Senior secondary

Physical Science: Revision units

Scholar study workbook

Forum for African Women Educationalists in Malawi (FAWEMA)

"Supporting Girls and Women to Acquire Education for Development"

The Open University

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‘Keeping Girls in School’ Scholarship Programme

MSCE Resources: 2014–15

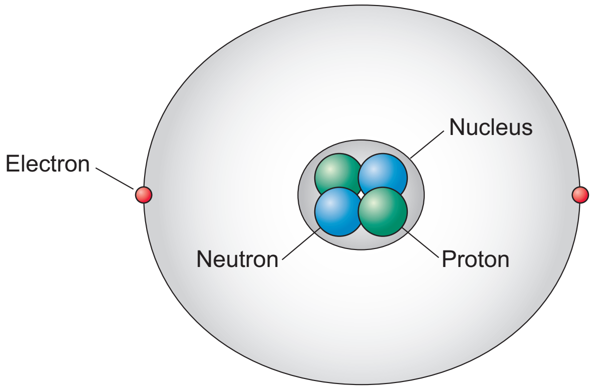
Contents

Revision S1: Elements and chemical bonding

Atoms

An atom is the smallest particle of an element that cannot be further divided without creating new particles.

The nucleus is very tiny and is in the middle of the atom. It contains **protons** and **neutrons**. **Electrons** orbit the nucleus in shells. The nucleus has a positive charge because it contains protons and has almost the entire mass of the atom because electrons are tiny and have almost no mass. The size of the orbit determines how big the atom is.



You must know the contents of the table below.

Particle	Mass	Charge
Proton	1	+1
Neutron	1	0
Electron	0	-1

Working out what's going on in an atom

mass number = protons + neutrons

atomic number (or the proton number) = protons = electrons

The **atomic number** of an element tells us how many electrons (or protons) an element has, so using the example of silicon, we can see that it has 14 electrons and 14 protons as it is electrically neutral.

atomic number=$^{14}\mathrm{Si}_{28}$ = mass number

The **mass number** is 28, which tells us that silicon has a total number of protons and neutrons that equals 28. As we already know that silicon has 14 protons from the atomic number, we can work out that it has 14 neutrons.

Tip: Sometimes the atomic number and mass number are shown the other way round on periodic tables, so remember, *the smallest number is always the atomic number*.

An **isotope** is a different atomic form of the same element. Isotopes have the same number of protons but a different number of neutrons (and therefore a different mass number).

Elements and compounds

Each element consists of only one type of atom. For example, oxygen only contains oxygen atoms and iron only contains iron atoms, whereas compounds consist of atoms of different elements that have been chemically bonded together during a chemical reaction. It is very difficult to separate out the original elements from compounds and also the properties of compounds are very different from their original elements.

Don't confuse compounds with mixtures – mixtures are physical not chemical combinations of elements! Air is a mixture but carbon dioxide is a compound (the suffix 'ide' means a compound).

Electrons are the key to understanding bonding: electronic configurations

You only need to know about the shell structures or electronic configurations for the first 20 elements.

1. The electronic shell structure is fixed in that only a certain number of electrons can occupy each shell.
2. Shell 1 = 2 electrons, shell 2 = 8, shell 3 = 8, shell 4 = 8. Look back at Unit 2 to see how you show the electronic shells on atomic diagrams.
3. How the electrons actually fill these energy levels determines the reactivity and other properties of the element concerned.
4. Full outside shells means an un-reactive element, i.e. the noble gases.
5. When the outside shells are not full, the element wants to react by bonding.
6. For metals the further away the outer electrons are from the nucleus, the easier they are lost. The same effect for non-metals means that extra electrons are harder to gain.

Types of bonding

There are 3 main types of bonding: ionic, covalent and metallic.

Ionic bonding: An ion is an atom that has lost or gained electrons. These are usually formed by Group 1, 2, 6 and 7 elements which have incomplete outer electronic shells. Group 1 and 2 elements lose electrons to form a + ion and Group 6 and 7 elements gain electrons to form a – ion.

