PHYSICS

PAPER 1 TOPICS

REVISION ORGANISER

Chapter 1: Conservation and dissipation of energy

Knowledge organiser

Systems

A **system** is an object or group of objects.

Whenever anything changes in a system, energy is transferred between its stores or to the surroundings.

A **closed system** is one where no energy can escape to or enter from the surroundings. The total energy in a closed system never changes.

Energy stores

kinetic	energy an object has because it is moving
gravitational potential	energy an object has because of its height above the ground
elastic potential	energy an elastic object has when it is stretched or compressed
thermal (or internal)	energy an object has because of its temperature (the total kinetic and potential energy of the particles in the object)
chemical	energy that can be transferred by chemical reactions involving foods, fuels, and the chemicals in batteries
nuclear	energy stored in the nucleus of an atom
magnetic	energy a magnetic object has when it is near a magnet or in a magnetic field
electrostatic	energy a charged object has when near another charged object

Energy transfers

Energy can be transferred to and from different stores by:

Heating
Energy is transferred from one object to another object with a lower temperature.

Waves
Waves (e.g., light and sound) can transfer energy.

Electricity
An electric current transfers energy.

Forces (mechanical work)
Energy is transferred when a force moves or changes the shape of an object.

Examples of energy transfers

When you stretch a rubber band, energy from your chemical store is mechanically transferred to the rubber band's elastic potential store.

When a block is dropped from a height, energy is mechanically transferred (by the force of gravity) from the block's gravitational potential store to its kinetic store.

When this block hits the ground, energy from its kinetic energy store is transferred mechanically and by sound waves to the thermal energy store of the surroundings.

The electric current in a kettle transfers energy to the heating element's thermal energy store. Energy is then transferred by heating from the heating element's thermal energy store to the thermal energy store of the water.

When an object slows down due to friction, energy is mechanically transferred from the object's kinetic store to its thermal store, the thermal store of the object it is rubbing against, and to the surroundings.

Work done

When an object is moved by a force **work** is done on the object. The force transfers energy to the object. The amount of energy transferred is equal to the work done. You can calculate the work done (and the energy transferred) using the equation:

L work done (J) = force (N) x distance moved along the line of action of the force (m)

Calculating the energy in an energy store

An object's gravitational potential energy store depends on its height above the ground, the gravitational field strength, and its mass.

gravitational potential energy (J) = mass (kg) × gravitational field strength (N/kg) × height (m)

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

An object's kinetic energy store depends only on its mass and speed.

kinetic energy (J) = 0.5 × mass (kg) × (speed)^2 (m/s)

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

The elastic potential energy store of a stretched spring can be calculated using:

elastic potential energy (J) = 0.5 × spring constant (N/m) × (extension)^2 (m)

$E_e = \frac{1}{2} k\,e^2$ (assuming the limit of proportionality has not been exceeded)

Power is how much work is done (or how much energy is transferred) per second. The unit of power is the watt (W).

1 watt = 1 joule of energy transferred per second

$$\text{power (W)} = \frac{\text{energy transferred (J)}}{\text{time (s)}}$$

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

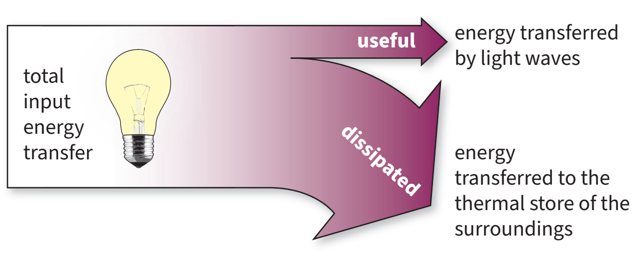
or

$$\text{power (W)} = \frac{\text{work done (J)}}{\text{time (s)}}$$

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

Useful and dissipated energy

Energy cannot be created or destroyed – it can only be transferred usefully, stored, or dissipated (wasted).



Energy is never entirely transferred usefully – some energy is always dissipated, meaning it is transferred to less useful stores.

All energy eventually ends up transferred to the thermal energy store of the surroundings.

In machines, work done against the force of friction usually causes energy to be wasted because energy is transferred to the thermal store of the machine and its surroundings.

Lubrication is a way of reducing unwanted energy transfer due to friction.

Streamlining is a way of reducing energy wasted due to air resistance or drag in water.

Use of thermal insulation is a way of reducing energy wasted due to heat dissipated to the surroundings.

Efficiency is a measure of how much energy is transferred usefully. You must know the equation to calculate efficiency as a *decimal*:

$$\text{efficiency} = \frac{\text{useful output energy transfer (J)}}{\text{total input energy transfer (J)}}$$

L *or*

$$\text{efficiency} = \frac{\text{useful power output (W)}}{\text{total power input (W)}}$$

To give efficiency as a *percentage*, just multiply the result from the above calculation by 100 and add the % sign to the answer.

Key terms

Make sure you can write a definition for these key terms.

chemical, closed system, dissipated, efficiency, elastic potential, electrostatic, gravitational potential, kinetic, lubrication, magnetic, nuclear, power, streamlining, system, thermal, work done

Chapter 2: Energy transfer by heating

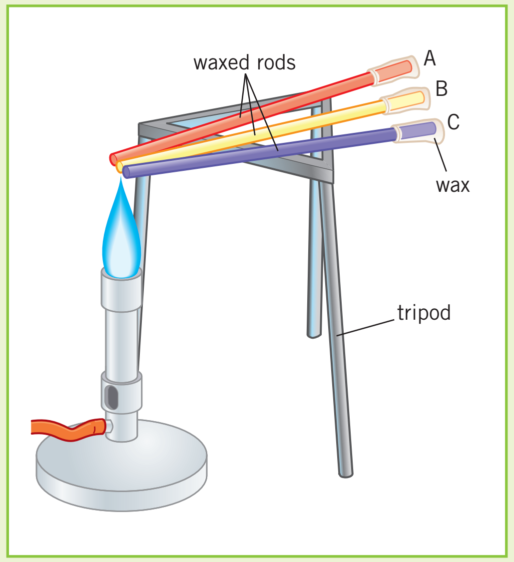
Knowledge organiser

Thermal conductivity

The **thermal conductivity** of a material tells you how quickly energy is transmitted through it by thermal conduction.

