West Norfolk Academies Trust

AQA GCSE PHYSICS

Knowledge Organiser

and

Required Practicals

Physics Knowledge Organiser
P1 - Conservation and dissipation of energy

Power

Going past measuring and describing energy transfers, we can consider how fast the energy transfer is (or, how fast the work is done). The rate (speed) of energy transfer is the **power**. The top two equations below show this.

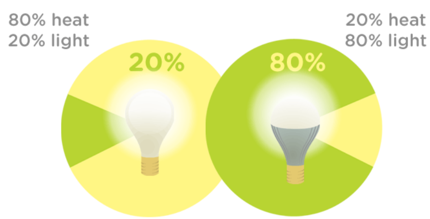
Two things might transfer the same amount of energy (do the same amount of work), but if one does it faster than the other, it has a higher power. For instance, if two people of the same mass run the same distance, they transferred the same amount of energy. However, if one of them completing it faster than the other, they had a higher power. (The 't' in the equation would be smaller, leading to a larger value for 'P'.)

Efficiency of Energy Transfers

As you know, energy cannot be created or destroyed, just transferred. It is often useful to measure how much energy is transferred in the way we want, and how much is dissipated. This measure is called **efficiency** (see equations). Since there is **always** some wasted energy, efficiency must always be less than 1, or less than 100% if you convert the efficiency to a percentage.

To improve efficiency, we reduce the energy transferred in ways that are not useful (i.e. reduce the wasted energy). In a simple example, the light bulb on the left wastes 80% (efficiency = 0.2 or 20%) of the input energy as heat energy, but the one on the right only wastes 20% (efficiency = 0.8 or 80%).

Similarly, the methods such as insulation or lubrication improve efficiency, since they reduce the energy transfer to wasted forms of energy.



Key Terms	Definitions
Power	Power is the **rate** of energy transfer – also known as the rate at which work is done. (Remember, energy transferred is the same as work done.) Since it is a rate, like speed, power is calculated by dividing by time (see equations).
Watt (W)	The watt is the unit for power. One watt is one joule transferred in one second – or 1 J/s (1 joule per second).
Efficiency	The measure of how much of the stored energy in a system is transferred usefully. More efficient devices transfer more energy usefully, which is the same as saying they waste less energy.

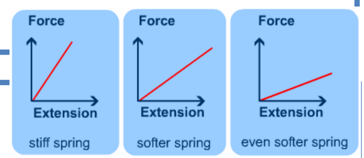
Equation	Meanings of terms in equation and units
$P = \frac{E}{t}$ *	*P = power (watts, W)* *E = energy transferred (joules, J)* *t = time (s)*
$P = \frac{W}{t}$ *	*P = power (watts, W)* *W = work done (J)* *t = time (s)*
$efficiency = \frac{useful\ output\ energy\ transfer}{total\ input\ energy\ transfer}$ *	*Efficiency doesn't have a unit. You can convert the efficiency (which will be a decimal) to a percentage by multiplying by 100.*
$efficiency = \frac{useful\ power\ output}{total\ power\ input}$ *	

Physics Knowledge Organiser
P1 - Conservation and dissipation of energy

Potential Energy

You already know how energy transfers take place when **work** is done. In these cases, energy is *changing form*. However, it is also possible for energy to be **stored** by an object or system. We call the stored energy **potential energy**. When something has potential energy, you won't be able to see anything going on, but if that energy is transferred to a new form, work will be done and you might be able to observe the results.

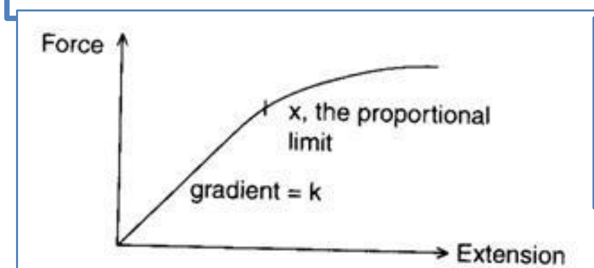
Chemical potential energy is an example: energy is stored in chemical bonds, and is transferred when a chemical reacts. Another example is gravitational potential energy – the energy stored by objects when they are above the ground in a gravitational field. Elastic potential energy is the form of energy stored by an object that is under **elastic deformation**. Think of a stretched rubber band – it isn't doing anything, but if you release it the stored elastic potential energy is transferred to kinetic energy, so you can fire it at someone.



Force and Extension/Compression

The extension of an elastic object, like a spring, is directly proportional to the force applied to it, provided the limit of proportionality of the spring is not exceeded. This also works with the compression of an object – you can use the equations below too, '*e*' just means the amount of compression. The **spring constant** measures how much extension you get for your force. A large spring constant means it won't stretch far compared to a spring with a small spring constant, if the same force is applied (see examples above). The spring constant can be calculated from the gradient of a graph of force against extension.

When force is applied to a spring, it moves a distance, so **work is done.** In other words, energy is transferred. The energy gets stored in the spring (or elastic object) as **elastic potential energy** ***(E_e)***. The amount of elastic potential energy is calculated by the equation shown on the right.



On graphs showing force against extension, you can see when the limit of proportionality is reached by looking at where the graph starts to curve. (Labelled x on this example)

Key Terms	Definitions
Elastic	Describes objects that return to their original shape after being deformed by a force, once the force is removed
Elastic deformation	Deformation (bending, stretching or compressing an object) is elastic if the object returns to its original shape once the force is removed
Deformation	Bending, stretching or compressing an object
Extension	The change in length of an object such as a spring. Subtract length when NO force is applied from the length when a force is applied.
Directly proportional	This term describes a type of relationship between two variables. The two variables are directly proportional if, for every increase of one variable by one unit, the other increases by the same amount. It is shown by a straight line on a graph that goes through the origin.
Limit of proportionality	The limit of a directly proportional relationship. It can be shown on a graph if the line is straight to being with (indicating a directly proportional relationship) then curves.
Linear relationship	Simply, a relationship between two variables that is graphed as a straight line.
Non-linear relationship	A relationship between two variables that is shown with a curved line on a graph.
Gradient	The gradient of a graph is how steep it is. Calculate gradient by dividing the change in the variable on the y-axis by the change in the variable on the x-axis.

Equation	Meanings of terms in equation
$F = k\,e$ *	*F = force (newtons, N)* *k = spring constant (newtons per metre, N/m)* *e = extension (metres, m)*
$E_e = \frac{1}{2} k\, e^2$	*E_e = elastic potential energy (joules, J)* *k = spring constant (newtons per metre, N/m)* *e = extension (metres, m) – this is **squared** in this equation*

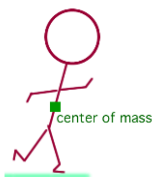
Physics Knowledge Organiser
P1 - Conservation and dissipation of energy

Weight

Weight is often mistaken for **mass**; for instance, when people say they are losing weight, they really mean they are losing mass. As a result, their weight will also drop (see equation), but really it is their mass they seek to change. Mass measures how much material there is (in kg), whereas weight measures the **force** acting on an object due to a **gravitational field**.

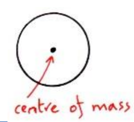
Looking at the equation, you can see that a person with a mass of 65 kg will have a weight of 65 x 10 = 650 N. You can also see that a mass of 100 g (=0.1 kg) has a weight of 1 N on Earth.

As the equation shows, weight and mass are **directly proportional**. We can show this like: $W \propto m$, using the symbol for a directly proportional relationship. On Earth, as mass increases by one unit, weight increases by ten units (as *g* = 10 N/kg).



Centre of Mass

When drawing force diagrams and performing calculations, it is useful to show the weight (or other forces) acting on just a single point on the object. This is the exact centre of a symmetrical object (it will be more complicated for an asymmetrical object), and is called the **centre of mass**. Think of the centre of mass as the point where we consider weight to act: as a result, force arrows should start on the centre of mass.



Measuring Weight

Weight can be determined by calculation using the equation, or directly measured using a **calibrated** (adjusted so the scale is right) spring balance – a newtonmeter. This can be mechanical or digital – a digital newtonmeter will likely have higher **<u>resolution</u>** (detects smaller differences in weight).

Key Terms	Definitions
Weight	Weight is different to mass. Weight is a **force** (hence, it is a vector quantity), caused by gravity acting on a mass. Since it is a force, it is measured in newtons.
Mass	Mass measures the amount of material in an object, and is measured in kilograms (kg). The weight of an object depends on the mass, but mass does not depend on weight. Mass is a scalar quantity.
Gravitational field strength	Simply, the measure of how strong the gravitational field of a large object is. For instance, the gravitational field strength on Earth is about 10 N/kg. This means that a weight of 10 N acts on each kg of mass on Earth.
Centre of mass	The point at which the weight of an object is considered to act – the 'middle' of the object's mass.
Newtonmeter	A device to measure weight. It simply consists of a spring and a calibrated scale.

Equation	Meanings of terms in equation
$W = m\ g$ *	*W = weight (newtons, N)* *m = mass (kilograms, kg)* *g = gravitational field strength (newtons per kilogram, N/kg) – on Earth, this is about 10 N/kg*

Physics Knowledge Organiser
P1 - Conservation and dissipation of energy

Power

You should recall that power is **the rate of energy transfer**, or the rate at which work is done. In electrical components, including any electrical appliance, the power relates to the potential difference across the component and the current through it. If either p.d. or current increases, the power increases. In other words, the rate of energy transfer increases. This should be clear from the first equation.

The second equation also finds the power. The equation comes from substituting in $V = IR$. The second equation is useful if you don't know the p.d. across a component.

Energy transfers in electrical appliances

The whole point of electrical appliances is to transfer energy. The electrical potential energy from the supply is transferred to something useful – such as light and sound in your TV. The other way of saying this is that **work is done** when **charge flows** in a circuit.

Some examples of energy transfers in electrical appliances:

- In your mobile phone, electrical potential energy from the dc supply (the battery) is transferred to light, sound and thermal energy. This means the energy from the battery is **dissipated** to the surroundings.
- A washing machine transfers electrical potential energy from the ac mains supply to kinetic energy in the electric motor (that's why it spins), along with heat. Eventually, all the energy of the input is dissipated to the surroundings.
- An electric heater transfers the electrical potential energy of the supply to thermal energy. The energy stored in the supply ends up stored in the air, the walls, the floor and so on around the heater: stored in the heat of the materials.

The amount of energy transferred by an appliance depends on the **power** of the appliance and the **time** it is switched on for. To find the amount of energy transferred, simply multiply the power of the appliance by the time it is on for (see third equation).

Furthermore, since p.d. is a measure of how much work is done per coulomb of charge, you can find out how much work is done (aka energy transferred) by a circuit by multiplying the charge flow by the p.d. (see fourth equation).

Key Terms	Definitions
Power	The rate of energy transfer. In electrical components, the power is found by multiplying p.d. by current.
Work	Transfer of energy.
Appliance	Any device that transfers electrical energy to other forms. The supply of electrical energy can be a cell, battery, or the mains ac supply.

Equation	Meanings of terms in equation
* $P = V\,I$	*P = power (watts, W)* *V = potential difference (volts, V)* *I = current (amps, A)*
* $P = I^2\,R$	*P = power (watts, W)* *I = current (amps, A)* *R = resistance (ohms, Ω)*
* $E = P\,t$	*E = energy transferred (joules, J)* *P = power (watts, W)* *t = time (seconds, s)*
* $E = Q\,V$	*E = energy transferred (joules, J)* *Q = charge flow (coulombs, C)* *V = potential difference (volts, V)*

High power, low power

The power of an appliance determines how much energy is transfers in a given length of time. If an appliance has a high power (e.g. a washing machine), it transfers lots of energy in a given time. If it has a low power (e.g. a lamp), it doesn't transfer much energy in a given time, in comparison.

The other way of looking at it is how long the appliance takes to transfer a given amount of energy, e.g. 1000 J. A washing machine will transfer the energy in a very short length of time, whereas a lamp will take much longer to transfer this energy.

Physics Knowledge Organiser
P1/2 - Energy transfer by heating

Energy Stores and Systems

A **system** is simply a small part of the universe that we choose to study. It consists of an object or objects, and we use systems to describe how energy changes in terms of how it is stored. Energy has to be conserved in a system, so it cannot be created or destroyed. However, it can change from one store to another, in an **energy transfer**.

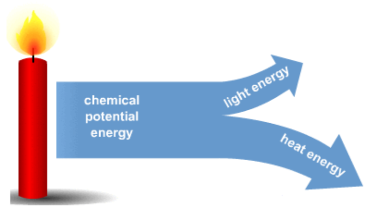
For example:
- Firing an object upwards transfers kinetic energy to gravitational potential energy
- When boiling water in kettle, electrical potential energy is transferred to thermal energy
- When using your phone, chemical potential energy is transferred to electrical energy, which is transferred to the surroundings, where it is stored as thermal energy.

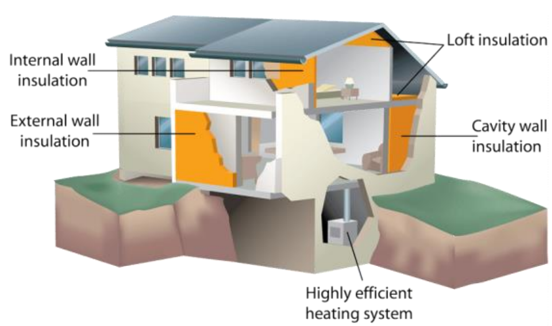
The amount of energy that a moving object has, the amount of energy stored by a stretched spring, and the amount of energy gained by lifting up an object can all be calculated. The equations for E_k, E_e, and E_p are on preceding pages.

Energy Transfers

In a system, the energy in the stores to start with can change form – we can say the overall energy in the system is **redistributed** – meaning it is transferred into other forms. In the end, the energy in the store is transferred to the surroundings. Often, the transfer to the surroundings is in the form of heat (thermal energy). With the candle example here, the chemical potential energy (energy store) is transferred to thermal energy, which is transferred to the surroundings in the end.

It is, in practice, very hard to go back the other way – for example, to transfer the heat energy from the candle back into chemical potential energy. This is what is really meant when people talk about 'saving energy' – overall, energy can't be destroyed so it can't be saved – but, we should try to save the energy stores we rely upon, such as fossil fuels (a huge store of chemical potential energy).





Key Terms	Definitions
Energy store	A system or object can act as an energy store. Energy allows work to be done (since work done = energy transferred). Good examples of energy stores are objects up high (they have gravitational potential energy), fuels (they have chemical potential energy), and stretched springs (they have elastic potential energy).
Energy transfer	The change of energy from one store to another. *Aka* work.
Dissipate	Simply, this means 'spread out'. When applied to energy being dissipated, this means that during energy transfers, some energy is stored in less useful ways. This can be called 'wasted' energy, since it is not transferred to form that is wanted.

Equation	Meanings of terms in equation and units
$\Delta E = m\,c\,\Delta\theta$	*ΔE = change in thermal energy (joules, J)* *m = mass (kg)* *c = specific heat capacity (joules per kilogram per degree Celsius, J/kg °C)* *$\Delta\theta$ = temperature change (°C)*

Unwanted Energy Transfers

During any energy transfer, energy can be transferred usefully, meaning that the stored energy is transferred in a way that does useful work. However, some **dissipation** of the stored energy, in ways that are not useful, is unavoidable. We call the energy transferred in this way 'wasted energy' – meaning unwanted energy transfers have taken place.

Unwanted energy transfers can be reduced by, for instance, oiling/lubricating moving parts (reducing friction, therefore transfer to thermal energy) or insulating systems.

Thermal insulation is insulation that reduces transfer of thermal energy to the surroundings. Thermal conductivity measures how rapidly thermal energy is conducted by a material (so, metals have high thermal conductivity). For effective thermal insulation, you want materials with very low thermal conductivity. The thickness of the material also affects the effectiveness of thermal insulation. Not surprisingly, the thicker the material, usually the better the insulation. Always a consideration in house building – see diagram for examples.

Physics Knowledge Organiser
P3 - Energy resources

Energy Resources

Don't get energy resources and stores of energy mixed up. Energy resources are energy stores that we know how to make use of for our needs, such as electricity. Stores of energy are the ways we find energy in objects or systems – e.g. chemical potential energy, gravitational potential energy, or thermal energy.

The main energy resources on Earth are: fossil fuels (oil, coal and gas); nuclear fuel; biofuel; wind; hydroelectricity; geothermal; tides; the Sun and waves in the sea. These all are stores of energy we can access and transfer usefully, usually to electrical energy. We can also use these energy resources for transport (especially fossil fuels) and heating (especially geothermal – although not in the UK!).

Using Energy Resources

Some energy resources are more reliable than others. For instance, as you may have noticed, the Sun as an energy resource (using solar panels) is not totally reliable in the UK. So we couldn't totally rely on the Sun as an energy resource. Fossil fuels are reliable for the time being, as the supply is good, but they are non-renewable, so this may change in the future. Fossil fuels are also relied upon for transport. This is changing, but still the vast majority of vehicles use fossil fuels as their energy resource.

Environmental considerations about the use of energy resources should also be made. For instance, the combustion of fossil fuels adds to greenhouse gases in the atmosphere, causing climate change. On the other hand, renewable methods like hydroelectricity involve building dams that may displace people and destroy habitats. There are always ethical factors to weigh up too. Although science can identify issues such as environmental problems, scientists are not politicians and big decisions to deal with issues are out of their hands a lot of the time. Political, social, ethical or economic factors also affect decisions made about the use of Earth's energy resources.

Key Terms	Definitions
Energy resources	Stores of energy on Earth that we can access and transfer to useful forms, such as electricity.
Nuclear fuel	Elements that can be used to release massive amounts of energy for generating electricity. Nuclear fuel is based on uranium.
Fossil fuel	A fuel, made from hydrocarbons, that formed millions of years ago from the bodies of animals and plants. Fossil fuels are a store of chemical potential energy.
Geothermal	The energy resource found in Earth's crust, due the thermal energy of the rock of the crust is certain places on Earth.
Biofuel	Any type of fuel made from the bodies of organisms – such as fuels made from plants.
Hydroelectricity	Water stored behind a dam has gravitational potential energy, so it is a store of energy we can make use of.
Tidal energy	Tides in the sea come in and out twice a day. This is a massive movement of water, whose kinetic energy can be transferred usefully to electrical energy.
Wave energy	Waves in the ocean have kinetic energy. With the right equipment, this energy can be transferred usefully to electrical energy.
Solar energy	The Sun is an abundant source of energy. Using solar panels, we can transfer light energy directly into electrical energy. We can also use the thermal energy from the Sun for heating and for generating electricity.
Electricity	A form of energy that we find extremely useful, since it can be used to run so many devices. We use the energy resources described here mainly (but not only) to generate electricity.
Renewable	Describes energy resources that are, or can be, replenished (replaced) as they are used. E.g. biofuels, geothermal.
Non-renewable	Describes energy resources that cannot be replenished. In other words, they get used up. E.g. fossil fuels, nuclear fuel.

Physics Knowledge Organiser
P4 - Electric circuits

Static charge

Every atom contains particles with an electric charge: protons and electrons. The electrons can be transferred from one material to another. When certain insulating materials are rubbed together, they both become charged because electrons are transferred from one material to the other.

- The material gaining electrons becomes negatively charged
- The material losing electrons becomes positively charged
- The size of the charge one each material is the same magnitude, but opposite in direction (+ vs -)

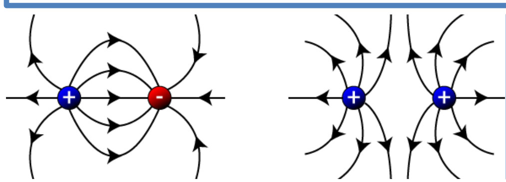
Electrically charged objects affect other charged objects. Like charges repel, whereas oppositely charged objects are attracted to each other. This is a **non-contact force**.

If there is a big enough difference in charge between two places, sometimes the charge can seem to 'jump'. This is seen as a spark. The charge does not, in fact, jump, but flows through the air, heating the air up enough to make it glow. This neutralises the charged objects, so is known as a **discharge**. In fact, this is the basic idea behind how lightning works.

Electric fields

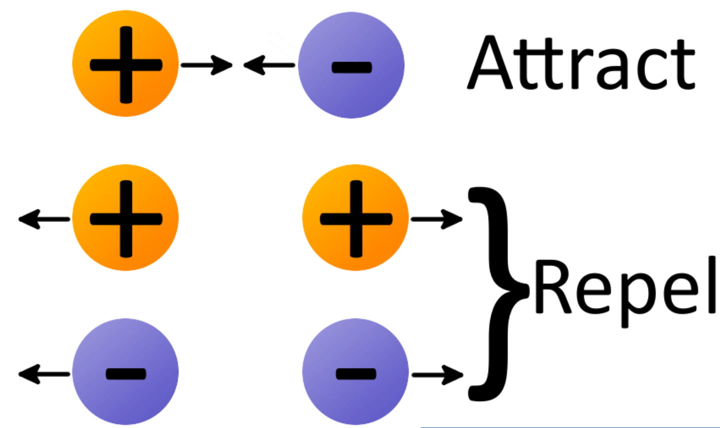
Any charged object produces an **electric field** around it, which extends in all directions away from the object. Other charged objects in this electric field are affected by it – either attracted or repelled as described above. The electric field gets weaker with distance from the charged object, which is obvious when you look at the diagram, right, because the **field lines** (the arrows) spread out going away from the charged object.

