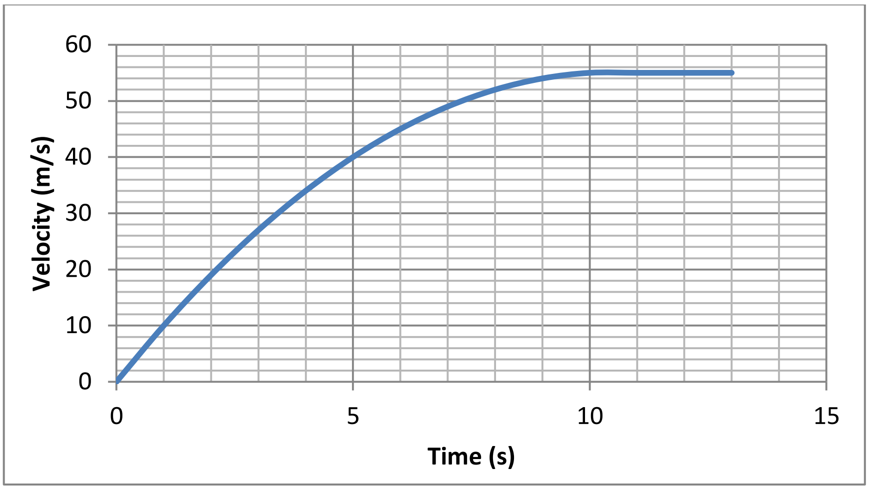
Non-scientists often use the terms mass and weight for the same thing (i.e. people say my weight is 70 kg, whereas they mean their mass is 70 kg). The problem is that we have no verb for finding our mass (you'd generally say that you are weighing yourself and not "massing" yourself).

1.17 describe the forces acting on falling objects and explain why falling objects reach a terminal velocity

- If I drop an object off a building, it starts to accelerate.
- This is because there is a resultant force downwards (as weight is greater than any drag acting).
- As the object accelerates its drag increases .
- Eventually the drag force up will be equal to the weight acting down.
- At this point there is no resultant force acting.
- As there is no resultant force the object does not accelerate and falls with a constant velocity known as terminal velocity.

This question comes up frequently, however, students often waffle and write down anything they can loosely link to falling and forces. Try to avoid this. The sentences above contain the key facts and no waffle.

If you were to sketch a graph to show velocity against time for a falling object you would get the following:



Initially the graph is steep; this is due to the high acceleration when the weight is much larger than the weight leading to a large resultant force downwards.

After a while the gradient reduces; the object is moving faster so more drag is acting, this means the resultant force is become lower so the acceleration is becoming lower.

Eventually the line becomes horizontal; the drag has increased to a point where it is equal to the weight of the object. This means that the resultant force is zero so no further acceleration happens. The object has reached their max speed (i.e. their terminal velocity).

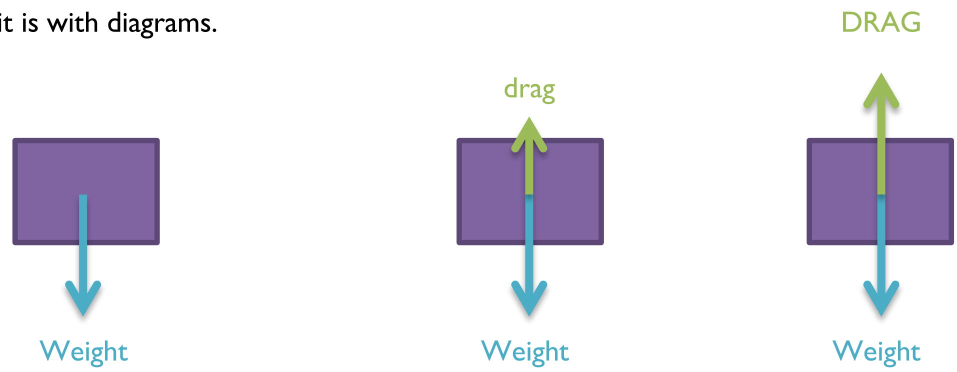
The resultant force at any point is weight minus drag; $F = W - D$
We also know that $F = ma$, this leads to

$$W - D = ma$$

The object accelerates throughout until it reaches its terminal velocity. As the object isn't moving down at t = 0 s the acceleration the object experience is equal to 10 m/s^2 on Earth; this is known as the acceleration due to gravity. As time goes on the acceleration becomes lower and lower until it reaches 0 m/s^2 at terminal velocity.

If there were no air in the way an object would continue to accelerate at 10 m/s^2 until it reached the ground.

Here it is with diagrams.



- No drag, W>>D
- high resultant force,
- high acceleration

- Drag increases, W>D
- resultant force decreases
- acceleration decreases

- Drag = Weight, W=D
- resultant force zero
- acceleration zero

1.18 describe experiments to investigate the forces acting on falling objects, such as sycamore seeds or parachutes

How would you go about investigating the forces acting on a falling object? This could be sycamore seed or a parachute. First we'll find the average speed of the falling object.

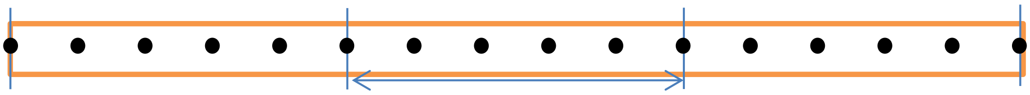
1) Method one;
    - You would measure out the distance between 2 points using a ruler, mark these points with some sort of marker (e.g. a line on the wall).
    - Start the stopwatch when the falling object passes the first marker.
    - Stop the stopwatch when it goes past the second marker.
    - Repeat this a couple of times to ensure that you are collecting consistent data.

    To find the average speed of the falling object you just need to divide the distance between markers by the average time measured on the stopwatch.

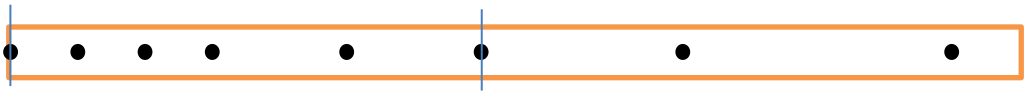
2) The next method uses a motion sensor connected to a datalogger. This uses echolocation similar to a bat.
    - A pulse of sound is created which bounces off the falling object.
    - When this echo returns to the motion sensor it calculates the distance of the object based on the speed of sound and how long it took for the sound to return.
    - The datalogger can use this to get lots of readings for the objects speed which allows you to plot a velocity-time graph for the falling object.

3) The next method is to use a high speed camera and markers in the scene.
    - Measure out a distance and mark with lines on the wall again.
    - Video the falling object moving past the two lines.
    - Watch back the video and look at the time when the falling object goes past the first line.
    - Let the video continue playing and then look at the time when it reaches the second line.
    - Average speed equals the distance measured divided by time taken .

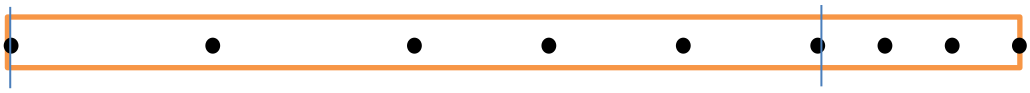
4) The final method is to use a ticker tape timer. This device marks a dot every 0.02 s on a piece of ticker tape (thin piece of paper). The other end of the ticker tape is attached to the falling object. Once the falling object has moved the ticker tape is processed. This involves marking a dot and then moving on 5 more dots; this represents 0.1 s of travel (5 x 0.02 s = 0.1 s). The speed of the everyday object is equal to the length covered by 5 dots divided by 0.1 s.



Above, each section of 5 dots (which represent 0.1s of travel) are the same length; this means the everyday object is travelling at a constant speed. In this example the falling object is moving at 5 cm/0.1 s = 50 cm/s or 0.5 m/s.

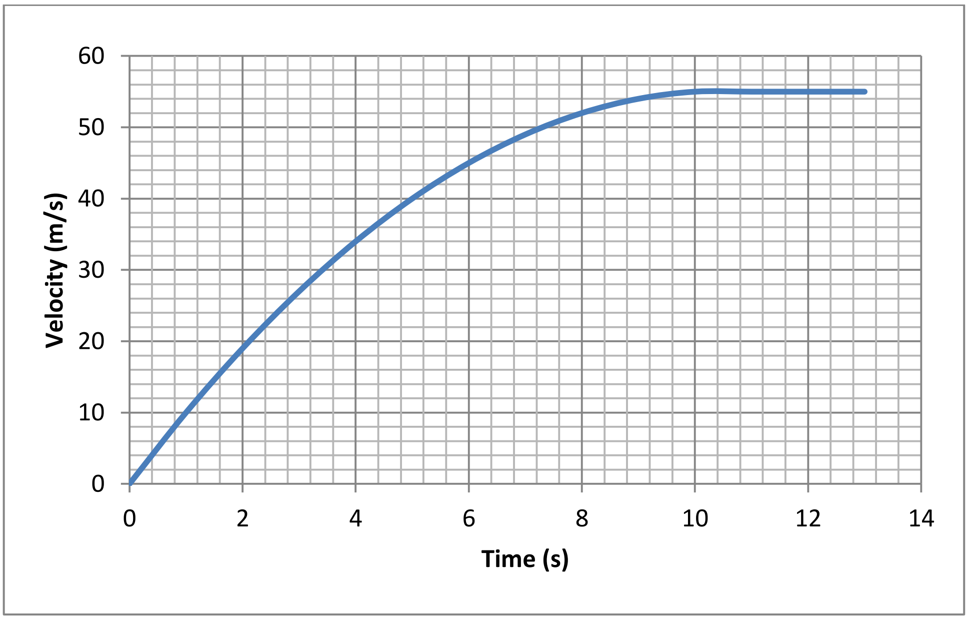


Above, the distance between dots has increased; however, the time between dots is still the same. This means the falling object is moving further in the same amount of time; i.e. it must be accelerating.



Above, the distance between the dots has decreased; however, the time between dots is the same. This means the falling object is moving less far in the same amount of time; i.e. it is decelerating.

Once we have the speed of the object we can work out the forces acting at different times. Plotting the velocity time graph will help.



To find the forces acting you need to know the acceleration at each time. You would find this by calculating the gradient every second (as the line is a curve you should draw a tangent to the line and find the gradient of this). The datalogger may be able to do this for you.

We know from earlier that resultant force = mass × acceleration. We know that the resultant force is equal to weight – drag. If we have the mass of the object we can work out its weight using W=mg.

So $drag = \frac{weight}{mass \times acceleration}$ where the acceleration has been found from the gradient of the velocity-time graph.

Types of experiment might involve changing the surface area of a parachute to see the effect on drag or changing the mass of the object and seeing the effect on terminal velocity. A suitably large drop height would be needed as you would aim to get each object to its terminal velocity.

1.19 describe the factors affecting vehicle stopping distance including speed, mass, road condition and reaction time

Stopping distance is made up of two components:

- **thinking distance**; this depends on the driver and their ability to react to the situation. It is the distance travelled between the danger occurring and the driver pressing the brake.
- **braking distance**; this depends on the vehicle and its braking ability. It is the distance travelled whilst the brakes are being applied.

There are several factors which affect thinking distance including:

- speed; the faster you are travelling the further you travel while reacting to the danger.
- alcohol; if the driver has been drinking their reactions are slower so they travel further before applying the brake (also drugs too).
- distractions; if the driver is trying to drive and text and tune the radio and set the GPS they are not giving the road their full attention, this means they are more likely to not see a danger until it is too late.
- tiredness; if the driver is tired they will react slower and therefore travel further before applying the brakes.

All the factors that affect thinking distance and factors that affect reaction time. The presence of fog or rain does not affect thinking distance.

There are several factors which affect the braking distance including;

- speed; the faster you are travelling the more kinetic energy you need to get rid of so the greater the braking distance.
- mass of car, how heavily loaded the vehicle is; as above, more mass means more kinetic energy to get rid of.
- quality of brakes; newer, higher quality brakes will stop you in a shorter distance than older more tired brakes.
- road surface conditions; if the road is wet then braking distance roughly doubles, if it is icy or snowy then it goes up by around 10 times.

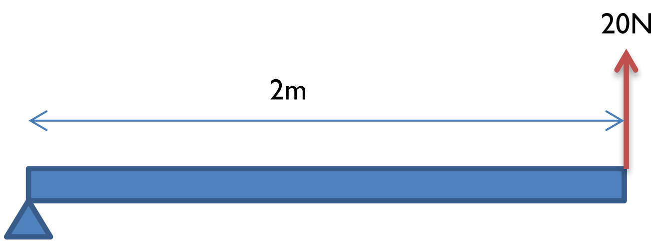
All the factors that affect stopping distance affect the force of friction that acts on the car.

You need to be specific when answering stopping distance questions. Remember thinking = driver and braking = car/road. Stopping is a combination of both. This question is often linked to data, if you are asked how the speed affects distance then be specific; does doubling one result in the other doubling?

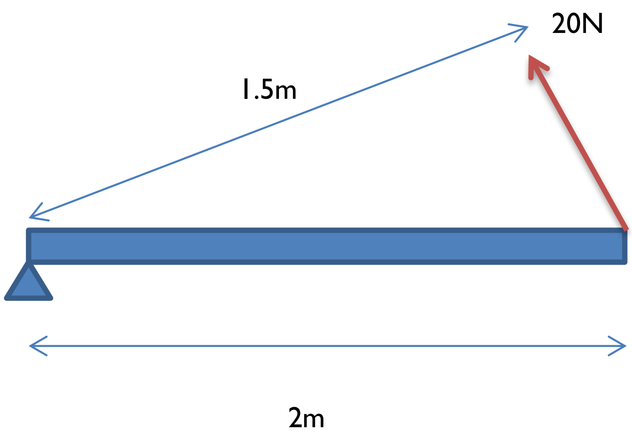
1.25 know and use the relationship between the moment of a force and its distance from the pivot:

moment = force × perpendicular distance from the pivot

A moment is the turning effect of a force. It is measured in newton metres, Nm.



Here the force is 2m from the pivot so the moment = 20N x 2m = 20Nm



Care must be taken when the force is not perpendicular to the beam. Although the force is 2 m from the pivot the force is applied at an angle and the perpendicular distance to the pivot is 1.5 m so the moment now is 20 N x 1.5 m = 30 Nm.

Consider where door handles are placed. The door needs a certain moment to allow it to open. If the handle is a long distance from the pivot (the hinges in this case) then you need to put in minimum force to achieve the necessary moment.

e.g 0.8 m x 15 N = 12 Nm

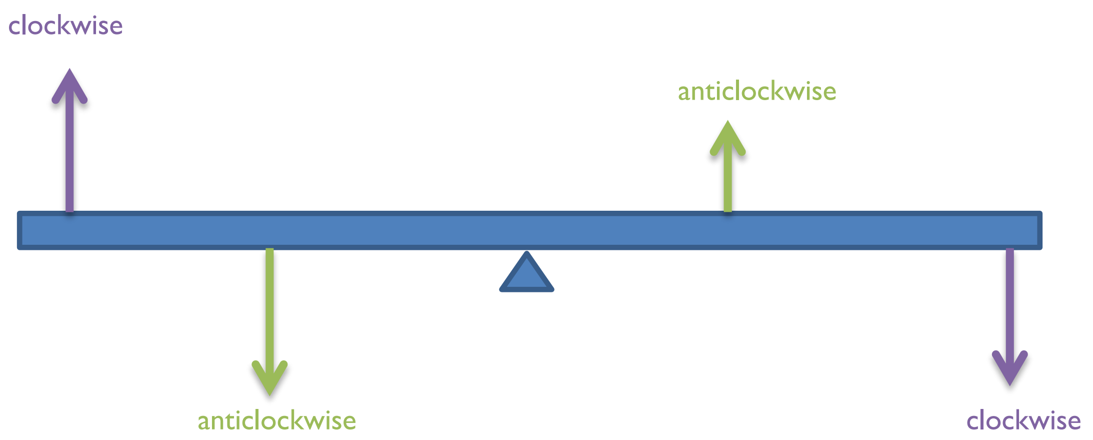
If the door handle is in the middle of the door you will need to put in twice the force to achieve the same moment as before.

