3c Subject content

Ref	Content
1	**Forces and their effects**
1.1	**Motion**
a)	Scalars are quantities that have magnitude only. Vectors are quantities that have magnitude and an associated direction. *Candidates should be aware that distance, speed and time are examples of scalars and displacement, velocity, acceleration, force and momentum are examples of vectors.*
b)	If an object moves in a straight line, how far it is from a certain point can be represented by a distance–time graph.
c)	The speed of an object can be determined from the gradient of a distance–time graph. If an object is accelerating its speed at any particular time can be determined by finding the gradient of the tangent of the distance–time graph at that time.
d)	The velocity of an object is its speed in a given direction.
e)	The velocity v of an object is given by the equation: $v = \frac{s}{t}$ where s is the displacement and t is the time taken.
f)	The acceleration a of an object is given by the equation: $a = \frac{v - u}{t}$ where u is the initial velocity, v is the final velocity and t is the time taken.
g)	The acceleration of an object can be determined from the gradient of a velocity–time graph.
h)	The distance travelled by an object can be determined from the area under a velocity–time graph.
1.2	**Resultant forces**
a)	Whenever two objects interact, the forces they exert on each other are equal and opposite.
b)	A number of forces acting at a point may be replaced by a single force that has the same effect on the motion as the original forces all acting together. This single force is called the resultant force. *Candidates should be able to determine the resultant of opposite or parallel forces acting in a straight line and determine the resultant of two coplanar forces by scale drawing.*
c)	A resultant force acting on an object may cause a change in its state of rest or motion.
d)	If the resultant force acting on a stationary object is: ■ zero, the object will remain stationary ■ not zero, the object will accelerate in the direction of the resultant force.
e)	If the resultant force acting on a moving object is: ■ zero, the object will continue to move at the same speed and in the same direction ■ not zero, the object will accelerate in the direction of the resultant force.
f)	The relationship between force F, mass m and acceleration a is: $F = m \times a$

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Ref	Content
1.3	**Momentum**
a)	The relationship between momentum p, mass m and velocity v is: $p = m \times v$
b)	In a closed system the total momentum before an event is equal to the total momentum after the event. This is called conservation of momentum. *Candidates may be required to complete calculations involving two objects. Examples of events are collisions and explosions.*
c)	The relationship between force F, change in momentum Δp and time t is: $F = \frac{\Delta p}{t}$ *Candidates should be able to use this relationship to explain safety features such as air bags, seat belts, gymnasium crash mats, cushioned surfaces for playgrounds and cycle helmets.*
1.4	**Forces and braking**
a)	When a vehicle travels at a steady speed the resistive forces balance the driving force. *Candidates should realise that most of the resistive forces are caused by air resistance.*
b)	The greater the speed of a vehicle the greater the braking force needed to stop it in a certain distance. *Candidates should understand that for a given braking force, the greater the speed, the greater the stopping distance.*
c)	The stopping distance of a vehicle is the sum of the distance the vehicle travels during the driver's reaction time (thinking distance) and the distance it travels under the braking force (braking distance).
d)	A driver's reaction time can be affected by tiredness, drugs and alcohol. *Candidates should appreciate that distractions may affect a driver's ability to react.*
e)	When the brakes of a vehicle are applied, work done by the friction force between the brakes and the wheel reduces the kinetic energy of the vehicle and the temperature of the brakes increases.
f)	A vehicle's braking distance can be affected by adverse road and weather conditions and poor condition of the vehicle. *Candidates should understand that 'adverse road conditions' includes wet or icy conditions. Poor condition of the car is limited to the car's brakes or tyres.*
1.5	**Forces and terminal velocity**
a)	The faster an object moves through a fluid the greater the frictional force which acts on it.
b)	An object falling through a fluid will initially accelerate due to the force of gravity. Eventually the resultant force will be zero and the object will move at its terminal velocity (steady speed). *Candidates should understand why the use of a parachute reduces the parachutist's terminal velocity.* *Candidates should be able to draw and interpret velocity–time graphs for objects that reach terminal velocity, including a consideration of the forces acting on the object.*
c)	The relationship between weight W, mass m and gravitational field strength (acceleration of free fall) g is: $W = m \times g$ *Candidates will **not** be expected to know the value of g.*