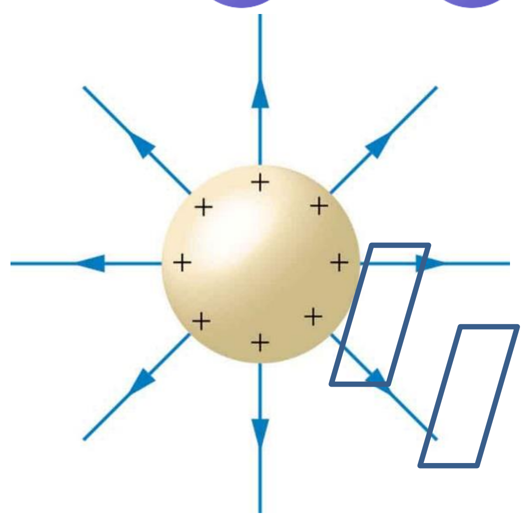
These field lines are not 'real things', but they represent the electric field. If you look at how many lines pass through a certain area, you can get a sense of the strength of the electric field. The more lines pass through the area, the stronger the field. When we say a field is stronger, it means it will exert more force on other charged objects. This concept of the electric field helps explain why electric attraction/repulsion is a non-contact force: the objects don't need to touch, but do need to be within each other's electric fields.



This diagram shows how field lines cause attraction between opposite charges and repulsion between like charges. Again, they don't need to touch to exert these forces on each other.

Key Terms	Definitions
Electric charge	Just a positive or negative charge!
Static	Not moving.
Insulator	Material that does NOT conduct electric current
Attraction	Being pulled together
Repulsion	Being pushed apart
Discharge	Movement of a charge from a charged object, making it neutral





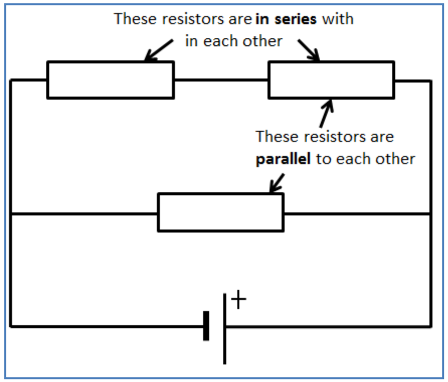
A charged sphere on its own (*isolated*). The arrows point the other way if the object is negatively charged. The rhombuses show how more lines cut through the same area if you are closer to the charged object. This indicates that the field is stronger closer to the charged object.

Physics Knowledge Organiser
P4 - Electric circuits

Series and parallel circuits

We can connect components in a circuit in series or in parallel. In some circuits, there are components in series AND components in parallel – see the example in the diagram.

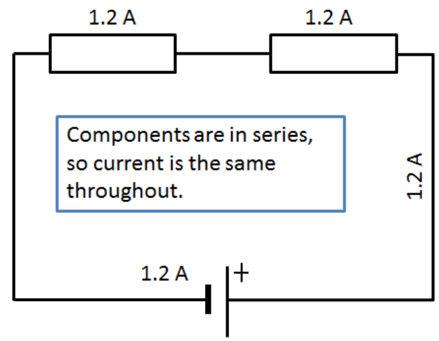
The quantities of resistance, current and potential difference behave differently in components connected in series compared to components connected in parallel. Study the table and diagrams carefully.

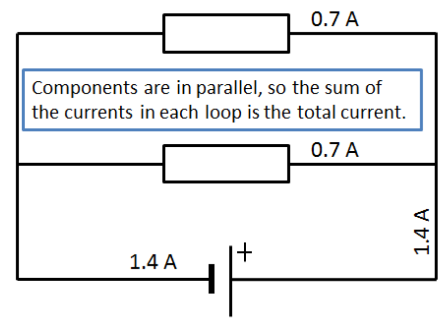


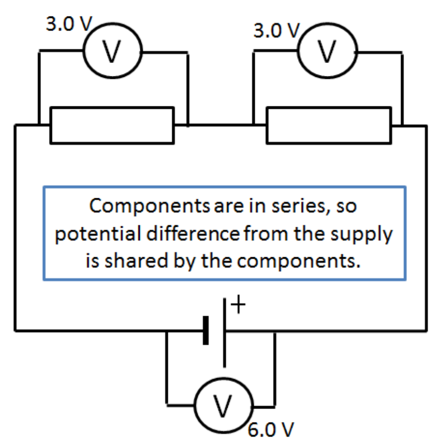
Key Terms	Definitions
Series	Components connected one after another in a closed loop.
Parallel	Components connected in different loops of a circuit.
Resistor	An electrical component that regulates current in a circuit. Bear in mind, all electrical components have **resistance**, so are resistors in some sense, as well as being e.g. bulbs.

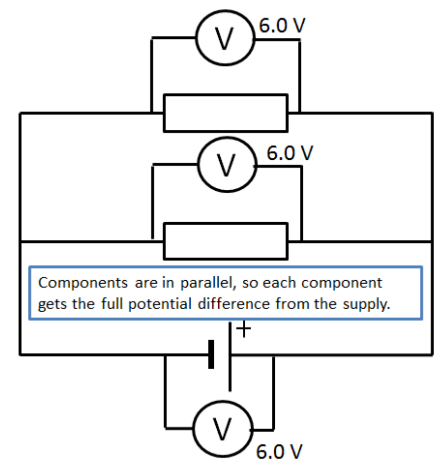
Equation	Meanings of terms in equation
for series circuits: $R_{total} = R_1 + R_2$ *	R_{total} = *total resistance (ohms, Ω)* R_1 = *resistance of first component (Ω)* R_2 = *resistance of next component (Ω) – and so on*

Quantity	Components connected in series…	Components connected in parallel…
Current	The current through each component is identical	Shared between the loops. The total current through the whole circuit is the **sum** of the currents through each loop of the circuit.
Potential difference	The potential difference provided by the power supply is shared between the components in series (not necessarily equally shared out – it depends on the resistance of each component).	Each loop receives the full potential difference provided by the power supply. If we are dealing with just two components in parallel, the potential difference across each is exactly the same, and exactly the same as the potential difference provided by the power supply.
Resistance	The total resistance of two components is the **sum** of the resistance of each component (see equation). So, adding more resistors in series *increases* the total resistance.	The total resistance of two components in parallel is always **less** than the smallest resistance of the components. As a result, adding **more** resistors in parallel actually *decreases* the overall resistance.









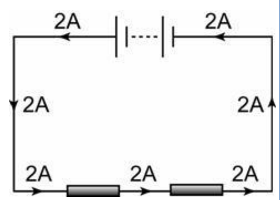
Physics Knowledge Organiser
P4 - Electric circuits

Electric charge and current

Every atom contains particles with an electric charge: protons and electrons. By getting electric charges to **flow**, we can get them to do work (i.e. transfer energy) in all sorts of useful ways. For that is what happens in any electric circuit you can think of: *flowing charges transfer energy*.

If we want to get electric charges to flow, we must make a **closed**, or complete circuit – a loop of conducting materials, like metal wires. Then, we must provide a source of **potential difference**. The source of potential difference could be a cell, battery or the mains. What these sources do is to create a *difference* in electrical *potential* energy – hence the name. This provides the force to make the **electric charges** in the conductors **flow**. When electric charges, like electrons, are flowing, we call it an **electric current**.

The size of an electric current is simply the **rate** of flow of electric charge.
So current (I) = $\frac{Q}{t}$ or $Q = It$



In a circuit, in any closed loop of the circuit, the size of the current is the same throughout the loop. As shown on the diagram, the current is the same in all parts of the loop, including through the battery and through the resistors.

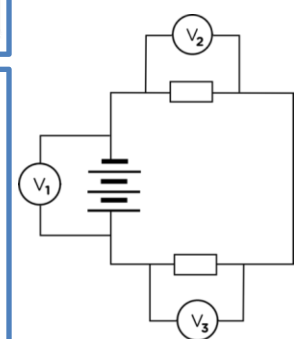
Current, resistance and potential difference

Cells and batteries etc. are **sources** of potential difference. This means they boost the potential energy of charges in a circuit. Other components, like resistors or bulbs, do **work** – so they take the potential energy of the charges and **transfer** it into some other form, like light or heat. In a circuit, all the energy provided by the cell/battery is transferred by the components in the circuit all together. So, in components like bulbs, the charges do work – i.e. they transfer energy. By definition, this means they have a potential difference **across** them. We say 'across' since it is a difference, from one side of the component to the other.

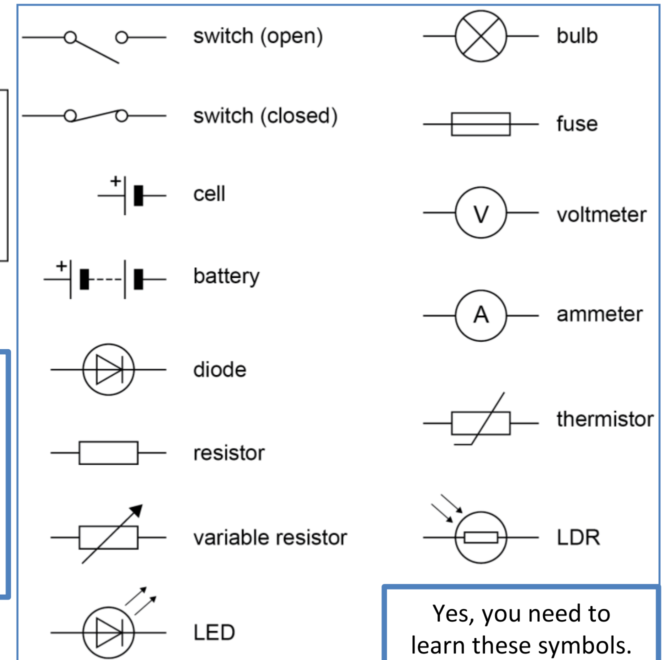
The current through a component depends on this potential difference across the component, but also its **resistance**. Without any resistance, a component would <u>do no work</u> (try putting a 0 in the equation!), so things like bulbs HAVE TO have resistance. The resistance of a component, along with the potential difference across it, determines the current through it, as shown in the second equation. It shows us that: if we keep the potential difference the same, but increase the resistance, the current must *decrease*. If we keep the potential difference the same, but decrease the resistance, the current must *increase*.

Key Terms	Definitions
Electric charge	Just a positive or negative charge! In most electrical circuits, the electric charges that are flowing are **electrons** – which are of course negatively charged. Symbol: Q
Current	The rate of flow of electric charge (i.e. speed). Calculated by dividing the size of the charge by the time. Symbol: I
Potential difference	Also known as voltage, or p.d.. The potential difference is a measure of how much work is done per coulomb of charge.
Resistance	Resistance determines the size of the current for a particular potential difference.

Equation	Meanings of terms in equation
* $Q = I\,t$	*Q = charge flow (coulombs, C)* *I = current (amperes, A)* *t = time (seconds, s)*
* $V = I\,R$	*V = potential difference (volts, V)* *I = current (amperes, A)* *R = resistance (ohms, Ω)*



Look how the voltmeters are added **across** the components to measure the potential difference across them.

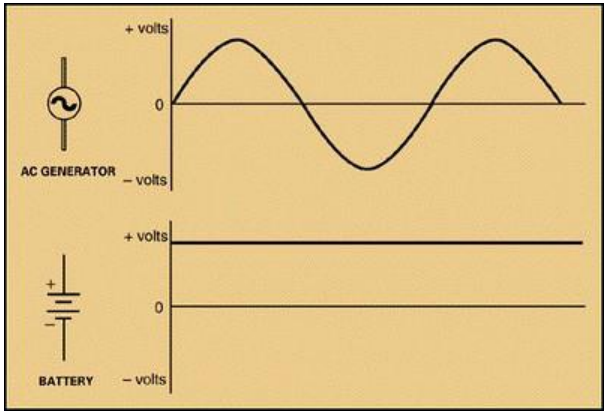


Yes, you need to learn these symbols.

Physics Knowledge Organiser
P5 - Electricity in the home

Direct and alternating potential difference

The flow of charge (current) in a circuit can travel in one direction around the circuit only. This is due to a **direct** supply of potential difference, also known as dc. Cells and batteries provide a direct potential difference. However, it is possible for the direction of the current to change back and forth in a circuit. This happens when there the supply provides an **alternating** potential difference – also known as ac. This means the p.d. is constantly switching from positive to negative, which you can see if you measure the p.d. and produce an image of is on an **oscilloscope**, as the diagram shows. The rate at which the p.d. switches from positive to negative is called the frequency of the supply. The bottom image, since the supply is a battery, shows a direct potential difference.



Three-core cables

We connect most electrical appliances to the mains with a three-core cable. The three pins on a plug are just the three ends, or terminals, of the three wires in the cable. Each wire in insulated in a different colour.

Mains electricity

Mains electricity (the supply into your house/school etc. that comes through the plugs) is an ac supply. In the UK, we have a supply with a p.d. of about 230V, and the frequency is 50 Hz.

Wire in three-core cable	Colour code of the insulation	Function
Live wire	Brown	Carries the alternating p.d. from the supply to the appliance
Neutral wire	Blue	Completes the circuit. The neutral wire is at 0 V (earth potential).
Earth wire	Yellow and green stripes	Earth wires are at 0 V. They are safety wires, and only carry a current if there is a fault and the appliance has become live (electrified).

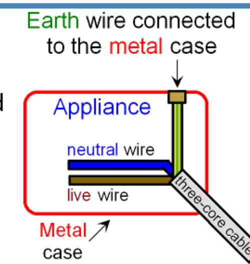
Key Terms	Definitions
Direct p.d.	A supply where the potential difference is fixed at a certain value, so the current flows in one direction only
Alternating p.d.	A supply where the p.d. switches between positive a negative, reversing the direction of the current frequently.
Frequency	The number of times the p.d. reverses direction every second. Measured in Hertz (Hz).

The national grid

The national grid connects power stations to consumers of the power – like you. It consists of a network of cables (i.e. power lines) and **transformers**. There are two types of transformers; together they improve the efficiency of the energy transfer from power station to homes and schools etc.:

1. Step-up transformers ***increase*** the p.d. from the power station to the transmission cables. This reduces the current so less energy is lost as heat.
2. Step-down transformers ***decrease*** the p.d. from the cables to a much lower value (230V, generally) for domestic use. This increases the current to suit electrical appliances used at home.

DANGER (and safety)



The earth wire carries current to the ground (literally, earth). This makes circuits safer because if there is a fault, it conducts the current to the ground rather than making the appliance 'live'. Appliances become live if the live wire touches the case. This is particularly a problem with metal-cased appliances, like cookers or toasters.

The live wire is the most dangerous one, since it is at 230 V. it should never touch the earth wire (unless the insulation is between them, of course!), because this would make a complete circuit from your mains supply to the ground (earth). A shock or fire would be highly likely.

Even if a circuit is switched off (i.e. the switch is **open**), the live wire can still be dangerous. If you touch it, you may complete a circuit between the live wire and the earth (because you'll be standing on the floor), so you get a shock.

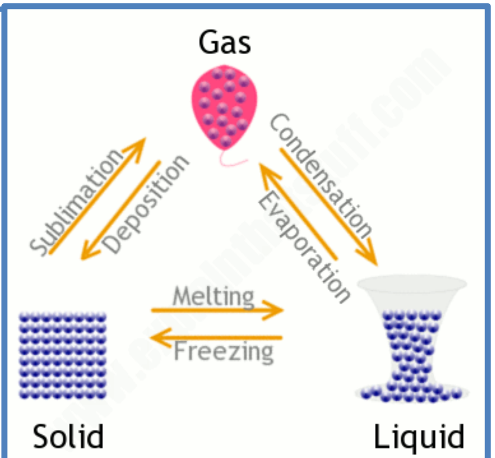
Physics Knowledge Organiser
P6 - Particle model of matter

States of matter and changes of state

Study the diagram. The particle model is used to explain differences between solids, liquids and gases, and to explain how changes from one state to another happen. Make sure you know how to draw the particles arrangement in each state, and know all the names for each state change shown on the diagram.

In a solid, the particles are **fixed in position** and only vibrate – they can't flow around. In a liquid, the particles are still **very close together** but they can **flow** past each other. In a gas, the particles move **randomly** and there is **empty space** between them.

In changes of state, no new substance is produced and there is no change in the **mass** of the substance. This is because no particles are created or destroyed.

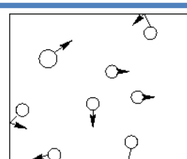


Density and the particle model

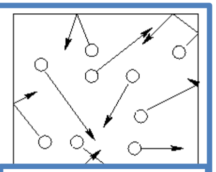
The particle model explains why 1 kg of a gas will have a **much** larger volume than 1 kg of a solid. This is because there is empty space between the particles in a gas, whereas in a solid, they are tightly packed together. Looking at the equation below, you should see that in this example the *m* is the same (1 kg), but the volume for the gas is much larger. Since we divide by volume, this must mean that the **density** of the gas is much smaller than the density of the solid.

Pressure in gases

Particles in a gas are constantly moving – so they store **kinetic energy**. They collide with the walls of their container, and exert a force when they do. The total force exerted on a certain area of the wall is the **gas pressure**.



Cooler gas – less kinetic energy



Hotter gas – more kinetic energy

The amount of kinetic energy that the particles have is related to the temperature of the gas. The higher the temperature, the more kinetic energy they have. This means they move faster, on average. Therefore, there are more collisions with the container walls and they exert a greater force when they collide with the walls. Thus, **increasing** the temperature of a gas (keeping the volume the same) **increases** the pressure of the gas.

Key Terms	Definitions
Model	Models are used all the time in science. A model represents the real world and can explain many things about the universe. However, models are never perfect and there are limits to what they can explain. That doesn't stop them being extremely useful though!
Particle model	The model that represents molecules or atoms as small, hard spheres. The important things to think about when using the particle model are the **arrangement** of the particles in each state of matter and the **kinetic energy** of the particles.
State of matter	The physical arrangement of particles determines the state of a particular substance: solid, liquid or gas. Changing from one state of matter to another is a physical process, NOT a chemical process. No new substance is produced, and if you reverse the state change, you have a substance with exactly the same properties as the stuff you started with.
Density	The quantity that defines how much material (i.e. mass) is in a certain volume. See equation. If you have two objects the same size but different densities, the more dense object will feel heavier in your hand as there is more mass in the same volume.
Melt/freeze	The change of state from solid to liquid/liquid to solid.
Evaporate/ condense	Change of state from liquid to gas/ gas to liquid.
Boil	Like evaporation, boiling is a change of state from liquid to gas. However, boiling involves heating of the liquid so it boils, rather than particles on the surface of the liquid becoming gas (like in evaporation).
Pressure	Pressure is caused by the force exerted by particles in a gas when they hit the walls of a container.

Equation	Meanings of terms in equation
$\rho = \frac{m}{V}$ *	*ρ = density (kilograms per metre cubed, kg/m^3)* *m = mass (kg)* *V = volume (metres cubed, m^3)*

Physics Knowledge Organiser
P7 - Radioactivity

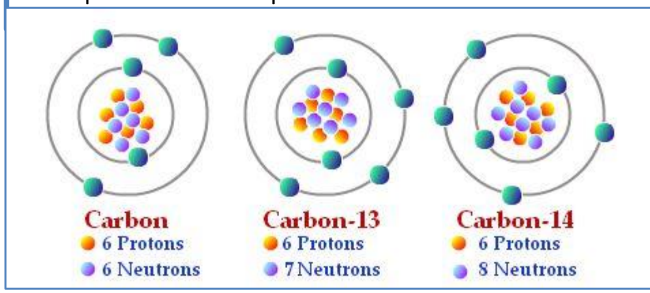
The structure of the atom and isotopes

You've already studied the structure of the atom – the small central nucleus surrounded by electrons – in the first chemistry topic. Go back and recap that first.

An important point about the shells, or energy levels, where electrons are found is that the energy level of an electron can *change*:

- Electrons move *up* an energy level with the **absorption** of a specific wavelength of EM radiation
- Electrons move *down* an energy level by **emitting** a specific wavelength of EM radiation.

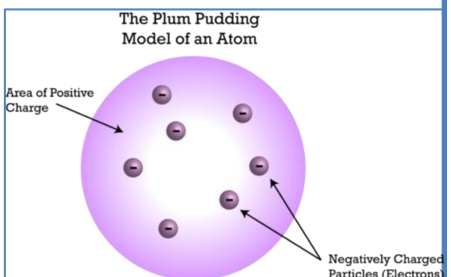
Atoms of a particular element always have the same number of protons (the atomic number in the periodic table). However, they don't all have to have the same number of *neutrons* to be the same element. If the number of neutrons varies between atoms of an element (but number of protons stays the same), we call the atoms **isotopes** of the element. Look at the diagram for the example of three isotopes of carbon.