12 Nm = F x 0.4 m

F = 12 Nm/0.4 m = 30 N

Often the key in these sorts of questions is that the moment needed to turn something is constant. You can then look at the effect of changing the distance from the pivot or the force.

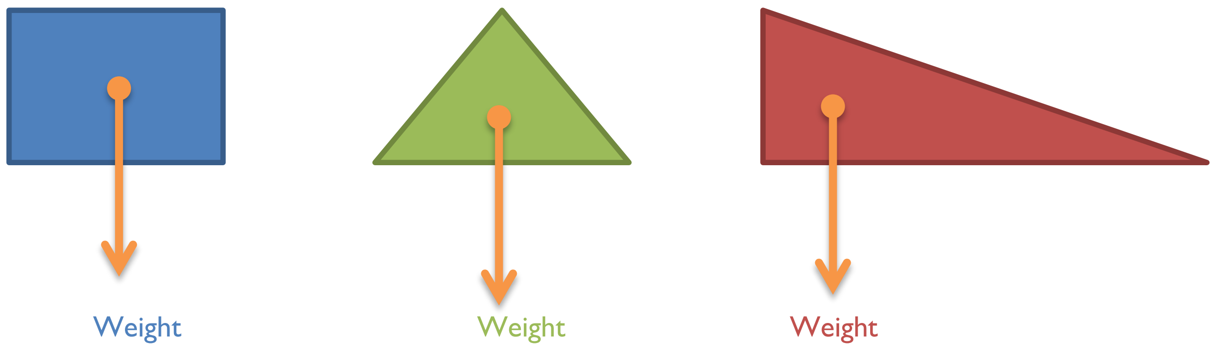
As moments are vectors and refer to the turning effect of a force, you need to consider their direction. Up and down will not do so we use clockwise and anticlockwise to discuss which way that moment would turn the object:



Just think about which way the beam would turn if only the moment you are looking at were acting

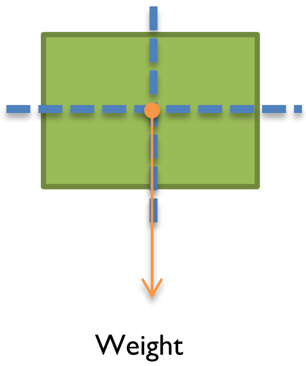
1.26 recall that the weight of a body acts through its centre of gravity

The centre of gravity is the point on an object where all of the weight of the object appears to act. This is where we draw the weight of an object on a diagram:



Putting it anywhere else will mean you will miss out on marks.

The centre of mass for a flat symmetric shape is simply the intersection of the lines of symmetry



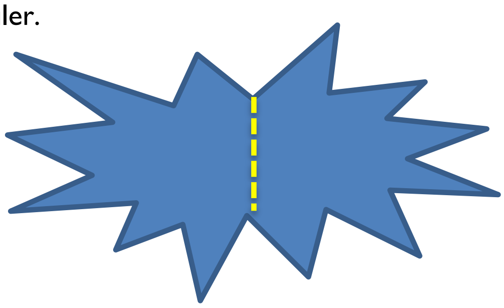
It is possible to balance an object on its centre of gravity; this is because the total clockwise moments are equal to the total anticlockwise moments.

For irregular shapes the centre of gravity needs to be found experimentally.

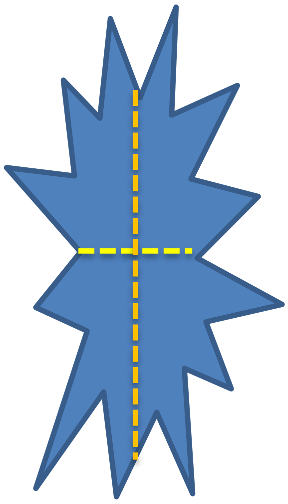
Hang the shape freely from a pin placed in a cork held by a clamp.

Hang a plumbline (weight on a string) from the pin; this will give you a vertical line.

Mark on the shape where the plumbline hangs; mark a couple of places and then connect with a ruler.



Then hang the shape from another point and repeat.



The centre of gravity is where these lines cross.

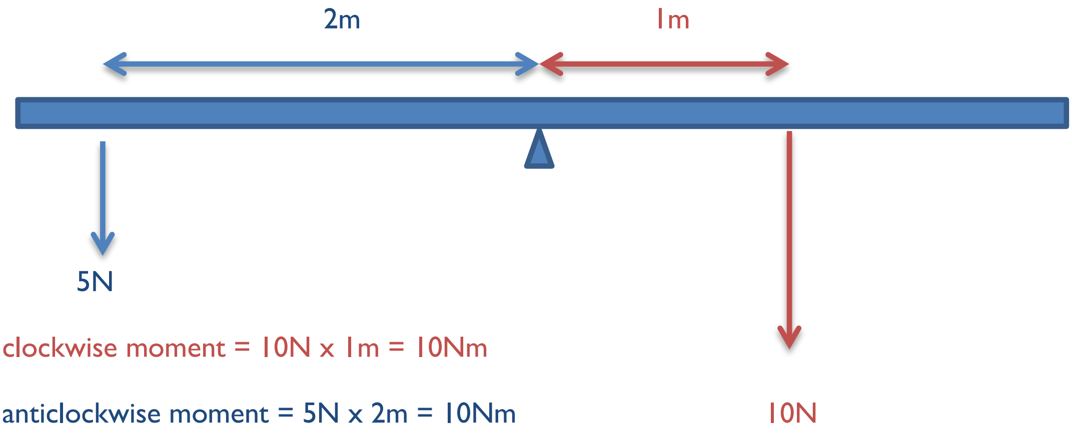
The centre of gravity does not always fall on the object for example the centre of gravity of a hulahoop is in the middle of the hole. The centre of gravity for an 'L' shape is just off from the inside corner.

Objects which have a low centre of gravity and a wide base are stable; this means they are hard to push over as they fall back into their stable position.

1.27 know and use the principle of moments for a simple system of parallel forces acting in one plane

The principle of moments states "a system is in equilibrium when the sum of the clockwise moments is equal to the sum of the anticlockwise moments."

A system in equilibrium is balanced. In addition to the moments being equal the total forces acting upwards are equal to the total forces acting downward; i.e. there is no net force.

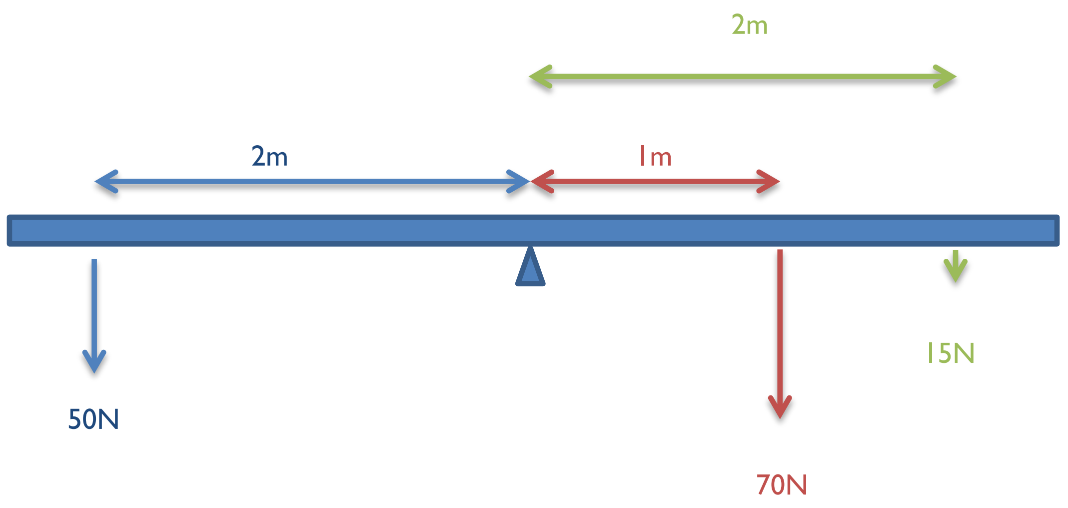


total clockwise moment = 10N x 1m = 10Nm

total anticlockwise moment = 5N x 2m = 10Nm

So the system is balanced. In addition we know the force on the pivot = 15N as this is the total downward force.

The same is true for more complex situations:



Total clockwise moment = 50 N x 2 m = 100 Nm

Total anticlockwise moment = 70 N x 1 m + 15 N x 2 m = 70 Nm + 30 Nm = 100 Nm

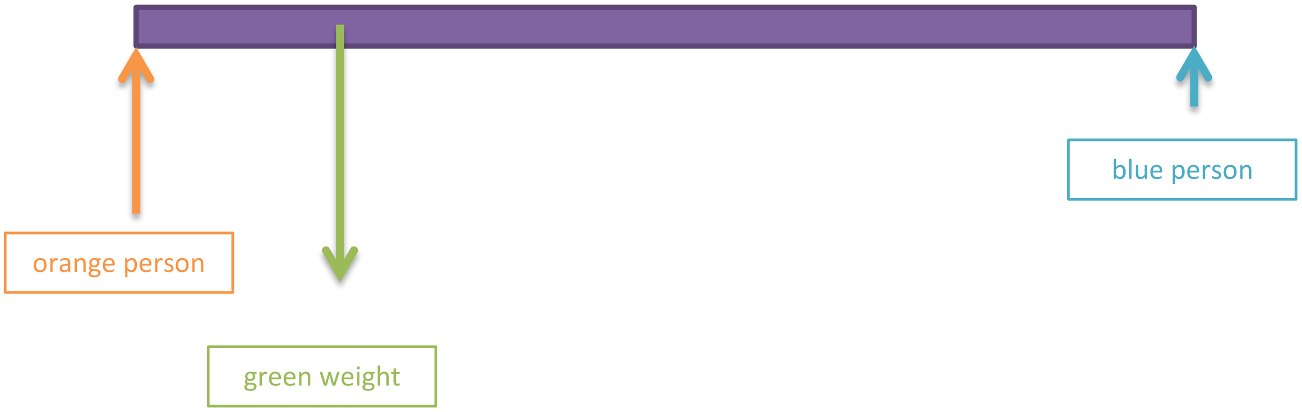
Again the system is balanced and this time the force on the pivot is 135 N

The key to solving moments problems is:

1) Find any moments you have enough information to find.
2) If you know the clockwise moment = 75 Nm then the anticlockwise moment must = 75 Nm. This is because of the principle of moments (it's sometimes worth a mark to mention this)
3) Rearrange to find you missing moment.

You can test this out with the example above. Assume you don't know the 15N force. Make sure you are able to find it.

1.28 understand that the upward forces on a light beam, supported at its ends, vary with the position of a heavy object placed on the beam



The beam is light; this means we can ignore its weight. Sometimes it is a bridge.

The diagram above represents 2 people carrying a long beam with a green weight closer to the orange person. Assume the beam is 2 m long and the weight is 0.5 m from the orange person.

If we take moments about the green weight, (this means we assume it to be the pivot) for the system to be balanced the moment due to the orange person must be the same as the moment due to the blue person.

If the orange person exerts a force of 60 N then his moment from the green weight is 60 N x 0.5 m = 30 Nm

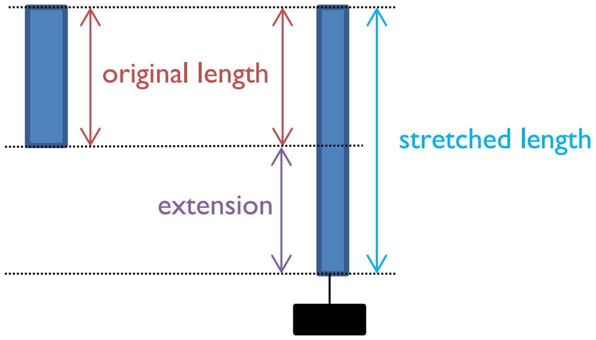
As the system is balanced the blue person must also produce a moment of 30 Nm. This means the force they exert is equal to 30 Nm/1.5 m = 20 N

So by being 3 times further away from the green weight, the blue person has to exert 3 times less force than the orange person to achieve the same moment and to keep the system balanced.

Finally, we know the weight of the green weight is equal to the total upward forces of the two people so = 80 N

1.29 describe experiments to investigate how extension varies with applied force for helical springs, metal wires and rubber bands

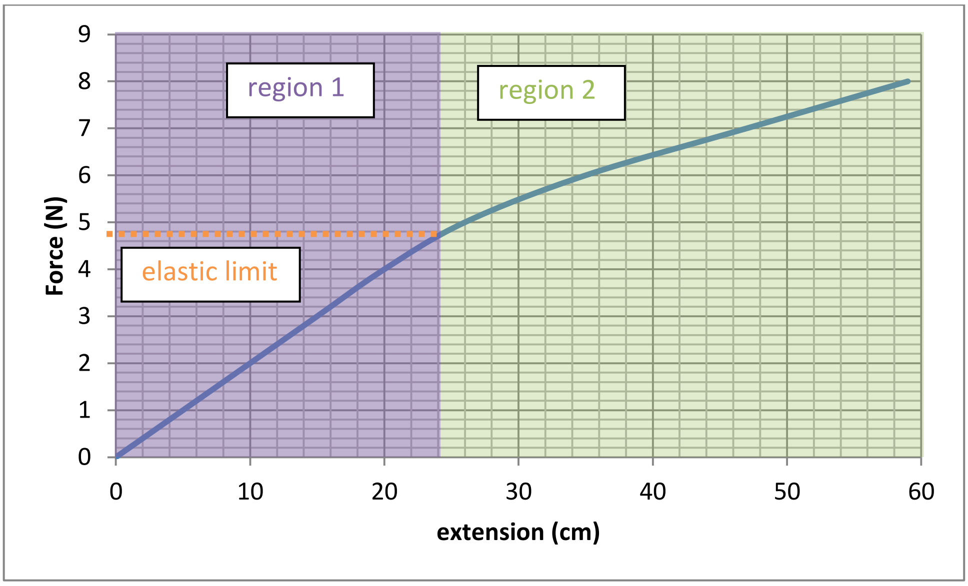
When force is applied to a spring, a wire or a rubber band they extend.



stretched length = original length + extension

extension = stretched length – original length

To investigate this experimentally the object which is being stretched is clamped in place and its original length measured (i.e. with no weights attached). Next weights are added and the new stretched length measured. These length measurements should be taken at eye level to improve accuracy. Another way to improve accuracy is to clamp the ruler vertically and attach a pointer to the bottom of the object. As with most experiments, it is useful to repeat and take an average of the readings. Once sufficient weights have been added (usually six good data points are sufficient) the extension is calculated and a graph of weight against extension can be plotted.