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1.6	**Forces and elasticity**
a)	A force acting on an object may cause a change in the shape of the object.
b)	An object behaves elastically if it returns to its original shape when the force is removed.
c)	A force applied to an elastic object such as a spring will result in the object stretching and storing elastic potential energy.
d)	For an object behaving elastically, the extension is directly proportional to the force applied, provided that the limit of proportionality is not exceeded. The relationship between the force F and the extension e is: $F = k \times e$ where k is a constant.
1.7	**Forces and energy**
a)	Work is done when a force causes an object to move through a distance.
b)	The relationship between work done W, force F and distance d moved in the direction of the force is: $W = F \times d$
c)	Energy is transferred when work is done.
d)	Work done against frictional forces causes energy transfer by heating. *Candidates should be able to discuss the transfer of kinetic energy in particular situations, for example shuttle re-entry into the atmosphere or meteorites burning up in the atmosphere and braking systems on vehicles.*
e)	The relationship between power P, work done or energy transferred W and time t is: $P = \frac{W}{t}$
f)	The relationship between gravitational potential energy E_p, mass m, gravitational field strength (acceleration of free fall) g and height h is: $E_p = m \times g \times h$ *Candidates should understand that when an object is raised vertically work is done against the gravitational force and the object gains gravitational potential energy.*
g)	The relationship between kinetic energy E_k, mass m and speed v is: $E_k = 1/2 \times m \times v^2$ *Candidates should understand that an object of double the mass of another object travelling with the same speed will have double the kinetic energy.* *Candidates should understand that an object travelling at double the speed of another object with the same mass will have four times the kinetic energy. They should be able to apply this idea in the context of road safety.*
1.8	**Centre of mass**
a)	The centre of mass of an object is the point at which the mass of the object may be thought to be concentrated. *Candidates will be expected to be able to describe how to find the centre of mass of a thin, irregular sheet of a material.*
b)	If freely suspended, an object will come to rest with its centre of mass directly below the point of suspension.
c)	The centre of mass of a symmetrical object is along the axis of symmetry.

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d)	The relationship between time period T, and frequency f is: $T = \frac{1}{f}$
e)	The time period of a pendulum depends on its length. *Applications of the pendulum should include simple fairground and playground rides.* *The equation for the time period of a pendulum is **not** required.*

1.9 Moments

a)	The turning effect of a force is called the moment.
b)	The relationship between the moment M, turning force F and perpendicular distance d from the force to the pivot is: $M = F \times d$
c)	If an object is not turning, the total clockwise moment must be exactly balanced by the total anticlockwise moment about any pivot. *Candidates should be able to calculate the size of a force, or its distance from a pivot, acting on an object that is balanced.*
d)	Simple levers can be used as force multipliers.
e)	If the line of action of the weight of an object lies outside the base of the object there will be a resultant moment and the body will topple. *Examples should include vehicles and simple balancing toys.*

1.10 Circular motion

a)	When an object moves in a circle it continuously accelerates towards the centre of the circle. This acceleration changes the direction of motion of the body, not its speed.
b)	The resultant force causing this acceleration is called the centripetal force and is always directed towards the centre of the circle. *Candidates should be able to identify which force provides the centripetal force in a given situation.*
c)	The centripetal force needed to make an object perform circular motion increases as: - the mass of the object increases - the speed of the object increases - the radius of the circle decreases. *The equation for calculating centripetal force is **not** required.*

1.11 Hydraulics

a)	Liquids are virtually incompressible, and the pressure in a liquid is transmitted equally in all directions. *Candidates should understand that this means that a force exerted at one point on a liquid will be transmitted to other points in the liquid.*
b)	The relationship between pressure P, force F and cross-sectional area A is: $P = \frac{F}{A}$
c)	The use of different cross-sectional areas on the effort and load side of a hydraulic system enables the system to be used as a force multiplier.