You can test the thermal conductivity of rods made of different metals using this experimental set-up. Each rod must have the same diameter and length, and the same temperature difference between its ends.

One end of each rod is covered in wax and the other ends are heated equally. The faster the wax melts, the higher the thermal conductivity of the metal.



Insulating buildings

Heating bills can be expensive so it is important to reduce the rate of heat loss from buildings.

Some factors that affect the rate of heat loss from a building include:

1. the thickness of its walls and roof
2. the thermal conductivity of its walls and roof.

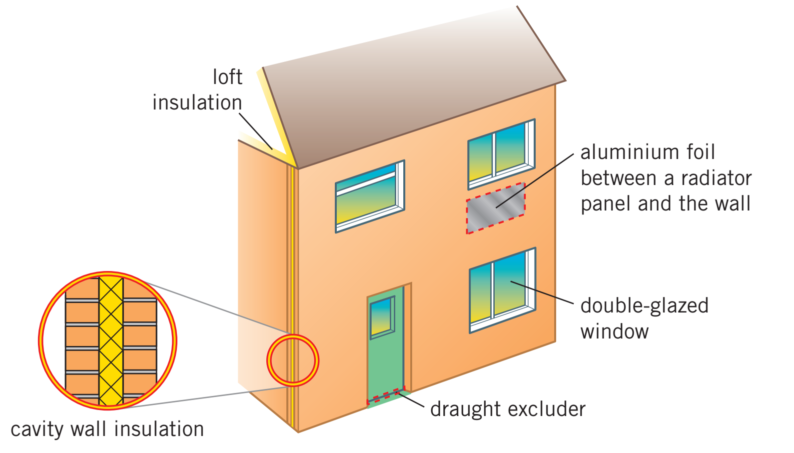
lower thermal conductivity = lower rate of heat loss

The thermal conductivity of the walls and roof can be reduced by using **thermal insulators**.

A thermal insulator is a material which has a low thermal conductivity. The rate of energy transfer through an insulator is low.

The energy transfer per second through a material depends on:

1. the material's thermal conductivity
2. the temperature difference between the two sides of the material
3. the thickness of the material.



Specific heat capacity

When a substance is heated or cooled the temperature change depends on:

- the substance's mass
- the type of material
- how much energy is transferred to it.

Every type of material has a **specific heat capacity** – the amount of energy needed to raise the temperature of 1 kg of the substance by 1 °C.

The energy transferred to the thermal store of a substance can be calculated from the substance's mass, specific heat capacity, and temperature change:

change in thermal energy (J) = mass (kg) × specific heat capacity (J/kg°C) × temperature change (°C)

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

This equation will be given to you on the equation sheet, but you need to be able to select and apply it to the correct questions.

Infrared radiation

Infrared radiation is part of the **electromagnetic spectrum**.

All objects **emit** (give out) and **absorb** (take in) infrared radiation.

The higher the temperature of an object, the more infrared radiation it emits in a given time.

A good absorber of infrared radiation is also a good emitter.

For an object at a constant temperature:

- infrared radiation emitted = infrared radiation absorbed
- infrared radiation is emitted across a continuous range of wavelengths.

An object's temperature will increase if it absorbs infrared radiation at a higher rate than it emits it. This rule applies to the planet Earth.

Black bodies

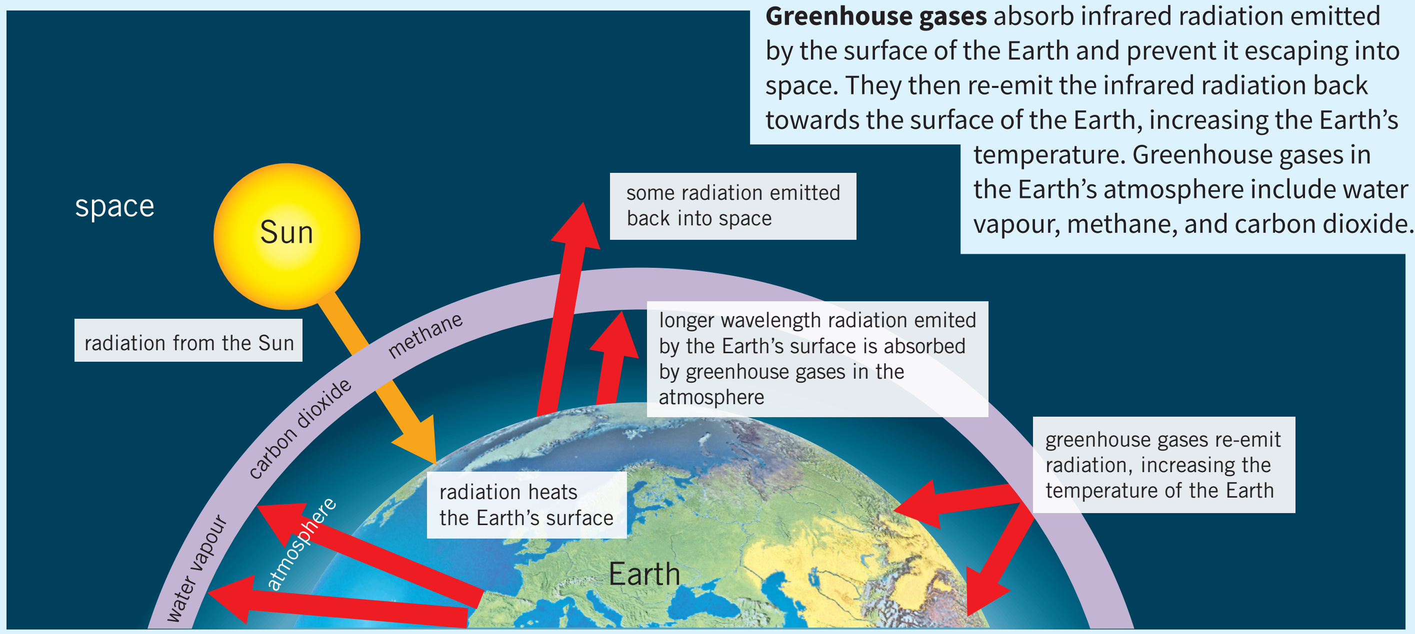
A **black body** is a theoretical object that absorbs 100% of the radiation that falls on it.