This graph is one of the few where the thing we control, the independent variable, goes on the y-axis. You could be asked to plot this graph either way round, but typically we plot force (*y*-axis) against extension (*x*-axis). The graph is split into two distinct regions;

- In region one the graph is a straight line through the origin.
- In region two the graph curves.

1.30 understand that the initial linear region of a force-extension graph is associated with Hooke's law

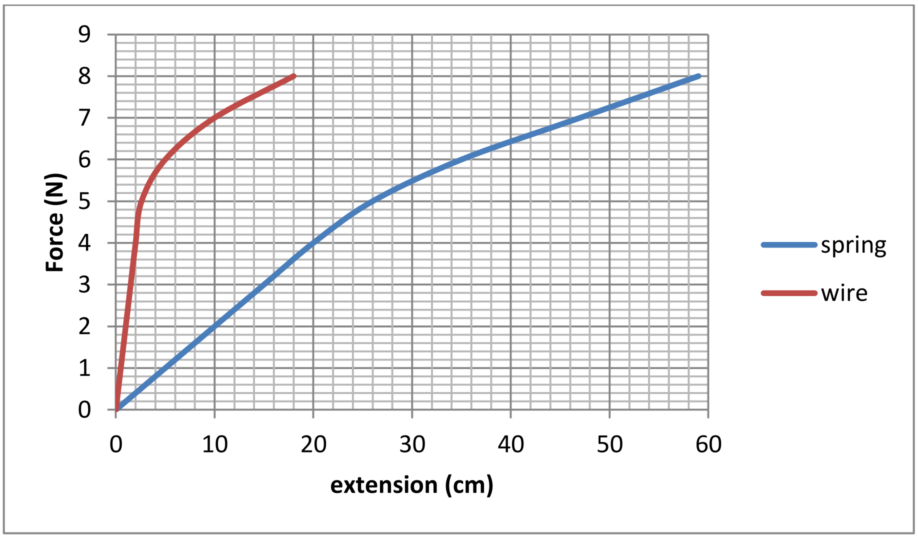
Hooke's Law states that force is directly proportional to extension; this means that if you double the force applied you will double the extension. This only applies up to the elastic limit; past this point force stops being directly proportional to extension. In the example above the elastic limit is 4.8 N

The first part of the graph is a straight line through the origin. Whenever a graph is a straight line through the origin it shows that the two variables are directly proportional.

So the initial linear region of the force-extension graph is where the spring is obeying Hooke's Law.

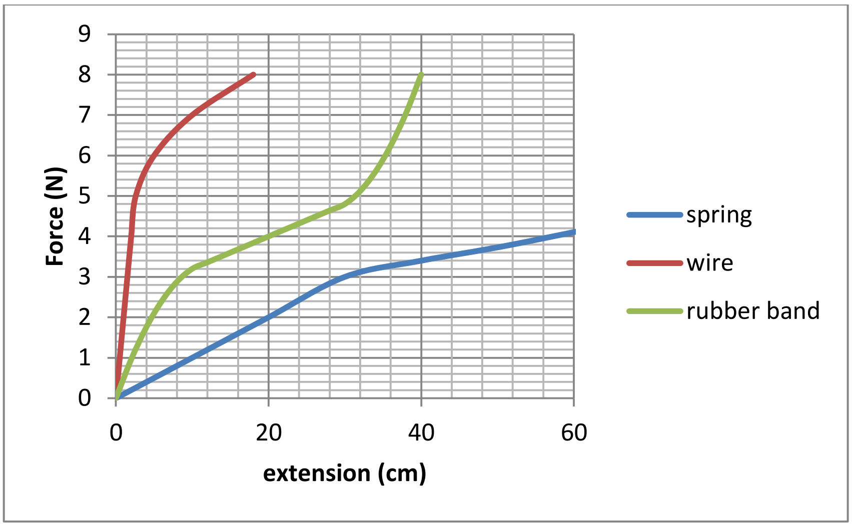
In the second part of the graph, the spring has gone past its elastic limit and no longer obeys Hooke's Law. It has been permanently deformed and when the force is removed it will not return to its original length.

Hooke's Law applies to metal springs and wires. The only difference is that wires generally require more force to stretch than springs.



Both wires and springs have elastic limits. Both obey Hooke's initially before going past their elastic limit.

The structure of the rubber is such that it is stiff initially, then easy to stretch, then very stiff. Hooke's Law does not apply to rubber bands as the graph does not show directly proportionality at any point.



A steep gradient means the object requires a large amount of force to extend it a given amount. Or it doesn't extend far with a given force. These materials are said to be stiff.

A shallow gradient means the object requires a small amount of force to extend it a given amount. Or it extends a long way with a given force.

1.31 describe elastic behaviour as the ability of a material to recover its original shape after the forces causing deformation have been removed.

There are two broad types of extension

- Elastic extension is where you apply a force to a material and then when you remove the force the object returns to its original length. Elastic bands are good examples of this; you can stretch them, then let go and they return to their original shape. In addition wires and springs show elastic behaviour up to a certain point (the elastic limit). You can stretch a spring to below its elastic limit and then when you remove the load it will be back to its original length.
- Plastic extension or non-elastic extension is where you apply a force to a material and then when you remove the object does not return to its original length. This means the material has been permanently deformed. Plastic bags are good examples of this; if you put too much in a plastic bag the handles deform and do not return to their original shape after you empty out the load. Wires and springs deform in this way if you take them past their elastic limit.

As the syllabus point above states; elastic materials return to their original shape after the stretching force has been removed.

Astronomy

Syllabus points:

1.32 understand gravitational field strength, g, and recall that it is different on other planets and the moon from that on the Earth

1.33 explain that gravitational force:

- causes moons to orbit planets
- causes the planets to orbit the sun
- causes artificial satellites to orbit the Earth
- causes comets to orbit the sun

1.34 describe the differences in the orbits of comets, moons and planets

1.35 use the relationship between orbital speed, orbital radius and time period:

1.36 understand that:

- the universe is a large collection of billions of galaxies
- a galaxy is a large collection of billions of stars
- our solar system is in the Milky Way galaxy.

Syllabus points:

1.32 understand gravitational field strength, g, and recall that it is different on other planets and the moon from that on the Earth

Gravitational field strength, *g*, represents how strong the gravitational field is in a given area. The gravitational field around a planet depends on its size, its mass and how far away you are from the centre of the planet. The units are newtons per kilogram i.e. how much force each kilogram in that field would feel.

On Earth's surface, g = 10 N/kg. This means that each kilogram of mass experiences 10 N of force.

Recall from an earlier section, $W=mg$, so a 70 kg person is 70 kg x 10 N/kg = 700 N.

On other planets or moons g is different. This is because they have different sizes and masses. On the moon, g = 1.6 N/kg; this means objects on the moon feel approximately 6 times lighter. Whereas on Jupiter, g = 25 N/kg so things would feel 2.5 times heavier. In both cases the object's weight changes but its mass stays the same.

1.33 explain that gravitational force:

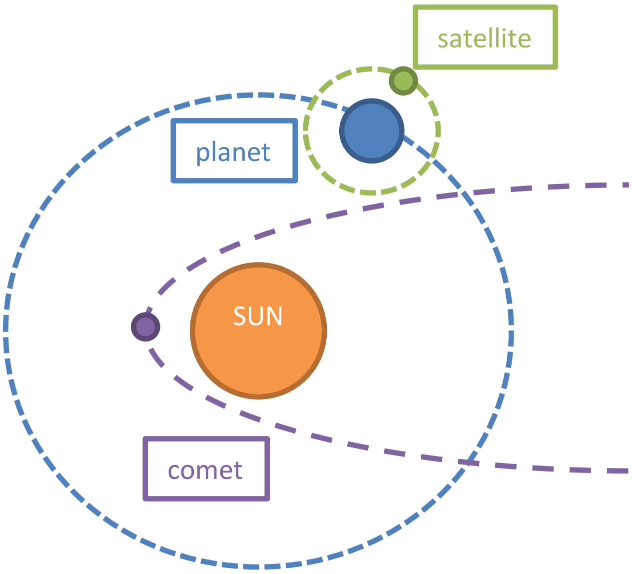
- causes moons to orbit planets
- causes the planets to orbit the sun
- causes artificial satellites to orbit the Earth
- causes comets to orbit the sun

Gravitational force is quite weak and so only becomes important when dealing with very large masses such as stars, planets or moons. Gravitational force is always attractive. All masses attract other masses; however, unless one of the masses is very massive the force is tiny.

One way to think about orbits is to consider a mass on the end of a string. If you rotate the string fast enough the mass can orbit in a horizontal circle. The tension in the string is acting towards the centre of the circle and is causing the mass to move in a circular path. However, if the string is cut, the object continues to move off in a straight line.

Without the gravitational pull of the Sun, our planet would be adrift in the Universe.

1.34 describe the differences in the orbits of comets, moons and planets



Above are the orbit shapes for:

- planets; these orbit stars in approximately circular orbits. We orbit the sun which is our local star.r
- satellites; these can be natural (e.g. moons) or man-made (e.g. weather satellites). Different satellites have different orbit periods, radii and shape.
- comets; these have very elliptical orbits (squashed circles). They whip around the sun before flying off into deep space.

In all of these cases it is gravitational force which keeps the objects in orbit.

1.35 use the relationship between orbital speed, orbital radius and time period:

$$orbital\ speed = \frac{2\pi \times orbital\ radius}{time\ period}$$

$$v = \frac{2\pi r}{T}$$

The orbital velocity equation is just a specific version of $speed = \frac{distance}{time}$.

As the orbit is a circle the distance travelled in one orbit is equal to the circumference of a circle which is equal to $2\pi r$

The time period is the time taken for on object to complete one orbit.

For example, Earth orbits the sun at an orbital radius of 1.5×10^{11} m and takes 365 days to complete an orbit.

$$orbital\ speed = \frac{2\pi \times 1.5 \times 10^{11}}{365 \times 24 \times 60 \times 60} = 29\ 900 m/s$$

1.36 understand that:

- the universe is a large collection of billions of galaxies
- a galaxy is a large collection of billions of stars
- our solar system is in the Milky Way galaxy.

The Universe includes everything that exists.

Our planet is a tiny, tiny part of the universe.

While our Solar System appears vast to us, our Sun is just one medium-sized and relatively cool star among billions in our galaxy.

Our galaxy is called the Milky Way.

To make us feel even more tiny, our galaxy, the Milky Way, is only one of billions of galaxies in the Universe.

Energy and Potential Difference in Circuits

Syllabus points:

2.8 explain why a series or parallel circuit is more appropriate for particular applications, including domestic lighting

2.9 understand that the current in a series circuit depends on the applied voltage and the number and nature of other components

2.10 describe how current varies with voltage in wires, resistors, metal filament lamps and diodes, and how this can be investigated experimentally

2.11 describe the qualitative effect of changing resistance on the current in a circuit

2.12 describe the qualitative variation of resistance of LDRs with illumination and of thermistors with temperature

2.13 know that lamps and LEDs can be used to indicate the presence of a current in a circuit

2.14 know and use the relationship between voltage, current and resistance:

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

2.15 understand that current is the rate of flow of charge

2.16 know and use the relationship between charge, current and time:

$$I = \frac{Q}{t}$$

2.17 know that electric current in solid metallic conductors is a flow of negatively charged electrons

2.18 understand that:

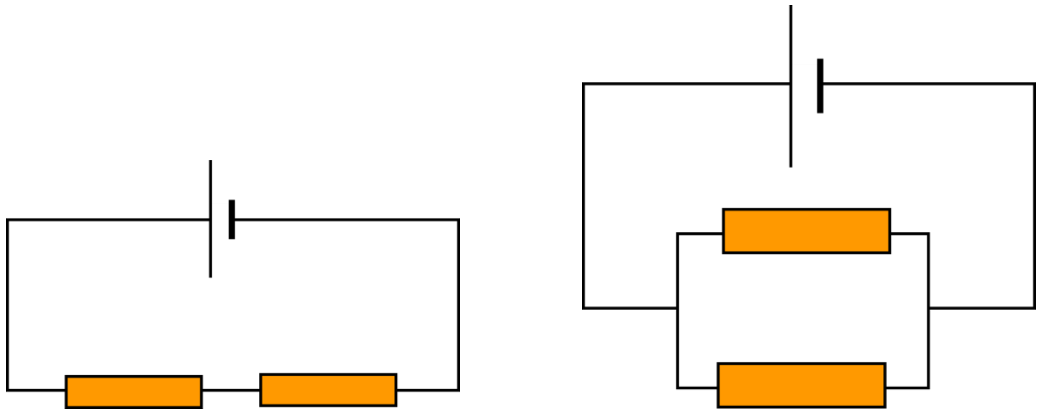
voltage is the energy transferred per unit charge passed

the volt is a joule per coulomb

Syllabus points:

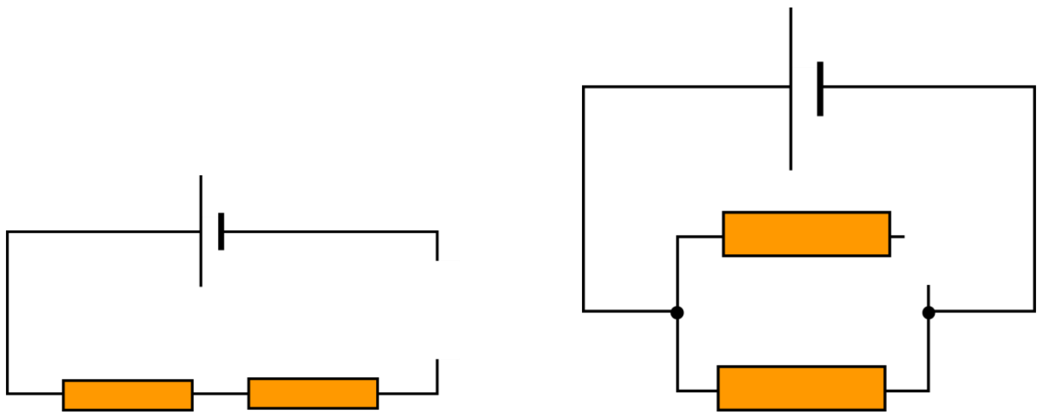
2.8 explain why a series or parallel circuit is more appropriate for particular applications, including domestic lighting

In a series circuit all of the circuit's components are connected to each other on a single branch. In a parallel circuit each component is on its own branch of the circuit.



Series on left, parallel on right.

In a series circuit, if one component fails then the circuit is broken and none of the other components can function. In a parallel circuit if one component breaks then only the branch of the circuit containing that component is broken and the rest of the components can continue to function as normal.



In the series circuit on the left neither resistor receives current.
In the parallel circuit on the right the bottom resistor will still receive current.

Speaking generally, you do not want an entire circuit to fail just because one of the components does. If the lightbulbs in a home were wired in series then when one bulb went out, all the other bulbs would go out and it would be difficult to work out which was the faulty one. When a new component is added to a series circuit all the components in the circuit must share the voltage from the power supply, and therefore they receive less power – if you add a new bulb to a collection of bulbs wired in series then all the bulbs become a bit dimmer.

Although series circuits are easier to construct, components are usually wired in parallel as it allows each component to receive the full supply voltage and to be independently controlled.