Ref	Content
2	**Waves**
2.1	**General properties of waves**
a)	Waves transfer energy and information without transferring matter.
b)	In a transverse wave the oscillations are perpendicular to the direction of energy transfer.
c)	In a longitudinal wave the oscillations are parallel to the direction of energy transfer. Longitudinal waves show areas of compression and rarefaction.
d)	Electromagnetic waves are transverse, sound waves are longitudinal and mechanical waves may be either transverse or longitudinal.
e)	Waves can be reflected, refracted and diffracted. *Candidates should appreciate that for appreciable diffraction to take place the wavelength of the wave must be of the same order of magnitude as the size of the obstacle or gap.*
f)	When identical sets of waves overlap they interfere with each other.
g)	Waves may be described in terms of their frequency, wavelength, time period and amplitude. *Candidates should be able to explain the meaning of these terms.*
h)	The relationship between wave speed v, frequency f and wavelength λ is: $v = f \times \lambda$
2.2	**The electromagnetic spectrum**
a)	Electromagnetic waves form a continuous spectrum and all types of electromagnetic wave travel at the same speed through a vacuum (space). *Candidates should know the order of electromagnetic waves within the spectrum, in terms of energy, frequency and wavelength.* *Candidates should appreciate that the wavelengths of the electromagnetic spectrum range from 10^{-15} m to 10^{4} m and beyond.*
b)	Radio waves, microwaves, infrared and visible light can be used for communication.
c)	Electromagnetic waves have many uses. For example: - radio waves – television and radio (including Bluetooth) - microwaves – mobile phones and satellite television - infrared – remote controls - visible light – photography - ultraviolet – security marking - X-rays – medical imaging - gamma rays – sterilising surgical instruments and killing harmful bacteria in food.
d)	Exposure to electromagnetic waves can be hazardous. For example: - microwaves – heating of body tissue - infrared – skin burns - ultraviolet – skin cancer and blindness - X-rays – high doses kill cells - gamma rays – genetic mutations.
e)	X-rays are part of the electromagnetic spectrum. They have a very short wavelength, high energy and cause ionisation.

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f)	Properties of X-rays include: ▪ they affect a photographic film in the same way as light ▪ they are absorbed by metal and bone ▪ they are transmitted by soft tissue.
g)	X-rays can be used to diagnose some medical conditions, for example in computed tomography (CT) scanning, bone fractures and dental problems. X-rays are also used to treat some conditions, for example in killing cancer cells.
h)	The use of high energy ionising radiation can be dangerous, and precautions need to be taken to monitor and minimise the levels of radiation that people who work with it are exposed to.
2.3	**Sound and ultrasound**
a)	Sound waves are longitudinal waves and cause vibrations in a medium, which are detected as sound.
b)	The range of human hearing is about 20 Hz to 20 000 Hz. ***No** details of the structure of the ear are required.*
c)	The pitch of a sound is determined by its frequency and loudness by its amplitude.
d)	Sound waves can be reflected (echoes) and diffracted.
e)	Ultrasound is acoustic (sound) energy, in the form of waves with a frequency above the human hearing range.
f)	Electronic systems can be used to produce ultrasound waves, which have a frequency higher than the upper limit of hearing for humans.
g)	Ultrasound waves are partially reflected when they meet a boundary between two different media. The time taken for the reflections to reach a detector can be used to determine how far away such a boundary is.
h)	The distance s between interfaces in various media can be calculated using: $s = v \times t$ where v is wave speed and t is time taken. *Candidates may be required to use data from diagrams of oscilloscope traces.*
i)	Ultrasound waves can be used in medicine. Examples include pre-natal scanning and the removal of kidney stones.
2.4	**Reflection**
a)	When waves are reflected the angle of incidence is equal to the angle of reflection.
b)	The normal is a construction line perpendicular to the reflecting surface at the point of incidence.
c)	The image produced in a plane mirror is virtual. *Candidates will be expected to be able to construct ray diagrams.*
2.5	**Refraction and total internal reflection**
a)	Light waves undergo a change of direction when they pass from one medium to another at an interface. This is called refraction. ▪ When light enters a more dense medium it is refracted towards the normal. ▪ When light enters a less dense medium it is refracted away from the normal. ▪ Waves are not refracted if travelling along the normal. ▪ Waves are refracted due to change of speed.
b)	Refraction by a prism can lead to dispersion.