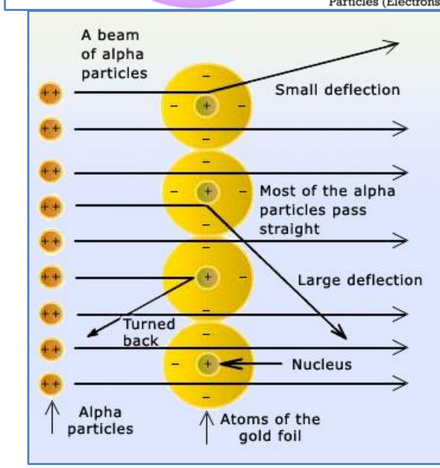


Radioactive decay

Some atomic nuclei are **unstable**. For instance, carbon-14 above is unstable. The nucleus will spontaneously and randomly change to become more stable. When the nucleus does this, it gives out nuclear radiation.

Since it is a random process, it is impossible to predict which particular nucleus will decay next. However, with a huge number of them, it is possible to measure the rate at which the whole source of radiation is decaying. This rate is measured in number of decays per second: the unit is the **becquerel (Bq).** One Bq = 1 decay per second. This can be measured with a detector called a Geiger-Muller tube – in this case, 1 Bq = 1 count per second.





Key Terms	Definitions
Isotopes	Isotopes of an element have the same number of protons but different numbers of neutrons in the nucleus.
Energy level	The other name for electron 'shells'. Each energy level is a specific distance from the nucleus and holds a limited number of electrons.
Radioactive decay	The process of an unstable nucleus becoming stable and giving out nuclear radiation in the process.
Nuclear radiation	Types of radiation that come from the nucleus of atoms during decay. Four types: alpha, beta, gamma, and neutrons.

How the modern model of the atom was developed

The model of the atom that you know all about has changed over time. Here's a brief timeline:

1. Before electrons were discovered, atoms were thought of as simply tiny, hard spheres that couldn't be divided into smaller particles.
2. Electrons were discovered (which are smaller than atoms!), so the model was modified. The **plum pudding** model of the atom was described: the atom as a ball of positive charge with negative electrons embedded in it like pieces of fruit in a pudding (see diagram).
3. A famous experiment by the scientists **Rutherford** and **Marsden** showed that the plum pudding model was wrong. Particles named **alpha particles** (more on these later) were fired at a sheet of atoms and some rebounded, some were deflected and others went straight through (see diagram). This showed that atoms have a hard, very small concentration of mass in the centre – which was named the **nucleus**. It also showed that the nucleus was charged, and we now know that is due to the protons in the nucleus. This model, that you use, is sensibly called the **nuclear model** of the atom.
4. The nuclear model was further developed to include the idea that electrons orbit at specific distances from the nucleus: in energy levels. The key scientist presenting this model was **Niels Bohr**.
5. Next, the nucleus was investigated further. It was found that the nucleus can be split up, producing particles with an equally-sized positive charge. These particles are named 'protons' – of course!
6. Then, in 1932, a scientist named **James Chadwick** proved that there were also uncharged particles in the nucleus. He called these particles 'neutrons' as they are neutral: no charge. This was about 20 years after the nucleus had already been accepted as the right idea about atoms.

Physics Knowledge Organiser
P7 - Radioactivity

Types of nuclear radiation

As you've seen, the rate of decay is measured in Bq, or can be measured as the count rate in Bq. What it actually 'counts' is the amount of radiation hitting the detector each second. The radiation emitted from the nucleus thanks to radioactive decay can be:

- An **alpha particle** (symbol: α). An alpha particle is made of two protons and two neutrons (making it identical to the nucleus of helium atoms). Since there are four subatomic particles in one alpha particle, it has a mass number of 4. Since there are two protons in an alpha particle, it has a proton number of 2.
- A **beta particle** (symbol: β). A beta particle is a high speed electron. Beta particles are emitted during a type of radioactive decay where a neutron turns into a proton. This process also makes an electron, and electrons aren't 'allowed' in nuclei, so it gets fired out.
- A **gamma ray** (symbol: γ). Yes, the same wave as in the electromagnetic spectrum. It has a very high frequency and very short wavelength.
- A **neutron** (symbol: n). An uncharged particle – you know all about them already.

Alpha, beta and gamma

As well as being different in form, alpha, beta and gamma are also different in terms of how they behave after emission from a nucleus.

Type of nuclear radiation	Range in air	Penetrating power	Ionising power
Alpha	A few centimet-res	Not very penetrating at all: absorbed by a thin sheet of paper.	Strongly ionising (as alpha particles are large and have a +2 charge)
Beta	A few metres	Fairly penetrating: completely absorbed by a sheet of aluminium 5mm thick.	Moderately ionising (as not as big as alpha particles and their charge is smaller, -1)
Gamma	Enormous distances	Penetrates most materials. Absorbed only by several metres of concrete or a thick sheet of lead.	Only weakly ionising.

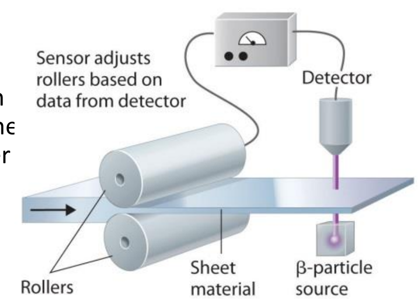
Key Terms	Definitions
Emission	Releasing or giving out. Nuclear radiation is **emitted** during radioactive decay.
Penetration	Passing through a material. Different types of nuclear radiation can penetrate different materials, and are absorbed by certain materials.
Ionisation	The process of making an ion by 'knocking off' electrons. Ionising radiation causes this, and can break up molecules into ions which go on to react with other chemicals. This is very dangerous in living organisms.

Using nuclear radiation

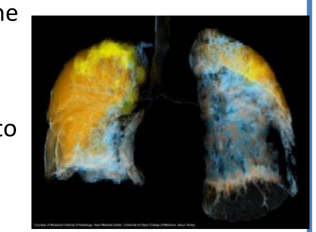
Nuclear radiation can be very useful. Here are some examples: notice that the type of nuclear radiation used depends on exactly what you need it for, so it links to the properties in the table opposite.

Radiotherapy: this is a treatment for cancer, using gamma rays. Gamma rays easily penetrate body tissues, so they can reach a tumour e.g. in the brain. The gamma rays can kill the cancer cells. However, since gamma rays are dangerous to healthy tissue, they use beams of gamma rays from many angles to the tumour, so healthy cells between source and tumour are not affected too badly.

Monitoring thickness of paper in a factory: As the diagram shows, a beta source is used. This is because beta will pass through materials such as paper. The detector on the other side of the sheet will measure a lower count rate if the sheet gets too thick, and a higher count rate if it gets too thin. The rollers can be automatically adjusted to fix this.



Medical diagnosis: sources of radiation can be taken into the body and the nuclear radiation monitored from the outside to give information about body function. Obviously, alpha is NOT suitable for this as it won't penetrate body tissues to get to the detector! For example, a radioactive xenon isotope can be inhaled to check lung function. On the image, the left lung isn't getting much air to the bottom parts.



Physics Knowledge Organiser
P7 - Radioactivity

Nuclear equations

To show what happens to an atom when it radioactively decays, we use nuclear equations. In these equations, we represent alpha and beta particles as shown in the key terms table.

Recalling what an alpha particle actually is (2 protons and 2 neutrons), it is clear that a nucleus going through alpha decay loses 4 subatomic particles (so the mass number has to **decrease** by *four*). Two of those are *protons*, so the *atomic number* must decrease by 2. Here's an example:

$$^{219}_{86}\text{radon} \longrightarrow {}^{215}_{84}\text{polonium} + {}^{4}_{2}\text{He}$$

This shows that a radon nucleus decays to produce a polonium nucleus and an alpha particle.

Beta decay results in a beta particle, and happens because a neutron turns into a proton and an electron. The electron is ejected from the nucleus. Since neutrons and protons have the same mass, the mass number does not change. However, there is an *extra proton*, so the atomic number must increase by one (therefore the charge of the nucleus increases by 1). Here's an example:

$$^{14}_{6}\text{carbon} \longrightarrow {}^{14}_{7}\text{nitrogen} + {}^{0}_{-1}\text{e}$$

This shows that the carbon nucleus decays to produce a nitrogen nucleus and a beta particle.

NB: emission of a gamma ray DOES NOT cause any change to the mass or atomic number.

Radioactive contamination

It is vital to realise that being exposed to nuclear radiation DOES NOT make something radioactive! (Despite what comic books show.) We say the exposed material/object is **irradiated**, and it is dangerous for living cells, as you know.

So, **radioactive contamination** is NOT being exposed to nuclear radiation. It means getting unwanted radioactive materials onto other materials. For instance, spilling a powdered radioactive source onto clothes. This is dangerous because the radioactive material keeps on emitting nuclear radiation through nuclear decay, so it can keep on irradiating the thing its on.

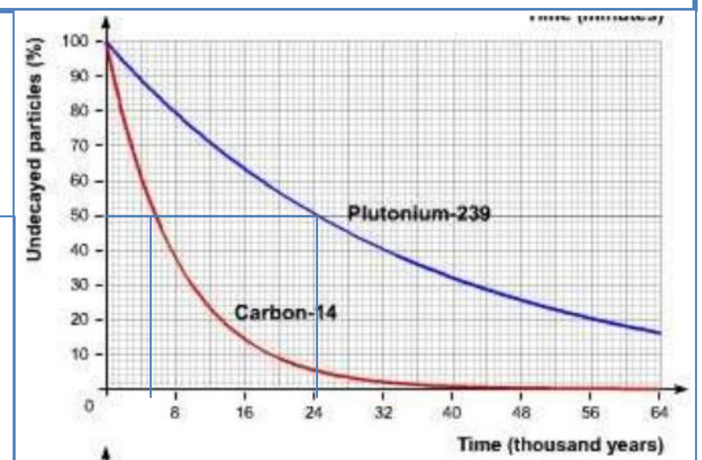
The hazards due to irradiation or contamination mean that *precautions* must be taken. For instance, the radioactive materials (e.g. uranium) used in nuclear power plant is only transferred, stored and used in containers that nuclear radiation can't penetrate. There is ongoing research by scientists into the effects of nuclear radiation on human health. Like all scientific findings, this research should be **published** and receive **peer review** – where other scientists check the methods and analysis performed, to make sure it is right!

Key Terms	Definitions
Mass number	The total number of subatomic particles in the nucleus of an atom (protons + neutrons).
Atomic number	The number of protons in the nucleus of an atom. In other words, the number of positive (+1) charges in the nucleus.
Alpha particle	Can be represented with the symbol: ${}^{4}_{2}\text{He}$
Beta particle	Can be represented with the symbol: ${}^{0}_{-1}\text{e}$
Half-life	The half-life of a radioactive isotope is the average time it takes for the number of radioactive nuclei to halve. It can be also be measured as the time it takes for the count rate of the sample to decrease to half its starting count rate.

Half life

Radioactive decay is **random** – so you don't know which nucleus will decay next. However, with a large number of radioactive nuclei, the time it takes for HALF of them to decay *is* predicable. This differs depending on the particular isotope involved. This length of time is called a **half-life** (see definitions too). Plotting the number of radioactive nuclei OR the count rate against time makes half-life easy to find. Read off the time it takes for the number on the y-axis to decrease by a half. So, in this example, we can see that the half-life of carbon-14 is 5.5 thousand years, whereas the half-life of plutonium-239 is 24 thousand years.

The y-axis could also show count rate (Bq) – the shape of the graph would be identical



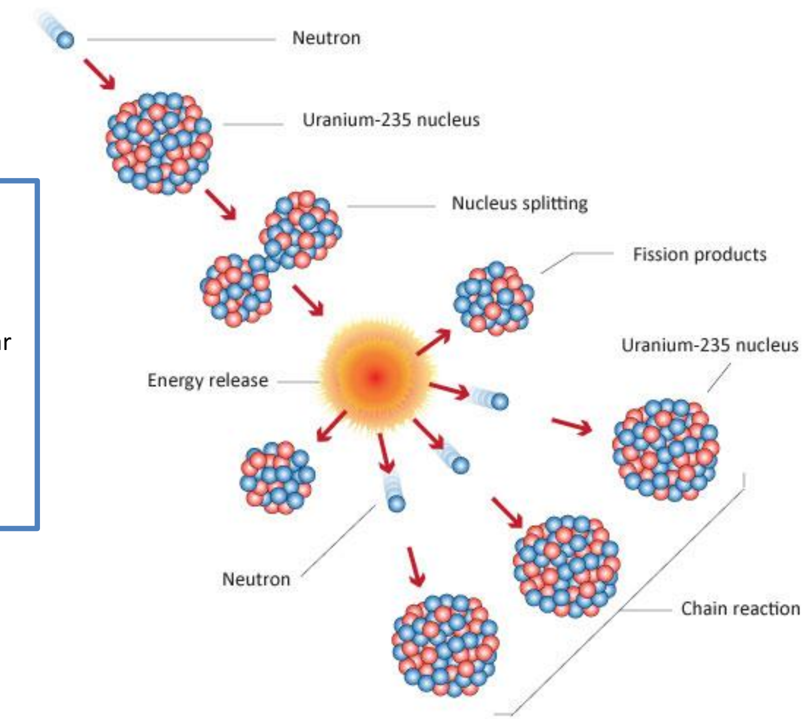
Physics Knowledge Organiser
P7 - Radioactivity

Key Terms	Definitions
Nuclear fission	Splitting of a large atomic nucleus into smaller nuclei, with release of energy
Chain reaction	A reaction where the first reaction starts another one of the same sort, which then sets off another reaction, and so on.
Uranium	Heaviest naturally occurring element (a metal). It has numerous isotopes, where U-235 can be used for fission in nuclear power stations. So it is nuclear fuel.
Nuclear fusion	Joining to two light atomic nuclei to form a new nucleus with higher mass number (i.e. a heavier element), with the release of energy.

Nuclear fission

When people say 'splitting the atom', they mean **nuclear fission**. Nuclear fission is the splitting of a large, unstable atomic nucleus. This rarely just happens spontaneously, but we can force it to happen by making a large, unstable atomic nucleus first absorb a **neutron**. Then it will split into two nuclei, but of smaller atoms. During this split, 2 or 3 neutrons will also be released, and gamma rays are emitted. LOTS of energy is released by this process – which is why it is used in nuclear power stations.

In nuclear power stations, the large, unstable nuclei used is usually uranium (but plutonium can also be split). The neutrons released by the fission of one nucleus can then be absorbed by other large, unstable nuclei. This is a **chain reaction** (shown in diagram). In nuclear power stations, some of the neutrons are absorbed to control the reaction and stop it getting out of control. In nuclear weapons, the chain reaction *does* get out of control, causing the massive explosion.

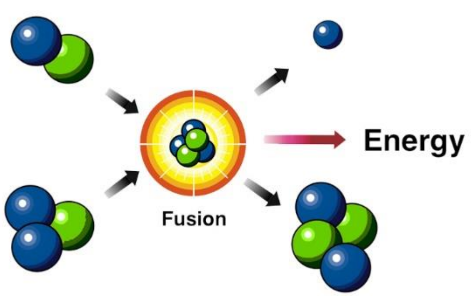


Nuclear fusion

Nuclear fusion involves small atomic nuclei, like hydrogen isotopes, joining – or *fusing* – together to make a heavier nucleus (such as helium). This occurs in stars. At the moment on Earth, this can be done, but not in a way that is any use for generating electricity, at least not yet. Very extreme conditions are required for nuclear fusion – extreme temperatures and pressures, which is why you only find it occurring naturally in stars.

An example of a fusion reaction is shown below.

Some of the **mass** of the fusing isotopes can be converted into energy, transferred by radiation.

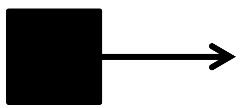
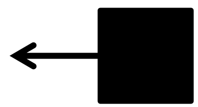


$${}^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{2}He + {}^{1}_{0}n$$

Physics Knowledge Organiser
P8 - Forces in balance

Representing Forces and Other Vector Quantities

Since forces are a vector quantity, it is useful to show their magnitude (size) AND direction using an arrow. The arrow points in the direction that the force acts, and its **length** shows the magnitude. For instance: in the first diagram, the force acting on the object is larger than in the second, and is opposite in direction.

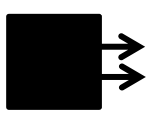
Contact and Non-contact Forces

Forces are always the result of objects **interacting** with each other. For instance, the force of gravity keeping this piece of paper on the desk is the result of the interaction between the Earth's mass and the paper's mass. All forces can be classified as contact or non-contact forces.

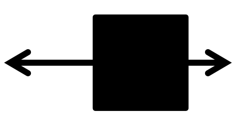
Examples of contact forces: friction, air resistance, tension, the normal contact force.
Examples of non-contact forces: gravitational force, electrostatic force and magnetic force.

The Resultant Force

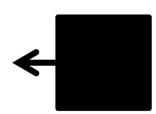
In real life, there are usually a few forces acting on any particular object. All the forces can be shown with vectors (arrows – see above). When we take all the forces into account, we can draw just one vector arrow to show a single force, which has the same effect on the object as all the other forces acting at once. This is simplest when the forces are in a straight line:



two forces are acting; by adding them we get the resultant force....



this time, the forces are opposite in direction, and are different in magnitude. We subtract one from the other to get the resultant force...

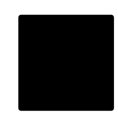


Key Terms	Definitions
Quantity	Anything that can be given a numerical value.
Magnitude	Size of a quantity. E.g. a distance of 5 metres has a higher magnitude than 2 metres.
Scalar	Describes quantities that only have a magnitude (size). E.g. speed (how fast something is moving).
Vector	Describes quantities that have a magnitude AND a specific direction. E.g. velocity (speed in a particular direction)
Force	A vector quantity. Forces are pushes or pulls that act on an object. Forces have size and direction. Forces are the result of objects interacting with each other.
Contact forces	For these forces to act, the interacting objects have to be physically touching.
Non-contact forces	For these forces to act, the interacting objects don't have to be touching (they are physically separate).
Resultant force	The single overall force acting on an object. It has the same effect as all the forces acting on the object all together. The resultant force is the vital thing in working out how an object will move. If there is a resultant force, the object's speed will change; or the shape of the object will change; or the direction of the object will change. If the resultant force is nothing (the forces cancel out), the object will keep doing what it was doing – either not moving at all, or moving along at a steady speed.

Resultant Force continued

If the forces acting on an object are equal in magnitude and opposite in direction, then the resultant force ends up being ZERO. You can say the forces are balanced. Reading the definition above should make it clear that a resultant force of zero means that an object's movement will not change. So if it was moving to start with, a resultant force of zero means it keeps moving at the same speed. Also, zero resultant force means the direction can't change.

The resultant force is.... nothing!



Physics Knowledge Organiser
P8 - Forces in balance

Work Done and Energy Transfer

'Work' has a particular meaning in physics. Whenever work is done, it means that energy has been transferred (in other words, energy has changed form). Work is always done as a result of a force acting on an object. The amount of work done is easily calculated: $W = F\ s$

For example, if a force of 1000 N makes this car move 200 m to the left…

The work done is calculated by: W = 1000 x 200 = 200 000 J
This means 200 000 J of energy was transferred.

Work Done Against Frictional Forces

When objects move, they are almost always moving *against* frictional forces – so the friction arrow is opposite to the direction of motion. As you know if you rub your hands together, doing work against frictional forces causes an energy transfer to heat (thermal) energy. This raises the temperature of the object (and the surrounding air!).

Remember, there are frictional forces even when an object moves through the air – often this is called air resistance (but it's just a type of friction).

The Joule

The joule (J) is the unit for energy, and therefore the unit for work done. It has a particular definition, based on the equation for work done. 1 joule = 1 newton metre. This means that 1 J is the amount of work done when a force of 1 N causes an object to move 1 m. This is because $W = F\ s$ and 1 = 1 x 1!

Distance vs. Displacement

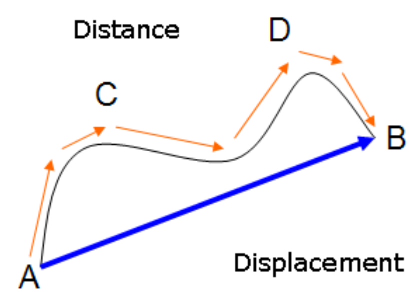
Displacement is different to distance because it involves the direction that an object has moved. The displacement is always measured in a straight line from start to end of a journey, missing out any wiggles along the way.

Key Terms	Definitions
Work done	The measure of how much energy is transferred when a force makes an object. You can say: 'a force does work on an object when it makes it move'. Doing work always involves the transfer of energy. This is a scalar quantity.
Joule	The unit joule (J) is how the amount of energy transferred by doing work is measured. 1 joule = 1 newton metre (thanks to the equation, below).
Distance	How far an object moves. It does not include direction , so distance is a scalar quantity.
Displacement	The distance an object moves from where it started. This is measured in metres. It is a vector quantity, because it includes the direction an object moved.
Friction	A contact force that results when two objects move past each other. They have to be touching.

Equation	Meanings of terms in equation and units
$W = F\ s$ *	*W = work done (joules, J)* *F = force (newtons, N)* *s = distance (metres, m) – aka displacement*

Distance vs. Displacement Diagram

Look how displacement is simply a straight line from A to B.
Distance is the total, with visits to C and D during the journey.