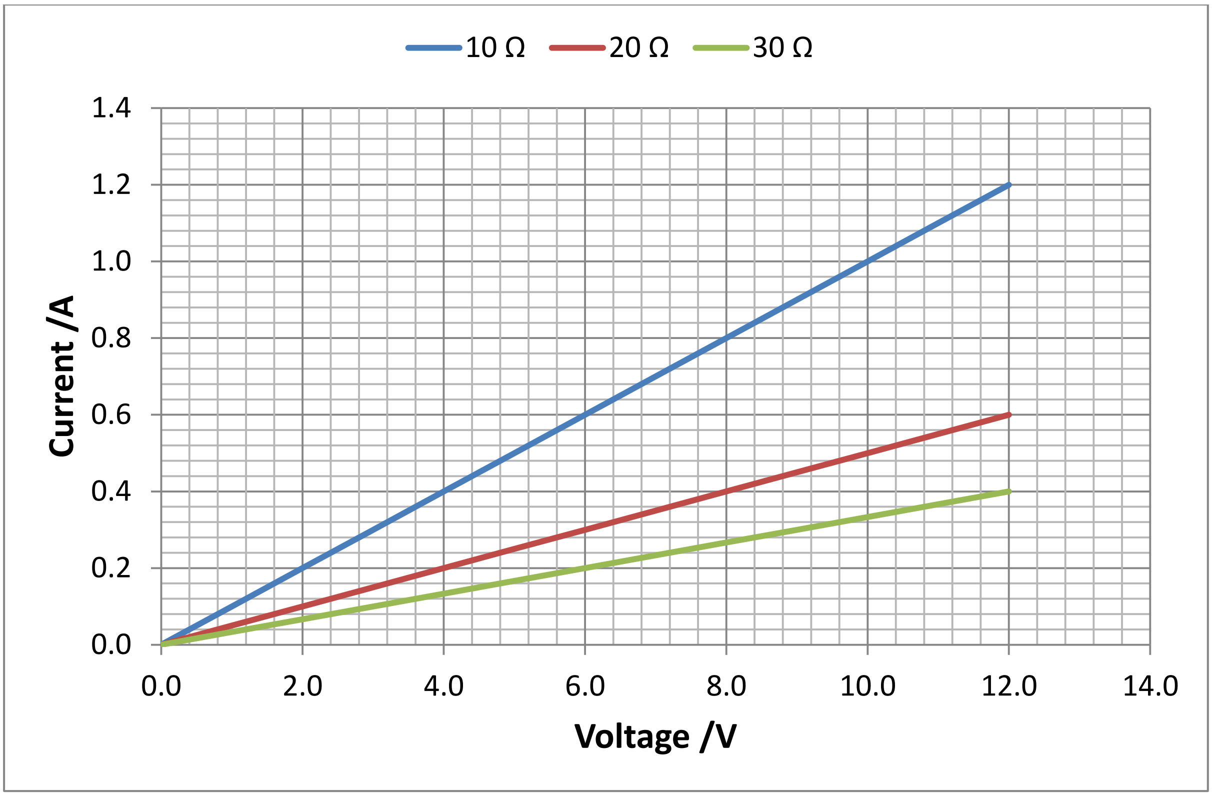
2.9 understand that the current in a series circuit depends on the applied voltage and the number and nature of other components

The current in a circuit is the rate of flow of charge around that circuit – it is measured in coulombs per second (also known as ampères or amps). The charge on an electron is very small so one coulomb per second (one amp) is about 6.25 million million million electrons per second.

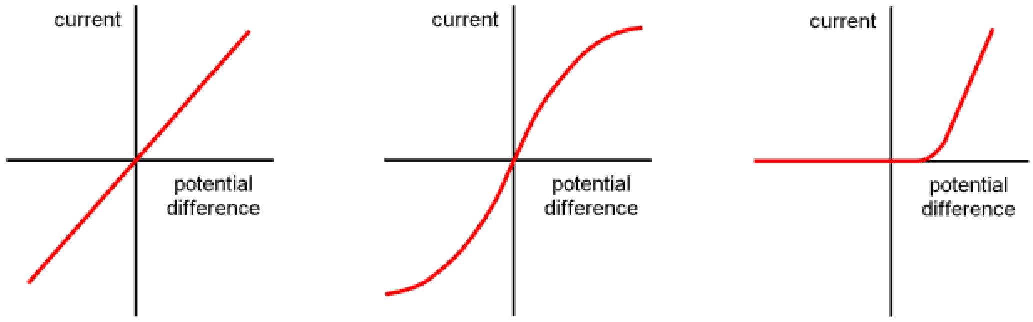
The voltage is what pushes electrons around a circuit. If the voltage increases the electrons are pushed harder and they therefore flow faster. If everything about a circuit stays the same whilst the voltage doubles then the current will also double; if the voltage halves then the current will also halve. Adding more cells increases the voltage, which will also increase the current.

Resistance opposes the flow of current. As resistance increases whilst everything else about the circuit stays the same (i.e. the voltage is constant) then the current will decrease. If more components are added to series circuit the total resistance increases and the current decreases.

If two identical bulbs are connected in series with a 6V battery each will have 3V across them. If a third identical bulb is added then each bulb now has only 2V across it.



2.10 describe how current varies with voltage in wires, resistors, metal filament lamps and diodes, and how this can be investigated experimentally



The resistance of a wire does not change with its temperature. The current that passes through it is therefore directly proportional to the voltage across it. This means that if the voltage is doubled then the current doubles too.

The shape of an I-V graph for a filament bulb is caused by the fact that the resistance of the bulb increases as it heats up. As more voltage flows through the filament it heats up and its resistance increases. Because its resistance increases the current that is able to flow through it drops and the curve flattens out.

A diode only allows current to flow through it in one direction. It does this by having a very high resistance in one direction and a very low resistance in the other direction. When resistance is high (when current is flowing in the “wrong” direction) the line is flat – indicating the high resistance. When resistance is low (when current is flowing in the “right” direction) the line is very steep – indicating the low resistance.

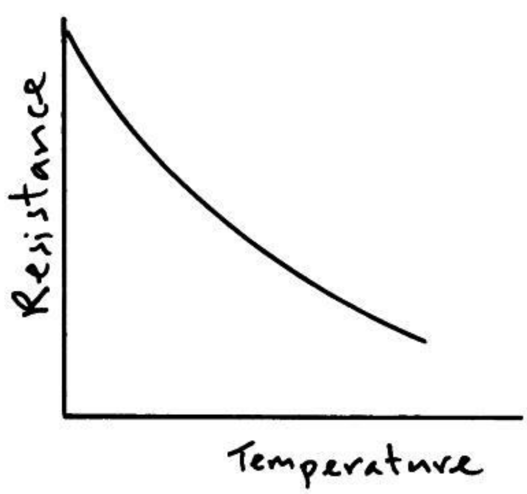
2.11 describe the qualitative effect of changing resistance on the current in a circuit

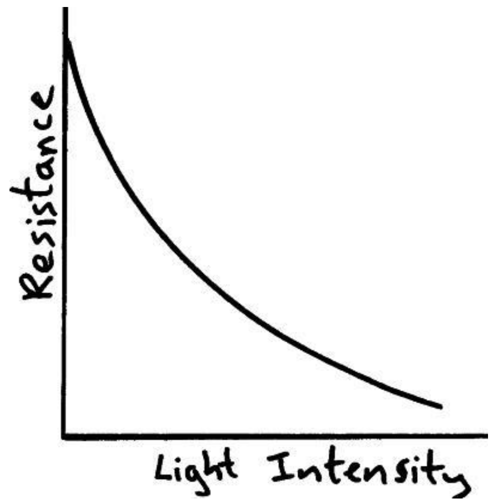
As the resistance in a circuit increases the current flowing through it decreases. This can be achieved by adding more components in series or by increasing the resistance of a variable resistor.

2.12 describe the qualitative variation of resistance of LDRs with illumination and of thermistors with temperature

An LDR is a light dependent resistor; its resistance depends on how bright the light hitting it is. As the light hitting an LDR gets brighter its resistance decreases, but not at a constant rate. An LDR’s resistance and illumination have a non-linear relationship.

A thermistor is a resistor whose resistance depends on how warm it is. As the temperature of a thermistor increases its resistance decreases; a warm thermistor has a lower resistance than a cold one. This seems a little odd as with almost all other components the opposite is true (e.g. the resistance of a bulb increases as the temperature increase). Like LDRs, the relation between a thermistor’s resistance and its temperature is not linear.





2.13 know that lamps and LEDs can be used to indicate the presence of a current in a circuit

When a bulb is placed in a circuit and current flows through the bulb the bulb lights up.

Er. That’s it.

Don’t forget as an LED is a diode it needs to be connected the correct way round.

2.14 know and use the relationship between voltage, current and resistance:

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

As explained in Section 2.9, current, voltage and resistance are all linked to each other. Voltage pushes current around a circuit and resistance opposes the flow of that current. Given two of the quantities (e.g. current and voltage) you can calculate the third (e.g. resistance). As with all calcualtions, don’t forget units; volts (V) for voltage, amps (A) for current and ohms (Ω) for resistance.

2.15 understand that current is the rate of flow of charge

A current is a flow of charge. If charge (i.e. electrons) are flowing faster through a circuit then the current in the circuit is higher.

2.16 know and use the relationship between charge, current and time:

$$I = \frac{Q}{t}$$

Because current is the rate of flow of charge, the current, the amount of charge that flows and the time taken for that charge to flow are linked. If 1 coulomb of charge flows in 1 second then the current is 1 amp. If 10 coulombs of charge flows in 2 second then the current is 5 amps. If you know two of the quantities (e.g. amount of charge and time) you can calculate the third (e.g. current). Watch out for time in minutes or hours and current in milliamps as these will need to be converted before calculating an answer.\

2.17 know that electric current in solid metallic conductors is a flow of negatively charged electrons

Electrical current is a flow of charge. The charge that flows is the charge possessed by tiny subatomic particles called electrons. The structure of metals is a positive ion lattice with a sea of delocalised (free) electrons. If the electrons (and therefore the charge) flow faster then the current is higher.

2.18 understand that:

- voltage is the energy transferred per unit charge passed
- the volt is a joule per coulomb

Voltage is a measure of how much energy is given to each electron. The higher the voltage, the more energy each electron that flows has. 1 volt is equivalent to 1 joule per coulomb of charge, or alternatively that 1 joule of energy is shared amongst each group of 6.25 million million million electrons. You don't need an equation for this relationship but may need to calculate some values. For example a voltage of 20V is the same as 20J/C. So if 5C of charge are flowing when a voltage of 20V is applied then 100J of energy is required.

Light and Sound

3.14 understand that light waves are transverse waves which can be reflected, refracted **and diffracted**

3.15 use the law of reflection (the angle of incidence equals the angle of reflection)

3.16 construct ray diagrams to illustrate the formation of a virtual image in a plane mirror

3.17 describe experiments to investigate the refraction of light, using rectangular blocks, semicircular blocks and triangular prisms

3.18 know and use the relationship between refractive index, angle of incidence and angle of refraction:

3.19 describe an experiment to determine the refractive index of glass, using a glass block

3.21 explain the meaning of critical angle *c*

3.22 know and use the relationship between critical angle and refractive index:

3.20 describe the role of total internal reflection in transmitting information along optical fibres and in prisms

3.23 understand the difference between analogue and digital signals

3.24 describe the advantages of using digital signals rather than analogue signals

3.25 describe how digital signals can carry more information

3.26 understand that sound waves are longitudinal waves and how they can be reflected, refracted **and diffracted**

3.27 understand that the frequency range for human hearing is 20 Hz – 20,000 Hz

3.28 describe an experiment to measure the speed of sound in air

3.29 understand how an oscilloscope and microphone can be used to display a sound wave

3.30 describe an experiment using an oscilloscope to determine the frequency of a sound wave

3.31 relate the pitch of a sound to the frequency of vibration of the source

3.32 relate the loudness of a sound to the amplitude of vibration.

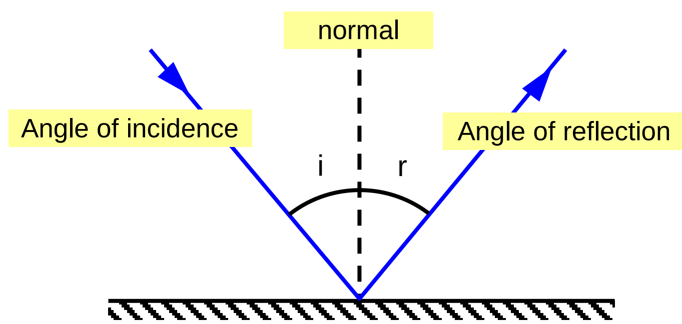
3.14 understand that light waves are transverse waves which can be reflected, refracted **and diffracted**

Light is a **transverse** wave; the direction of wave travel is at 90° to the oscillation which caused it It can be reflected (for example in a mirror), refracted (i.e. its path bends as it crosses from one medium into another) and diffracted (i.e. spreads out as it passes through a narrow gap). Another way to think of these three properties is bounce, bend and spread.

3.15 use the law of reflection (the angle of incidence equals the angle of reflection)

When light falls on a smooth, highly polished surface such as a piece of polished metal it is reflected (turned back). Glass mirrors have a thin layer of silvering on the back of a piece of glass which is protected with a coat of paint, and it is this silver surface that causes the reflection.