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c)	Refractive index can be defined in terms of wave speed. *Candidates need to understand that the refractive index of a medium is defined as:* $\dfrac{\textit{speed of light in vacuum (air)}}{\textit{speed of light in the medium}}$
d)	The relationship between refractive index *n*, angle of incidence *i* and angle of refraction *r* is: $n = \dfrac{\sin i}{\sin r}$
e)	The relationship between refractive index *n* and critical angle *c* is: $n = \dfrac{1}{\sin c}$ *Candidates need to understand the concept of critical angle but knowledge of the values of critical angles is not required.*
f)	Total internal reflection is a special case of refraction, which occurs if the angle of incidence within the more dense medium is greater than the critical angle.
g)	Visible light can be transmitted through optical fibres by total internal reflection. Examples of use include the endoscope for internal imaging.

2.6	**Lenses and the eye**
a)	A lens forms an image by refracting light. Each section of a lens acts like a tiny prism, each section refracting light as it goes in and again as it comes out.
b)	In a convex lens, parallel rays of light are brought to a focus at the principal focus. A convex lens is also called a converging lens. *Candidates should be aware of the nature of the image produced by a converging lens for an object placed at different distances from the lens, including the use of the converging lens as a magnifying glass.*
c)	The distance from the lens to the principal focus is called the focal length.
d)	The focal length of a lens is determined by: - the refractive index of the material from which the lens is made, and - the curvature of the two surfaces of the lens.
e)	For a given focal length, the greater the refractive index, the flatter the lens. This means that the lens can be manufactured thinner.
f)	In a concave lens, parallel rays of light diverge as if coming from the principal focus. A concave lens is also called a diverging lens. *Candidates should be aware of the nature of the image produced by a diverging lens for an object placed at different distances from the lens.*
g)	The nature of an image is defined by its size relative to the object, whether it is upright or inverted relative to the object and whether it is real or virtual.
h)	Ray diagrams may be constructed to show the formation of images by converging and diverging lenses. *Candidates may be asked to draw and interpret ray diagrams drawn on graph paper.*
i)	The relationship between object distance *u*, image distance *v* and focal length *f* is: $\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$ *Candidates should be aware that all distances are measured from the centre of the lens.*
j)	The magnification produced by a lens may be calculated using the equation: $\text{magnification} = \dfrac{\text{image height}}{\text{object height}}$

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k)	The relationship between the power P of a lens and focal length f is: $P = \frac{1}{f}$ where P has units of dioptre, D or m^{-1}
l)	The eye contains the following structures: - retina - lens - cornea - pupil/iris - ciliary muscle - suspensory ligaments. *Candidates should know the function of each of these parts and understand how the action of the ciliary muscle causes changes in the shape of the lens that allow light to be focused at varying distances.*
m)	Usually the near point of the human eye is approximately 25 cm and the far point is infinity. The eye can focus on objects between the near point and the far point. The distance between these points is the range of vision.
n)	Lenses can be used to correct defects of vision: - long sight, caused by the eyeball being too short, or the eye lens being unable to focus - short sight, caused by the eyeball being too long, or the eye lens being unable to focus. *Candidates should understand the use of convex and concave lenses to produce an image on the retina.*
o)	Lasers are a concentrated source of light and can be used for cutting, cauterising and burning. Lasers can be used in eye surgery, to correct visual defects. *Knowledge of how lasers work is **not** required.*
p)	Comparisons can be made between the structure of the eye and the camera. In the eye the image is brought to focus on the retina by changing the shape of the lens, in a camera the image is brought to focus on the film by varying the distance between the film and the lens. *Candidates should be aware that the film in a camera is the equivalent of the retina in the eye.*