A perfect black body would not reflect or transmit any radiation, and would also be a perfect emitter of radiation.

Radiation and the Earth's temperature

The temperature of the Earth depends on lots of factors, including the rate at which visible light and infrared radiation are reflected, absorbed, and emitted by the Earth's atmosphere and surface.

Greenhouse gases absorb infrared radiation emitted by the surface of the Earth and prevent it escaping into space. They then re-emit the infrared radiation back towards the surface of the Earth, increasing the Earth's temperature. Greenhouse gases in the Earth's atmosphere include water vapour, methane, and carbon dioxide.



Human activities such as burning fossil fuels, deforestation, and livestock farming are increasing the amount of greenhouse gases in the Earth's atmosphere. This is causing the Earth's temperature to increase – a major cause of climate change.

Key terms

Make sure you can write a definition for these key terms.

absorb | *black body* | *electromagnetic spectrum* | *emit* | *greenhouse gas* | *infrared radiation* | *specific heat capacity* | *thermal conductivity* | *thermal insulator*

Chapter 3: Energy resources

Knowledge organiser

Energy resources

The main ways in which we use the Earth's energy resources are:

- generating electricity
- heating
- transport.

Most of our energy currently comes from **fossil fuels** – coal, oil, and natural gas.

Reliability and environmental impact

Some energy resources are more reliable than others. **Reliable** energy resources are ones that are available all the time (or at predictable times) and in sufficient quantities.

Both **renewable** and **non-renewable** energy resources have some kind of **environmental impact** when we use them.

Non-renewable energy resources

- not replaced as quickly as they are used
- will eventually run out

For example, fossil fuels and nuclear fission.

Renewable energy resources

- can be replaced at the same rate as they are used
- will not run out

For example, solar, tidal, wave, wind, geothermal, biofuel, and hydroelectric energies.

Non-renewable energy resources

Resource	Main uses	Source	Advantages	Disadvantages
coal	generating electricity	extracted from underground	• enough available to meet current energy demands • reliable – supply can be controlled to meet demand • relatively cheap to extract and use	• will eventually run out • release carbon dioxide when burned – one of the main causes of climate change • release other polluting gases, such as sulfur dioxide (from coal and oil) which causes acid rain • oil spills in the oceans kill marine life
oil	generating electricity transport heating			
natural gas	generating electricity heating			
nuclear fission	generating electricity	mining naturally occurring elements, such as uranium and plutonium	• no polluting gases or greenhouse gases produced • enough available to meet current energy demands • large amount of energy transferred from a very small mass of fuel • reliable – supply can be controlled to meet demand	produces nuclear waste, which is: • dangerous • difficult and expensive to dispose of • stored for centuries before it is safe to dispose of. nuclear power plants are expensive to: • build and run • decommission (shut down).

Key terms

Make sure you can write a definition for these key terms.

biofuel carbon neutral environmental impact fossil fuel geothermal hydroelectric non-renewable reliability renewable

Renewable energy resources

Resource	Main uses	Source	Advantages	Disadvantages
solar energy	generating electricity	sunlight transfers energy to solar cells	can be used in remote places very cheap to run once installed no pollution/greenhouse gases produced	supply depends on weather expensive to buy and install cannot supply large scale demand
	heating	sunlight transfers energy to solar heating panels		
hydroelectric energy	generating electricity	water flowing downhill turns generators	low running cost no fuel costs reliable and supply can be controlled to meet demand	expensive to build hydroelectric dams flood a large area behind the dam, destroying habitats and resulting in greenhouse gas production from rotting vegetation
tidal energy	generating electricity	turbines on tidal barrages turned by water as the tide comes in and out	predictable supply as there are always tides can produce large amounts of electricity no fuel costs no pollution/greenhouse gases produced	tidal barrages: – change marine habitats and can harm animals – restrict access and can be dangerous for boats – are expensive to build and maintain cannot control supply supply varies depending on time of month
wave energy	generating electricity	floating generators powered by waves moving up and down	low running cost no fuel costs no pollution/greenhouse gases produced	floating generators: – change marine habitats and can harm animals – restrict access and can be dangerous for boats – are expensive to build, install, and maintain dependent on weather cannot supply large scale demand
wind energy	generating electricity	turbines turned by the wind	low running cost no fuel costs no pollution/greenhouse gases produced	supply depends on weather large amounts of land needed to generate enough electricity for large scale demand can produce noise pollution for nearby residents
geothermal energy	generating electricity heating	radioactive substances deep within the Earth transfer heat energy to the surface	low running cost no fuel costs no pollution/greenhouse gases produced	expensive to set up only possible in a few suitable locations around the world
biofuels	generating electricity transport	fuel produced from living or recently living organisms, for example, plants and animal waste	can be **carbon neutral** – the amount of carbon dioxide released when the fuel is burnt is equal to the amount of carbon dioxide absorbed when the fuel is grown reliable and supply can be controlled to meet demand	expensive to produce biofuels growing biofuels requires a lot of land and water that could be used for food production can lead to deforestation – forests are cleared for growing biofuel crops

Chapter 4: Electric circuits

Knowledge organiser

Charge

An atom has no **charge** because it has equal numbers of positive protons and negative electrons.

When electrons are removed from an atom it becomes *positively* charged. When electrons are added to an atom it becomes *negatively* charged.

Static charge

Insulating materials can become charged when they are rubbed with another insulating material. This is because electrons are transferred from one material to the other. Materials that gain electrons become negatively charged and those that lose electrons become positively charged.

Positive charges do not usually transfer between materials.

Electric charge is measured in coulombs C.

Sparks

If two objects have a very strong electric field between them, electrons in the air molecules will be strongly attracted towards the positively charged object. If the electric field is strong enough, electrons will be pulled away from the air molecules and cause a flow of electrons between the two objects – this is a **spark**.