The charged particles or ions are very strongly attracted to oppositely charged ions. For example, Na+ and Cl- ions form a strong ionic bond with each other and all nearby ions in a giant 3-D lattice structure, hence the high melting points and boiling points. Ionic compounds also dissolve to form conducting solutions and when molten also conduct electricity. Look back at your diagram of Na+Cl- in Unit 2 to see how to represent ionic bonding.

Covalent bonding: Covalent bonds are created when electrons are shared. Each covalent bond provides one extra shared electron for each atom. Common examples of covalently bonded compounds are: hydrogen, oxygen, ammonia, methane and water. Covalent bonds are represented by dot and cross diagrams. Look back at your diagram of HCl in Unit 2 to see how to represent covalent bonding. Remember that you only need to show the electrons in the last shell for these dot and cross diagrams.

Metallic bonding: Metals form metallic bonds because they have *free electrons* in the last shell which become de-localised. These electrons are therefore free to move between the metal ions in the giant structure and this is why metals are good at conducting heat and electricity.

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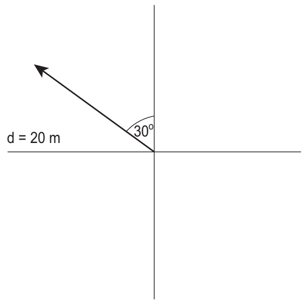
Revision S2: Forces and motion

Scalars and vectors

A scalar quantity is any quantity that is fully defined when the magnitude or size is given. A vector quantity must be defined with not only the magnitude of the force but also with the direction it acts in. The main examples of each are given in the table below.

Scalar	Vectors
distance	displacement
speed	force
mass	velocity
	weight
	acceleration

Although it is not included in the MSCE unit, you might want to read up in your spare time on how you represent vector quantities more fully. But in brief, you should be aware that vectors are usually represented by vector diagrams. Vector diagrams depict a vector by use of an arrow drawn to scale in a specific direction where the magnitude and direction are given – see the example given alongside.



Displacement, speed and velocity

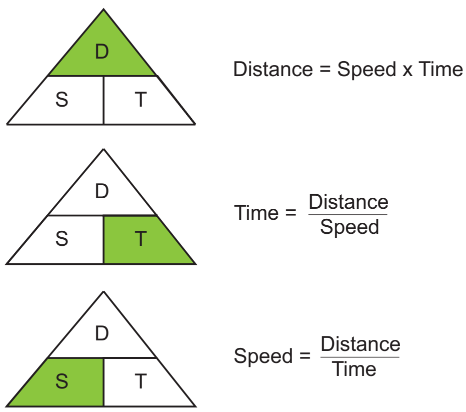
Displacement is the *change in position of an object* and its units are metres. You can think about displacement as being the vector of distance.

Speed and velocity are both just how *fast* you are going so they both have the same units: m/s or ms^{-1}. The key difference is that for velocity, which is a vector, you must give the direction as well. As you already know, speed is a scalar so no direction needs to be stated.

The equation for both however, is exactly the same:

speed = distance/time

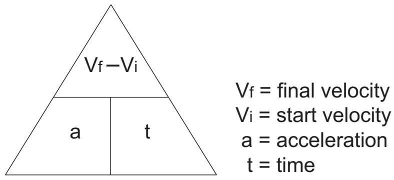
An easy way to remember this equation for all three possible unknowns is to use the triangle method. In the triangle shown alongside, you will see that if you cover up what you want to find out (shown in green), then the triangle 'shows' you what the right equation is. Try it out for yourself!



Acceleration tells you how quickly your velocity is increasing (or decreasing). In other words it is a measure of the rate of change of velocity so it has units of metres per second per second i.e. ms-2 , m/s2.

Acceleration = change in velocity/time

To remember this you can use the triangle method again.