2.7 Red-shift

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a)	If a wave source is moving relative to an observer there will be a change in the observed wavelength and frequency. This is known as the Doppler effect. *Candidates should understand that:* - *the wave source could be light, sound or microwaves* - *when the source moves away from the observer, the observed wavelength increases and the frequency decreases* - *when the source moves towards the observer, the observed wavelength decreases and the frequency increases.*
b)	There is an observed increase in the wavelength of light from most distant galaxies. The further away the galaxies, the faster they are moving and the bigger the observed increase in wavelength. This effect is called red-shift.
c)	The observed red-shift provides evidence that the universe is expanding and supports the Big Bang theory (that the universe began from a very small initial point). *Candidates should be able to explain how red-shift provides evidence for the Big Bang.*
d)	Cosmic microwave background radiation (CMBR) is a form of electromagnetic radiation filling the universe. It comes from radiation that was present shortly after the beginning of the universe.
e)	The Big Bang theory is currently the only theory that can explain the existence of CMBR.

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3	**Heating processes**
3.1	**Kinetic theory**
a)	Kinetic theory can be used to explain the different states of matter. *Candidates should be able to recognise simple diagrams to model the difference between solids, liquids and gases.*
b)	The particles of solids, liquids and gases have different amounts of energy.
c)	The specific heat capacity of a substance is the amount of energy required to change the temperature of one kilogram of the substance by one degree Celsius.
d)	The relationship between energy E, mass m, specific heat capacity c and temperature change θ is: $E = m \times c \times \theta$
e)	The specific latent heat of vaporisation of a substance is the amount of energy required to change the state of one kilogram of the substance from a liquid to a vapour with no change in temperature.
f)	The relationship between energy E, mass m and specific latent heat of vaporisation L_V is: $E = m \times L_V$
g)	The specific latent heat of fusion of a substance is the amount of energy required to change the state of one kilogram of the substance from a solid to a liquid with no change in temperature.
h)	The relationship between energy E, mass m and specific latent heat of fusion L_F is: $E = m \times L_F$
i)	The melting point of a solid and the boiling point of a liquid are affected by impurities.
	Throughout Section 3.1, candidates should be able to explain the shape of the temperature–time graph for a substance that is either cooled or heated through changes in state.
3.2	**Energy transfer by heating**
a)	Energy may be transferred by conduction and convection. *Candidates should be able to explain, in terms of particles, how these energy transfers take place.* *Candidates should understand in simple terms how the arrangement and movement of particles determine whether a material is a conductor or an insulator and understand the role of free electrons in conduction through a metal.* *Candidates should be able to use the idea of particles moving apart to make a fluid less dense, to explain simple applications of convection.*
b)	Energy may be transferred by evaporation and condensation. *Candidates should be able to explain evaporation, and the cooling effect this causes, using the kinetic theory. Candidates should be able to discuss the factors that affect the rate of evaporation.*
c)	The rate at which an object transfers energy by heating depends on: - its surface area and volume - the material from which the object is made - the nature of the surface with which the object is in contact. *Candidates should be able to explain the design of devices in terms of energy transfer, for example cooling fins.* *Candidates should be able to explain animal adaptations in terms of energy transfer, for example relative ear size of animals in cold and warm climates.*
d)	The bigger the temperature difference between an object and its surroundings, the faster the rate at which energy is transferred by heating.
e)	Most substances expand when heated. *Candidates should understand that the expansion of substances on heating may be a hazard (for example, the expansion of roofs and bridges) or useful (for example, the bi-metallic strip thermostat).*