Reminder: The law of reflection
Angle of incidence (i) = Angle of reflection (r)

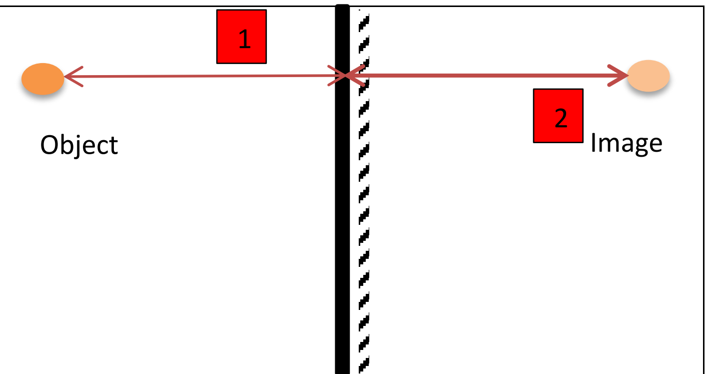
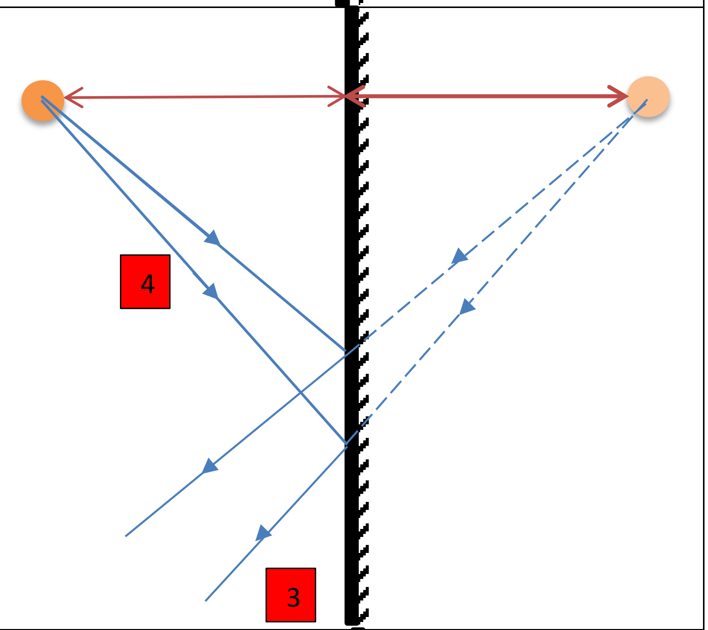
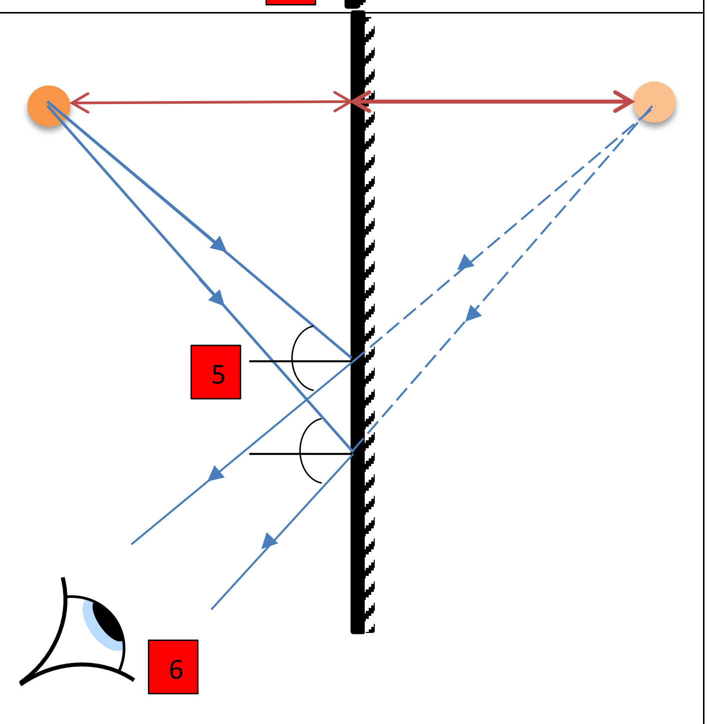


Remember you always measure the angle of incidence and angle of reflection from the normal; this is a line at 90° to the surface.

3.16 construct ray diagrams to illustrate the formation of a virtual image in a plane mirror

The image of an object is as far behind the mirror as the object is in front, and the same size. However if you look behind the mirror for the image it isn’t really there. The image is therefore said to be **virtual.** In addition, the actual rays do not cross where the image is formed.

To draw a **ray diagram** to illustrate the reflection of an object in a plane mirror follow these steps:

1 2	First draw a line from the object which crosses the mirror at right angles. Mark the image the same distance behind the line as the object is in front of the line	
3 4	Now draw 2 rays coming from the **image** which cross the mirror. The rays should be dotted behind the mirror and solid in front of the mirror. Don't forget to put arrows on the lines to show that they are coming from the image. Now connect the points at which the rays crosses the mirror to object	
5 6	Now add normals at right angles to the mirror where the rays bounce off it. Mark the angles of incidence and reflection – which should be identical Finally draw an eye to show where the virtual image is being viewed from.	

3.17 describe experiments to investigate the refraction of light, using rectangular blocks, semicircular blocks and triangular prisms

Refraction

Light bends when it passes from one medium (material) to another. This is called **refraction**. It is caused by a change in the speed of the light.

Method

Apparatus

power supply	semicircular block of glass or plastic
ray box	protractor
ray box slit	pencil
paper	

A Set up a ray box so that it produces a single ray of light.

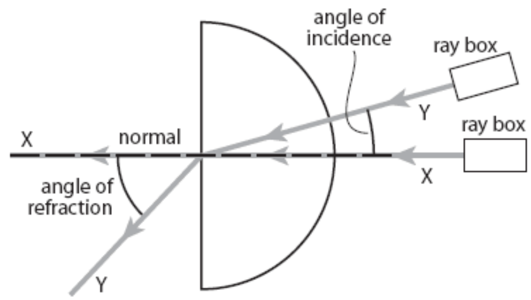
B Lay a piece of plain paper on your desk so you can see the path of the ray across the paper.

C Lay the semicircular block flat in the middle of the paper and draw around it in pencil. This will ensure you always put it in the same place.

D Aim your light ray into the curved side of the block to cut the semicircular block in half. You will know when the ray is in the right place as it will pass through the block without bending. A ray that crosses the boundary between air and glass/plastic at 90° (along the normal) will not bend at all (see ray X on the diagram).

E Mark on the paper the point on the flat side of the semicircle where ray X emerges. This is the centre of the flat side and is where you should aim all rays to hit that edge.

F Mark the path of ray X on your paper – this is the normal.



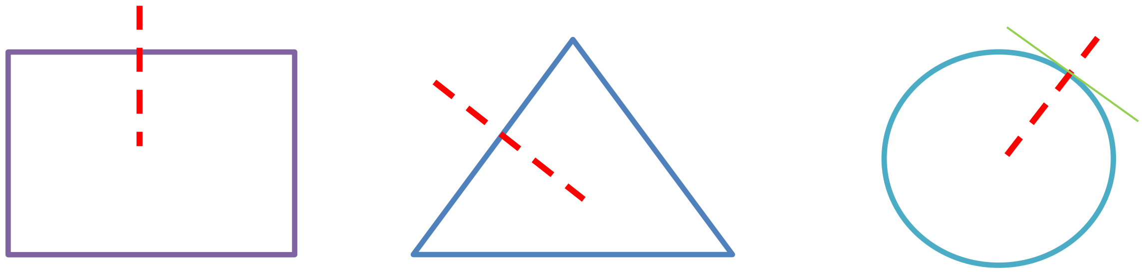
G Now aim the ray in at an angle to the normal (as ray Y on the diagram). You will see that ray Y bends away from the normal when it leaves the block.

H Set the angle of incidence to be exactly 10° and then mark the path of the refracted ray so that you can measure the angle of refraction.

I Repeat step **H**, increasing the angle of incidence by 10° each time until you reach 80°. Measure the angle of refraction in each case.

J Some odd things may happen to the refracted ray as you increase the angle of incidence. Note them down and always measure the angle of refraction to the nearest normal. Try to find the exact angle of incidence where the change in behaviour of the refracted ray occurs. This is called the critical angle.

Refraction can also be seen in rectuangular and triangular glass blocks. You need to be able to add normal to different shapes:



Regtangles are the easiest, followed by triangles. Circular and semi-circular blocks are slightly trickier as the normal is a 90° to the tangent where the light enters the block.

3.18 know and use the relationship between refractive index, angle of incidence and angle of refraction:

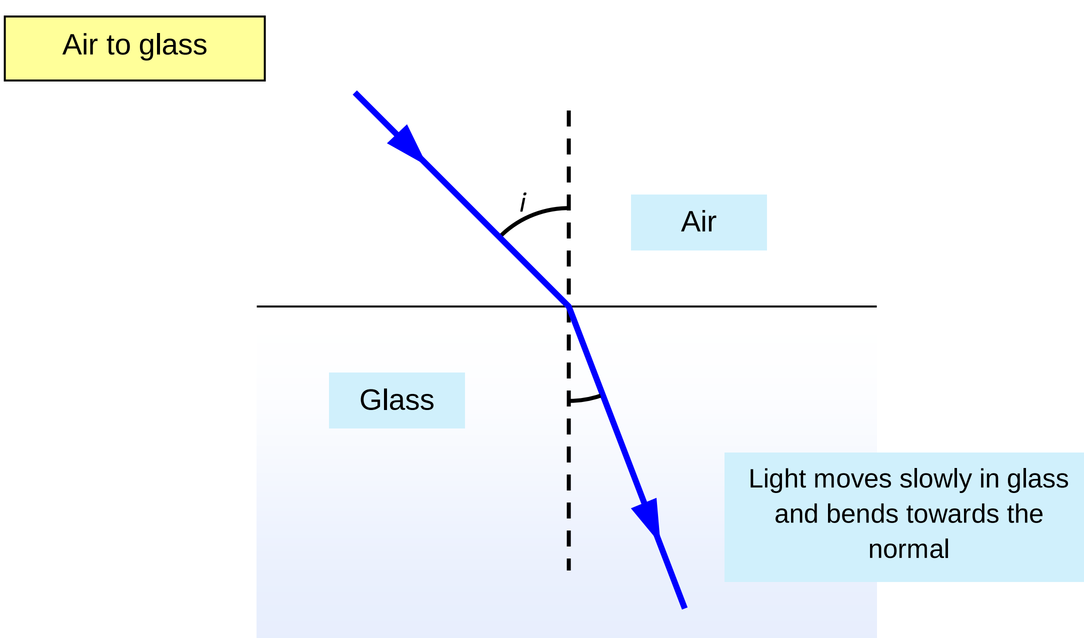
The refractive index (n) of a substance is given by the relationship:

$$n = \frac{sin\ (i)}{sin\ (r)}$$

Where *i* is the angle of incidence and *r* is the angle of refraction. Remember that both of these angles are measured from the normal. You will **not** be given this equation so need to be able to remember it. You will also need to be able to rearrange it to find i or r. You need to be careful when rearranging trig functions; to find i get sin(i) on its own first and then use the inverse sin function (or anti sin or shift sin whichever you want to call it).

$$i = sin^{-1}[n\ sin(r)]$$

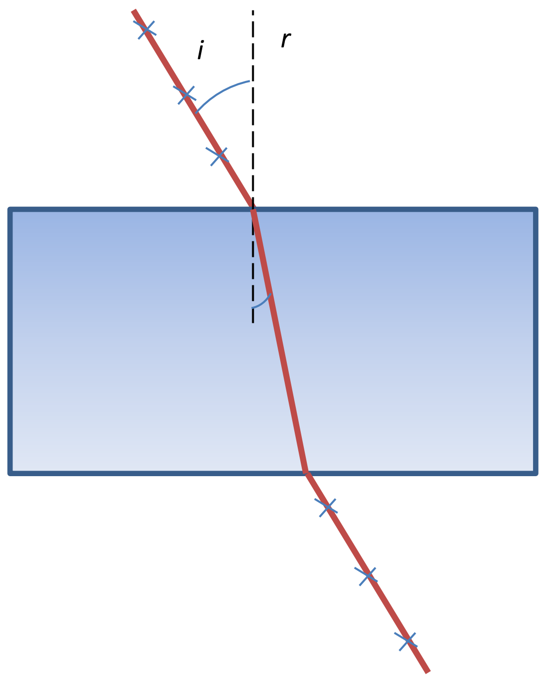
$$r = sin^{-1}\left(\frac{sin(i)}{n}\right)$$



The greater the refractive index, the more the light ray will be turned. When the light is enters the glass it is slowed down. Its frequency stays the same which means the wavelength must get smaller ($v=f\lambda$).

One last thing to watch out for is that n must never be less than 1. Very occasionally they show the light leaving the glass block and ask you to calculate a value. Remember, for the calculation the bigger angle is i and the smaller angle is r. If you get a math error on your calculator or a refractive index of less than 1 then try switching your angles.

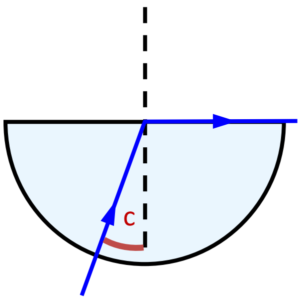
3.19 describe an experiment to determine the refractive index of glass, using a glass block



#

1. Place a glass block onto a sheet of white paper and draw around the block.
2. Use a ray box to shine a single incident ray into the block (this can be formed with a slit).
3. Mark crosses on the paper along the incident and emerging rays.
4. Remove the glass block and use a ruler to mark the incident and emerging rays, and to connect the entry and exit points to show the path of light within the block.
5. Draw the normal at the entry point
6. Use a protractor to measure the angle of incidence
7. Use a protractor to measure the angle of refraction
8. Calculate the refractive index using the equation $n = sin\frac{sin\,(i)}{sin\,(r)}$
9. Repeat for two other incident angles, and take the average value of n.

3.21 explain the meaning of critical angle *c*



Light is bent away from the normal at is goes from a high refractive index to a low refractive index. At a certain angle, the critical angle c, the light will be refracted so that is goes along the surface of the material; here the angle of refraction is 90°.

If light hits the surface at a greater angle than this it will not escape the material but instead will totally reflected. This is effect is known as **total internal reflection.**

Remember, for total internal reflection to occur the angle of incidence must be greater than the critical angle and the light must be going from a high refractive index to a low refractive index.

3.22 know and use the relationship between critical angle and refractive index:

The critical angle c can be calculated from the refractive index n using the equation

$$n = \frac{1}{sin(c)}$$

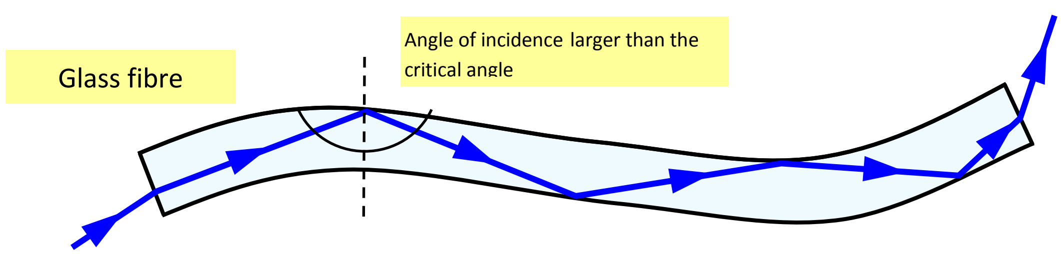
Again, you need to be able to recall this equation and rearrange it:

$$c = sin^{-1}\left(\frac{1}{n}\right)$$

3.20 describe the role of total internal reflection in transmitting information along optical fibres and in prisms

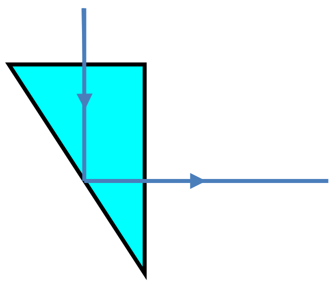
Optical Fibres and Prisms

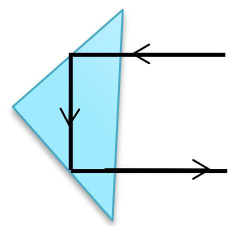
Fibre optics are thin solid tubes of glass or transparent plastic. Information can be sent along them by shining 'pulses' of light in at one end. Since the light hits the surface at greater than the critical angle it is totally internally reflected. Fibre optics are widely used for telecommunications – for example carrying telephone calls and internet data across the Atlantic ocean. Outside of the glass fibre is a material with a lower refractive index than the glass to ensure total internal reflection happens.



Total internal reflection can be used to make prisms act like mirrors – if the angle of incidence on the face is greater than the critical angle for the material, the light will be reflected.

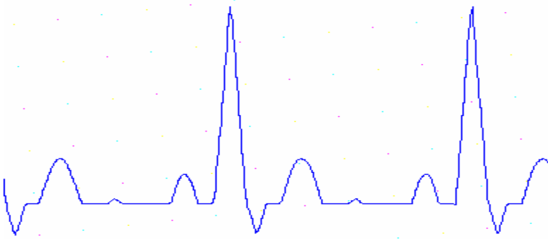
As the critical angle for glass is 42° this means that light can be shone in at 45° and so turned by 90° or 180°.