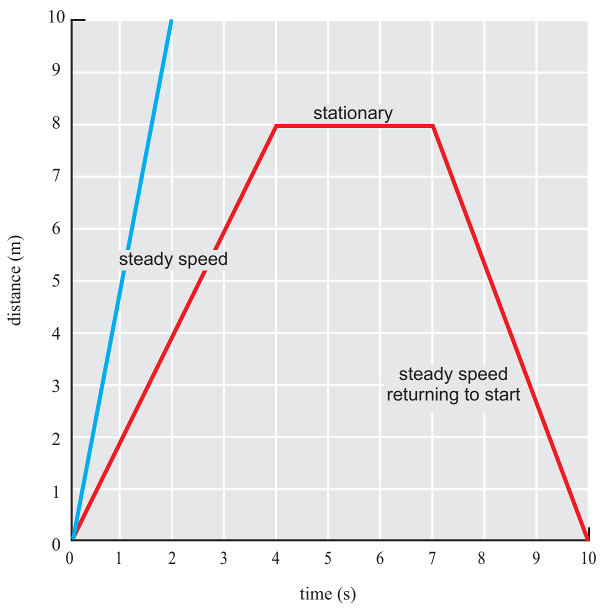
Acceleration formula

Motion graphs

There are two types of motion graph: distance–time graphs and velocity–time graphs. You need to learn the differences between the two types, as shown below. In the exam make sure you are clear about which type of graph you are dealing with; it is very easy to get the two types muddled up and then all your calculations could be wrong, so be sure to check and re-check the axes to establish whether you have a D-T or a V-T graph.

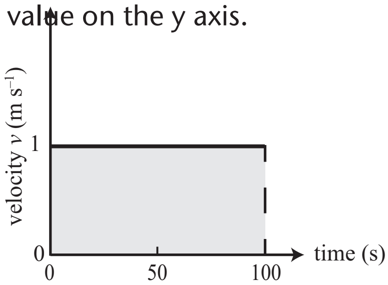
Key features of a distance–time graph

1. The gradient is the speed. The steeper the gradient, the higher the speed. The shallower the gradient, the slower the speed.
2. A straight line means a steady speed whereas a curve means a varying speed.
3. A steepening curve means acceleration and a levelling off curve means deceleration (slowing down).
4. A flat section means that the object has stopped.
5. Downhill sections mean that the object is travelling back to its starting point.



Key features of a velocity–time graph

1. The gradient is the acceleration. The steeper the gradient the greater the acceleration or deceleration.
2. A curve represents a change in the acceleration or deceleration.
3. A forward-facing or uphill line (/) means acceleration but a backward or downhill facing line (\) means deceleration.
4. The area underneath any portion of the graph tells you the distance travelled. You calculate this by dividing the area into rectangles and triangles and then summing the calculated areas of these smaller shapes.
5. The velocity for any time on the graph is found by reading off the value on the y axis.



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Revision S3: Periodic table and reactions

Reactions

Compounds are only formed by chemical reactions. In a chemical reaction the **reactants** chemically react to produce the **products**. Chemical reactions can be represented by simple word equations.

For example, iron + sulphur ⟶ iron sulphide
Here iron and sulphur are the reactants and the product is iron sulphide.

A **balanced symbol equation** shows the numbers of reactant atoms at the start and the product atoms at the end of a reaction and how also they are arranged.

Element atoms	Reactant	Products
Ca	1	1
C	1	1
O	3	3

For example, $CaCO_3 \longrightarrow CaO + CO_2$

Here the reactant is calcium carbonate and the products are calcium oxide and carbon dioxide.

The table shows that there are exactly the same numbers of atoms of each element before and after the reaction.

Balancing rules:

- You can't change the formulas of the reactants/products.
- A number in front of a compound or element applies to all those elements whereas a number after an element only applies to that particular element.

Balancing strategies:

- Find an element that doesn't balance and pencil in a number in front of it on one side of the equation to try to balance it.
- Check to see if your number has now balanced the element on both sides. If not try another number on the first side or try a new number on the other side and see what effect that has.
- Continue the last two steps with this unbalanced element and then with other unbalanced elements until the problem is solved.