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3.3	**Infrared radiation**
a)	All objects emit and absorb infrared radiation.
b)	The hotter an object is the more infrared radiation it radiates in a given time.
c)	Dark, matt surfaces are good absorbers and good emitters of infrared radiation.
d)	Light, shiny surfaces are poor absorbers and poor emitters of infrared radiation.
e)	Light, shiny surfaces are good reflectors of infrared radiation.
3.4	**Energy transfers and efficiency**
a)	Energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.
b)	When energy is transferred only part of it may be usefully transferred; the rest is 'wasted'.
c)	Wasted energy is eventually transferred to the surroundings, which become warmer. This energy becomes increasingly spread out and so becomes less useful.
d)	The efficiency of a device can be calculated using: $\text{efficiency} = \frac{\text{useful energy out}}{\text{total energy in}} (\times 100\%)$ and $\text{efficiency} = \frac{\text{useful power out}}{\text{total power in}} (\times 100\%)$ *Candidates may be required to calculate efficiency as a decimal or as a percentage.*
e)	The energy flow in a system can be represented using Sankey diagrams. *Candidates should be able to draw and interpret Sankey diagrams.*
3.5	**Heating and insulating buildings**
a)	Solar panels may contain water that is heated by radiation from the Sun. This water may then be used to heat buildings or provide domestic hot water.
b)	There are a range of methods used to reduce energy loss and consumption. *Candidates should be familiar with different methods of insulating a building and with the idea of payback time as a means of evaluating the cost effectiveness of each method.*
c)	U-values measure how effective a material is as an insulator. *Knowledge of the U-values of specific materials is* ***not*** *required, nor is the equation that defines U-value.*
d)	The lower the U-value, the better the material is as an insulator.

4 Electricity

Ref	Content
4.1	**Electrical circuits**
a)	Electrical charges can move easily through some substances, for example metals.
b)	Electric current is a flow of electric charge.
c)	The relationship between current *I*, charge *Q* and time *t* is: $I = \frac{Q}{t}$
d)	The relationship between potential difference *V*, energy transferred *E* and charge *Q* is: $V = \frac{E}{Q}$ *Teachers can use either of the terms potential difference or voltage. Questions will be set using the term potential difference. Candidates will gain credit for the correct use of either term.*

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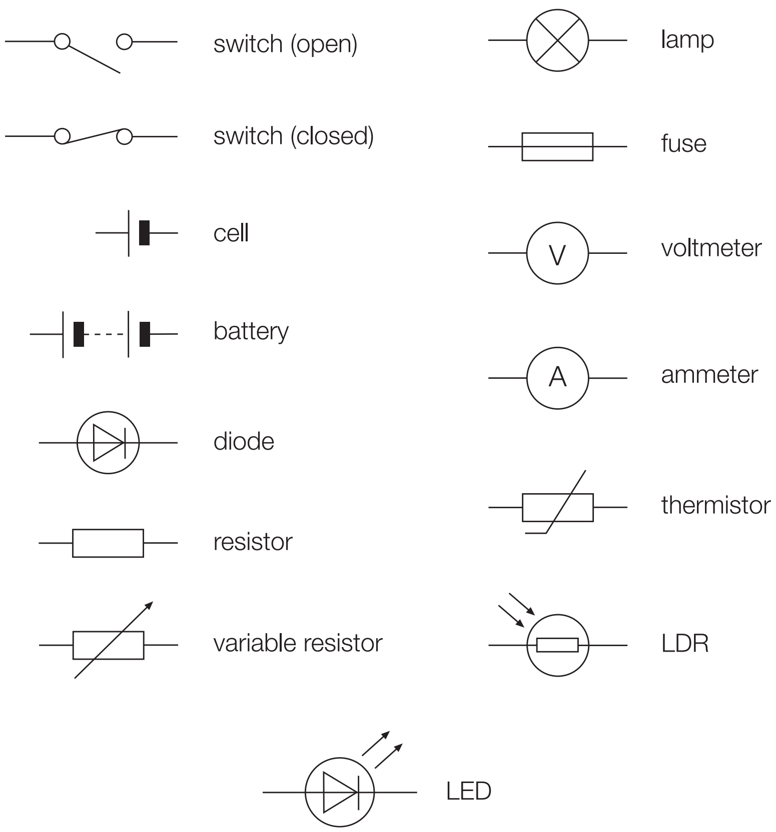
e)	Circuit diagrams use standard symbols. *Candidates will be required to interpret and draw circuit diagrams. Candidates should know the following standard symbols:*



Candidates should understand the use of thermistors in circuits, for example thermostats.