Physics Knowledge Organiser
P8 - Forces in balance

Newton's First Law

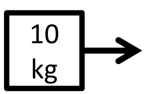
Read the definition. Newton's first law tell us:

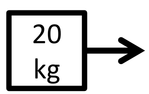
- Vehicles moving at a constant speed have a driving (push) force exactly equal to the resistive forces (like friction);
- Velocity (speed and direction) will only change if there is a resultant force acting (so the resultant force is NOT zero).
- If an object changed direction, it must have been because of a resultant force.

Newton's Second Law

Read the definition. This law follows on very sensibly from the first law. It reminds us that an object will only change in velocity (accelerate) if there is a resultant force acting on it. It also shows that the amount of acceleration depends on the resultant force and the mass of the object.

For instance, if a resultant force of 20 N acts on this object, the acceleration will be 20 / 10 = 2 m/s^2.





But with this object, the same resultant force only causes 20 / 20 = 1 m/s^2 acceleration.

Newton's Third Law

Read the definition. This law is often written as: 'for every action, there is an equal and opposite reaction'. In this version, action means the force exerted by object A on object B, and reaction means the force exerted by object B on object A.

This law explains why pushing **down** with your legs makes you jump **up** (the ground pushes back with the same size force as your push). It also explains why rockets can fly through space: the gases pushing out the back cause the rocket to move forward.

Key Terms	Definitions
Stationary	Not moving. The velocity is 0.
Newton's First Law	The law says that if the resultant force on an object is zero: ➢ Stationary objects stay stationary ➢ Moving objects keep moving at the same velocity (same speed and direction)
HT inertia	Inertia is the tendency of objects to stay at the same speed or stay stationary.
Newton's Second Law	Objects accelerate if there is a resultant force acting on them. The amount of acceleration is proportional to the magnitude of the resultant force and inversely proportional to the mass of the object. (see equation)
Proportional	Just like in maths: if the magnitude of one quantity increases because another quantity increases, they are proportional. The symbol is $\propto$.
Inversely proportional	The opposite of proportional: if one quantity **decreases** because another one increases, they are inversely proportional.
Newton's Third Law	This law says that when objects interact, the forces they cause to act on each other are equal and opposite.

Equation	Meanings of terms in equation and units
$F = m\,a$ *	*F = resultant force (N)* *m = mass (kg)* *a = acceleration (m/s^2)*

HT only: Inertial mass

Inertial mass measures how difficult it is to change the velocity of an object. It is defined as the ratio of force over acceleration.

For instance, it requires more force to slow down (change the velocity) a lorry compared to a bike. It also requires more force to make a lorry accelerate compared to a car.

Physics Knowledge Organiser
P8 - Forces in balance

Moments

Forces can cause rotation. There has to be a resultant force on a rotating object, because it rotation involves changes in direction! Even when pushing on a door, you are using an applied force to cause rotation of the door. The centre of rotation (the **pivot**) is the hinge of the door. The turning effect is called the **moment** of the force.

If an object is balanced (for example, a see saw or a shelf with stuff on it), in the system the **clockwise moment is equal to the anticlockwise moment**. Notice that this doesn't mean the forces are the same each way (unless the distance from the pivot is the same) – but you can calculate the moment and/or the forces involved using the equation shown.

Levers

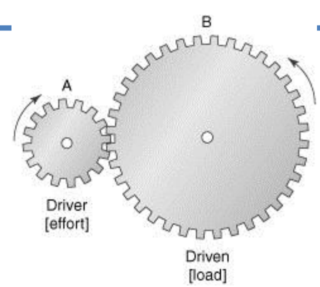
A lever is a simple system used to transmit a force. Levers can be distance multipliers or force multipliers.
Distance multiplier – this means the lever allows one end of the lever to move much further than where the force is applied, but this does reduce the force at that end. An example is a broom – see diagram.
Force multiplier – this means the lever is used to produce a larger force for the force applied, but this does mean the other end moves a smaller distance. A ring pull on a drinks can is an example – you apply a force at one end of the ring pull, the other end doesn't move as far but there is a big enough force to open the can. The pivot is in the middle.

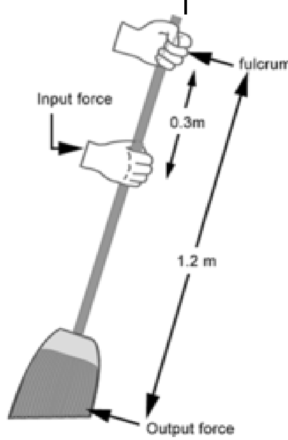
Gears

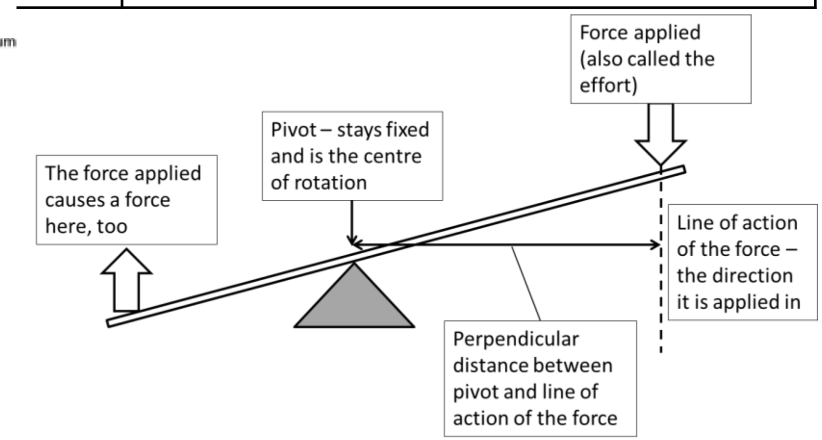
Systems with gears are force multipliers or speed multipliers. One gear is the 'driver', which is where the force is applied in the first place. Other gears are driven by this one – they can be connected directly like in the diagram or indirectly, like how gears are joined by a chain on a bike.
Force multipliers – if the driver gear (aka cog) is smaller than the one it drives, the force is multiplied. This is as shown in the example in the diagram.
Speed multipliers – if the driver is larger than the driven gear, the driven gear goes faster. So it's a speed multiplier.

Key Terms)	Definitions
Rotation	Turning motion
Moment	Full name: "moment of a force". This is the turning effect of a force
Pivot	The centre of rotation of a turning object. It stays in a fixed position while other parts move – for example, the hinges of a door.
Line of action	The line along which a force arrow points.
Clockwise moment	The turning effect of a force in the direction hands move around a clock face.
Anticlockwise moment	The turning effect of a force in the direction opposite to the way hands move around a clock face.
Lever	A simple system in which something turns around a pivot, and where a force applied is transmitted to somewhere else.
Gear	A simple system in which wheels transmit the turning effect of a force to somewhere else.

Equation	Meanings of terms in equation and units
$M = F\,d$ *	*M = moment of a force* (Nm) *F = force* (N) *d = perpendicular distance from the pivot to the line of action of the force* (m)







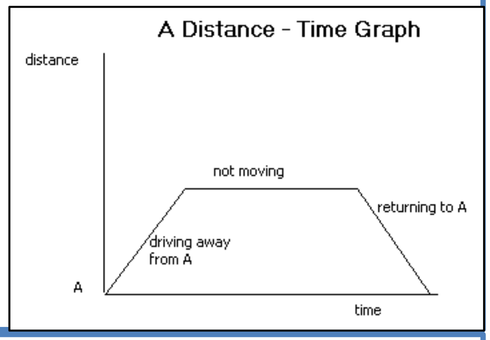
Physics Knowledge Organiser
P9 - Motion

Speed vs. Velocity

Speed and velocity are both quantities that measure the rate of change of distance, but velocity includes the direction. This makes velocity a vector quantity, so we can show velocity with an arrow.

Distance-time Graphs

A distance-time (DT) graph shows how far an object has gone from its starting point at a certain time.
A slope means the object is moving, because distance is changing as time changes. If the line of the graph is horizontal, the object cannot be moving because distance is not changing with time.
The gradient (steepness of the slope) tells you the speed of the object.

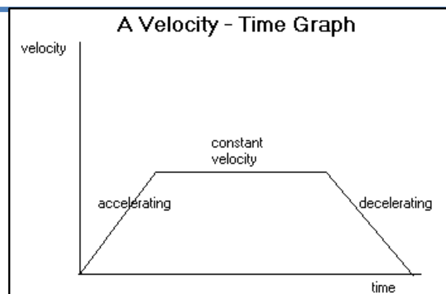


Acceleration

Acceleration is the measure of how quickly velocity changes. It is a vector quantity, because direction is included. (see equation)
Acceleration is shown on a DT graph by a line whose gradient *changes* – i.e. a curve, rather than straight line.

Velocity-time Graphs

A velocity-time (VT) graph shows the velocity of an object at any particular time on its journey. Using the gradient of a slope, you can find the acceleration.
The distance travelled during the journey is also shown on a VT graph – but you have to work it out by calculating the area under the line on the graph. Sometimes the area can be found by counting squares, other times you'll need to use area of a rectangle/ triangle to find the area and therefore distance.



The distance travelled is area under graph.
The acceleration and deceleration can be found by finding the gradient of the lines.

Key Terms	Definitions
Speed	The measure of how quickly distance changes. Speed does not include direction, so it's a scalar quantity. It is measured in metres per second (m/s).
Velocity	Velocity is a vector quantity. Like speed, it is a measure of how quickly distance changes BUT it includes the direction of movement. It is measured in m/s **HT**: moving in a circle, even if speed is the same, involves a constantly changing velocity because the **direction** is constantly changing.
Gradient	Gradient means slope. The gradient of a line on a graph is found by dividing the vertical (y-axis) change by the horizontal (x-axis) change.
Acceleration	Acceleration is the rate of change in velocity. It usually means speeding up, because we use the term **deceleration** for slowing down. You must recall that objects in freefall near Earth's surface have an acceleration of 10 m/s^2.
Deceleration	A **negative** acceleration – slowing down.

Equation	Meanings of terms in equation and units
$s = v\,t$ *	*s = distance (m)* *v = speed (m/s)* *t = time (s)*
$a = \frac{\Delta v}{t}$ *	*a = acceleration (metres per second squared,* m/s^2*)* Δv *= change in velocity (m/s)* *t = time (s)*
$v^2 - u^2 = 2\,a\,s$	*v = final velocity (m/s)* *u = initial (starting) velocity (m/s)* *a = acceleration (*m/s^2*)* *s = distance travelled (m)*

Freefall through a fluid (gas, like air, or a liquid)

Freefalling object initially accelerate due to gravity, but friction (/air resistance) increases with speed until the forces are balanced (resultant force = 0 N). Then, the object is falling at its **terminal velocity**.

Physics Knowledge Organiser
P10 - Force and motion

Momentum – *whole page is HT only*

Momentum is a property that any moving object has. It is defined as the product of mass and velocity of the object, so if the velocity is 0 m/s (stationary), the momentum is also 0.

Since momentum is calculated using **velocity**, which has a direction, momentum is a vector quantity. Just like with velocity, you can show the momenta (the plural of momentum) of objects moving in opposite directions by using a + sign for one of them and a – sign for the other.

Conservation of Momentum

Momentum is a property that is conserved in closed systems. This means the total momentum before an event is exactly equal to the total momentum after the event. This is called **conservation of momentum**. You can see conservation of momentum in action when objects collide (like snooker balls or cars in a crash) or when something stationary separates (e.g. firing a bullet from a gun or jumping off a stationary skateboard – it also explains why you should be very careful when jumping from a small boat onto the bank).

In this example: the boat is stationary at the bank, meaning its momentum is 0 kg m/s. When the person jumps out, they have a velocity and therefore a momentum. The boat **must** move away from the bank, since momentum is conserved (so must add up to 0 **after** the event too) so the boat has momentum in the opposite direction to the person – the boat moves away from the bank.

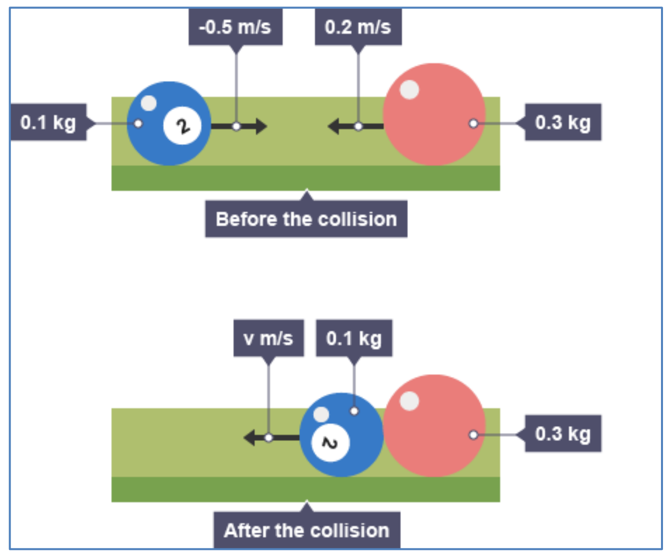
Conservation of Momentum in a Collision

Look at the diagram far right. The '2' ball has a negative velocity because it is moving in the opposite direction of the other ball. The total momentum before they collide = (0.1 x -0.5) + (0.2 x 0.3) = 0.01 kg m/s. According to the rule of conservation of momentum, the total momentum after the collision is also 0.01 kg m/s. Also, by looking at the diagram, you can see that both balls are now moving to the left, together. The total mass is 0.1 + 0.3 = 0.4 kg.

Rearranging to make velocity the subject, $v = \frac{p}{m}$,
v = 0.01/0.4 = <u>0.025 m/s</u> is the velocity after the collision.

Key Terms	Definitions
Momentum	A property of any moving object, calculated as the product of mass and velocity. Measured in kg m/s.
System	Systems are how physicists divide up the universe. Systems involve an object or objects and their interactions. They can be very simple (e.g. a falling object) or very complicated (e.g. our whole galaxy).
Closed system	A system where objects are not thought to be affected by external forces or other objects outside the system. We only think about the objects inside the system, which means the quantities *momentum* and *energy* are **conserved**.
Conservation	Simply means 'keeping the same.' To add detail, conservation of a quantity means that the total amount of it is the same before and after an event. In any closed system, the total amount of energy and momentum before and after an event is equal.

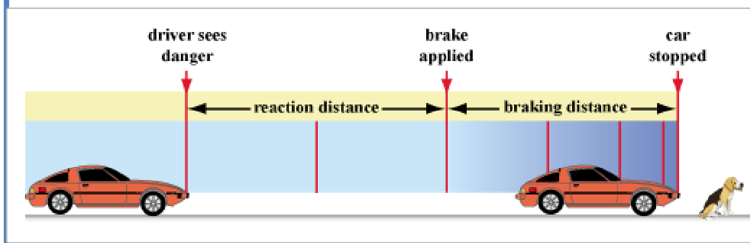
Equation	Meanings of terms in equation and units
$p = m\,v$ * HT only	*p = momentum (kilogram metres per second, kg m/s)* *m = mass (kg)* *v = velocity (m/s)*



Physics Knowledge Organiser
P10 - Force and motion

Forces and Braking

Stopping a vehicle requires a force to be applied, since the speed must change – the vehicle must decelerate to 0 m/s. The **stopping distance** of a vehicle depends on two factors, which add up to make the stopping distance. These are the **thinking distance** (distance travelled while the driver reacts) and the **braking distance** (distance travelled under the braking force).



Things which affect stopping distance

Thinking distance
(all these things are to with the drive)
drinking alcohol, taking drugs, tiredness, illness, not concentrating,

Braking distance
(all these things are to do with the car and road conditions)
worn tyres, poor brakes, wet roads, icy conditions, oil or grease on the road, etc.

For a particular braking force, the greater the speed of the vehicle, the greater the stopping distance. This is because going from a higher speed to 0 m/s is a bigger change in speed than going from a lower speed to 0 m/s. The thinking distance is longer at a higher speed, because reaction times won't change according to the speed – so you'd go further in the same time if you're going faster. Typical reaction times vary from 0.4 s to 0.9 s. Different factors affect the thinking and braking distances – see the box.

Braking Force and Work Done

When force is applied to the brakes, work is done by the friction force between the brake pads and the wheel. The **kinetic energy** of the vehicle is transferred to **thermal energy** – this is why brakes get hot.

To stop a vehicle in a certain distance, the faster the vehicle the larger the force needed, since a larger deceleration is needed (*F = ma* again). However, this can lead to overheating of the brakes and/or loss of control of the vehicle.

Forces cause a change in momentum

F = ma tells us a resultant force causes an acceleration. Substituting the equation for acceleration into *F = ma* gives you the equation above. It tells us that **reducing** the time taken to change momentum **increases** the force. This is why it hurts more to land on pavement than a trampoline. It also explains seatbelts, air bags, cycle helmets and cushioned tiles in playgrounds: all of these **increase** the time taken to slow to a stop, therefore **decreasing** the force acting on the object.

Key Terms	Definitions
Stopping distance	The distance a vehicle travels after the driver spots a danger and decides to stop. It is the sum of the thinking distance and braking distance.
Thinking distance	Distance travelled during a driver's reaction time.
Braking distance	Distance travelled while the driver is applying the brake (i.e. distance travelled under the braking force).
Kinetic energy	The form of energy of any moving object. Since the equation uses speed, not velocity, this is a scalar quantity.
Thermal energy	The form of energy associated with heat. The thermal energy of an object is proportional to its temperature.
System	An object or group of object, and its/their interactions.
Conservation of energy	A fundamental concept in physics. In a system, total energy is always conserved (it cannot be created or destroyed). However, it can be transferred from one store of energy to another.

Equation	Meanings of terms in equation and units
$E_p = m\,g\,h$ *	*E_p = gravitational potential energy (joules, J)* *m = mass (kg)* *g = gravitational field strength (newtons per kilogram, N/kg)* *h = height (metres, m)*
$E_k = \frac{1}{2} m\,v^2$ *	*E_k = kinetic energy (joules, J)* *m = mass (kg)* *v = speed (m/s) – this is **squared** in this equation*
$F = \frac{m\,\Delta v}{t}$	*F = force* (N) *m = mass (kg)* *Δv = change in velocity (m/s)* *[and remember m Δv is change in momentum]* *t = time (s)* ***NOTE: This equation can be stated as: "force equals the rate of change of momentum"***

Physics Knowledge Organiser
P12 - Wave properties

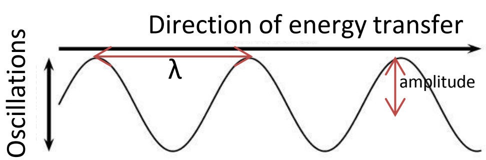
Types Of Wave

You can see waves easily in the sea, or if a tap is dripping into a sink of water. However, waves are far more common than just that. Waves can be **mechanical**, which means they involve particles moving, or **oscillating**, such as waves in the sea or sound waves in the air. Or, they can be **electromagnetic**, which don't involve any particles oscillating – instead, EM waves involve vibrations or oscillations of the electromagnetic field. All waves involve the transfer of energy.

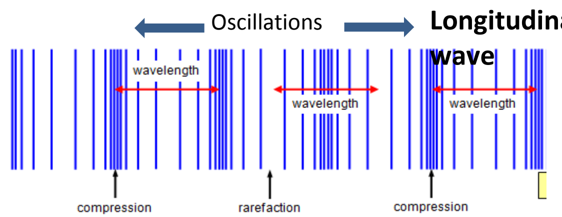
The other way of defining types of wave is whether they are **longitudinal** or **transverse**. Which one they are depends on the direction of the oscillations compared to the direction of energy transfer by the wave.

- In **transverse waves**, the oscillations are **perpendicular** to the direction of energy transfer.
- In **longitudinal waves**, the oscillations are **parallel** to the direction of energy transfer. They show areas of <u>compression</u> and <u>rarefaction</u> – see diagram.

Examples: ALL electromagnetic waves are transverse. Mechanical waves can be either longitudinal or transverse. For instance: sound waves are mechanical and are longitudinal. Ripples in water are mechanical waves, and are transverse.



Transverse wave

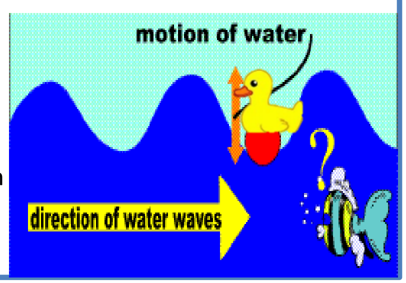


Longitudinal wave

Particles Don't Travel, But The Wave Does. Particles Just Oscillate.

An easy way to see that the particles aren't travelling but the wave is (so energy is being transferred): put a rubber duck in a tank of water where waves are moving across. The duck goes up and down, just like the water particles (oscillations perpendicular to direction of energy transfer, remember), while the waves move across.

With longitudinal waves, you can tell the particles aren't flowing either – just oscillate. When you speak, you don't breathe into someone else's ear! Also, when a tuning fork is vibrating to produce a sound wave, it doesn't create a vacuum around it due to air particles travelling away.