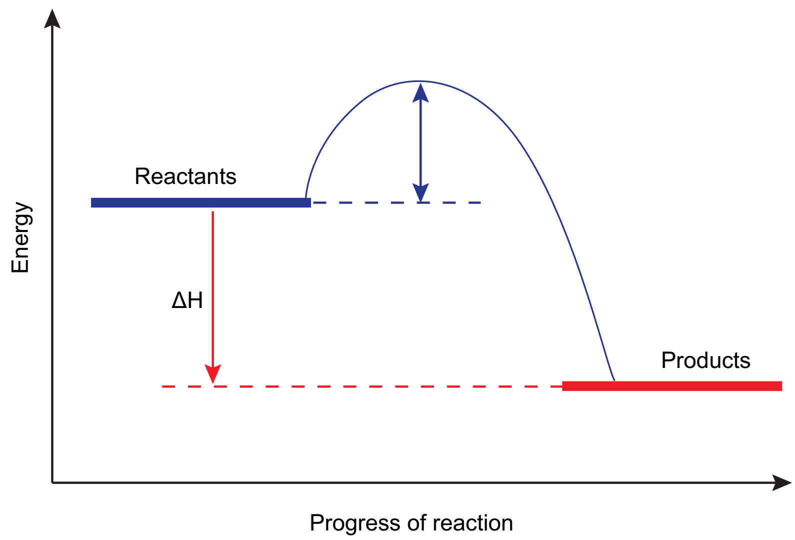
Energy transfer

In terms of energy transfer, there are two types of chemical reaction: exothermic and endothermic. The difference between them is to do with **whether heat is given out or taken in**.

Exothermic reactions release energy to the surroundings. In an exothermic reaction, most of the energy is given out as heat and this results in a temperature rise. Examples include burning fuels and neutralisation reactions. Exothermic reactions involve bond forming (as bond forming releases energy).

Endothermic reactions take in heat energy from the surroundings and therefore the temperature falls. Endothermic reactions involve bond breaking, these are much less common than exothermic reactions. Thermal decomposition is a type of endothermic reaction. The balanced symbol equation above is an endothermic reaction involving the conversion of calcium carbonate into quicklime (calcium oxide).

Energy level diagrams are a quick way of showing the energy differences between exothermic and endothermic reactions. You need to be able to draw both types so you need to just learn these and be able to explain the key features listed below.



Key features of an exothermic energy level diagram

1. This is an exothermic reaction because the products are at a lower energy level than the reactants.
2. The difference in height equal the amount of energy (ΔH) released per mole. ΔH is negative.
3. The graph initially rises because the old bonds need to be broken.
4. The energy represented by the blue arrow is called the activation energy.

In an endothermic reaction the products are at higher energy levels than the reactants. On an endothermic energy level diagram the products and reactants would be in the opposite places to where they are on an exothermic energy level diagram.

Concentration calculations

Concentration is usually measured in grams per fixed volume of water. The fixed volume of water is one litre or one cubic decimetre.

The equation to use when calculating concentrations of solutions is:

$$\text{concentration (c)} = \text{mass (m)}/\text{volume (v)}$$

The reactivity series

Most metals need to be extracted from their ores with a chemical reaction. Some metals like gold are un-reactive and are found in their pure state rather than as a compound.

The reactivity series which is shown in Unit 3 tells you the relative reactivity of each metal. Metals at the top, like potassium and sodium, are more reactive than the metals at the bottom like tin and copper. As you already know from your Unit 1 revision notes, reactivity is to do with electrons in outer shells.

More reactive metals displace less reactive metals from dissolved metal compounds.

If you have time, you might like to read up on the reactivity series in more detail to understand displacement reactions more fully.

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Revision S4: Matter and electricity

Theory of matter

Matter is made up of particles (atoms or molecules –you know about these from Unit 1). Matter exists in three states. Below is a summary of what you need to know. Be sure to check out the diagram in Unit 4 which summarises the ideas about the theory of matter.

A **solid** has a definite size and shape (volume) which may be affected by a change in temperature. When a solid is heated it usually increases in size and then slightly decreases on cooling. Solids are not compressible. In solids the particles are arranged in a very orderly way and vibrate about a fixed point.