Candidates should understand the use of light-dependent resistors (LDRs) in circuits, for example switching lights on when it gets dark.

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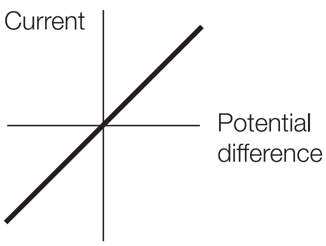
f)	Current–potential difference graphs are used to show how the current through a component varies with the potential difference across it.
g)	The resistance of a component can be found by measuring the current through and potential difference across, the component.
h)	The current through a component depends on its resistance. The greater the resistance the smaller the current for a given potential difference across the component.
i)	The relationship between potential difference V, current I and resistance R is: $V = I \times R$
j)	The current through a resistor (at a constant temperature) is directly proportional to the potential difference across the resistor.



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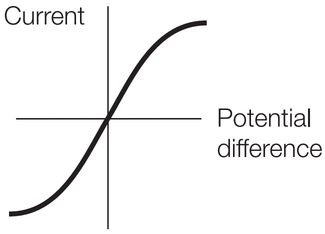
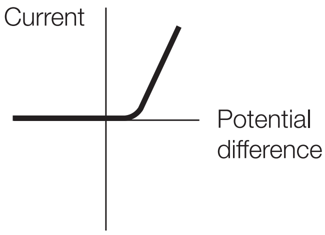
k) The resistance of a filament bulb increases as the temperature of the filament increases.



Candidates should be able to explain change in resistance in terms of ions and electrons.

l) The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction.



m) The potential difference provided by cells connected in series is the sum of the potential difference of each cell (depending on the direction in which they are connected).

n) For components connected in series:

- the total resistance is the sum of the resistance of each component
- there is the same current through each component
- the total potential difference of the supply is shared between the components.

o) For components connected in parallel:

- the potential difference across each component is the same
- the total current through the whole circuit is the sum of the currents through the separate components.

p) An LED emits light when a current flows through it in the forward direction.

Candidates should be aware that the use of LEDs for lighting is increasing, as they use a much smaller current than other forms of lighting.

q) When an electrical charge flows through a resistor, the resistor gets hot.

Candidates should understand that a lot of energy is wasted in filament bulbs by heating. Less energy is wasted in power saving lamps such as Compact Fluorescent Lamps (CFLs).

Candidates should understand that there is a choice when buying new appliances in how efficiently they transfer energy.

4.2 Household electricity

a) Cells and batteries supply current that always passes in the same direction. This is called direct current (d.c.).

b) An alternating current (a.c.) is one that is constantly changing direction.

Candidates should be able to determine the period, and hence the frequency, of a supply from diagrams of oscilloscope traces.

Candidates should be able to compare and calculate potential differences of d.c. supplies and the peak potential differences of a.c. supplies from diagrams of oscilloscope traces.

c) Mains electricity is an a.c. supply. In the UK it has a frequency of 50 cycles per second (50 hertz) and is about 230 V.

d) A diode may be used for half wave rectification of a.c.

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e)	Most electrical appliances are connected to the mains using a cable and a three-pin plug. *Candidates should be familiar with the structure of both two-core and three-core cable* *Candidates should be familiar with the structure and wiring of a three-pin plug. Knowledge and understanding of the materials used in three-pin plugs is required, as is the colour coding of the covering of the three wires.*
f)	If an electrical fault causes too great a current to flow, the circuit is disconnected by a fuse or a circuit breaker in the live wire.
g)	When the current in a fuse wire exceeds the rating of the fuse it will melt, breaking the circuit. *Candidates should have an understanding of the link between cable thickness and fuse value.*
h)	Some circuits are protected by Residual Current Circuit Breakers (RCCBs), which operate much faster than a fuse. *Candidates should understand that RCCBs operate by detecting a difference in the current between the live and neutral wires. Knowledge of the mode of operation of how the devices do this is **not** required.*
i)	Appliances with metal cases are usually earthed. *Candidates should be aware that some appliances are double insulated, and therefore have no earth wire connection.*
j)	The earth wire and fuse together protect the wiring of a circuit.