Key Terms	Definitions
Wave	A wave transfers **energy** from one place to another, and can also carry information. All waves involve movements or **oscillations**, allowing energy to be transferred **without** particles having to flow or travel from one place to another.
Oscillations	Vibrations or movements. These movements are of particles in **mechanical** waves, or of the electromagnetic field when it comes to **electromagnetic** waves.
Perpendicular	At right angles to.
Amplitude	The amplitude of a wave is the <u>maximum</u> <u>displacement</u> of a point on the wave from the undisturbed position. *Translated*: the distance from a peak or trough to the 'midline' of the wave.
Wavelength	The distance from a point on one wave to the equivalent point on the next wave along. This is easiest to measure at the distance from the centre of one area of compression to the next (longitudinal waves) or the distance from peak to peak (transverse waves). Symbol: λ
Frequency	The frequency of a wave is the number of complete waves that pass a point per second. Symbol: f
Period	The period, or time period, of a wave is the time it takes to complete a full wave. Symbol: T

Equation	Meanings of terms in equation
$T = \frac{1}{f}$	*T = time period (seconds, s)* *f = frequency (hertz, Hz)*
* $v = f\lambda$	*v = wave speed (m/s)* *f = frequency (Hz)* *λ = wavelength (metres, m)*

The Wave Equation

The equation is directly above. You could measure the speed of sound in air, with a long distance between you and a friend. They make a loud noise (you start your clock when you see them do it) and you time how long it takes to get to you. Just use distance/time to calculate the speed.

Physics Knowledge Organiser
P12 - Wave properties

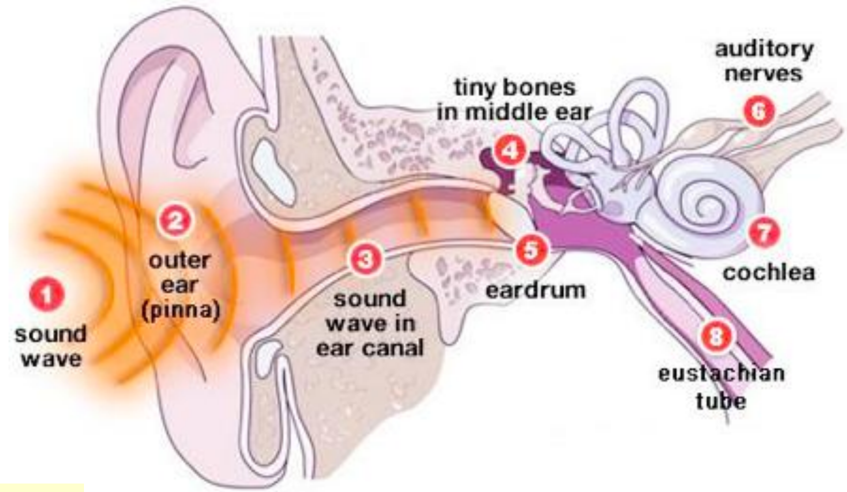
Sound waves

Sound waves a longitudinal waves caused by **vibrations** in matter. Sound waves can travel through solid, liquid or gas media, but not in vacuum because there is no matter (no particles) to actually vibrate.

We **hear** sound waves because the vibrations travel in the air into our ears, and cause the eardrum to vibrate. In turn, this transmits the vibrations to the inner ear where the vibrations cause electrical impulses, which travel along the auditory nerves to the brain. However, this conversion of vibrations in the air to vibrations in the solid of our eardrum only happens over a certain range of frequencies of vibration. As a result, some sounds are too low pitched for us to hear and some are too high pitched.

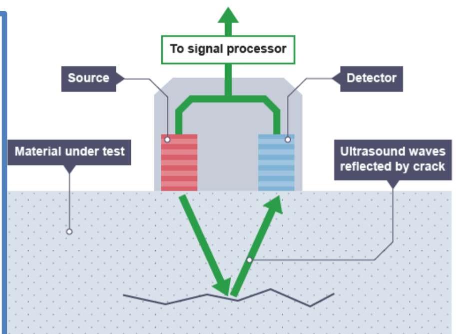
The human auditory range is 20 – 20 000 Hz. Sounds with a higher frequency than 20 000 Hz (20 kHz) are called ultrasound.

Key Terms	Definitions
Medium	Material a wave is travelling through (or being **transmitted** through). Plural = media.
Auditory	Anything relating to hearing or parts of the ear.
Ultrasound	Sounds too high in pitch to be heard (higher frequency than 20 kHz)
Seismic waves	Vibrations caused by earthquakes that travel through the Earth
P – waves	Longitudinal seismic waves
S – waves	Transverse seismic waves
Echo	Reflection of a sound (including ultrasound)

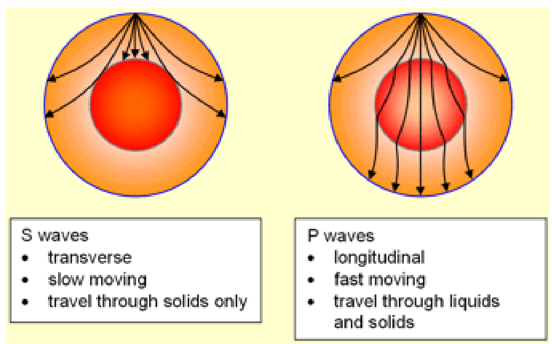


Using waves for detection and exploration...

Ultrasound is useful for <u>detection</u> – finding things that you can't directly see. It can be used for medical diagnosis (such as scans of a foetus), for finding things in a medium – e.g. cracks in a solid block, or shoals of fish in the sea, or where the bottom of the sea is. This works because ultrasound is **partially reflected** when there is a change in medium (some ultrasound waves continue through). By detecting the waves reflected – or echoed – back, you can work out how far away the boundary between the two media is. This can be calculated if you know the speed of the ultrasound and the time it takes to reflect back – use $s = vt$. See diagram.



Seismic waves are produced by earthquakes, and they can be detected. There are two kinds: S-waves and P-waves, with different properties, as shown on diagram. This is very helpful, because they provide evidence that there is a liquid outer core to the Earth, and evidence that the mantle is solid – fantastic news, because no-one can dig down to find these structures. So waves help us <u>explore</u> the deep structure of the Earth.



Physics Knowledge Organiser
P13 - Electromagnetic waves

Electromagnetic Waves (EM Waves): Producing Them

EM waves can be generated by changes in atoms or the nuclei of atoms. For instance, gamma rays are produced due to changes in the nucleus of an atom (nuclear decay – more on this in a later topic).

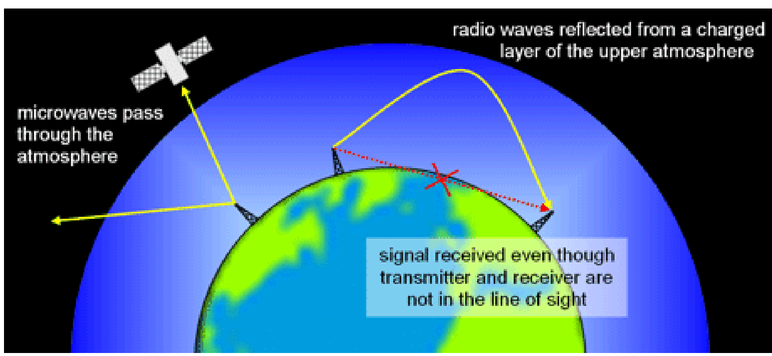
HT: radio waves can be produced by oscillations in electrical circuits. This is how a TV/radio broadcast is produced. It is received (e.g. by your TV aerial) by another electrical circuit; the radio waves create an alternating current with the same frequency as the radio wave itself. More on alternating current in the electricity topic – but it is enough to say for now that it involves oscillations.

Dangers Of EM Waves

Ultraviolet waves, X-rays and gamma rays are potentially dangerous types of EM waves, since they can have hazardous effects on human tissues. How severe the effects are depends on the type of radiation and the size of the **dose** received.

Doses of radiation are measured according to how great the risk of harm to the body is. The radiation dose, or danger due to **exposure** to radiation, is measured in **sieverts** (Sv).

A specific risk due to exposure to ultraviolet waves: they cause skin to prematurely age and increase the risk of skin cancer.
X-rays and gamma rays are **ionising** types of radiation. This means they can damage DNA, causing mutations and therefore increasing the risk of cancer.



Key Terms	Definitions
Radiation dose	The risk of harm due to exposure to radiation.
Exposure	Receiving and absorbing radiation (by the body).
Sievert	The measure of radiation dose. As with the usual prefix: 1000 millisieverts (mSv) = 1 sievert (Sv)
Ionising	Describes radiation that forms ions by 'knocking' electrons off atoms to make ions.
Cancer	Type of disease caused by specific mutations to DNA, resulting in cells dividing out of control (making a tumour).

Applications Using EM Waves

It is not exaggerating to say that EM waves dominate our technology and our lives. Here are some examples of the practical applications of EM waves:

- **Radio waves**: used for *television*, *radio* and Bluetooth. A signal carried by radio waves can get from a transmitting mast to a receiver by being reflected off a layer in the atmosphere.
- **Microwaves**: obviously, cooking food, but also communication with *satellites* and *mobile phones*; Wi-Fi internet. Unlike radio waves, microwaves can pass through the atmosphere (see diagram bottom left). In microwave ovens, the microwaves cause the water particles in the food to vibrate, heating it up.
- **Infrared**: electrical heaters, cooking food, infrared cameras. All objects emit infrared, but hotter objects emit more. An infrared camera detects infrared instead of visible light, so it can see hotter objects in the dark – night vision.
- **Visible light**: *fibre optic communication* (like the best broadband). Optical fibres reflect pulses of light all the way along their length. The pulses of light transmit the information.
- **Ultraviolet**: *sun tanning* beds… however, look at the dangers of UV in the other box.
- **X-rays**: both medical imaging for *diagnosis* (like broken bones) and medical *treatments*. X-rays can pass through soft tissue (like muscle), but not bone. That's why an X-ray image works to show up bones, and any breaks.
- **Gamma rays**: used in medical treatments such as radiotherapy.

Physics Knowledge Organiser
P13 - Electromagnetic waves

Key Terms	Definitions
Reflection	Rebounding of a wave from a surface. The angle between the **incident** (in-going) wave and the **normal** is the same as the angle between the reflected wave and the normal.
Refraction	Changing direction of a wave due to a change in the **medium** it is travelling through.
Absorption	'Taking in' energy from a wave and transferring it to another form, usually heat. For instance, you warming up if you lie in the sunshine (revising science, of course).
Transmission	A wave travelling through a material. Right now, visible light waves are being transmitted through the air to your eyes.
Media	*Singular 'medium'*. The medium is the material through which a wave travels.
Normal	A 'construction line' (made up line to help with diagram drawing) at right angles to a surface at the point where the wave hits the surface.

Electromagnetic Waves (EM Waves)

EM waves are always **transverse waves**. They transfer energy from the source of the waves to an **absorber** – object that absorbs the wave. EM waves occur all over the universe naturally, and we can produce them ourselves for all sorts of uses.

EM waves all travel at the **same velocity** through empty space (a vacuum) – at what we call the <u>speed of light</u>. However, the wavelength of EM waves varies from a few kilometres to wavelengths even smaller than an atom. The EM waves form a **continuous spectrum**, but for convenience we've grouped the infinite types of waves into seven groups of wavelengths, based on their properties. Learn the order of EM waves in the EM spectrum. Notice that a *longer* wavelength equates to a *lower* frequency and vice versa – this is clear from the wave equation.

Long wavelength → Short wavelength

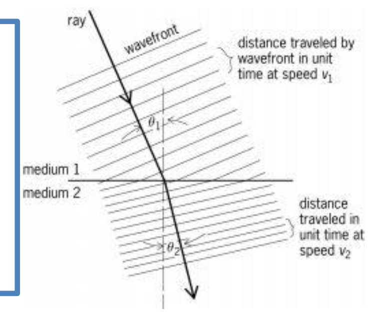
Radio waves	Microwaves	Infrared	Visible light	Ultraviolet	X-rays	Gamma rays

Low frequency → High frequency

Visible light is the only kind of EM wave we can detect with our eyes (hence the name). Thus, we can only detect a limited range of EM waves without special equipment. However, it is easy to understand examples of how EM waves transfer energy. If you are standing in front of a fire, you feel the warmth thanks to infrared. Getting sunburn is due to the transfer of energy by ultraviolet waves from the Sun. Using Wi-Fi means a transfer of energy by microwaves.

HT: More On Refraction

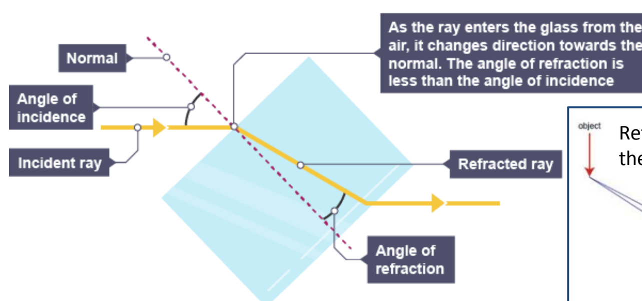
Refraction is due differences in the velocity of the waves in difference media. The diagram shown here represents the **wave fronts**. The wave slows down as it enters medium 2, but the near edge slows first. The other end is faster, as it is still in medium 1. This is what causes the 'bending' of the wave towards the normal.



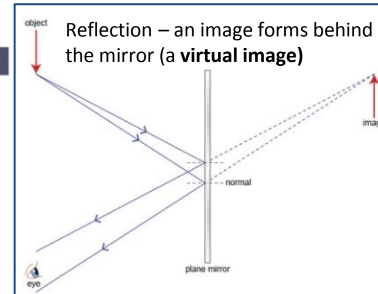
Properties Of EM Waves

All EM waves can be **reflected**, **refracted**, **absorbed** or **transmitted** *depending* on the wavelength of the EM wave and the **medium** they are travelling through, or surface they are reaching. Reflection is shown in the ray diagram far right – the <u>angle of incidence is equal to the angle of reflection</u> for any ray of light.

Refraction occurs when a wave changes the medium it is travelling through. Refraction is a change in direction of the wave, and it happens at the boundary, or junction, between the media – for instance, the surface of a sheet of glass would be the boundary between the glass and the air. You need to be able to draw diagrams to show refraction, like the example opposite. Notice that the light ray refracts *towards* the normal as it enters the glass (this is because it slows down), and refracts *away* from the normal as it leaves the glass (it speeds back up), ending up parallel to the original ray in air.



Reflection – an image forms behind the mirror (a **virtual image)**

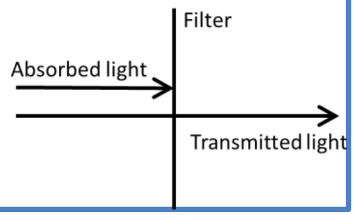


Physics Knowledge Organiser
P13 - Electromagnetic waves

Visible light

We can only see a miniscule proportion of the EM spectrum. The visible light part of the spectrum is divided into narrow bands of frequencies (and therefore wavelengths) that we see as different colours. We can separate mixtures of colours of light (e.g. white light, which is a mixture of all colours) using filters. These work by absorbing certain wavelengths of light by allowing others through (**transmitting** them). This is shown on the diagram.

The colour of an **opaque** object depends on which wavelengths of visible light it absorbs, and which it reflects. Whichever it reflects, that's the colour it looks. If it reflects all colours, the object looks white. If it doesn't reflect any, but absorbs them all, it looks black.

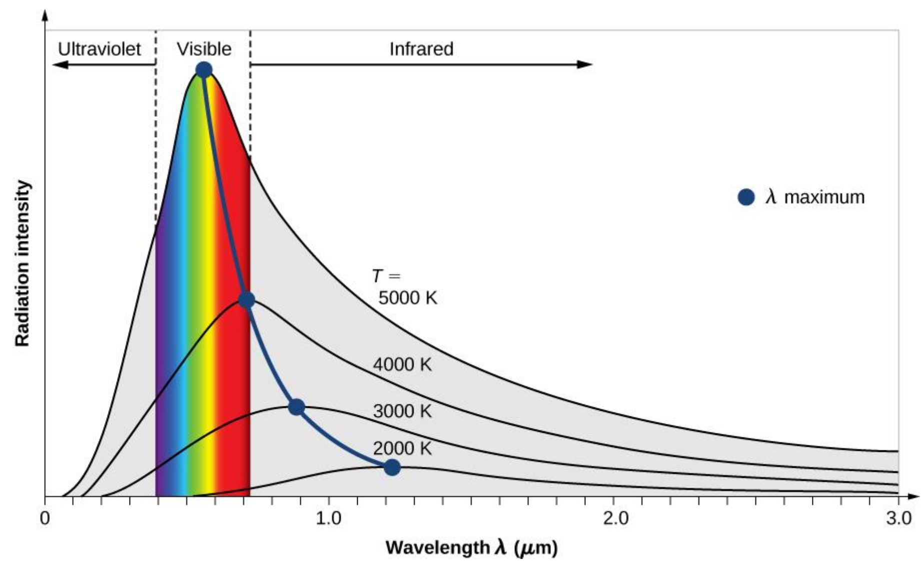


Infrared radiation

All objects (called 'bodies' in this topic!), at any temperature, will emit and absorb infrared radiation. The hotter the object, the more infrared radiation it radiates per second (or per minute, or whatever). The amount of infrared also depends on the colour of the object/body. Black surfaces are better absorbers and emitters than pale coloured surfaces. In theory (but not real life), there exist **perfect black bodies**, which absorbs ALL the radiation that hits it. These perfect black bodies would also be the best possible emitters of radiation. Although they don't really exist, black bodies are helpful models for understanding infrared radiation.

- Any body/object at a constant temperature is absorbing and emitting radiation at the same rate (because otherwise its temperature would change). If it absorbs radiation at a faster rate than it is emitted, then the body warms up.
- Increasing the temperature of a body increases the intensity of the radiation it emits increases (as already stated), but the intensity of the *shorter* wavelengths increases faster than the others (as shown on the graph). This is why, if you get something hot enough, it will glow with visible light.
- We can model the Earth as a black body, absorbing infrared radiation from the Sun and emitting it back into space. If this is in perfect balance, the temperature of the Earth stays exactly the same. Awkwardly, however, the emission of infrared radiation back into space is being disturbed somewhat by greenhouse gases.

Key Terms	Definitions
Specular reflection	Reflection of light from a smooth surface in a single direction
Diffuse reflection	Reflection of light from a rough surface in many directions. The light is 'scattered'.
Opaque	Object that is not transparent, so it does not transmit light. It reflects (some) light instead.
Transparent	Object that transmits all light wavelengths. See-through.
Translucent	Object that transmits some light, so not totally see-through, but partially.
Body	When talking about infrared radiation, we refer to objects as bodies.
Black body	A hypothetical perfect absorber and emitter of radiation.



Black body radiation

The graph shows the distribution of wavelengths of radiation emitted by a body at four different temperatures (shown on the Kelvin scale). The peak emission shifts into the visible part of the spectrum if the body is hot enough. At everyday temperatures, bodies don't glow because they simply aren't hot enough to emit in that part of the spectrum.

Physics Knowledge Organiser
P14 - Light

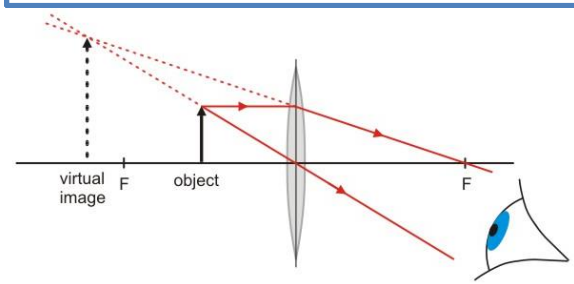
Lenses

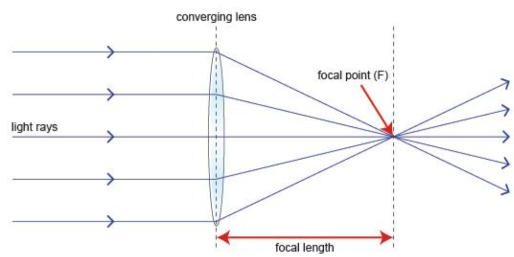
Lenses are curved bits of glass. They **refract** light coming from an **object** to produce an **image**. How the image looks depends on the type of lens and where the object is positioned relative to the lens.

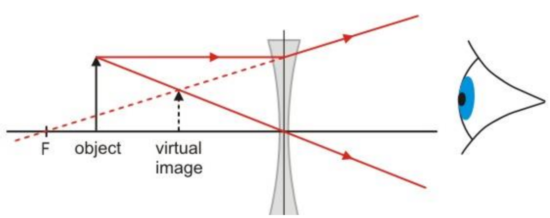
You can work out how the image looks (e.g. bigger/smaller than the object) by drawing ray diagrams, which are drawn to show the whole situation from the side. There are just a few simple rules to follow:

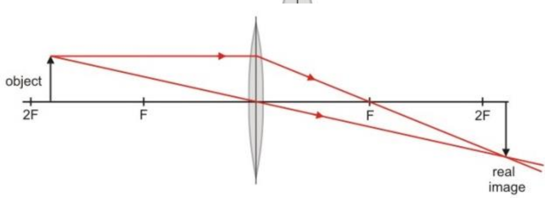
- To produce your **image**, draw rays of light from the top of the **object**. Two rays will do: wherever they cross is where the top of the image will be.
- The first ray goes from the top of the object through the centre of the lens. It does not refract, because this is already the shortest route through the medium.
- Draw the next ray from the top of the object to the lens parallel with the principal axis. At the lens, it refracts.
  - For a **convex lens**, the ray refracts to go through the focal point. Keep it going until it crosses the other ray. If it won't meet your first ray, a virtual image will form. Follow both of the rays back behind the lens until they cross – this produces a magnified virtual image.
  - For a **concave lens**, the ray refracts 'outwards' – it diverges. It should continue as though it came from the focal point, which is behind the lens. This makes it virtual – because it looks like it came from somewhere it didn't.