Drawing electric fields

A charged object creates an **electric field** around itself.

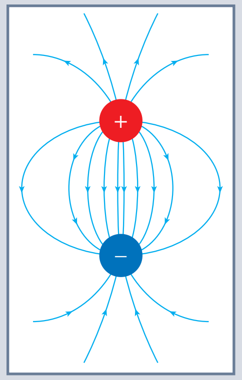
If a charged object is placed in the electric field of another charged object it experiences **electrostatic force**. This means that the two charged objects exert a non-contact force on each other:

- like charges repel each other
- opposing charges attract each other.

The electric field, and the force between two charged objects, gets stronger as the distance between the objects decreases.

Drawing electric fields

Electric fields can be represented using a diagram with field lines. These show the direction of the force that a small positive charge would experience when placed in the electric field.



When drawing electric fields, make sure:

- field lines meet the surface of charged objects at 90°
- arrows always point away from positive charges and towards negative charges.

Resistance

When electrons move through a circuit, they collide with the ions and atoms of the wires and components in the circuit. This causes **resistance** to the flow of charge.

The unit of resistance is the ohm (Ω).

A long wire has more resistance than a short wire because electrons collide with more ions as they pass through a longer wire.

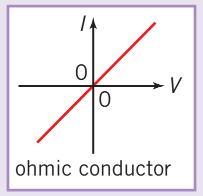
The resistance of an electrical component can be found by measuring the current and potential difference:

potential difference (V) = current (A) × resistance (Ω)

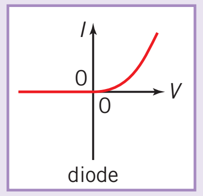
$V = IR$

Current-potential difference graphs

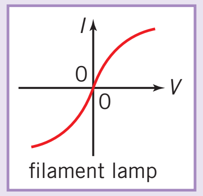
A graph of current through a component against the p.d. across it (I–V graph), is known as the component characteristic.



Current is directly proportional to the p.d. in an ohmic conductor at a constant temperature. The resistance is constant.



The current through a diode only flows in one direction – called the forward direction. There needs to be a minimum voltage before any current will flow.



As more current flows through the filament, its temperature increases. The atoms in the wire vibrate more, and collide more often with electrons flowing through it, so resistance increases as temperature increases. The resistance of a thermistor decreases and temperature increases. The resistance of a light dependent resistor (LDR) decreases as light intensity increases.

The resistance of an ohmic conductor can be found by calculating the gradient at that point and taking the inverse:

$$\text{resistance} = \frac{1}{\text{gradient}}.$$

Electric current

Electric current is when **charge** flows. The charge in an electric circuit is carried by electrons.

The unit of current is the ampere (amp, A).

1 ampere = 1 coulomb of charge flow per second

Charge (C) = current (A) x time (s)

In circuit diagrams, current flows from the positive terminal of a cell or battery to the negative terminal. This is known as conventional current.

In a single closed loop, the current has the same value at any point in the circuit.

Metals are good conductors of electricity because they contain delocalised electrons, which are free to flow through the structure.

Potential difference

Potential difference (p.d.) is a measure of how much energy is transferred between two points in a circuit. The unit of potential difference is the volt (V).

- The p.d. across a component is the work done on it by each coulomb of charge that passes through it.
- The p.d. across a power supply or battery is the energy transferred to each coulomb of charge that passes through it.

For electrical charge to flow through a circuit there must be a source of potential difference.

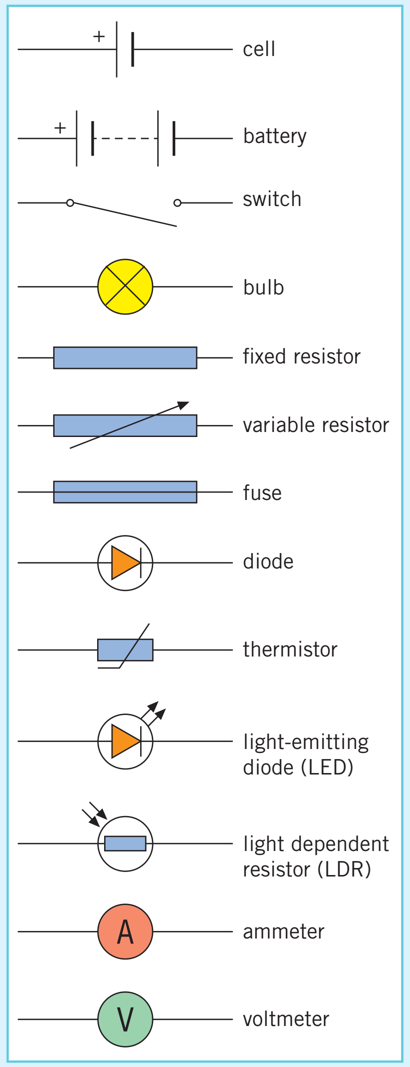
Potential difference (V) = energy transferred (J)/ charge (C)

Key terms

Make sure you can write a definition for these key terms.

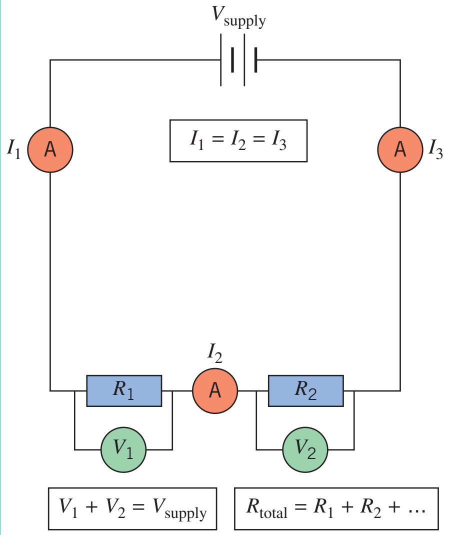
ampere
charge
coulomb
current
electric field
electrostatic force
LDR
parallel
potential difference
resistance
series
static
thermistor

Circuit components



Series circuits

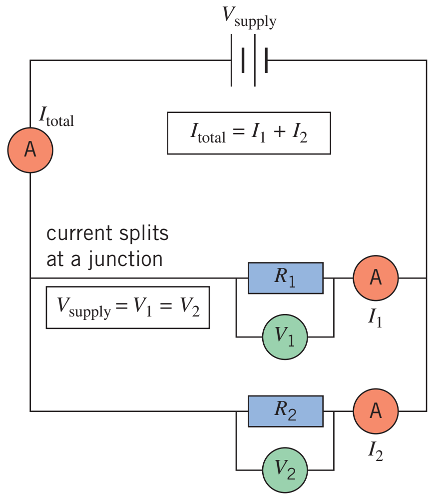
In a series circuit, the components are connected one after the other in a single loop. If one component in a series circuit stops working the whole circuit will stop working.