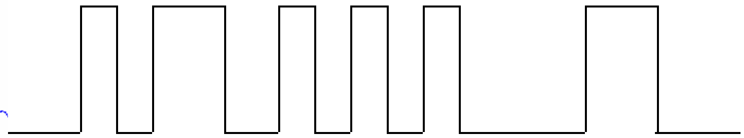


3.23 understand the difference between analogue and digital signals

Information is transmitted using either analogue or digital signals. Digital signals are a coded form of signal that can only have a value of 1 or 0 (i.e. ON or OFF). Examples include CDs and signals inside a computer. Analogue signals however can have any value – for example a mercury thermometer reading or a vinyl record.



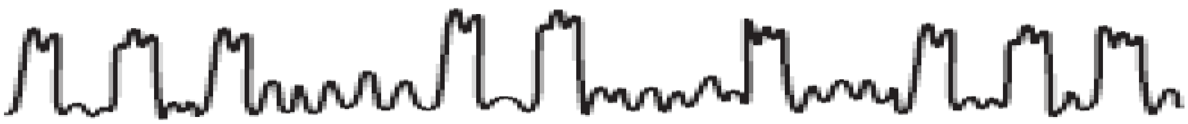
Analogue signal



Digital Signal

3.24 describe the advantages of using digital signals rather than analogue signals

Digital signals have several advantages, the main advantage is that because they can only be on or off then they are very simple to deal with.



- Less affected by interference – the digital signal above has been affected by significant interference but it is still possible to tell where the signal is 'on' and where it is 'off'
- Interference is not increased when the signal is amplified (since values can still only be 'on' or 'off' and signals can be cleaned before amplification)
- Easily processed by a computer

3.25 describe how digital signals can carry more information

Digital signals are able to carry more information which is why digital TV has so many more channels.

Different frequencies of light can be used to send more data at the same time (e.g. different coloured light can carry different streams of data). This is known as multiplexing.

As digital signals are simpler, more data can be sent in the same period of time (the frequency of transmission is higher).

Because digital signals can be easily cleaned the quality of the data can be maintained over longer distances.

3.26 understand that sound waves are longitudinal waves and how they can be reflected, refracted **and diffracted**

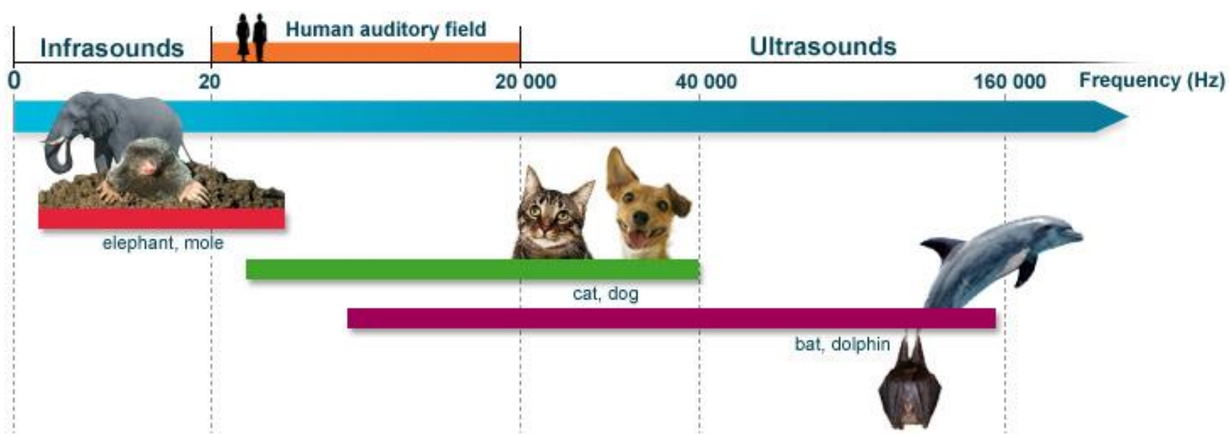
Sound waves are longitudinal waves – the vibrations occur parallel to the direction the wave is travelling. They exhibit all the features that are common to all waves:

Echoes are **reflections** of sound. You can work out how far away an object (such as a cliff) is by clapping your hands and timing how long the sound wave takes to travel to the cliff and return. Remember to halve this time, as you are only interested in the time taken to travel to the cliff.

Sound waves are usually **refracted** (bent) downwards at night – speed of sound increases with air temperature and the warmer air at higher altitudes causes this effect.

Sound waves are **diffracted (spread out)** through doorways, allowing us to hear what is happening in the corridor outside.

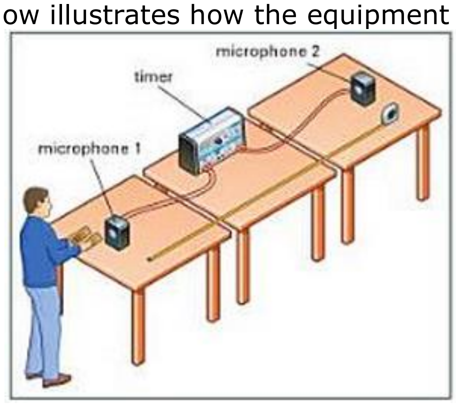
3.27 understand that the frequency range for human hearing is 20 Hz – 20,000 Hz



Humans can hear sounds with frequencies between 20Hz (a very low pitched hum) and 20 000Hz (a very high pitched squeek). Sounds higher than 20000Hz cannot be heard by humans and are known as ultrasound. Sound waves with this frequency can be used for medical imaging (e.g. imaging foetuses or bloodflow). You need to be able to recall these values.

3.28 describe an experiment to measure the speed of sound in air

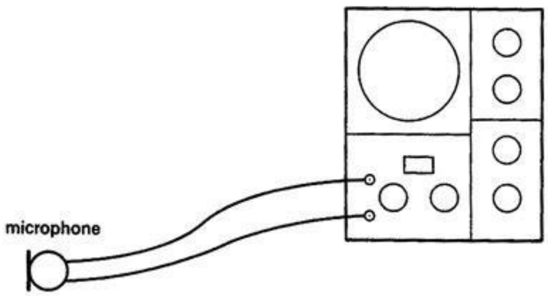
A common exam question asks you to describe an experiment to measure the speed of sound in air. The diagram below illustrates how the equipment should be set up.



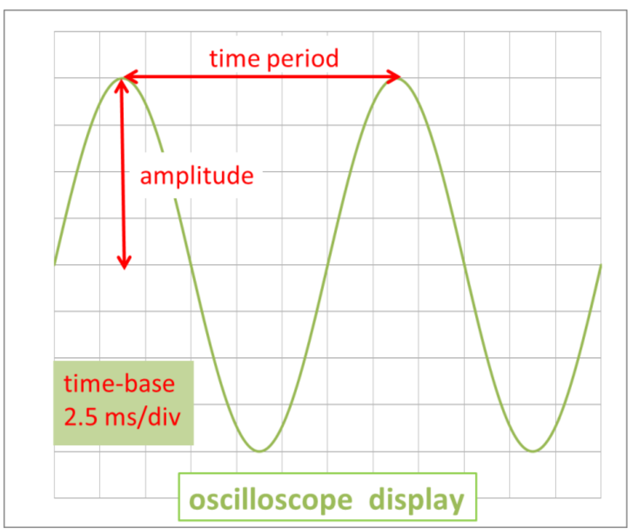
- Use a tape measure to position two microphones a distance of 2m apart.
- Bang a pair of wooden blocks so that that sound wave travels first past microphone 1, and then past microphone 2.
- When microphone 1 'hears' the sound, the timer starts
- When microphone 2 'hears' the sound the timer stops
- Repeat the experiment 5 times to find the average time (in seconds) that the sound takes to travel 2m.
- Use the equation $average\ speed = \frac{distance}{average\ time}$ to calculate the speed of sound.

3.29 understand how an oscilloscope and microphone can be used to display a sound wave
3.30 describe an experiment using an oscilloscope to determine the frequency of a sound wave

Sound waves can be turned into electrical signals using a microphone. If this microphone is connected to an oscilloscope it visualise the sound wave.



A typical oscilloscope display is shown below.
The **vertical** axis shows the **amplitude** – this wave has an amplitude of 4 squares.
Time is shown across the **horizontal** axis. The 'time-base' scale tells you how much each square (or 'division') represents. Often time-base is in ms/div i.e. milli-seconds per division or 1/1000th of a second per division.



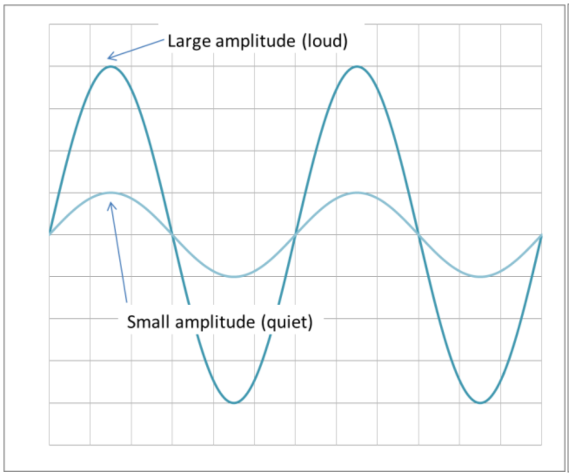
The **time period** is measured between consecutive peaks on the display. In this example the time-base is 2.5ms/div, and the time period is measured as 6 squares. The time period is therefore equal to 6 x 2.5ms = 15ms.

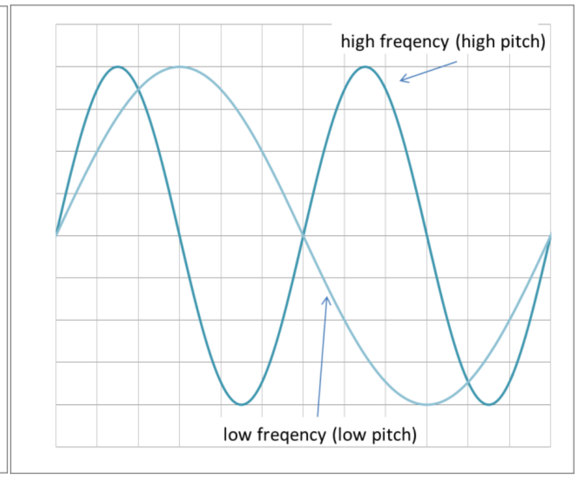
Since $frequency = \frac{1}{Time\ Period}$ we can calculate that the wave has a frequency of $\frac{1}{0.015} = 66Hz$

3.31 relate the pitch of a sound to the frequency of vibration of the source
3.32 relate the loudness of a sound to the amplitude of vibration.

When something vibrates is produces sound (think of a guitar string, a drum or a loudspeaker).
The **greater the amplitude**, the **louder the sound**.

The **higher the frequency**, the **higher the pitch**.





Work and Power

Syllabus points

4.9 recall and use the relationship between work, force and distance moved in the direction of the force:

work done = force × distance travelled

$$W = F \times d$$

4.10 understand that work done is equal to energy transferred

4.11 recall and use the relationship:

gravitational potential energy = mass ×g ×height

$$GPE = m \times g \times h$$

4.12 recall and use the relationship:

$$\text{kinetic energy} = \frac{1}{2}\text{mass} \times \text{velocity}^2$$

$$\mathrm{KE} = \frac{1}{2}\mathrm{m}v^2$$

4.13 understand how conservation of energy produces a link between gravitational potential energy, kinetic energy and work

4.14 describe power as the rate of transfer of energy or the rate of doing work

4.15 use the relationship between power, work done (energy transferred) and time taken:

$$power = \frac{\text{work done}}{time\ taken}$$

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

4.9 recall and use the relationship between work, force and distance moved in the direction of the force:

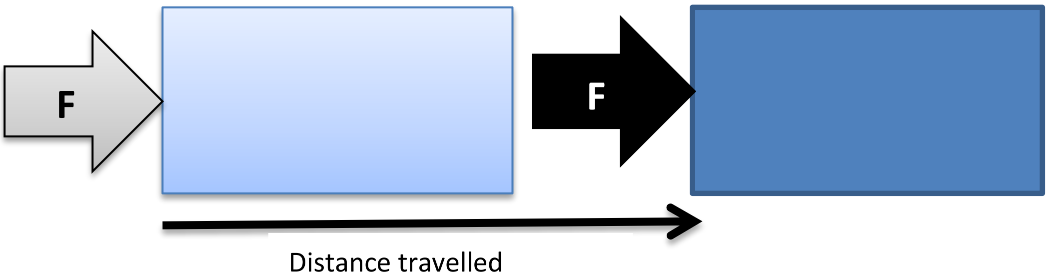
work done = force × distance travelled

$$W = F \times d$$

In this section we are going to have a closer look at the **mechanical** forms of energy, including kinetic energy and gravitational potential energy.

We begin by defining **work**, a concept that provides a link between the concepts of force and energy.

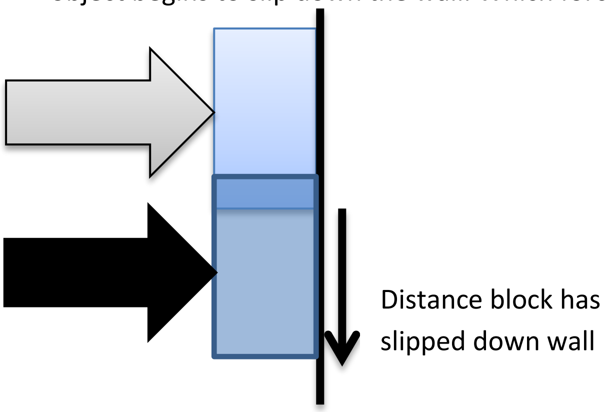
When a force *F* moves an object, energy is transferred and **work is done** on that object.



Bear in mind that the object must move for work to be done, or rather, a force does no work on an object if the object does not move. For example, if a person pushes against a brick wall, a force is exerted on the wall but the person does no work since the wall is fixed. However, the person's muscles are contracting in the process so the body is using some energy to contract muscles. Likewise, if you hold a weight at arm's length for some period of time, no work is done on the weight.

Think about this

If a person is holding an object steady against a brick wall by pushing horizontally on it and the object begins to slip down the wall. Which force is doing work on the object?



Answer

Only the gravitational pull or force from the Earth is doing work, since the displacement or distance travelled is in the direction of this force

The factors which affect the amount of work done are:

1. Force F

2. Distance travelled (in direction of force) d

If the force exerted on the object is doubled, work done doubles (assuming the distance remains constant). Work and force are directly proportional.

If the object is displaced twice as far or pushed twice the distance, work done also doubles.

A mathematical equation to satisfy both of these relationships is as follows;

Work = Force x distance

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

Work done is measured in joules (J).Work is a **scalar quantity**. We can therefore combine the work done by each of the separate forces to get the total work done.

Work done = energy transferred 1 Nm = 1 Joule Or 1 joule of work is done when a force of 1N moves through 1m (in the direction of the force).

Examples

1. A man lifts a parcel weighing 5N from the ground onto a shelf 2m high. How much work does he do on the parcel?

2. Some kids drag an old tyre 500 cm over rough ground. They pull with a total force of 340N. Find the energy transferred.

3. Which of the following involve mechanical work?

A) A shelf holding up a stack of books.

B) A hamster moving a tread wheel

C) A foot pump being pushed down

D) A strong man leaning against a brick wall.