A **liquid** has a fixed volume and will take up the shape of any container into which it is poured. It is also affected by a temperature increase or decrease. Liquids are difficult to compress. In liquids the particles are still quite close together but they move around in a random way and collisions between the particles are commonplace. These collisions with the walls of a container cause pressure – the faster the speed of particles, the more collisions and the higher the pressure.

A **gas** has no fixed volume or shape. When poured into a container, it will spread out evenly (**diffusion**) and take on the shape of the container. Gases are readily compressible. Gases are very affected even by small changes in temperature and changes in pressure. In gases the particles are relatively far apart and travel at very high speeds. Because of the large spaces involved, collisions do happen but not as often as in liquids. These collisions with the walls of a container cause pressure.

Electrostatics and electrical circuits

You will find the key revision points about electrostatics and circuits in the revision notes for Unit 6. However, one additional tip for this section of work is to make sure you know and can draw the circuit symbols.

Electrical power

The **power rating** of an electrical device tells you the *rate at which the device converts electricity into other forms of energy*. The higher the power rating, the faster the device transfers electrical energy. The units of power are Watts, W. kW and MW are often used because of the large quantities involved.

1 Watt is the transfer of 1 Joule of electrical energy per second

or

P = Energy converted (J) / time (s)

Paying for electricity

- An electricity meter counts the *amount of electricity* used in units of kilowatt-hours (kWh).
- A kilowatt-hour is a measure of how much energy is used, so
- 1 kWh is equivalent to 1 kW of energy supplied every second for one hour.

To calculate the cost of electricity, you need to know 2 equations:

1. **units = kW × hours**
2. **cost = Units × price per unit**

You can put both of these formulas into the triangle shape if you want. You should know how to do this by now, but if not, ask your tutor to help.

In most calculations, you will need to use equation 1 to calculate the units used first and then equation 2 to calculate the total cost.

Very important – you must always convert times in seconds or minutes into hours for these calculations, so practise doing this if you are unsure.

Magnets

Only certain types of metal are magnetic: certain steels, iron, nickel and cobalt.

Magnets can be created naturally or by us deliberately. A simple way is to stroke a metal from the list above in one direction with a magnet you already have. This method is called induction.

Destroying magnetism can be easy too – either heat or hit your magnet.

Electromagnetism

Temporary magnets can be created by passing an electric current through a coil of wire. We call these types of magnets 'electromagnets' as they are only magnetic for the duration of the current. Electromagnets are very useful because they can be switched on and off and because you can vary their strength.

You can increase the strength of your electromagnet by the following three simple adjustments:

1. Increase the number of coils of wire.
2. Increase the size of the electric current.
3. Add a soft iron core into the coil.

Transformers

Transformers are basically two separate coils of wire around iron arms that are used to change voltages in electrical devices. There are two different types: step up and step down transformers.

- A **step-up transformer** increases the voltage.
- A **step-down transformer** reduces the voltage.

The transformer equation you need to know is:

secondary voltage/primary voltage = number of turns on secondary (or output) coil / number of turns on primary (or input) coil,
or: $V_s/V_p = N_s/N_p$

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Revision S5: Organic chemistry

Hydrocarbons

Organic chemistry is based on **hydrocarbons**. Hydrocarbons are made up from the elements carbon and hydrogen only. They are very important chemicals to us as they form the basis of fuels and many other useful substances.

Counting the carbon atoms

As you already know from Unit 5, the key to understanding organic chemistry is knowing the prefixes for the first 10 carbon atoms. This is a really important point. To remind you, these are:

Prefix	**Meth**	**Eth**	**Prop**	**But**	**Pent**	**Hex**	**Hept**	**Oct**	**Non**	**Dec**
No of carbon atoms	1	2	3	4	5	6	7	8	9	10

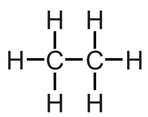
You must learn these! If you can't remember them as they are shown above, make yourself a mnemonic that you can count out on your fingers to represent the number of carbons. For example:

My **E**lephant **P**aused **B**ut **P**ainted **H**er **H**orrible **O**range **N**ails **D**isgracefully. (Though you will still have to work out a way of remembering Hex and Hept.)