There are three example diagrams – you'll see they follow these rules.









Types of image

Images produced by convex lenses can be real or virtual, depending on where the object is placed relative to the lens. Images produced by concave lenses are always virtual, because the image forms from **diverging** rays.

Convex lenses magnify objects if the object is closer to the lens than the focal point. You already know about magnification, but you can work it out from ray diagrams too – measure the image and object height in matched units and divide. See equation.

Key Terms	Definitions
Lens	A curved piece of transparent material (like glass) used to produce images of objects.
Convex lens (symbol -)	A lens that is fatter in the middle than the edges. It causes parallel rays of light heading for the lens to refract so they come together at the **focal point/principal focus**. We say the rays of light **converge**. See diagram.
Concave lens (symbol -)	A lens that is fatter at the edges than the middle. It causes parallel rays of light heading for the lens to refract so they spread apart, or **diverge**.
Object	The thing you look at through a lens.
Image	The way the object looks when viewed through a lens.
Principal focus	The point near a lens where the rays of light converge (for a convex lens) OR the point where they look like they come from (for a concave lens).
Principal axis	Line through the middle of the lens. Rays of light travelling along the principal axis don't refract – they go straight through the lens.
Converge	Bring together.
Diverge	Spread apart.
Real image	An image produced by converging rays of light.
Virtual image	An image produced by diverging rays of light.

Equation	Meanings of terms in equation
$magnification = \frac{image\ height}{object\ height}$	*Magnification has no unit* *Heights must be in matched unit (e.g. mm)*

Physics Knowledge Organiser
P15 - Electromagnetism

Magnets

The <u>poles</u> of a magnet are where the magnetic forces are strongest. This is because the magnetic field lines are *most concentrated* at the poles, as you can see on the diagram below.

Magnets exert forces on one another when they are brought together: a **non-contact** force. If like poles (N-N or S-S) are brought together, the force is of repulsion. If unlike poles are brought together (N-S), the force is of attraction.

Magnets can be classified as **permanent** or **induced** (temporary). Permanent magnets have their own magnetic field, and it doesn't go away. Induced magnets are made when a material is placed in a magnetic field. (In most cases, this needs to be a magnetic material. The <u>only</u> magnetic materials are iron, steel, cobalt and nickel.) Induced magnets are always **attracted** to the magnet that turned them into a magnet – this is why you can pick up paper clips or nails with a bar magnet: the paper clip becomes an induced magnet with poles that are aligned so there is a force of attraction. See the poles labelled on the diagram. Induced magnetism is quickly lost when the material is removed from the magnetic field that induced it.

Magnetic fields

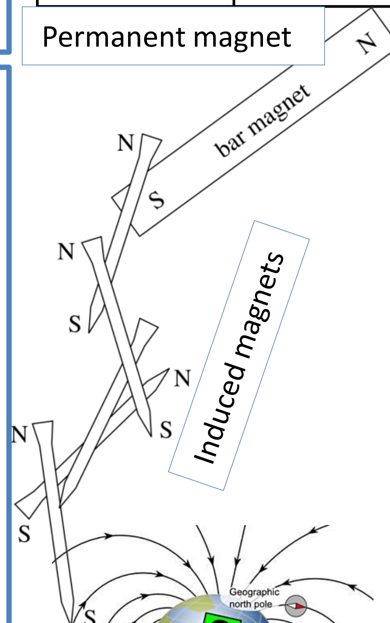
Magnetic fields are around all magnets (permanent or induced). The **<u>direction</u>** of the magnetic, as the diagram shows, is from **north** to **south**. The north pole of a magnet is properly defined as: *the pole that causes a force **away** from it, if a north pole is placed at that end.* This makes sense when you remember that like poles repel. So you can decide which end in north on an 'unknown magnet' by looking at the direction of the force that acts if a north pole (on another magnet) is brought to one end of your magnet. Repulsion (force away) means that end must be a north pole. Sometimes the north pole is called the **north seeking pole**, because it will point north on Earth if left freely suspended.

Magnetic fields are *strongest* at the poles and get weaker as the <u>distance</u> from the magnet increases. Using a **magnetic compass** (sometimes called a plotting compass), we can find out the direction of a magnetic field – the diagram shows how to do this.

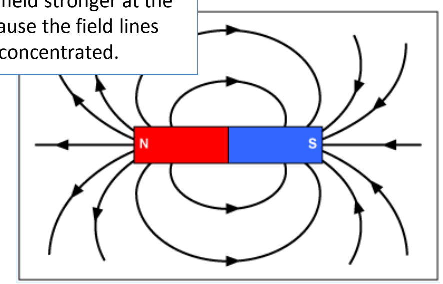
Earth has a **magnetic field**. Using a compass, you can tell that the magnetic field points towards the north pole (Santa's house), so this actually means that the geographic north pole of Earth is a south pole of a magnet! See diagram.

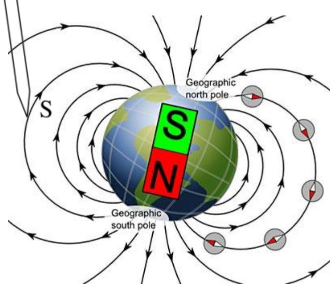
Furthermore, we know it is the **core** of the Earth that is magnetic (not the whole thing) because a compass at the north pole (in the Arctic circle) points down below your feet. It is worth realising, too, that the geographic north pole (the top of Earth's axis) is in a different location to 'magnetic north' – the latter is actually in northern Canada. So a magnetic compass actually wouldn't be much use if you were trying to get to Father Christmas's house.

Key Terms	Definitions
Permanent magnet	A magnet that always has its own magnetic field. Attracts magnetic materials, and can attract or repel other magnets.
Induced magnet	A temporary magnet: make one by putting a suitable material in a magnetic field.
Poles	The ends of a magnet. Named north and south, based on which way on Earth they'd point if suspended freely. The other name is 'north seeking' or 'south seeking' as a result.
Magnetic field	The region around a magnet where a force acts on other magnets or on magnetic materials. (3D, unlike diagrams usually show)
Magnetic compass	A small bar magnet balanced on a pin so it can spin around. Points towards Earth's magnetic north due to Earth's magnetic field, but can also be used to find the direction of a magnetic field for another magnet.

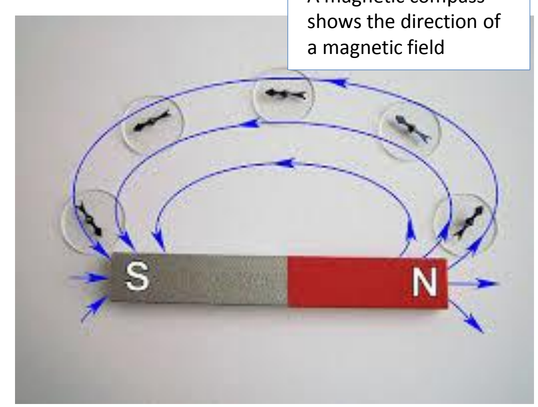


Magnetic field stronger at the poles because the field lines are more concentrated.





A magnetic compass shows the direction of a magnetic field



Physics Knowledge Organiser
P15 - Electromagnetism

Electromagnetism – current and magnetic fields

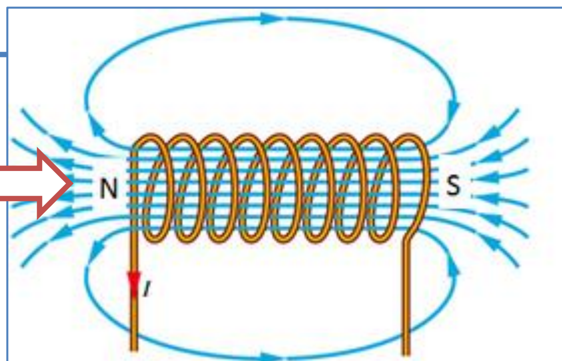
A wire that is carrying a current has a magnetic field around it. No current means no magnetic field, but switch it on and you get a magnetic field. As the diagram shows, switching the direction of the current switches the direction of the magnetic field. Also notice that the magnetic field gets stronger as you get closer to the wire carrying the current – this is shown by the field lines getting closer together (more concentrated).

Not surprisingly, increasing the current increases the strength of the magnetic field. You can easily check the *direction* of the magnetic field with a magnetic compass, just like with bar magnets. We can dramatically increase the strength of the magnetic field by winding the current-carrying wire into a coil called a **solenoid**. Even with the same size current, the magnetic field is stronger in a solenoid. Once you've made a solenoid, notice that the magnetic field is very similar in shape to the magnetic field of a bar magnet – it has a north and south pole, and it strongest at the poles. The magnetic field is also strong *inside* the coil – as the concentrated field lines show.

We can increase the strength of the magnetic field even further by putting a magnetic (e.g. iron) **core** in the solenoid – literally a cylinder of iron. We call this an **electromagnet**. (see diagram)

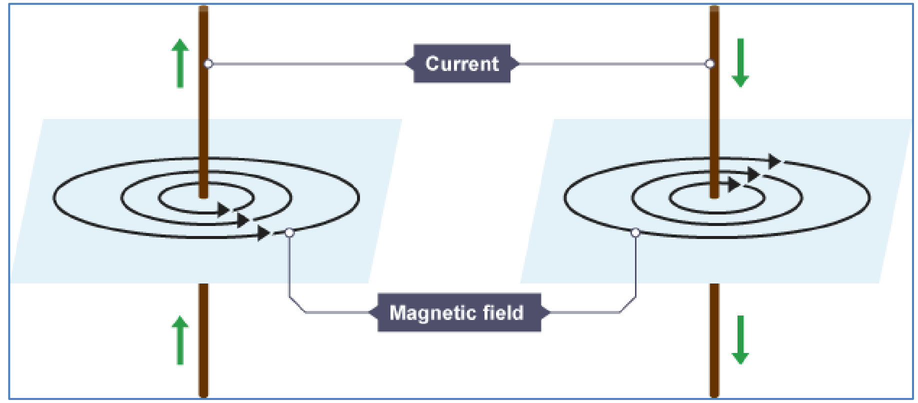
You can make an electromagnet **stronger** by:
- Increasing the **current** in the wire (probably by increasing the potential difference of the power supply)
- Increasing the **length** of wire in the solenoid – perhaps by adding more turns to the coil of wire.

A north pole, since another north pole brought to this end would be repelled.

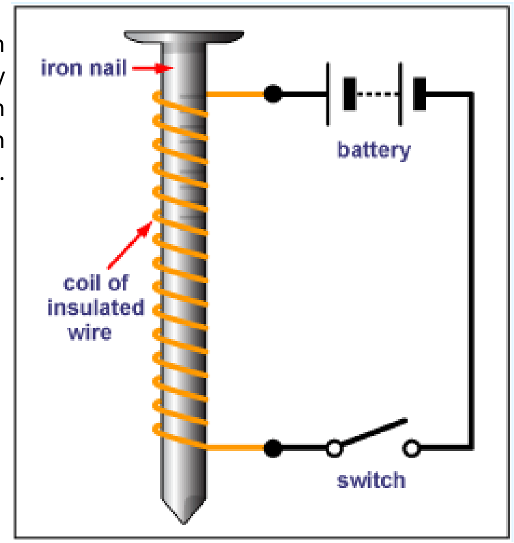


Solenoid

Key Terms	Definitions
Current	The rate of flow of charges in a circuit. If a current is flowing in a component, charges (e.g. electrons) are flowing through it.
Solenoid	A coil of wire.
Iron core	A piece of iron placed in the middle of a solenoid.
Electromagnet	A coil of wire with an iron core



In school, an iron nail is an easy choice for the iron core of an electromagnet.



Physics Knowledge Organiser
P15 - Electromagnetism

Fleming's left hand rule and the motor effect

If you have a current-carrying wire and a permanent magnet, each have their own magnetic fields. This means that if you put them near each other, there'll be a force acting on each other – just thanks to magnetic attraction or repulsion. This is called the **motor effect**. You can work out the direction that the force acts if you know the direction of the magnetic field and the direction of the current – we use **Fleming's left hand rule**. It has to be your left had to work. Hold it as shown, and you can work out the direction of whichever thing you don't know. You have to think in three dimensions here. You can twist your hand at the wrist to get it right – confirm using the example of the wire cutting through the magnetic field in the diagram – field from N to S with first finger, current with middle finger pointing downwards, meaning force must be out of the page towards you, like the diagram shows.

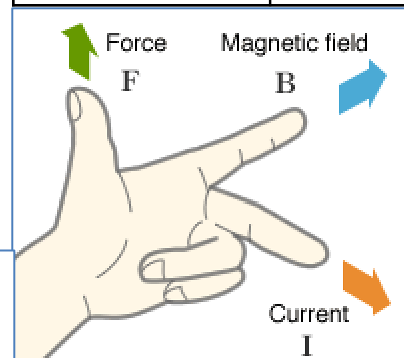
Now, the size (or *magnitude*) of the force on the conductor (the bit of wire) depends on three factors:

1. The **length** of the wire in the magnetic field, measured in metres
2. The **strength** of the magnetic field (formally, the **magnetic flux density**, in teslas, T)
3. The **size** of the **current** (A, as usual).

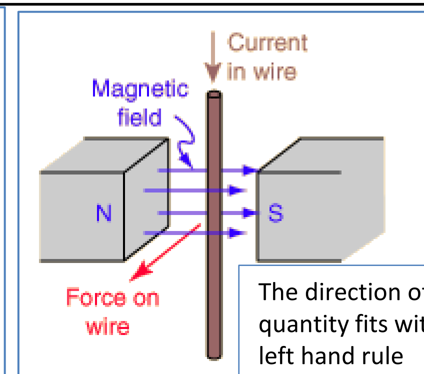
As the equation shows, increasing any or all of these factors will increase the size of the force on the conductor. [NB this equation only applies when the current and magnetic field are at right angles to each other]

Key Terms	Definitions
Motor effect	The forces exerted on each other by a wire carrying a current and a magnetic field, thanks to the two magnetic fields interacting.
Magnetic flux density	A measure of the strength of a magnetic field – think of it as the number of magnetic field lines going through a set area – see diagram to help explain.
Electric motor	Device that causes rotation of a coil of wire carrying a current when it is placed in a magnetic field.

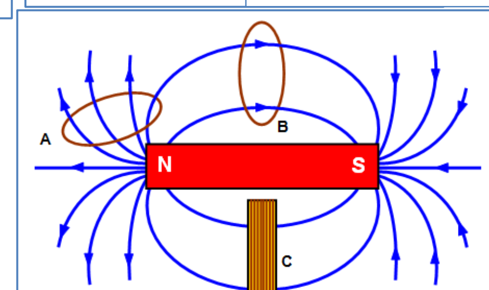
Equation	Meanings of terms in equation
$F = B I l$	*F = force (newtons, N)* *B = magnetic flux density (tesla, T)* *I = current (amps, A)* *l = length (m)*



Fleming's left hand rule. FBI – easy to remember!



The direction of each quantity fits with the left hand rule

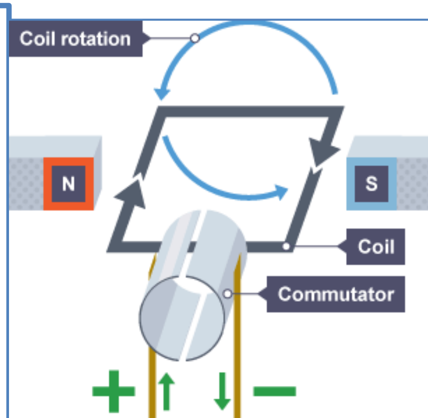


Magnetic flux density is larger at A than B since more magnetic field lines cut through a given area (shown by the oval).

Electric motors

Electric motors make use of the motor effect. A coil of wire carrying a current is placed in a magnetic field; as you know, the magnetic fields interact to cause a force each other. If the coil is set up so it can spin, it most certainly will. In fact, it will spin round and round (**rotate**). This is thanks to the force acting **up** on one side of the coil, and **down** on the other – see the diagram and use Fleming's left hand rule to understand why…

The magnetic field goes from N to S of course, and the arrows on the coil show the direction of the current. So, the left side of the coil has a force **downwards** exerted on it (use the left hand rule). The right side of the coil has a force **upwards** exerted on it, so it rotates as shown. (NB the commutator just allows the coil to spin without the wires getting tangled up!)



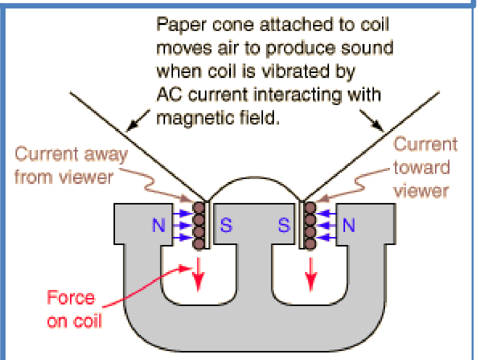
Physics Knowledge Organiser
P15 - Electromagnetism

Key Terms	Definitions
Moving coil	Describes a loudspeaker that involves a coil of wire moving in a magnetic field, to vibrate a cone and produce sound waves.
Induce	To cause something to happen.
AC	Alternating potential difference – the direction of the current switches back and forth.
Cone	Literally a cone-shaped piece of material found in loudspeakers. They vibrate, causing pressure changes in the air – i.e. sound waves.
Induced potential	A potential difference caused by either: a) moving a coil in a magnetic field, or b) changing the magnetic field around a coil.
Generator effect	Using the interaction between a magnetic field and a conductor to generate electric current.

Loudspeakers and microphones

The motor effect is also put to good use in loudspeakers and headphones. They have a 'moving coil' which moves in a magnetic field according to the current running through the coil. This moving coil is connected to a cone that moves with it. The cone causes vibrations in the air around it – in other words, it causes sound waves. Microphones do the exact opposite: sound waves (pressure variations) cause the cone the move, which causes a changing current in the coil.

Study the diagram. Just like in a motor, a force is produced on the coil of wire by placing it in a magnetic field (that's a permanent magnet at the bottom) and turning on the current. As the current alternates in direction (i.e. AC is used), and the size of the current is varied, the coil moves back and forth. As you can see, the coil is joined to a cone, which moves with it. The cone vibrates the air according to the current, then. The current transfers the information about the sound being played.



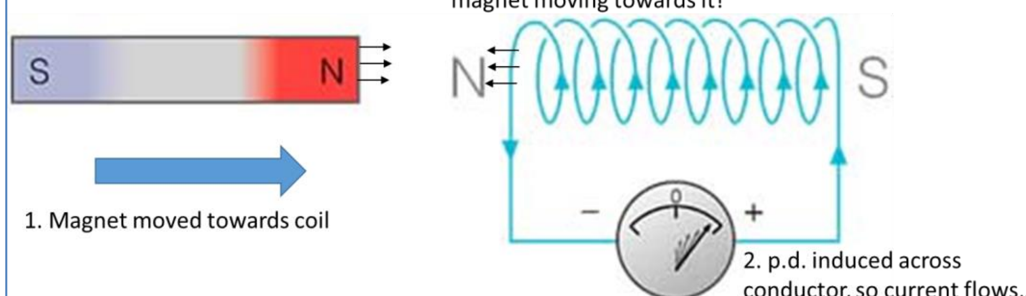
Induced potential and the generator effect

You can switch the motor effect around – instead of using interacting magnetic fields to produce movements, you can use movements to produce a current in a wire.
Here's how it works:

1. Place a conductor (e.g. coil of wire/solenoid) in a magnetic field and move it around (e.g. rotate the coil)
2. OR keep the coil still but change the magnetic field (e.g. flip N and S back and forth)
3. Either of these **induces** a potential difference across the ends of the conductor
4. Assuming your conductor is part of a complete circuit, a current starts to flow in the conductor thanks to this potential difference.

This is called the GENERATOR EFFECT, because the method is used to generate electricity. It is also known as electromagnetic induction.

Now, importantly, the current in the conductor produces a magnetic field, as always. But the direction of the magnetic field <u>acts to oppose the change</u>, the 'change' being the original 1 or 2 from the steps above. This is shown in the diagram right.