E) A weightlifter holding 40kg above her head.

F) A railway porter holding a passenger’s two cases

Answers

1. A man lifts a parcel weighing 5N from the ground onto a shelf 2m high. How much work does he do on the parcel?

W= F x d *(you should always write the equation down when answering a calculation question*)

W = 5N x 2m = 10J (*Do not write Nm down as the unit*)

2. Some kids drag an old tyre 500 cm over rough ground. They pull with a total force of 340N. Find the energy transferred.

Work done = energy transferred

W = F x d

W = 340 N x 5 m *(it is always best to write the units alongside the values, you will notice if you need to convert units such as cm to m)*

W = 1700J

3. Which of the following involve mechanical work?

A) A shelf holding up a stack of books.

B) A hamster moving a tread wheel

C) A foot pump being pushed down

D) A strong man leaning against a brick wall.

E) A weightlifter holding 40kg above her head.

F) A railway porter holding a passenger's two cases

B & C only

4.10 understand that work done is equal to energy transferred

If you do 10J of work on an object you have transferred 10J of energy from you to the object. You could have lifted it up, giving it 10J of gravitational potential energy or you could have hit it, accelerating it and giving it 10J of kinetic energy.

If energy is transferred then work is done, and vice-versa.

4.14 describe power as the rate of transfer of energy or the rate of doing work

If two children who have the same mass climb the same hill then they do the same amount of work. But what if child one climbs the hill in a shorter time?

We say that child one is more powerful.

It is interesting to know not only the work done on an object, but also the rate at which the work is being done.

Power is defined as the **rate of working** or how quickly you work. What does this mean? It means the **work done per unit time**.

4.15 use the relationship between power, work done (energy transferred) and time taken:

$$power = \frac{\text{work done}}{time\ taken}$$

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

How is power related to the amount of work done on an object?

If the work done on an object in a given time doubles, then the power doubles. For a given time, work done is directly proportional to power.

How is power related to the amount of time it takes to do the work?

If it takes you half the time to move an object over the same distance, you are twice as powerful. In short, it if time is doubled power is halved. For a given amount of work done, power is **inversely proportional** to time

Mathematically this is written as;

$$Power = \frac{\textit{work done}}{\textit{time taken}}$$

$$\boxed{P = \frac{W}{t}}$$

What would the SI unit for power be?

Joule per second or $\frac{J}{s}$

1 Joule per second is also called a **watt or W**.

Remember: 1 kW = 1000W 1 MW = 1 000 000 W

Examples

1. A crane lifts a load weighing 3000N through a height of 5m in 10 seconds. What is the power of the crane?

2. An electric kettle is rated at 2400W. How long would it take to supply 288kJ to the water in the kettle? In real life the time needed would be longer than this. Why?

3. An electric hoist is supplied with 5A and 240V. What would its power output be? How far would it lift a 3000N block in 3 seconds?

Answers:

1. A crane lifts a load weighing 3000N through a height of 5m in 10 seconds. What is the power of the crane?

P = W/t = (Fxd)/t

P = (3000N x 5m)/10s

P = 1500W

2. An electric kettle is rated at 2400W. How long would it take to supply 288kJ to the water in the kettle?

P = W/t *(Sometimes you need to rearrange an equation to make another variable the subject, in this case time was made the subject of the equation)*

t = W/P

t=288,000J/ 2400Js^{-1} *(here the energy supplied was given in kilojoules and must be converted to joules)*

t = 120s = 2 min *(in this step the time has been divided by 60 to give time in minutes)*

In real life the time needed would be longer than this. Why?

Not all the energy of 288,000J will go to the water, some will be lost the surrounding or used to heat the kettle walls and element.

3. An electric hoist is supplied with 5A and 240V. What would its power output be?

P = IV *(here we have had to use the power equation from the electricity topic)*

P = 5A x 240V

P = 1200W

How far would it lift a 3000N block in 3 seconds?

P = W/t

P = (F x d) / t *(here we substituted in F x d for work done to introduce the distance variable which is what we are being asked to find)*

d = (P x t) / F *(we now needed to make distance the subject of the equation)*

d = (1200W x 3s) / 3000N

d = 1.2 m

4.11 recall and use the relationship:

gravitational potential energy = mass ×g ×height

$$GPE = m \times g \times h$$

Gravitational potential energy is the energy possessed by something due to its height above its surroundings.

To derive the equation for gravitational potential energy or GPE we will work through an example.

Example

A weightlifter has lifted a mass of 200kg up to a height of 2m. What work or energy has he put into the weights?

Work done = F x d

Remember,

force vertically = weight (*one must exert a force equal to the weight of the object to lift it and W = mg*)

Work done = W x d $_{\textit{lifted}}$

But, here on Earth

Weight = mass x gravitational field strength

Where g = 10 N/kg

Therefore,

Work done=(mass x gravitational field strength) x distance lifted

The energy the weights have at 2m above ground is equal to the work the weightlifter put into the weights

The energy is called Gravitational Potential Energy- it is stored until the weightlifter drops the weights.

G.P.E = mass x gravitational field strength x height

G.P.E. = mgh

Example

1. A piano of mass 960kg is raised through 4.3m. Find the gain in potential energy.

2. A book ‘weighing’ 3000g is sitting on a shelf 2 m above the ground. Find the potential energy stored in the book.

Answers

1. A piano of mass 960kg is slowly raised through 4.3m. Find the gain in potential energy.

G.P.E = mgh

G.P.E. = 960 kg x 10 N/kg x 4.3m *(notice that that kg unit cancels and you are left with a Nm or J)*

=41280 J

2. A book 'weighing' 3000g is sitting on a shelf 2 m above the ground. Find the potential energy stored in the book.

G.P.E = mgh

G.P.E = 3kgx10 N/kg x2m *(don't forget the SI unit for mass is kg)*

G.P.E. = 60J

4.12 recall and use the relationship:

$$\text{kinetic energy} = \frac{1}{2}\text{mass} \times \text{velocity}^2$$

$$\text{KE} = \frac{1}{2}\text{m}v^2$$

Kinetic energy is energy due to movement.

An object with a constant unbalanced force will accelerate and gain speed. If an object on a shelf with stored GPE falls, the force doing the work is gravity and the stored energy is transferred to kinetic energy as it falls.

Which has more kinetic energy, a man running at 10m/s or an elephant running at 10 m/s?

The elephant has more kinetic energy because it has more mass. Which one would you rather try and stop?

What has more kinetic energy, a Formula 1 car travelling at 40m/s or a family car of the same mass travelling at 25m/s?

The formula 1 car would have more kinetic energy because it is travelling faster. It has a greater velocity or speed.

It should be obvious now that Kinetic Energy or KE is affected by only two variables including mass and velocity.

The equation for kinetic energy is:

$$\boxed{\text{K.E.} = \tfrac{1}{2}\, m\, v^2}$$

This equation shows us that if the mass is doubled, the KE would double but how about the velocity?

The formula for kinetic energy has the speed squared. So, if the speed of the car doubles than the kinetic energy will quadruple ($2^2 = 4$)

Example

Q1 What is the K.E. of an elephant of mass 2000kg travelling at 5m/s?

K.E. = ½ mv^2

K.E. = ½ x 2000kg x (5^2) *(Remember: square the 5 first or you may square the whole lot)*

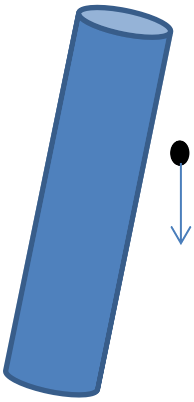
K.E. = ½ x 2000kg x 25

K.E. = 25,000J

4.13 understand how conservation of energy produces a link between gravitational potential energy, kinetic energy and work

Calculating the speed of a falling object using conservation of energy. This is a typical exam question which we'll tackle step by step:

Galileo drops a 100g stone from the leaning tower of pisa, which is 45m high.



A) How much potential energy does the stone have at the top?

GPE = mgh

GPE = 0.1kg x 10N/kg x 45m

GPE= 45J

B) What is the potential energy transferred into as it falls?

Kinetic energy

C) If the energy is conserved. How much K.E. would the stone have just before it hits the ground?

45J since all the GPE has transferred into KE – conservation of energy

D) If the stone has 45J of kinetic energy, what speed would it hit the ground at?

We need to rearrange the kinetic energy equation:

$$KE = \frac{1}{2}mv^2$$

First make v^2 the subject of the equation:

$$v^2 = \frac{2KE}{m}$$

(note dividing by ½ is the same as multiplying by 2)

Get rid of the square by taking the square root of each side

$$v = \sqrt{\frac{2KE}{m}}$$

Finally substitute in the values

$$v = \sqrt{\frac{2 \times 45J}{0.1kg}} = \sqrt{900} = 30m/s$$

E) Equate the GPE equation and the KE equation.

$$mgh = \frac{1}{2}mv^2$$

$$gh = \frac{1}{2}v^2$$

$$v = \sqrt{2gh}$$

Do you need to know the mass of the stone to find its speed when it hits the ground?

No-mass cancels, so all you need is the height. If you remember the equation in D then you can use it to help you answer questions and eliminate loads of steps!

F) What will the energy transfer to when the stone hits the ground?

Thermal and sound

G) What assumptions have you made?

Right at the start we assumed that all of the GPE was converted into KE. This means the transfer is 100% efficient; i.e. no energy has been converted to less useful forms (such as heat due to air resistance). Assuming the rock is on Earth is not a suitable assumption.

Rearranging the KE equation is one of the trickier things you'll need to do in a physics exam. Make sure that you can make v the subject of the KE equation.

The same sort of analysis could be applied in the opposite direction. For example you may have a bullet being fired vertically. The only information you are given is the speed of the bullet as it leaves the gun and the bullet's mass. From this you can work out the kinetic energy. The KE lost as the bullet slows down will be equal to the GPE gained as it gets higher and higher. The final GPE will be equal to the initial KE (assuming no energy is lost due to air resistance). You can then calculate how high it will go into the air.

Example

A bullet is fired straight into the air at a speed of 300m/s. The mass of the bullet is 50g. How high will the bullet travel? Would a 200g bullet travel higher, lower or to the same height?

Answer

A bullet is fired straight into the air at a speed of 300m/s. The mass of the bullet is 50g. How high will the bullet travel? Would a 200g bullet travel higher, lower or to the same height?

First find the KE

$$KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.05kg \times 300^2 = 2250J$$

State what the final GPE will be:

GPE gained = KE lost. At the top of the flight the bullet will stop (zero KE) so will have 2250J of GPE

Find h

$$GPE = mgh$$

$$h = \frac{GPE}{mg} = \frac{2250J}{0.05kg \times 10N/kg} = 4500m$$

As we saw earlier the mass cancels so the height will be independent of mass:

$$mgh = \frac{1}{2}mv^2$$

$$h = \frac{\frac{1}{2}v^2}{g}$$

So both bullets reach the same height.

Finally you could be asked to work out the braking distance or the braking force for a vehicle. Earlier we said that work done is equal to energy transferred. When a car brakes, kinetic energy is transferred to the brakes. The brakes to work which stops the car.

KE lost by car = work done by brakes

So all we need to do here is find the KE of the car (using KE = ½ mv^2) and then find the braking distance using work done = force x distance.

Example:

A 1 tonne car (1000kg) travels at 20m/s. Its brakes can apply a force of 2.8kN. What is the braking distance?

Answer:

A 1 tonne car (1000kg) travels at 20m/s. Its brakes can apply a force of 2.8kN. What is the braking distance?

First find the KE

$$KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 1000kg \times 20^2 = 200\ 000J$$

Then rearrange the work done equation

$$W = Fd$$

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

Don’t forget, the work done by the brakes is equal to the energy transferred to them:

$$d = \frac{200\ 000J}{2800N} = 71.4m$$

Energy Resources and Electricity Generation

Syllabus points

4.16 describe the energy transfers involved in generating electricity using:

a) wind

b) water

c) geothermal resources

d) solar heating systems

e) solar cells

f) fossil fuels

g) nuclear power

4.17 describe the advantages and disadvantages of methods of large-scale electricity production from various renewable and non-renewable resources.

This is one of the wordiest sections of the entire IGCSE. There are lots of facts to learn and a few core answers which can be applied to lots of different situations.

4.16 describe the energy transfers involved in generating electricity

With the exception of solar cells, all methods of electricity production include the following energy transfers:

… energy → kinetic energy → electrical energy

The main differences are what comes first.

In general, some sort of *turbine* is spun which in turn drives a *generator*. Generators use a spinning coil of wire and a magnet to convert kinetic energy into electrical energy; this is covered in a lot more depth in 6.15 & 6.16. For now it is enough to know the names turbine and generator and the energy transfers.

4.16 a) describe the energy transfers involved in generating electricity using wind

kinetic energy → electrical energy

Wind turbines use the kinetic energy of the wind to directly drive a generator.

4.16 b) describe the energy transfers involved in generating electricity using water

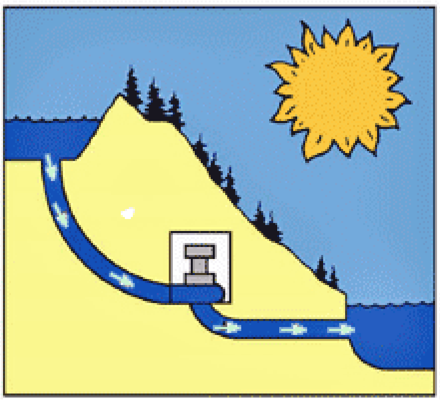
There are three different methods of generating electricity using water.

Hydroelectricity:

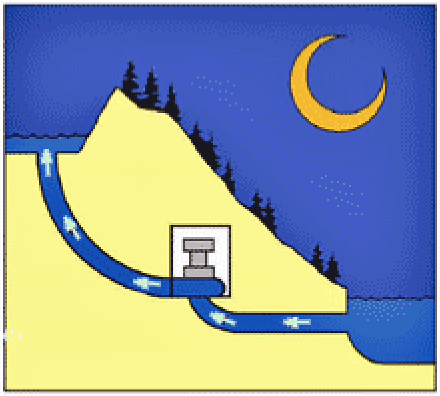
gravitational potential energy → kinetic energy → electrical energy

Hydroelectric power stations build water up behind a dam and allow it to fall through turbines to spin generators. To produce more electricity, dams can be taller or wider. The river is kept topped up by the water cycle.

Hydroelectric dams have the added benefit of pumped storage as a way of coping with high demand for electricity. Water is released to provide enough electricity to cope with the increased demand. The water is then pumped back up into the lake, ready for the next surge in demand. This typically occurs at night when there is spare energy on the grid.



Daytime: Water flows downhill through turbines, producing electricity



Nightime: Water pumped uphill to reservoir for tomorrow's use

Tidal

gravitational potential energy → kinetic energy → electrical energy

Tidal power uses the in and out motion of the tide. The process is similar to hydroelectric, however, rather than relying on rain to top up the river, tidal power stations are built across estuaries (tidal inlets) where the tide flows in and out. Tide flows in, spins turbines (which spin generators). Tide flows out, the same thing happens. Water can be held behind the tidal barrage and released when needed.

Wave

kinetic energy → electrical energy

Wave power uses the up and down motion of waves to produce electricity. This can be out at sea where long floating systems bend when waves pass; this motion moves hydraulic fluid to turn generators.