Humorous ones are better in terms of memory so try to think of your own funny one.

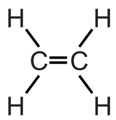
Simple hydrocarbons – alkanes and alkenes

Alkanes are the simplest hydrocarbons as they only contain single, covalent carbon to carbon bonds, C-C.


Ethane

The general formula for an alkane is: C_nH_{2n+2}

Alkenes are slightly more complicated than alkanes because they contain at least one double covalent carbon to carbon bond (C=C).


Ethene

The general formula for an alkene is: C_nH_{2n}

NB You can't automatically assume that if a compound has the molecular formula that matches the general formula, C_nH_{2n}, that the compound is an alkene, because there are other hydrocarbons which also fit this general formula.

In general, the **naming of alkanes and alkenes** proceeds along the general premise that you take the prefix name for the number of carbons and add the suffix **ane** for carbon-to-carbon single bond for alkanes and the suffix **ene** for carbon-to-carbon double bonds for alkenes. See Unit 5 for more detailed guidance on naming protocols for alkanes and alkenes for the first 10 carbons.

Alkanols and carboxylic acids

Other elements such as oxygen can be added to hydrocarbons to make other organic substances, such as **alkanols** and **carboxylic acids**.

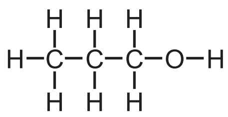
Alkanols

An alkanol is an unbranched alcohol. An alcohol is a compound that contains one or more OH group. This means that all the carbons are arranged in one long chain and that only the extra functional OH group branches off it.

An OH functional group is also called a hydroxyl group and as its name suggests it only contains an oxygen and hydrogen atom bonded together covalently.

An alkanol has the same structure as an alkane except that one, and only one of the hydrogen atoms is replaced with a hydroxyl group.

The general formula for alkanols is C_nH_{2n+1} OH, as can be seen from the diagram of propan -1-ol below.



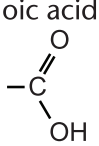
Propan-1-ol

In terms of naming you should remember that the '-1-' refers to the carbon atom the functional group is attached to. You always take the smallest number counting from either side, where the first carbon atom is always numbered one.

Carboxylic acids

When a COOH functional group (see below) is added to an alkane, we create a carboxlic acid. Examples are milk, vinegar and citrus fruit juices. They are weak acids.

They are named in much the same way as alkanols are, with a number part to show which carbon atom the COOH is attached to (remember that the chain is always numbered to show the COOH group attached to the lowest carbon number) and the word part, based on the equivalent alkane, with the 'e' dropped and replaced with 'oic acid', e.g. methane → methanoic acid.



Methanoic acid

The general formula for carboxylic acids is $C_nH_{2n}O_2$.

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Revision S6: Electricity, magnetism and electromagnetic induction

Electrostatics – some basics

- **Static electricity** is created by rubbing two materials together. The friction causes electrons to be pulled off the atoms of one of the materials and deposited onto the surface of the other material.
- There are only two types of charge: **positive** (electrons lost) or **negative** (electrons gained).
- These charges can induce or temporarily create other charges in objects they are close to, giving rise to forces of **attraction** or **repulsion**.
- **Like charges** repel each other; **unlike charges** attract each other.
- Whether or not like or unlike charges are formed depends on whether the materials are **conductors** (where the electrons can move easily) or **insulators** (where the electrons are relatively fixed).
- **Applications** include paint sprayers, photocopiers and dust precipitators in fossil fuel power stations.

Current electricity

There are three key quantities you need to know about in an electrical circuit:

Current is a flow of charge. It is measured in amps, A with an ammeter in series in the circuit. The symbol for current is I.