Factors affecting induced potentials

The size of the induced potential in the generator effect depends on:

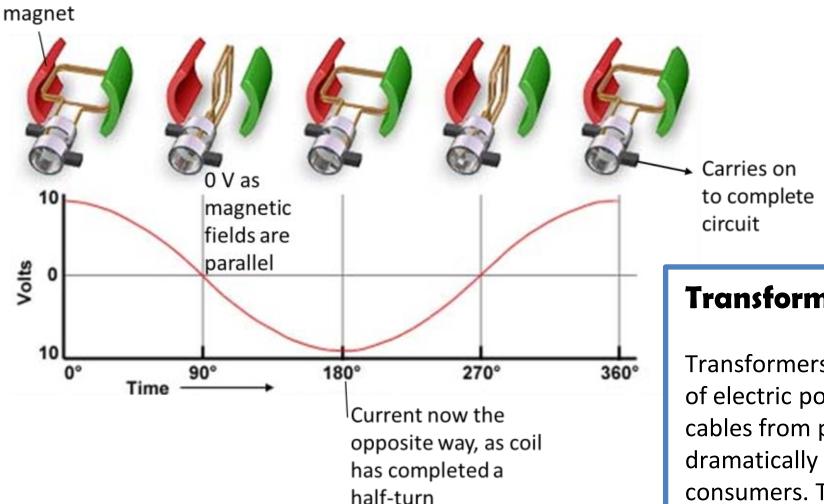
- The size/strength of the magnetic field (larger magnetic field → larger induced potential)
- The number of turns on the solenoid (more turns → larger induced potential)
- The speed of movements/changes to magnetic fields (faster → larger induced potential)

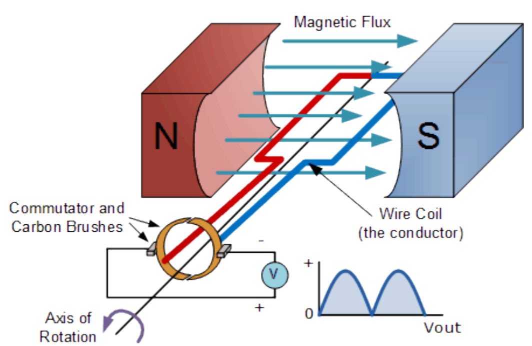
Physics Knowledge Organiser
P15 - Electromagnetism

Using the generator effect

Depending on the set-up, you can use the generator effect to generate ac or dc.

- ac is generated in an alternator. In this set-up, each end of the coil of wire spin inside, and make contact with, a complete loop of conductor that's connected to the rest of the circuit. Since every 180° of turn of the coil the current flips direction (just like the left hand rule tells us), you get ac. This is shown on the diagram below, with a graph showing alternating potential difference.
- dc is generated in a dynamo. To prevent the current flipping direction every half-turn, a clever **commutator** is used. This ensures the current is restricted to one direction only in the coil – i.e. direct potential difference. See second diagram and graph.



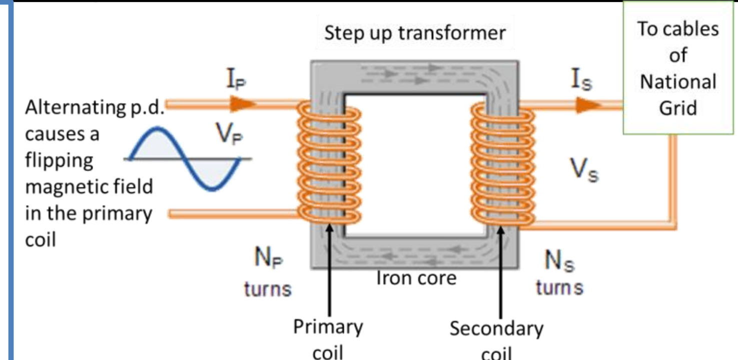


Key Terms	Definitions
National Grid	A system of cables and transformers linking power stations to consumers of electricity. The National Grid is used to transfer electrical power from the power stations to users.
Commutator	Device used in dynamo, made of two half-rings of conductor, not quite joined up to each other. Keeps the current flowing one way only.
Step-up transformer	Device that increases potential difference in an electric supply, using more turns on the secondary coil than the primary coil. Step-down transformers do the opposite.

Equation	Meanings of terms in equation
$\frac{V_P}{V_S} = \frac{N_P}{N_S}$	V_p = *potential difference across primary coil* (V) V_s = *potential difference across secondary coil* (V) N_p = *number of turns on primary coil* N_s = *number of turns on secondary coil*
$V_p \times I_p = V_s \times I_s$	V_p = *potential difference across primary coil* (V) V_s = *potential difference across secondary coil* (V) I_p = *current in primary coil* (A) I_s = *current in secondary coil* (A)

Transformers

Transformers exist to firstly, massively increase the p.d. of electric power to transmit it efficiently through cables from power stations, then, secondly, to dramatically decrease it again for safe use by consumers. They work using the second sort of generator effect – a changing magnetic field inducing a p.d. in a conductor nearby. Transformers are made of two coils of wire, wrapped around each end of a square-shaped iron core. Iron is used because it is easily magnetised. An alternating current in the primary coil causes a magnetic field in this coil, that constantly changes direction. This in turn induces a changing magnetic field in the iron core, which then induces a changing magnetic field (and therefore current) in the secondary coil.



Transformer equations

In transformers, the ratio of the potential differences across the coils is equal to the ratio of the number of turns on each coil. This is shown in the first equation.

Assuming transformers are 100% efficient, the power input is equal to the power output. This leads to the second equation (since *P* = *IV*).

Physics Knowledge Organiser
P16 - Space

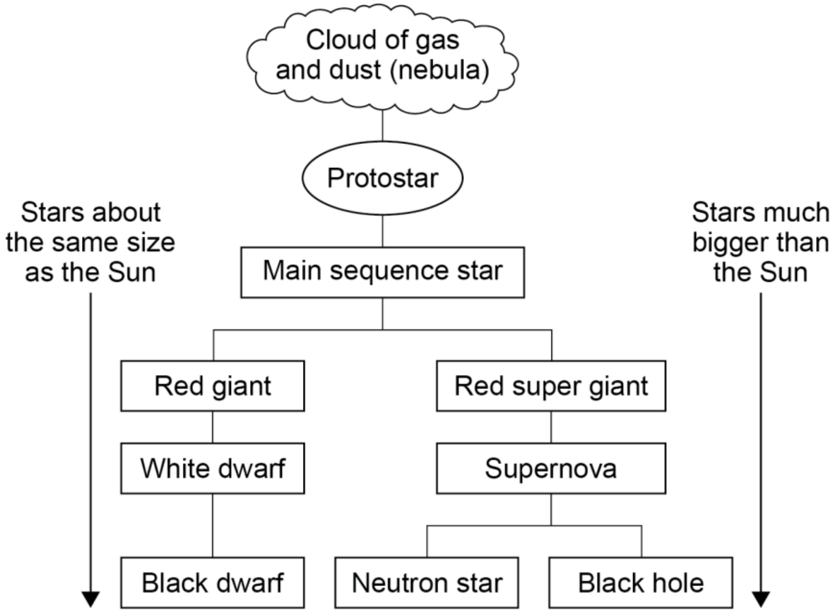
Our solar system

Our solar system consists of:
- One star: the Sun;
- Eight planets, which orbit the Sun;
- Dwarf planets, such as Pluto, which also orbit the Sun;
- Natural satellites: the moons that orbit some of the planets (including our moon);
- Other objects like asteroids and comets.

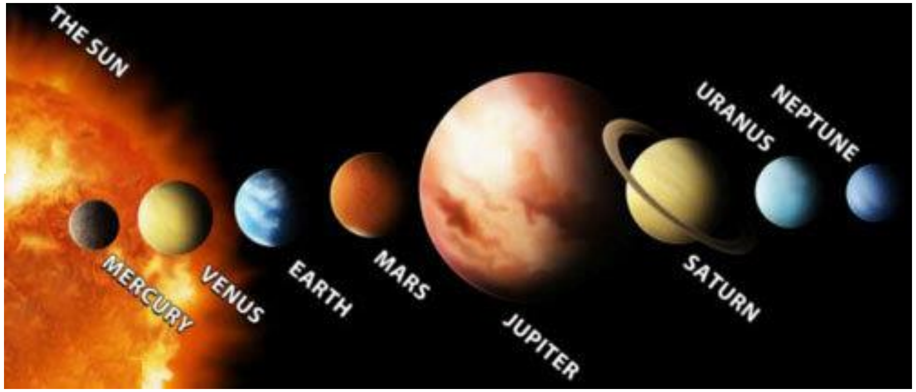
Our solar system is a very small part of the Milky Way galaxy. Galaxies consist of millions of stars, held together by their gravitational attraction to one another.

Stars and their life cycle

Stars form when a huge cloud of gas and dust (a **nebula**) comes together thanks to the **gravitational** attraction between the particles from which it is made. The diagram outlines the stages a star goes through during its life cycle. Note that the stages of the life cycle depend on the **initial mass** of the star. Lower mass stars (like the Sun) end more discreetly than others with much larger masses.



Key Terms	Definitions
Star	A huge (compared to Earth) sphere of superhot gas (plasma) undergoing nuclear fusion reactions.
Planet	A spherical object much smaller than a star, made of rocky or gaseous material (or a combination), which orbits a star.
Dwarf planet	Small planets that have not cleared their orbit of other material. Like planets, they orbit a star.
Satellites	Object that orbit a planet. Natural satellites are not launched by humans – so moons are natural satellites. Ones that we launch are called artificial satellites.
Orbit	To follow a path around another object due to the gravitational attraction between the objects, while being physically separated. Orbits can be circular, or elliptical (oval shaped).
Galaxy	A giant cluster of stars held together by their gravitational attraction to one another. Our galaxy is called the Milky Way.
Nebula	A cloud of gas and dust in space.
Nuclear fusion	A nuclear (not chemical) reaction in which the nuclei of atoms are joined together to make larger nuclei, releasing energy. For example, hydrogen nuclei are fused to helium nuclei in the Sun and other stars. Thus, fusion processes cause the formation of new elements. This can only happen at immense pressures and temperatures, when gases have ionised to become plasma. Nuclear fusion allows **nucleosynthesis** - making new nuclei.



Physics Knowledge Organiser
P16 - Space

Stages of star life cycles

You've seen the basic life cycle. Now for some detail.

- A **protostar** is a dense region in a nebula, which is still gathering mass by pulling in material from the nebula by its gravitational pull. So, at this stage, the star is still forming and has **not** yet started nuclear fusion reactions.
- **Main sequence** star: the Sun is a main sequence star. During this stage of a star's life cycle, the star is stable in size because the forces acting towards the centre and the outward forces caused by the nuclear fusion processes are in **equilibrium**. With an object as big as a star, the gravitational force acting on any particular particle is intense, so the star might be expected to collapse. However, there is an outward force leading to expansion, caused by the fusion processes occurring in the star. Essentially, this outward force is due to gas pressure (ok, plasma pressure) in the star. Pressure in gases increases if their temperature increases, making the star expand; in turn, this decreases the pressure and therefore cuts the rate of nuclear fusion. Therefore, main sequence stars are nicely self-regulating systems (using negative feedback).
- **Red giant** and **red super giant** stages: as the diagram showed, this is where the life cycle diverges according to the mass of the star. Stars finish their main sequence when the hydrogen in the core runs out (it has all been fused to helium). This reduces the outward pressure, so the star begins to collapse inwards due to gravity. In turn, this allows some of the hydrogen *outside* the core (the layer of a star we actually see) to begin going through nuclear fusion, and at a much more rapid rate than during the main sequence. This higher rate of nuclear fusion produces a larger outward pressure, so the outer layer of the star expands by a great deal, perhaps as far as the orbit of Venus in the case of the Sun! (Hence the 'giant' in the name.)
- The red giant or red super giant stage ends as the fuel runs out. This causes a drop in outward pressure, so gravity wins out and causes the collapse of the star. This is really rapid, though, and causes a shock wave outwards. In stars like the Sun, this is violent but not crazy – the outer layers of the star are ejected relatively slowly out. However, in larger stars this outwards shock wave is extremely violent, resulting in a **supernova**. A supernova is such a colossal explosion that a red supergiant entering its supernova stage can outshine its whole galaxy! This spreads the new elements made in the star by nuclear fusion (or **nucleosynthesis**) out across the universe. This is actually the reason why large elements (anything larger than iron) are found on Earth – the atoms were spread out after their formation in supernovae.
- The core of the Sun, and similar sized stars, will become a **white dwarf**. When it has totally cooled off, it will be a **black dwarf** – just the cold remnants of its core. The core of larger stars will be left as **neutron stars**, which are insanely dense objects: as illustrative values, a neutron star may be only 20 km in diameter but have a mass *twice* that of the Sun! Should the star have started as a *really* massive star, the core will collapse to make a **black hole**, which is even more dense than a neutron star and a place where conditions are so extreme that physicists are struggling to express the rules that govern the behaviour of matter in black holes.

Key Terms	Definitions
Protostar	An early star – basically a big dense part of a nebula that is gathering mass but hasn't started nuclear fusion yet.
Main sequence	The stable stage of a star's life cycle, where inward and outward forces are in equilibrium.
Plasma	The 'fourth state of matter' – a superhot gas, where electrons are stripped from nuclei, leaving a sea of positive nuclei and negative electrons.
Red giant	The stage after the main sequence for stars with a similar mass to the Sun.
Red supergiant	The stage after the main sequence for stars much more massive than the Sun.
White dwarf	The collapsed core of a star like the Sun. Very dense (about 200 000 times more dense than Earth), but not as dense as neutron stars or black holes.
Black dwarf	When a white dwarf has fully cooled down, it no longer emits any radiation so it is a black dwarf. So in the universe, there aren't any black dwarves because it isn't old enough for white dwarves to have cooled off yet!
Supernova	The enormous explosion resulting from the collapse and resulting shock wave of a star much more massive than the Sun.
Neutron star	The collapsed core of a star after a supernova (but not of a star large enough to form a black hole).
Black hole	The collapsed core of really massive stars – about five or more times the mass of the Sun.

Physics Knowledge Organiser
P16 - Space

Orbits

Gravity is the force that allows orbits to be maintained. Since an object in motion is moving in a circle, its direction and therefore velocity is constantly changing, even as its speed stays constant. The orbiting object is accelerating towards the object it orbits, as the diagram shows. The velocity at any moment you pick (called the **instantaneous velocity**) is at a tangent to the orbital path.

For an orbit to remain stable, the radius of the orbital path must change if the speed changes. This means, for example, Mercury travels much faster on its orbital path around the Sun than Earth, since the radius of its orbital path is much smaller than ours.

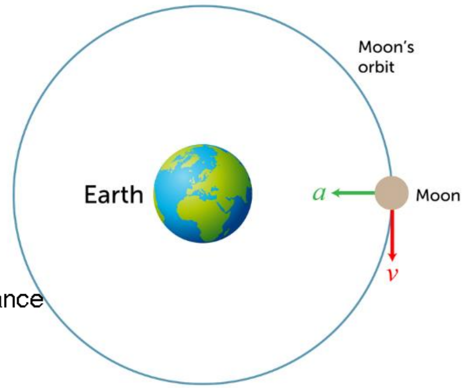
Red Shift

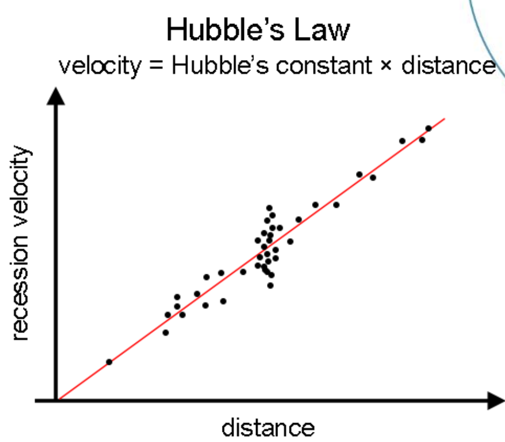
When we examine the light (electromagnetic radiation) from distant galaxies in space, the wavelength is *increased* compared to what is 'should be'. This stretching of waves that are emitted from a wave source moving away from an observer is called the Doppler effect in general, and **red shift** when we're talking about electromagnetic radiation. Working backwards logically, we know that distant galaxies are *receding* (moving away from us). This shows that the universe (i.e. space itself) is expanding. In turn, this provides great evidence for the Big Bang theory, since when you turn the clock back, the galaxies must have been much closer together in the past, all the way back until the whole universe (space and all the matter in it) was a single hot, dense point.

In 1998 some breakthrough studies of supernovae in distant galaxies showed that the rate of recession of galaxies is greater the further away they are, findings that have been confirmed in numerous studies since. The findings showed that the more distant the galaxy is, the greater the red shift of its light, showing that they are moving away faster than nearer galaxies. The graph shows this – each dot is a galaxy which has been observed and its red shift used to calculate its recessional velocity (how fast it is moving away from us, the observers).

There are still many unsolved questions about all this, though. No-one knows what is causing the acceleration of the universe's expansion (so it often gets the opaque name 'dark energy'). Another giant mystery is 'dark matter' – astronomers know there is a giant 'halo' of matter around objects in space like galaxies, but have no idea what it is made of, hence the name.

Key Terms	Definitions
Instantaneous velocity	Velocity at a single moment (remember it is vector quantity, with both direction and magnitude).
Red shift	The observed increase in wavelength of light emitted by objects moving away (receding) from an observer.
Big Bang theory	The theory, which is by far the dominant scientific theory for the origin of the universe, that states that the whole universe was once tiny and very hot and dense.
Recessional velocity	How fast something (like a galaxy) is moving away from an observer.
Dark matter	Aka dark mass. A mysterious type of matter that is known to exist (from observations of other galaxies), but no-one knows what it is made of.
Dark energy	The name given to the mysterious energy driving the acceleration in the expansion of the universe.





Required Practical
Physics – Specific heat capacity

Objective: An investigation to determine the specific heat capacity of one or more materials.

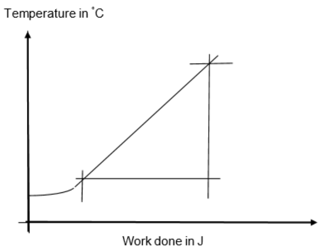
In this practical you will:

- heat up blocks of different metals using an electric heater.
- measure the mass and temperature of the block.
- calculate the work done by the heater.
- plot a graph of temperature change against work done and use the gradient to calculate the specific heat capacity of the metal.

Method

Mass of copper block in kg	
Current reading on the ammeter in amps	
Potential difference reading on the voltmeter in volts	
Power (Power = IV)	

1. Measure and record the mass of the copper block in kg.
2. Wrap the insulation around the block.
3. Place the heater in the larger hole in the block.
4. Connect the ammeter, power pack and heater in series.
5. Connect the voltmeter across the heater.
6. Use the pipette to put a small amount of water in the other hole.
7. Put the thermometer in this hole.
8. Set the power pack to 12V. Switch on the power pack to turn on the heater.
9. Record the ammeter and voltmeter readings. These shouldn't change during the experiment.
10. Measure the temperature and start the stop clock.
11. Record the temperature every minute for 10 minutes. Record your results in the table overleaf.
12. Calculate the power of the heater in watts. Power in watts = potential difference in volts x current in amps



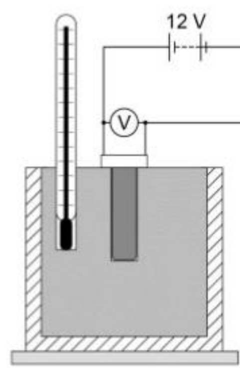
13. Calculate the energy transferred (work done) by the heater. To do this, multiply the time in seconds by the power of the heater. Record these values in your table.
14. Plot a graph of the temperature in ^{o}C against work done in J.
15. Draw a line of best fit. Take care as the beginning of the graph may be curved.
16. Calculate the gradient of the straight part of your graph. The gradient = change in temperature rise in ^{o}C/change in work done in J.
17. The heat capacity of the copper block is calculated using the formula: 1 ÷ gradient
    It is the amount of heat energy in J needed to increase the temperature by 1^{o}C.
18. The specific heat capacity of copper is the amount of heat energy in J needed to increase the temperature of 1kg of copper by 1^{o}C.
    Calculate the specific heat capacity of the copper block using the equation:
    Change in thermal energy in J = mass in kg x specific heat capacity in J/kg/ ^{o}C x temperature change.
19. Repeat the experiment for the blocks made from aluminium and iron.

Required Practical
Physics – Specific heat capacity

Objective: An investigation to determine the specific heat capacity of one or more materials.

Apparatus

- three metal blocks, one copper, one iron and one aluminium, each with two holes for a thermometer and heater some insulation material to wrap around the blocks
- a thermometer
- a pipette to put water in the thermometer hole
- a 12V immersion heater (30 – 110W)
- a 12V power supply
- an ammeter and a voltmeter
- five connecting leads
- a stopwatch or stop clock
- a balance



Health and safety

- Do not touch electrical equipment, plugs, or sockets with wet hands.
- Do not touch the heater: it becomes very hot when in use, and can stay hot for a long time after it is switched off.
- Switch the heater off if you think it is overheating.
- Switch the heater off when you have finished using it.
- When the thermometer is not being used, make sure it is placed where it cannot easily roll off the table.