Components with a higher resistance will transfer a larger share of the total p.d. because $V = IR$ (and current is the same through all components).

Parallel circuits

A parallel circuit is made up of two or more loops through which current can flow. If one branch of a parallel circuit stops working, the other branches will not be affected.



The total resistance of two or more components in parallel is always less than the smallest resistance of any branch. This is because adding a loop to the circuit provides another route for the current to flow, so more current can flow in total even though the p.d. has not changed. Adding more resistors in parallel decreases the total resistance of a circuit.

Chapter 5: Electricity in the home

Knowledge organiser

Mains electricity

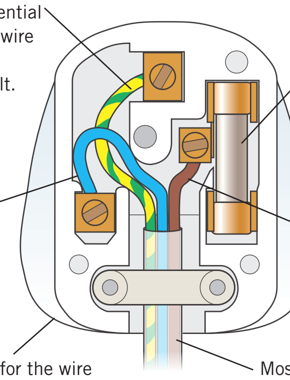
A cell or a battery provides a **direct current (dc)**. The current only flows in one direction and is produced by a **direct potential difference**.

Mains electricity provides an **alternating current (ac)**. The current repeatedly reverses direction and is produced by an **alternating potential difference**.

The positive and negative terminals of an alternating power supply swap over with a regular frequency.

The frequency of the mains electricity supply in the UK is 50 Hz and its voltage is 230 V.

Plugs



Why do transformers improve efficiency?

A high potential difference across the transmission cables means that a lower current is needed to transfer the same amount of power, since:

power (W) = current (A) × potential difference (V)

$$P = IV$$

L

A lower current in the cables means less electrical power is wasted due to heating of the cables, since the power lost in heating a cable is:

power (W) = current^2 (A) × resistance (Ω)

$$P = I^2R$$

L

This makes the National Grid an efficient way to transfer energy.

If 100% efficiency is assumed:

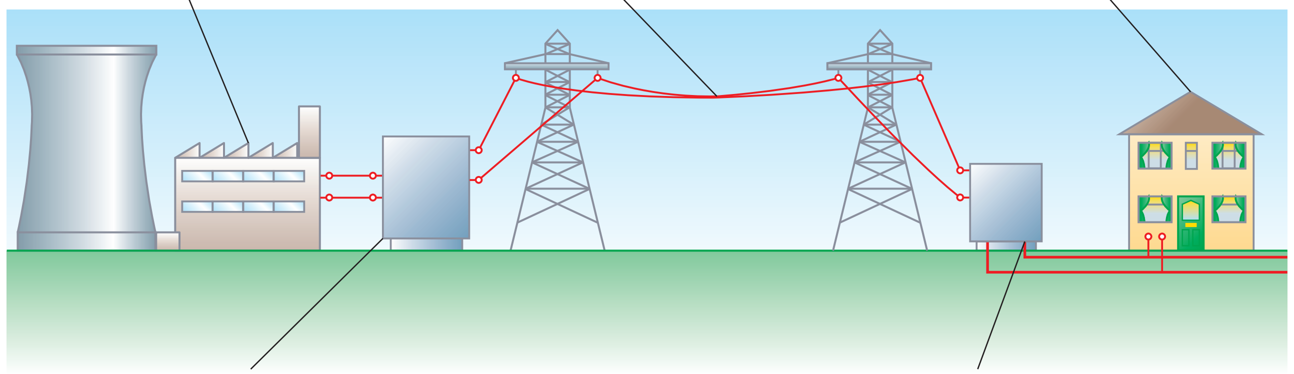
primary potential difference × primary current = secondary potential difference × secondary current

$$V_p I_p = V_s I_s$$

The National Grid

The **National Grid** is a nationwide network of cables and transformers that link power stations to homes, offices, and other consumers of mains electricity.

Transformers are devices that can change the potential difference of an alternating current.



By making the grid potential difference much higher, a smaller current is needed to transfer the same power. Therefore, the National Grid is an efficient way to transfer power due to less heating loss in the wire.

Energy transfer in electrical appliances

Electrical appliances transfer energy.

For example, an hairdryer transfers energy electrically from a chemical store (e.g., the fuel in a power station) to the kinetic energy store of the fan inside the hairdryer and to the thermal energy store of the heating filaments inside the hairdryer.

When you turn an electrical appliance on, the potential difference of the mains supply causes charge (carried by electrons) to flow through it.

You can calculate the **charge flow** using the equation:

L charge flow (C) = current (A) × time (s)

$$Q = It$$

You can find the energy transferred to an electrical appliance when charge flows through it using:

L energy transferred (J) = charge flow (C) × potential difference (V)

$$E = QV$$

You can find the energy transferred by an electrical appliance using the equation:

L energy transferred (J) = power (W) × time (s)

Key terms

Make sure you can write a definition for these key terms.

alternating current · alternating potential difference · charge flow · coulombs · direct current · direct potential difference · fuse · National Grid · short circuit · step-down transformer · step-up transformer

Chapter 6: Molecules and matter
Knowledge organiser

Changes of state

Changes of state and conservation of mass

Changes of state are physical changes because no new substances are produced. The mass always stays the same because the number of particles does not change.

Particles and kinetic energy

When the temperature of a substance is increased, the kinetic energy store of its particles increases and the particles vibrate or move faster.