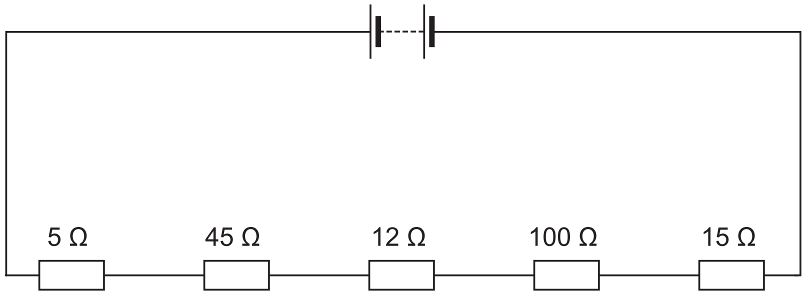
Voltage is a measure of how much energy is gained or lost by each coulomb of charge between two points. It is measured volts, V with a voltmeter in parallel in the circuit. The symbol for voltage is V.

Resistance is a measure of how much the flow of electricity is resisted by the component or conductor. It is measured in ohms, Ω and is represented with the symbol R. The resistance of a conductor depends on:

1. its length – longer means more R.
2. its cross-sectional area – bigger means less R.
3. the material of which it is made – some materials have low resistance while other materials have high resistance.

Calculating total resistance

You can expect to see circuits which have either **multiple series resistors** or **multiple parallel resistors**. Series resistors are connected one after the other. Parallel resistors are connected across each other. You need to be able to recognise the difference between the two types of connections as well as being able to calculate the total resistance for each type of circuit.

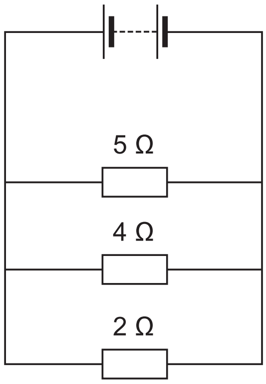


For multiple series resistors like the diagram above use this equation,

$$R_T = R_1 + R_2 + R_3 + \dots\dots\dots$$

where RT = total resistance in ohms, R1 = resistance of resistor 1, R2 = resistance of resistor 2 and R3 = resistance of resistor 3.

Tip: You can just add up all the resistances in a series circuit to get the total R.



For multiple parallel resistors like in the diagram above use this equation:

$1/R_T = 1/R_1 + 1/R_2 + 1/R_3 + \dots\dots\dots$

where RT = total resistance in ohms; R1 = Rresistance of resistor 1, R2 = resistance of resistor 2, R3 = resistance of resistor 3.

Tip: Parallel resistances are more complicated than series and you need to add up the reciprocals of each resistance and then take its inverse.

Look at the worked example in Unit 6 for more help!

All three quantities of V, I and R are linked by Ohm's Law. Ohm's Law says that the voltage is equal to the product of current and resistance:

voltage = current × resistance

or

$$V = I \times R$$

(You can also put Ohm's law into the triangle arrangement you saw in Unit 1. Try this for yourself!)

Semiconductors

By adding tiny amounts of other substances like phosphorus or boron to elements like silicon or germanium, their conductivity can be significantly improved.

n-type semiconductors

A phosphorus atom has five outer electrons so one is 'spare'. For each phosphorus atom **doped** into the base semiconductor, an additional free electron is introduced, increasing the overall conductivity – more electrons, more conduction!

How do p-type semiconductors work?

A boron atom has three outer electrons. So, for each boron atom added as an impurity to the semiconductor, a positive 'hole' is created, thereby increasing its conductivity. An electron from the surrounding silicon atoms moves into the gap, leaving behind another gap, and so on. The gap can 'move' through the silicon, 'conducting' as it goes.