4.16 c) describe the energy transfers involved in generating electricity using geothermal resources

(nuclear energy) → thermal energy → kinetic energy → electrical energy

Geo (Earth) Thermal (Heat) uses the high temperatures below the Earth's surface to heat water (and then do the whole spin a turbine, spin a generator thing). Some rocks below the Earth's surface are hot due to energy left over from when the Earth formed and from radioactive decay. Water is pumped down to the rocks where it is heated and returns to the surface as high pressure steam.

4.16 d) describe the energy transfers involved in generating electricity using solar heating systems

thermal energy → thermal energy

Solar panels on people's rooves consist of a series of black pipes with water flowing through them. The water is heated by the thermal energy from the sun which means it requires less heating from a boiler later. This reduces energy use. If the sun's thermal energy can be collected and focused with mirrors and lenses this can heat water sufficiently to boil it. Steam spins turbine which spins generator.

This should not be confused with…

4.16 e) describe the energy transfers involved in generating electricity using solar cells

light energy → electrical energy

Photovoltaics is the process of generating electricity directly from sunlight hitting a solar cell. Within a solar cell are special semiconductors and when photons of light hit the solar cell, electrons are made to flow producing a current.

4.16 f) describe the energy transfers involved in generating electricity using fossil fuels

chemical potential energy → thermal energy → kinetic energy → electrical energy

Fossil fuels (oil, coal and gas) are burned to heat water to produce steam to turn turbines to turn generators to produce electricity.

4.16 g) describe the energy transfers involved in generating electricity using nuclear power

nuclear potential energy → thermal energy → kinetic energy → electrical energy

The only big difference between a fossil fuel power station and a nuclear power station is where the heat comes from. In a nuclear power station uranium or other suitable nuclei are split in a process called nuclear fission. This produces a huge amount of energy which can be used to heat water etc.

4.17 describe the advantages and disadvantages of methods of large-scale electricity production from various renewable and non-renewable resources.

Here are some general pros and cons of renewable energy vs. non-renewable:

	General Advantages	General Disadvantages
Renewable (wind, water, geothermal, solar)	No air pollution Does not contribute to global climate change Will not run out No fuel costs – low running costs	High initial set-up costs Require large area of land – visual pollution Low energy output Weather dependent Location specific
Non-renewable (fossil fuels, nuclear)	High output Independent of weather Already established Requires little land	Very polluting (air) and contributes to global climate change Extraction of fuels is also polluting Running out

Care should be taken with questions looking at energy resources. Often the questions will include a phrase along the lines of "other than cost give two advantages and two disadvantages of…" Obviously talking about costs here will not score you the marks.

In addition phrases such as "no pollution" need to be avoided. Be specific; are you talking about air pollution, visual pollution or damage to ecosystems?

Here are some more detailed pros and cons

	Advantages	Disadvantages
Wind (renewable)	Renewable – will not run out No air pollution and does not contribute to global climate change No fuel costs and minimal running costs	Reliability issues; If the wind stops, so does the electricity generation A large number are needed to replace more traditional power station Large environmental impact – Large numbers of wind turbines take up a lot of space and can spoil the view. Needs to be built in windy places which tend to be remote making maintenance tricky.
Hydroelectricity (renewable)	Renewable – will not run out Once the dam is built the running costs are low Dams can provide a lot of electrical energy (The Hoover dam powers most of Las Vegas) Can provide electrical energy quickly should the need arise No air pollution and does not contribute to global climate change	Set up costs are high and there needs to be a suitable area to build the dam Large impact on the environment – Lots of land has to be flooded to create the lake which feeds the dam – Loss of housing/habitat

Tidal (renewable)	Renewable – will not run out No air pollution and does not contribute to global climate change Low running costs Tides are predictable (changes four times a day) Ability to store water behind the barrage ready for times of peak demand Can be used as a bridge Turbines are turned when the tide comes in and when it is let out	Prevents access to the estuary for boats Alters habitat for local wildlife Ruins the view High initial set up costs
Wave (renewable)	Renewable – will not run out No air pollution and does not contribute to global climate change Low running costs	Very weather dependent as wave height depends on wind Only suitable for small scale electricity generation Spoil view Can be hazardous to small boats
Geothermal (renewable)	Renewable – will not run out Minimal environmental impact – Power stations can be relatively small Low running costs No air pollution and does not contribute to global climate change Not affected by weather Can be used for Combined Heat and Power (CHP) where plant provides heating as well as electricity	Hot rocks need to be quite close to the surface (<10km deep) Drilling to the rocks can be expensive There are not many suitable places in the world where a geothermal power station is viable Location specific
Solar (renewable)	Renewable – will not run out Practically free electricity once set up Able to power remote places such as Antarctica or space Can easily power small appliances such as calculators No air pollution and does not contribute to global climate change	High initial set-up costs Needs a very sunny place (long sunny days, minimal cloud) to produce sufficient electricity (e.g. close to the equator). Not really viable in the UK

	Advantages	Disadvantages
Fossil fuels (non-renewable)	Already established Able to produce large amounts of energy.	Non-renewable – will eventually run out Burning fossil fuels adds more CO_2 into the atmosphere which is affecting the climate. Impurities in fuels can lead to acid rain and lung disease. Mining can be dangerous
Nuclear fuels (non-renewable)	Already established Able to produce large amounts of energy. No air pollution and does not contribute to global climate change Small amounts of fuel needed and waste produced; fewer transportation issues Power stations can be small	Non-renewable – will eventually run out Waste needs to be securely stored for a long period. Radioactive waste is dangerous to people and the environment. If problems occur they can have wide ranging ramifications Mining can be dangerous Increased security risks/terrorism

Other notes:

The greenhouse effect is the key reason that the Earth is not a freezing rock floating through space. Light which hits the ground is absorbed and then remitted. This remitted thermal radiation can be trapped by greenhouse gases. No greenhouse effect is very bad news; however, increased greenhouse effect is a major concern leading to a big push towards renewables and away from fossil fuels.

Other considerations need to be considered when building power stations such as proximity to where the power is needed. Lots of renewable power stations require large amounts of land in more remote areas which can be a challenge.

RGS
physics

Magnetism

Syllabus points:

6.2 understand that magnets repel and attract other magnets and attract magnetic substances

6.3 describe the properties of magnetically hard and soft materials

6.4 understand the term ‘magnetic field line’

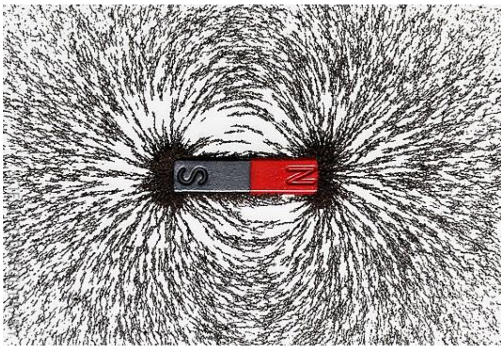
6.5 understand that magnetism is induced in some materials when they are placed in a magnetic field

6.6 describe experiments to investigate the magnetic field pattern for a permanent bar magnet and that between two bar magnets

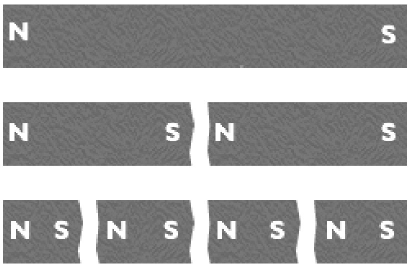
6.7 describe how to use two permanent magnets to produce a uniform magnetic field pattern.

Magnetism

The most familiar magnets are the common bar magnet. If a bar magnet is dipped into iron filings, the filings cling to the magnet in concentrations near the ends of the bar.



These regions of apparent magnetic strengths are called **magnetic poles**. There is both a **north (seeking) pole** and a **south (seeking) pole**. This comes from the properties of a compass. The north magnetic pole 'seeks' and points north (toward the north pole of the Earth), and the south magnetic pole points south.



You cannot isolate a single magnetic pole, they always occur together. If you break a magnet in two, you get two smaller dipole magnets. If you continue to break the magnet into two over and over again then you would end up with an atom which acts like a little magnet (a magnetic moment). Adjacent atoms, and large groups of atoms line up with each other. These groups of aligned atoms are called **magnetic domains**.

An ordinary piece of iron by itself is not a magnet. This is because the magnetic domains are randomly orientated, and their effects cancel.

In the presence of a magnetic field, the domains are induced into alignment, and the iron becomes magnetised. The degree of magnetism depends on the degree of alignment. When all the domains are aligned in the same direction then the magnetism is at its strongest and the magnet is said to be saturated.

If the magnetic field is removed, thermal motion (vibration of particles) causes the domains to go back into a random orientation, and the magnetism is lost. Iron is considered to be ‘**magnetically** soft’ because it loses its magnetism easily when it is removed from a magnetic field. Other material such as steel (an alloy of iron) is ‘**magnetically hard’** since its domains are ‘locked in’ their alignment. These magnets can be destroyed by heating them or striking it on a hard surface to effectively jumble the aligned domains.

	Example	Use
Magnetically Hard	Steel	Permanent magnet
Magnetically Soft	Iron	Core of electromagnet, transformer core, motor, generator

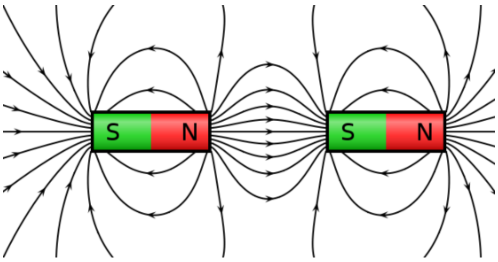
When magnets are brought close together, it is quickly observed that the magnets attract each other in some cases and repel in others. This action is described by the law of magnetism.

Law of Magnetism

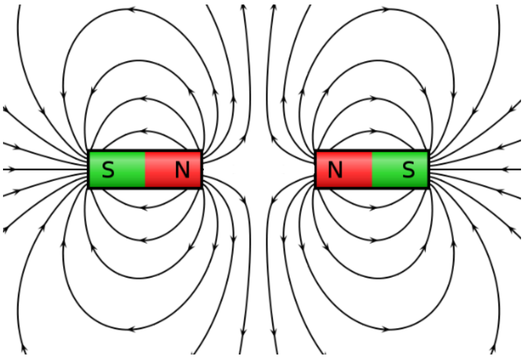
Opposite poles attract

Like poles repel

Attracting Magnets:



Repelling Magnets:



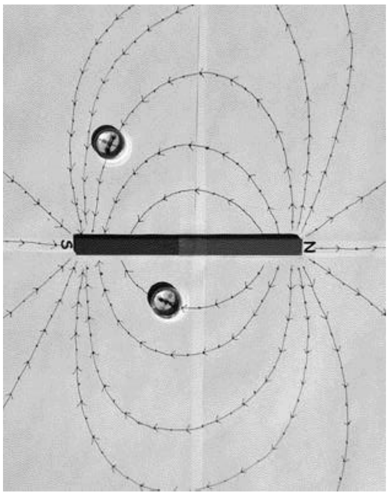
You need to be able to sketch these field shapes.

The force that is felt by a magnet or a piece of magnetic material by another magnet is called the magnetic force. Magnetic materials feel a **magnetic force** when they are in a magnetic field.

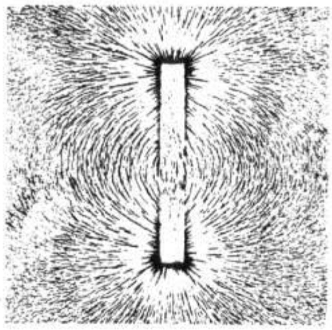
A **magnetic field** is a region where a magnetic material experiences a force.

A **magnetic field line** shows the direction of the force that would act on a small N pole placed there (i.e. if you placed a N pole on an arrow facing left the N pole would be pushed left). The field lines also show the strength of the field; tightly packed field lines indicate a strong magnetic field.

The direction of the field runs from North to South or is in the direction of the force experienced by a north magnetic pole. If you place a compass in the vicinity of a magnet, the magnetic field can be mapped out and is in the direction of the north pole of the compass.

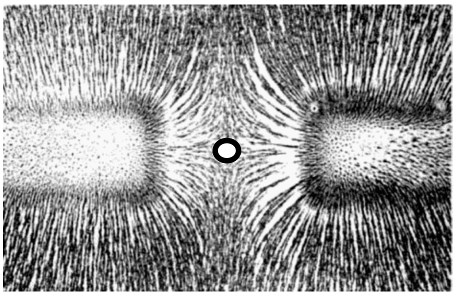


This method is best carried out on a piece of blank paper. The bar magnet is placed in the centre of the paper and the field is traced using a compass and pencil. A compass is best started at the edge of the North Pole. Once the compass is settled, place a small dot where the North pole of the compass is pointing. Move the compass so that the south end is lined up with dot that you just plotted and once again place another dot where the north end is pointing. If you continue this across the page the magnetic field line that you are plotting should end at the South Pole. To see the entire shape of the magnetic field you should start the compass at the north end in another position and repeat on both sides of the magnet.



The magnetic field can be also be 'seen' by using iron filing patterns. When iron filings are sprinkled on a piece of paper over a magnet, they become induced magnets and line up with the field.

Some common questions about magnetic fields

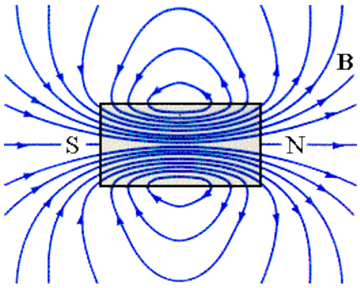


Q Explain what a neutral point is?

A position between two repelling magnets where the resultant field is zero

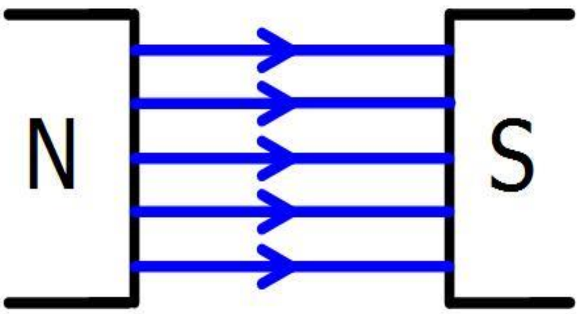
Q Do magnetic fields have a beginning and an end?

No, the field lines continue through the magnet forming a closed loop



Q Can magnetic field lines intersect?

No, they do not cross



Q How is a uniform magnetic field represented?

By parallel, equally spaced lines

Q How do you create a uniform magnetic field with two bar magnets.

If you place two bar magnets North and South poles facing then the region between the two poles will contain a uniform field.

Magnetic or not?

A bar magnet easily picks up nails, paper clips and iron filings, and we say that these are magnetic materials. On the other hand, a magnet has no observable effect on nonmagnetic materials such as wood or aluminium. The magnetic properties of a material depend on the magnetic field of its electrons. Common magnetic materials, called ferromagnetic materials, are iron, nickel and cobalt. There are more nonmagnetic metals that than magnetic.

Material	Magnetic	Non-magnetic
Copper		√
Steel	√	
Iron	√	
Tin		√
Aluminium		√
Nickel	√	
Brass		√
Magnesium		√
Zinc		√

The Earth's magnetic field is similar to that of a bar magnet tilted 11 degrees from the spin axis of the Earth. Circulating electric currents in the Earth's molten metallic core are the origin of the magnetic field.