If the kinetic store of a substance's particles increases or decreases enough, the substance may change state.

Density

You can calculate the density of an object if you know its mass and volume:

$$\text{density (kg/m}^3) = \frac{\text{mass (kg)}}{\text{volume (m}^3)}$$

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

L

States of matter

Gas

Arrangement	• particles are spread out • almost no forces of attraction between particles • large distance between particles on average
Movement	• particles move randomly at high speed
Properties	• low density • no fixed volume or shape • can be compressed and can flow • spread out to fill all available space

Liquid

Arrangement	• particles are in contact with each other • forces of attraction between particles are weaker than in solids
Movement	• particles are free to move randomly around each other
Properties	• usually lower density than solids • fixed volume • shape is not fixed so they can flow

Solid

Arrangement	• particles held next to each other in fixed positions by strong forces of attraction
Movement	• particles vibrate about fixed positions
Properties	• high density • fixed volume • fixed shape (unless deformed by an external force)

Internal energy

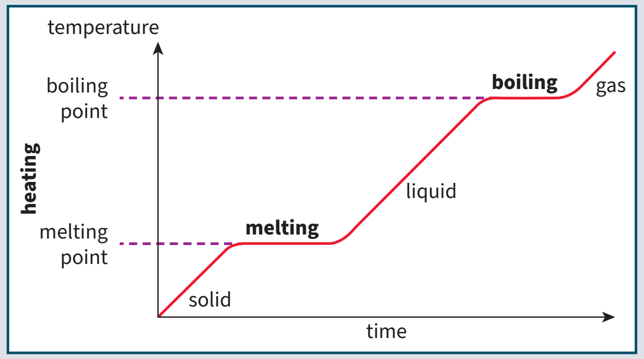
Heating a substance increases its **internal energy**.

Internal energy is the sum of the total kinetic energy the particles have due to their motion and the total potential energy the particles have due to their positions relative to each other.

Latent heat

In a graph showing the change in temperature of a substance being heated or cooled, the flat horizontal sections show when the substance is changing state.

The energy transfers taking place during a change in state do not cause a change in temperature, but do change the internal energy of the substance.



The energy transferred when a substance changes state is called the **latent heat**.

Specific latent heat – the energy required to change 1 kg of a substance with no change in temperature.

Specific latent heat of fusion – the energy required to melt 1 kg of a substance with no change in temperature.

Specific latent heat of vaporisation – the energy required to evaporate 1 kg of a substance with no change in temperature.

The energy needed to change the state of a substance can be calculated using the equation:

$$\text{thermal energy for a change in state (J)} = \text{mass (kg)} \times \text{specific latent heat (J/kg)}$$

$$E = m \times l$$

The relationship between temperature and pressure in gases

Gas temperature

The particles in a gas are constantly moving in random directions and with random speeds.

The temperature of a gas is related to the average kinetic energy of its particles.

When a gas is heated, the particles gain kinetic energy and move faster, so the temperature of the gas increases.

Gas pressure

The pressure a gas exerts on a surface, such as the walls of a container, is caused by the force of the gas particles hitting the surface.

The pressure of a gas produces a net force at right angles to the walls of a container or any surface.

If the temperature of a gas in a sealed container is increased, the pressure increases because

- the particles move faster so they hit the surfaces with more force
- the number of these impacts per second increases, exerting more force overall.

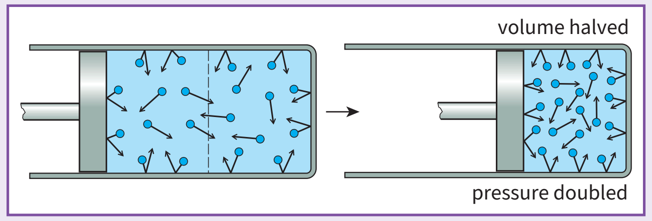
If a gas is compressed quickly, for example, in a bicycle pump, its temperature can rise. This is because

- compressing the gas requires a force to be applied to the gas – this results in work being done to the gas, since work done = force × distance
- the energy gained by the gas is not transferred quickly enough to its surroundings.

The relationship between volume and pressure in gases

If the volume of a fixed mass of gas at a constant temperature is decreased, the pressure increases because

- the distance the particles travel between each impact with a container wall is smaller
- the number of impacts per second increases, so the total force of impacts increases.



Similarly, if the volume is increased, the pressure decreases. This is because

- the distance the particles travel between each impact with a wall of the container is greater
- the number of impacts per second decreases, so the total force of the impacts decreases.

The pressure and volume of a fixed mass of gas at a constant temperature are linked by the equation:

$$\text{pressure (Pa)} \times \text{volume (m}^3) = \text{constant}$$

$$p \times V = \text{constant}$$

Rearranging this equation gives:

$$p = \frac{\text{constant}}{V} \quad \text{and} \quad V = \frac{\text{constant}}{p}$$

This shows that pressure is inversely proportional the volume of a gas.

Key terms

Write a definition for these key terms.

boiling, condensation, conservation of mass, density, evaporation, freezing, fusion, internal energy, latent heat, melting, specific latent heat, sublimation, vaporisation

Chapter 7: Radioactivity 1

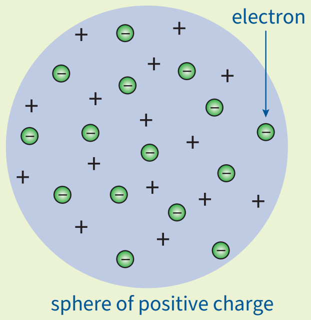
Knowledge organiser

Dalton's model

John Dalton thought the atom was a neutral solid sphere you cannot divide into smaller parts.

Plum pudding model

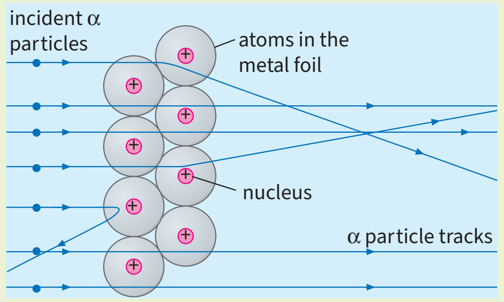
The discovery of negatively charged electrons led to the plum pudding model – a cloud of positive charge with electrons embedded in it.