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Revision S7: Waves and radiation

Waves

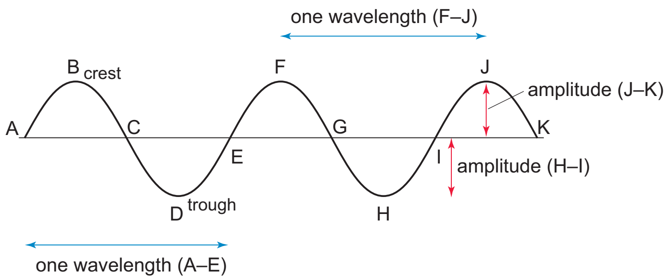
- All waves carry energy but they do not transfer matter.
- In a **longitudinal** wave the energy is transferred in the same direction as the vibration.
- In a **transverse** wave the energy is transferred at right angles to the direction of the vibration.
- Most waves are transverse waves, for example light and other electromagnetic waves, and water waves. Sound and seismic P-waves are the only main longitudinal waves.
- All waves can be **reflected**, **refracted** and **diffracted**.

Describing waves - amplitude, wavelength and frequency

Amplitude, a is shown by distance J–K. Units = metres.

Wavelength, λ is shown by distance A–E. The wavelength covers the full cycle of the wave. Units = metres.

Frequency, f is how many complete waves there are per second. Units = Hz (Hertz). Higher frequencies are measured in multiples of hertz, usually using the prefixes of kilo or mega to create units of kilohertz (kHz) or megahertz (MHz).



The wave equations

There are two equations used for waves:

$$\text{speed} = \frac{\text{distance the wave travels (m)}}{\text{time taken (s)}}$$

or

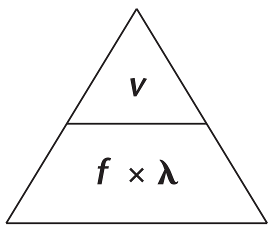
$$V = d/t$$

$$\text{speed} = \text{frequency (Hz)} \times \text{wavelength (m)}$$

or

$$V = f\,\lambda$$

Both of these equations can be remembered in the triangle format. You already have the triangle for v=d/t from Unit 2.



Tip: The equation you use depends on what you are being asked to find and what quantities you have been given. If the question mentions Speed, Frequency and Wavelength, then you need to use V = f λ, but if it mentions Speed, Distance and Time, then you need to use V= d/t.

Light

Light is an electromagnetic wave. It is the visible part of the electromagnetic spectrum and like all other electromagnetic waves it has the following properties:

- It is a transverse wave.
- It has a speed of 3×10^8 m/s.
- It travels in straight lines.
- It can travel through a vacuum.
- It can be reflected, refracted and diffracted.

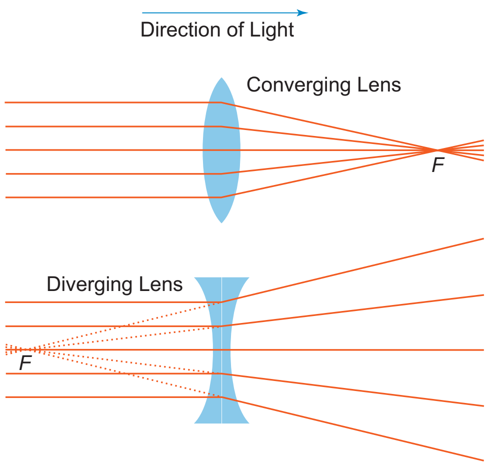
The table below shows the main differences between these key properties of waves in the context of light. If you have time, you might like to read up some more about these properties.

Refraction	Reflection	Diffraction
Light waves change direction as they travel from one medium into another. The change of direction is caused by the change in speed of the waves in the different media. The wavelength changes as well as the speed but the frequency remains constant.	This is when the light waves bounce off even surfaces. The more polished the surface (like a mirror), the more uniformly the light is reflected and a clear reflection is obtained. The angle of reflection = the angle of incidence.	Light waves spread out or diffract when they pass through gaps or around objects. Diffraction happens a lot with sound waves because they have long wavelengths.

Lenses

Lenses are optical tools that used to refract light. Lenses are also used in cameras, projectors, microscopes and telescopes, as well as in everyday spectacles. The two main types are **converging** and **diverging**. To some extent the clue about what they each do is in the name.

- **Converging lenses** are also known as **convex** lenses. Convex lenses are used to magnify the image.
- **Diverging lenses** are also known as **concave** lenses. Concave lenses are used to give a diminished or reduced image.



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