Metal	Copper	Aluminium	Iron	Lead	Steel	Brass
Specific heat capacity in J/kg/˚C	385	913	500	126	452	380

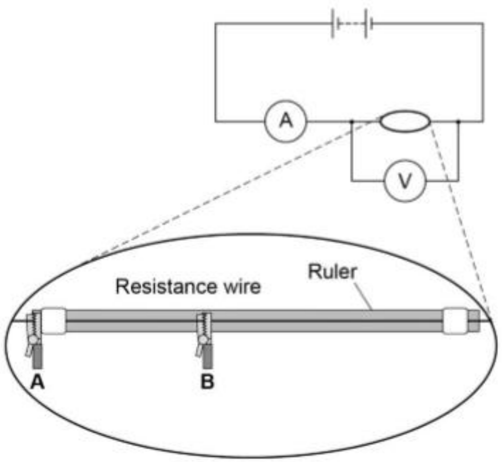
Time in seconds	Temperature in °C	Work done in J (time x power of the heater)
0		0
60		
120		
180		
240		
300		
360		
420		
480		
540		
600		

Required Practical
Physics – Resistance 1

Activity 1: How does the length of the wire affect the resistance at a constant temperature?

Apparatus

- a battery or suitable power supply
- ammeter
- voltmeter
- crocodile clips
- resistance wire attached to a metre ruler
- connecting leads



Factors that affect the resistance of electrical circuits:

- length of a wire at constant temperature.
- combination of resistors in series and parallel.

In this practical you will:

Activity 1:

- set up a circuit which can measure the potential difference and current across a wire at different lengths along the wire.
- calculate the resistance for different lengths of wire and state the relationship between resistance and length.

Method – Activity 1

1. Use the circuit diagram to set up and connect the circuit.
2. Connect a lead from the negative side of the ammeter to the crocodile clip at the zero end of the ruler. Connect a lead from the other crocodile clip to the negative side of the battery. Use this lead as a switch to disconnect the battery between readings.
3. Decide the interval distance (eg 10cm) you will investigate and connect the first distance to be tested between crocodile clips A and B.
4. Measure the readings on the voltmeter and ammeter at this distance.
5. Record your results in a table.
6. Move crocodile clip B and record the readings for the different lengths of wire eg 20cm, 30cm etc.
7. Calculate the resistance for each length of wire using the equation:

$$\text{resistance in } \Omega = \frac{\text{potential difference in V}}{\text{current in A}}$$

8. Plot a graph of resistance against length of wire.
9. You should be able to draw a straight line of best fit although it may not go through the origin.

   Why might this be the case?

   What type of relationship is there between resistance and length?

Required Practical
Physics – Resistance 1

Factors that affect the resistance of electrical circuits:

- length of a wire at constant temperature.
- combination of resistors in series and parallel.

Length of wire in cm	Potential difference in volts	Current in amps	Resistance in ohms
10			

In this practical you will:
Activity 1:

- set up a circuit which can measure the potential difference and current across a wire at different lengths along the wire.
- calculate the resistance for different lengths of wire and state the relationship between resistance and length.

Required Practical
Physics – Resistance 2

Factors that affect the resistance of electrical circuits:

- length of a wire at constant temperature.
- combination of resistors in series and parallel.

Activity 2: How does the arrangement of resistors in series and in parallel affect resistance?

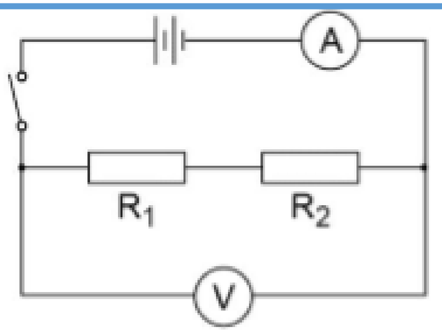
Apparatus

- a battery or suitable power supply
- a switch
- ammeter
- voltmeter
- crocodile clips
- two 10 Ω resistors
- connecting leads

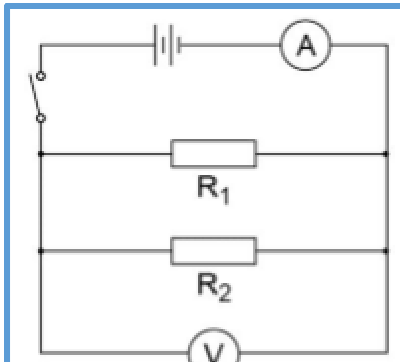
In this practical you will:

Activity 2:

- use circuit diagrams to construct circuits with resistors in series and in parallel.
- measure the potential difference and current in circuits with resistors in series and then in parallel.



1



2

Method – Activity 2

1. Use the circuit diagram 1 to set up and connect the circuit for two resistors in series R1=R2.
2. Switch on and record the readings of the ammeter and the voltmeter.
3. Calculate the total resistance of the series circuit.
4. Set up the circuit for two resistors in parallel. Use the circuit diagram 2 below. R1=R2.
5. Switch on and record the readings of the ammeter and the voltmeter.
6. Calculate the total resistance of the parallel circuit.
7. What conclusions can you make about the effect of adding resistors
   - in series
   - in parallel
8. How could you check the value of the resistance of R1 and R2 in either circuit?

Required Practical
Physics – IV Characteristics 1

Objective: Investigating the I-V characteristics of circuit components.
What happens to the current through a component when the potential difference across it changes?
For some circuit components, the value of resistance can change as the current changes. You can use the graph of current against potential difference to help identify the component in a circuit.

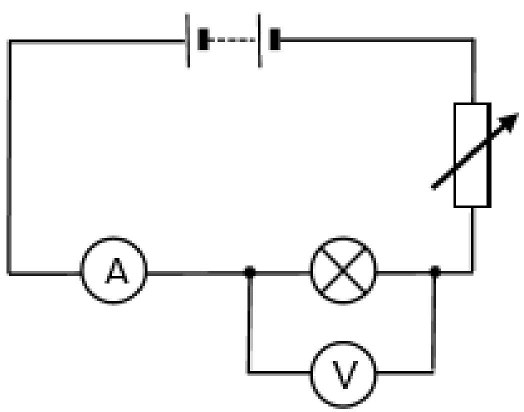
Activity 1: The characteristic of a filament lamp

Apparatus

- a digital ammeter
- a digital voltmeter
- element holders
- a variable resistor
- connecting leads
- a filament lamp
- a battery or suitable power supply

In this practical you will:

- construct circuits and draw circuit diagrams.
- measure the current across a component as you change the potential difference.
- plot graphs of current against potential difference for each component.



Method – Activity 1

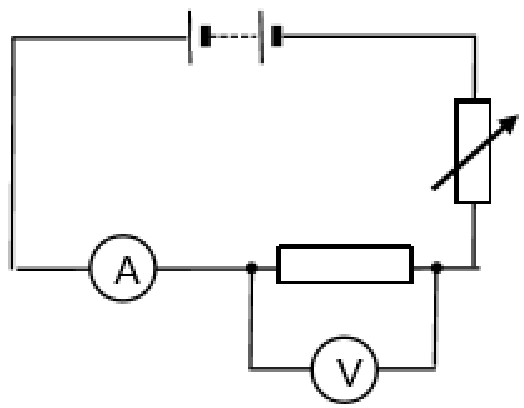
1. Use the circuit diagram (left) to set up your circuit.
2. Record the readings on the ammeter and voltmeter in a suitable table.
3. Adjust the variable resistor and record the new readings on the ammeter and voltmeter.
4. Repeat this to obtain several pairs of readings.
5. Swap the connections on the battery/power supply. The ammeter is now connected to the negative terminal and variable resistor to the positive terminal. The readings on the ammeter and voltmeter should now be negative.
6. Continue to record pairs of readings of current and potential difference with the battery reversed.
7. Plot a graph of current against potential difference. As the readings include negative values the origin of your graph will be in the middle of the graph paper. You should be able to draw a line of best fit through the origin. This is the characteristic of a filament lamp.

Required Practical
Physics – IV Characteristics 2

Activity 2: The characteristic of a resistor

Apparatus

- the circuit that you set up in activity 1
- a resistor



Objective: Investigating the I-V characteristics of circuit components.
What happens to the current through a component when the potential difference across it changes?
For some circuit components, the value of resistance can change as the current changes. You can use the graph of current against potential difference to help identify the component in a circuit.

In this practical you will:

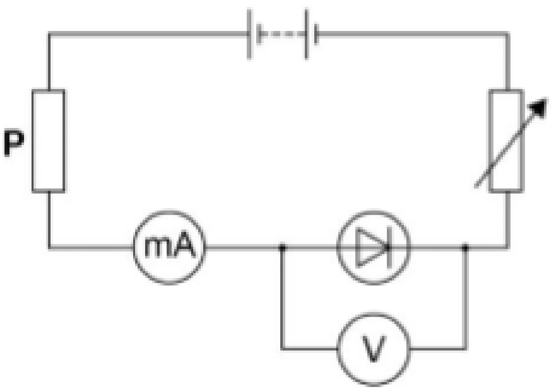
- construct circuits and draw circuit diagrams.
- measure the current across a component as you change the potential difference
- plot graphs of current against potential difference for each component.

Method – Activity 2

1. Swap the leads on the battery/power supply back to their original positions. See left.
2. Replace the filament lamp with the resistor.
3. Record the readings on the ammeter and voltmeter in a suitable table.
4. Adjust the variable resistor and record the new ammeter and voltmeter readings. Repeat this to obtain several pairs of readings.
5. Swap the connections on the battery/power supply. Now the ammeter is connected to the negative terminal and variable resistor to the positive terminal. The readings on the ammeter and voltmeter should now be negative.
6. Continue to record pairs of readings of current and potential difference with the battery reversed.
7. Plot a graph of current against potential difference. As the readings include negative values the origin of your graph will be in the middle of the graph paper. You should be able to draw a straight line of best fit through the origin. This is the characteristic of a resistor.

Required Practical
Physics – IV Characteristics 3

Activity 3: The characteristic of a diode
Apparatus
- the circuit you set up in activity 1
- a milliammeter
- a diode
- an extra resistor labelled P



Objective: Investigating the I-V characteristics of circuit components.
What happens to the current through a component when the potential difference across it changes?
For some circuit components, the value of resistance can change as the current changes. You can use the graph of current against potential difference to help identify the component in a circuit.

In this practical you will:
- construct circuits and draw circuit diagrams.
- measure the current across a component as you change the potential difference.
- plot graphs of current against potential difference for each component.

Method – Activity 3
1. Swap the leads on the battery/power supply back to their original positions.
2. If you can, reduce the battery/power supply potential difference to less than 5V.
3. Connect the extra resistor labelled P.
4. Replace the ammeter with a milliammeter.
5. Replace the resistor used in activity 2 with the diode.
6. Record the readings on the milliammeter and voltmeter in a suitable table.
7. Adjust the variable resistor and record the new milliammeter and voltmeter readings.
8. Repeat this to obtain several pairs of readings.
9. Swap the connections on the battery/power supply. Now the milliammeter is connected to the negative terminal and variable resistor to the positive terminal. The readings on the milliammeter and voltmeter should now be negative.
10. Continue to record pairs of readings of current and potential difference with the battery reversed.
11. Plot a graph of current against potential difference. As the readings include negative values the origin of your graph will be in the middle of the graph paper. You should be able to draw a line of best fit through the origin. This is the characteristic of a diode.

Required Practical Physics – Density

Objective: Investigating density of regularly and irregularly shaped solids and liquids using a range of appropriate apparatus.

In this practical you will
- use a ruler and a balance to determine the density of a regularly shaped object.
- use a displacement method to determine the density of an irregularly shaped object.
- use measurements of volume and mass to determine the density of a liquid.

Method

Density of a solid (in the shape of a cube or cuboid).

1. For each of your selected objects measure and record the:
   - length
   - width
   - height
2. Calculate the volume of each object.
3. Record your results in a table like this:

Regular shaped object	Length in cm	Width in cm	Height in cm	Volume in cm^3	Mass in g	Density in g/cm^3

4. Measure the mass of each object using the digital balance. Record the results in your table.
5. Calculate and record the density of each object using: density = $\frac{mass}{volume}$

Apparatus
- various regular shaped objects
- various irregular shaped objects
- a suitable liquid (eg sugar solution)
- a 30cm ruler marked off in millimetres
- a digital balance
- a displacement can
- a variety of measuring cylinders
- two 250cm^3 beakers
- paper towels

Required Practical
Physics – Density

Objective: Investigating density of regularl and irregularl shaped solids and liquids using a range of appropriate apparatus.

In this practical you will
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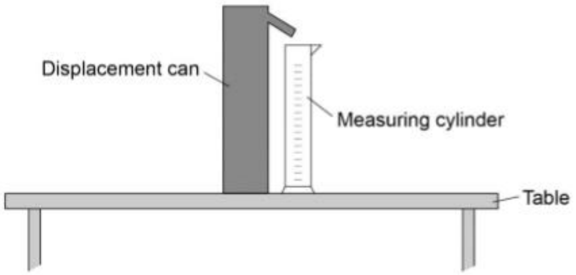
- use a displacement method to determine the density of an irregularl shaped object.
- use measurements of volume and mass to determine the density of a liquid.

Method

Density of an irregular shaped solid.

1. Measure the mass of one of the irregular shaped objects.
2. Record your results in a simple table.
3. Put the displacement can on your desk. Put an empty beaker under the spout and fill the can with water. Water should be dripping from the spout and you should wait until you see this stop.
4. Then put a measuring cylinder that you think will give the most accurate reading under the spout instead of the beaker.
5. Very carefully lower the object into the displacement can so that it is completely submerged. Collect all of the water that comes out of the spout in the measuring cylinder.
6. Measure the volume of the collected water. This volume is equal to the volume of the object.
7. Calculate and record the density of the object.
8. Repeat the activity for some other objects. Remember to refill the can with water each time.

Apparatus
- various regular shaped objects
- various irregular shaped objects
- a suitable liquid (eg sugar solution)
- a 30cm ruler marked off in millimetres
- a digital balance
- a displacement can
- a variety of measuring cylinders
- two 250cm^3 beakers
- paper towels



Object	Mass / g	Volume / cm^3	Density / g/cm^3

Required Practical
Physics – Density

Objective: Investigating density of regularly and irregularly shaped solids and liquids using a range of appropriate apparatus.....

In this practical you will
- use a ruler and a balance to determine the density of a regularly shaped object.
- use a displacement method to determine the density of an irregularly shaped object.
- use measurements of volume and mass to determine the density of a liquid.

Method

Density of a liquid
1. Measure the mass of the empty measuring cylinder 2.
2. Record your results in a table like this:

Mass of the empty cylinder in g	Volume of liquid in cm^3	Mass of cylinder plus liquid in g	Mass of liquid in g	Density of liquid in g/cm^3

3. Pour about 100cm^3 of the liquid into the measuring cylinder. Record the volume accurately.
4. Measure and record the mass of the measuring cylinder and liquid. From this calculate and record the mass of just the liquid.
5. Calculate the density of the liquid.

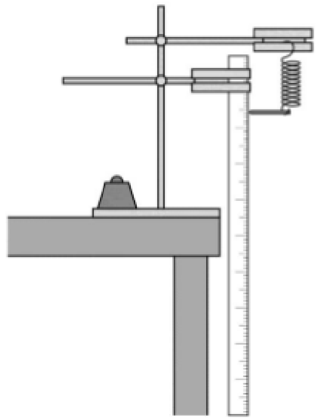
Apparatus
- various regular shaped objects
- various irregular shaped objects
- a suitable liquid (eg sugar solution)
- a 30cm ruler marked off in millimetres
- a digital balance
- a displacement can
- a variety of measuring cylinders
- two 250cm^3 beakers
- paper towels

Required Practical
Physics – Force and extension

Objective: Investigate the relationship between force and extension of a spring.

In this practical you will:
- hang different masses from a spring and measure the extension of the spring for each mass used.
- convert mass into weight.
- use your results to plot a graph of extension against weight.

Method
1. Set up your apparatus as in the diagram making sure that:
    1. the ruler is vertical. The zero on the scale needs to be at the same height as the top of the spring;
    2. the splint is attached securely to the bottom of the spring. Make sure that the splint is horizontal and that it rests against the scale of the ruler.
2. Take a reading on the ruler – this is the length of the unstretched spring. Record this reading in your results table.
3. Carefully hook the base of the weight stack onto the bottom of the spring. This weighs 1.0 newton (1.0N). Don't forget that the mass added will have to be converted to newtons.
4. Take a reading on the ruler – this is the length of the spring when a force of 1.0 N is applied to it.
5. Add further weights. Measure and record the length of the spring each time.
6. Calculate the extension for each weight and record it on the table.



Weight in N	Length of spring in cm	Extension of spring in cm
0.0 (No weight stack added)		0
1.0 (weight stack added)		
2.0		

Required Practical
Physics – Force and extension

Objective: Investigate the relationship between force and extension of a spring.

Apparatus

- a spring
- a metre ruler
- a splint and tape to act as a pointer
- a 10N weight stack
- a clamp stand
- two clamps and bosses
- a heavy weight or G-clamp to prevent the apparatus tipping over
- safety goggles

Health and safety

- Take care with heavy masses being placed on the spring. Ensure that they cannot fall on the floor or onto feet.
- Goggles should be worn in case the spring snaps.

Analysis of results

Use your results to plot a graph with:

- 'extension of spring in cm' on the y-axis.
- 'weight in N' on the x-axis.

a) State the relationship between force and extension of a wire.
b) Calculate the spring constant (force = spring constant x extension).

A force that stretches or compresses a spring does work and elastic potential energy is stored in the spring. Providing that the spring is not elastically deformed the work done on the spring and the elastic potential energy stored are equal.

c) Calculate the work done in stretching your spring using the equation: elastic potential energy = 0.5 x spring constant x $(extension)^2$
d) Hang an unknown object on the spring. Measure the extension and use your graph to determine the object's weight. Check it with a newton meter.

Required Practical
Physics – Acceleration

Objective: Investigate the effect of varying the force on the acceleration of an object of constant mass, and the effect of varying the mass of an object on the acceleration produced by a constant force.

In this practical you will:

- time how long it takes for a toy car or trolley of constant mass to move a distance when different forces are applied to it.
- time how long it takes for a toy car or trolley to move a distance if the force applied is constant but the mass of the toy car or trolley is varied.
- calculate the acceleration of the toy car or trolley in each case.

Method – Activity 1

1. Use the ruler to measure intervals on the bench and draw straight lines or place tape across the bench at these intervals.
2. Attach the bench pulley to the end of the bench.
3. Tie a length of string to the toy car or trolley. Pass the string over the pulley and attach the weight stack to the other end of the string.
4. Make sure the string is horizontal and is in line with the toy car or trolley.
5. Hold the toy car or trolley at the start point.
6. Attach the full weight stack (1.0N) to the end of the string.
7. Release the toy car or trolley at the same time as you start the stopwatch, press the stop watch (lap mode) at each measured interval on the bench and for the final time at 100cm.
8. Record the results in the table.
9. Repeat steps 5-8 for decreasing weights on the stack for example, 0.8 N, 0.6 N, 0.4 N, 0.2 N.

Activity 1 & 2: Measuring the effect of force on acceleration at constant mass
Apparatus

- a toy car (or trolley)
- a metre ruler
- pencil, chalk or masking tape to mark the intervals
- a bench pulley
- string
- a small weight stack
- a stopwatch
- Blu-tac

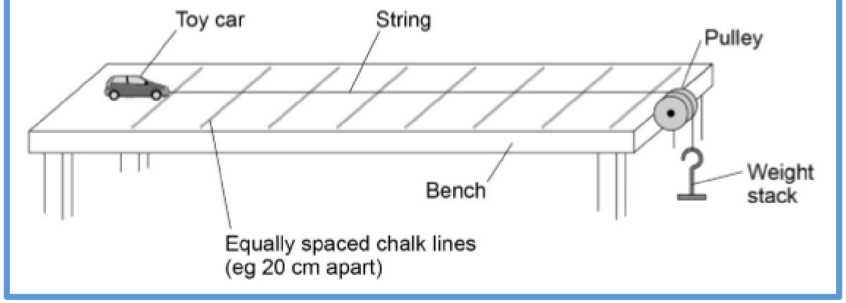
Distance travelled in cm	**1.0 N**	**0.8 N**	**0.6 N**	**0.4 N**	**0.2 N**
	Time in s	**Time in s**	**Time in s**	**Time in s**	**Time in s**
20					
40					
60					
80					
100					

Required Practical
Physics – Acceleration

Objective: Investigate the effect of varying the force on the acceleration of an object of constant mass, and the effect of varying the mass of an object on the acceleration produced by a constant force.

Method – Activity 2

1. Setup the bench, pulley, weight stack and car as in steps 1-5 of activity 1.
2. Use your results from activity 1 to select a weight for the weight stack that will just accelerate the car along the bench.
3. Put a 200g mass on the car.
4. Hold the car at the start point.
5. Attach your chosen weight stack to the end of the string.
6. Release the car at the same time as you start the stopwatch, press the stopwatch (lap mode) at each measured interval on the bench and for the final time at 100cm.
7. Record the results in the table outline below.
8. Repeat steps 5-8 for increasing more masses on the car.



Health and safety

- Take care not to drop weights or cars on the floor or on your feet.

	Change in mass of the toy car				
Distance travelled in cm					
20					
40					
60					
80					
100					

Conclusion

a) Write a sentence to state the relationship that you have seen in both activities. Do the results of your activities reflect Newton's Second Law?
b) Identify and classify the sources of error in this investigation.
c) How could you change the method or the apparatus used to improve the accuracy and reproducibility of your results?