Alpha scattering experiment

Positively charged alpha particles were fired at a thin sheet of gold foil.

- Most went straight through
- Some were deflected by small amounts
- 1 in 10 0000 deflected through large angles



Nuclear model

To explain the results, scientists deduced that there is a small positively charged nucleus at the centre of the atom where most of the mass is concentrated. The negative electrons orbit the nucleus.

Bohr's model

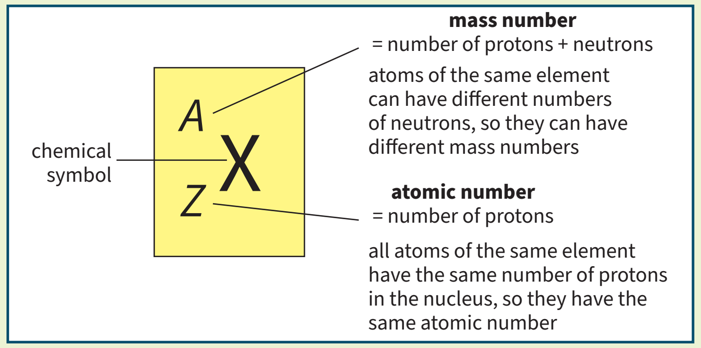
Bohr suggested the electrons orbit at specific distances called energy levels.

Basic structure of an atom

The nucleus, which is 10 000 times smaller than the radius of the atom, consists of two particles:

- positively charged protons
- neutrons which are neutral

An atom is uncharged overall and has equal numbers of protons and electrons.



Isotopes are atoms of the same element, with the same number of protons but a different numbers of neutrons.

Radioactive decay

Radioactive decay is when nuclear radiation is emitted by unstable atomic nuclei so that they become more stable. It is a *random* process. This radiation can knock electrons out of atoms in a process called **ionisation**.

Type of radiation	Change in the nucleus	Ionising power	Range in air	Stopped by	Decay equation
α alpha particle (two protons and two neutrons)	nucleus loses two protons and two neutrons	highest ionising power	travels a few centimetres in air	stopped by a sheet of paper	${}^{A}_{Z}X \rightarrow {}^{(A-4)}_{(Z-2)}Y + {}^{4}_{2}\alpha$
β beta particle (fast-moving electron)	a neutron changes into a proton and an electron	high ionising power	travels ≈ 1 m in air	stopped by a few millimetres of aluminium	${}^{A}_{Z}X \rightarrow {}^{A}_{(Z+1)}Y + {}^{0}_{-1}\beta$
γ gamma radiation (short-wavelength, high-frequency EM radiation)	some energy is transferred away from the nucleus	low ionising power	virtually unlimited range in air	stopped by several centimetres of thick lead or metres of concrete	${}^{A}_{Z}X \rightarrow {}^{A}_{Z}X + {}^{0}_{0}\gamma$

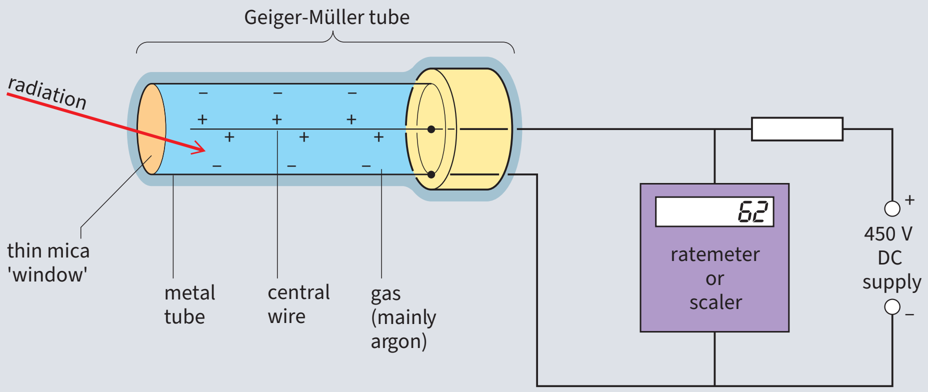
Activity and count rate

The **activity** of a radioactive source is the rate of decay of an unstable nucleus, measured in becquerel (Bq).

1 Bq = 1 *decay per second*

Detectors (e.g., **Geiger-Müller tubes**) record a **count rate** (number of decays detected per second).

$$\text{count rate after } n \text{ half-lives} = \frac{\text{initial count rate}}{2^n}$$



Half-life

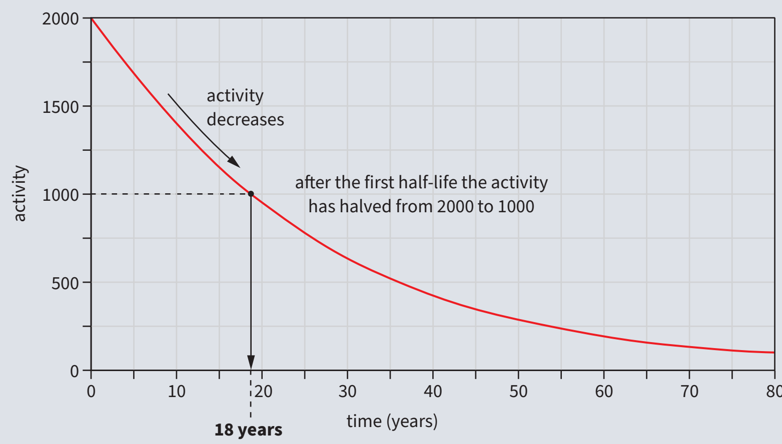
The **half-life** of a radioactive source is the time

- for half the number of unstable nuclei in a sample to decay
- for the count rate or activity of a source to halve.

The half-life of a source can be found from a graph of its count rate or activity against time.

To find the reduction in activity after a given number of half-lives:

1. calculate the activity after each half-life
2. subtract the final activity from the original activity.



The time taken for the activity to halve is 18 years. This is the half-life of this substance.

(HT only) Net decline can be given as a ratio: $\textit{net daecline} = \dfrac{\text{reduction in activity}}{\text{original activity}}$

Chapter 7: Radioactivity 2

Knowledge organiser

Ionising radiation

Living cells can be damaged or killed by ionising radiation.

The risk depends on the half-life of the source and the type of radiation.

Alpha radiation is very dangerous inside the body because it affects all the surrounding tissue. Outside the body it only affects the skin and eyes because it cannot penetrate further.

Beta and gamma radiation are dangerous outside and inside the body because they can penetrate into tissues.

Radiation dose

Radiation dose, measured in sievert (Sv), measures the health risk of exposure to radiation. It depends on the type and amount of radiation.

Background radiation

Background radiation is radiation that is around us all the time. It comes from:

- natural sources like rocks and cosmic rays
- nuclear weapons and nuclear accidents.

Background radiation is always present but the levels are higher in some locations and in some jobs.

Nuclear waste

When fuel rods are removed from the reactor, they are stored in large tanks in water for up to a year until they cool down.

Machines are then used to open up fuel rods and extract the unused plutonium and uranium. Any material that is left then has to be stored securely as they have lots of radioactive isotopes with long half-lives. This is done to prevent radioactive contamination.

Irradiation versus contamination

irradiation	when an object is exposed to nuclear radiation	cause harm through ionisation	prevented by shielding, removing, or moving away from the source of radiation
contamination	when atoms of a radioactive material are on or in an object		object remains exposed to radiation as long as it is contaminated contamination can be very difficult to remove

Nuclear radiation in medicine

Exploration of internal organs

Gamma-emitting **tracers** are injected or swallowed by a patient. Gamma cameras can then create an image showing where the tracer has gone.

The half-life of the tracer must be short enough so that most of the nuclei will decay shortly after the image is taken to limit the patient's radiation dose (normally about six hours).

Control or destruction of unwanted tissue

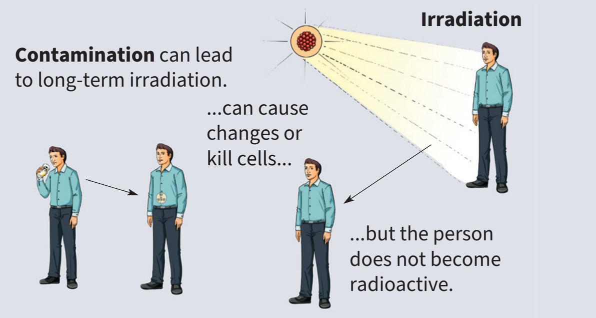
1. Narrow beams of gamma radiation can be focused on tumour cells to destroy them. Gamma is used because it can penetrate tumours from outside the body.
2. Beta- or gamma-emitting implants can be surgically placed inside (or next to) tumours. Their half-lives must be long enough to be effective, but short enough that it does not continue to irradiate the patient after treatment.

Protection against irradiation and contamination

You can protect against irradiation and contamination by:

- maintaining a distance from the radiation source
- limiting time near the source
- shielding from the radiation.

Studies on the effects of radiation should be published, shared with other scientists, and checked by **peer review** as they are important for human health.



Nuclear fission

Nuclear fission is when a large unstable nucleus absorbs an extra neutron and splits into two smaller nuclei of roughly equal size.

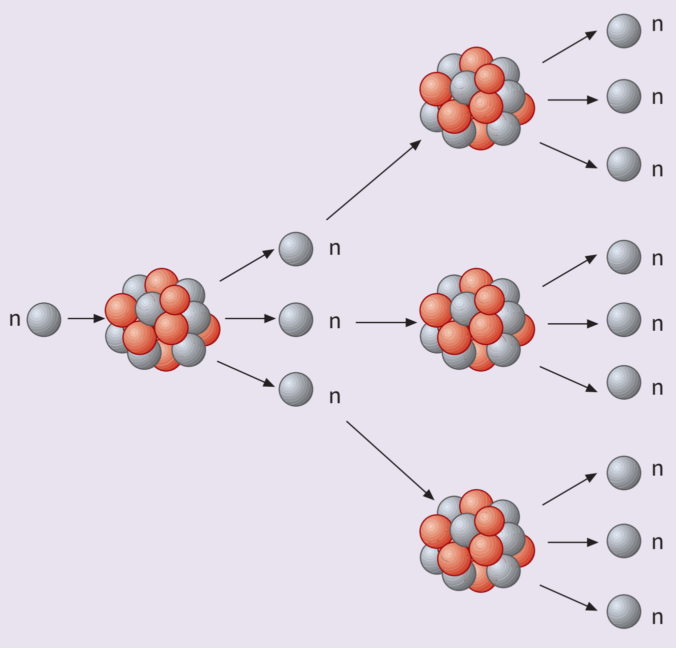
During nuclear fission:

- gamma radiation is emitted and energy is released
- two or three neutrons are emitted that can go on to cause a **chain reaction**.

The chain reaction in a power station reactor is controlled by absorbing neutrons.

Nuclear explosions are uncontrolled chain reactions.

On rare occasions an unstable nucleus splits apart without absorbing a neutron. This is called **spontaneous fission**.



Nuclear fusion

Nuclear fusion is when two light nuclei join to make a heavier one.

Some of the mass is converted to energy and transferred as radiation.

Nuclear fusion in the sun's core releases energy. A fusion reactor has to be at a very high temperature so the nuclei can overcome their repulsion.

Nuclear fusion in the future

Future fusion reactors could meet energy needs for a growing population. This is because:

- The fuel for fusion reactors is easily available as heavy hydrogen is naturally present in sea water.
- The product, helium, is an unreactive gas and non-radioactive so is harmless.
- The energy released could be used to generate electricity in the future.

Key terms

Make sure you can write a definition for these key terms.

atom alpha activity atomic number background radiation beta chain reaction contamination count rate electron fission fusion gamma Geiger-Müller tube half-life ionisation irradiation isotope mass number net decline neutron plum pudding model proton peer review radiation dose radioactive decay spontaneous tracer