4.3 Transferring electrical energy

a)	The rate at which energy is transferred by an appliance is called the power.
b)	The relationship between power P, energy transferred E and time t is: $P = \frac{E}{t}$
c)	The relationship between power P, current I and potential difference V is: $P = I \times V$ *Candidates should be able to calculate the current through an appliance from its power and the potential difference of the supply and from this determine the size of fuse needed.*
d)	The relationship between energy transferred E, potential difference V and charge Q is: $E = V \times Q$
e)	Everyday electrical appliances are designed to bring about energy transfers. *Candidates should be able to give examples of such devices and energy transfers.*
f)	The amount of energy an appliance transfers depends on how long the appliance is switched on for and its power.
g)	The relationship between energy transferred E from the mains, power P and time t is: $E = P \times t$ *Candidates will **not** be required to convert between kilowatt-hours and joules.* *Candidates should be able to calculate the cost of mains electricity given the cost per kilowatt-hour and interpret and use electricity meter readings to calculate total cost over a period of time.*

4.4 The National Grid

a)	Electricity is distributed from power stations to consumers along the National Grid. *Candidates should be able to identify and label the essential parts of the National Grid.*
b)	For a given power, increasing the voltage reduces the current required. This reduces the energy losses in the cables.
c)	Step-up and step-down transformers are used to change voltages in the National Grid. *Candidates should know why transformers are an essential part of the National Grid.*

Ref	Content
5	**Motors, generators and transformers**
5.1	**The motor effect**
a)	Magnets attract and repel other magnets. *Candidates should be able to recognise magnetic field patterns using one or two bar magnets.* *Candidates should know how to produce a uniform magnetic field using two bar magnets.*
b)	When a current flows through a wire a magnetic field is produced around the wire. The shape of the magnetic field can be seen as a series of concentric circles in a plane, perpendicular to the wire. The direction of these field lines depends on the direction of the current. *Candidates should understand the structure of, and be familiar with some uses of, electromagnets.*
c)	When a wire carrying a current is placed in a magnetic field it experiences a force. This is called the motor effect. The conductor will not experience a force if it is parallel to the magnetic field. *Candidates should be able to apply the principles of the motor effect in any given situation.*
d)	The size of the force can be increased by: - increasing the strength of the magnetic field - increasing the size of the current.
e)	The direction of the force is reversed if either the direction of the current or the direction of the magnetic field is reversed. *Candidates should be able to identify the direction of the force using (Fleming's) left-hand rule.*
5.2	**The generator effect**
a)	If an electrical conductor 'cuts' through a magnetic field a potential difference is induced across the ends of the conductor.
b)	If a magnet is moved into a coil of wire a potential difference is induced across the ends of the coil. This is called the generator effect.
c)	The generator effect also occurs if the magnetic field is stationary and the coil is moved. *Candidates should be able to apply the principles of the generator effect in any given situation.*
d)	If the coil of wire is part of a complete circuit, a current is induced in the wire.
e)	If the direction of motion, or the polarity of the magnet, is reversed, the direction of the induced potential difference and any induced current is reversed.
f)	The size of the induced potential difference increases when: - the speed of the movement increases - the strength of the magnetic field increases - the number of turns on the coil increases - the area of the coil increases. *Candidates should be able to explain the action of a simple a.c. generator and a simple d.c. generator, including graphs of potential difference generated in the coil against time.*

Ref	Content
5.3	**Transformers**
a)	A basic transformer consists of a primary coil and a secondary coil wound on a soft iron core.
b)	An alternating current in the primary coil of a transformer produces a changing magnetic field in the iron core and hence in the secondary coil. This induces an alternating potential difference across the ends of the secondary coil. *Candidates should be able to describe the basic structure and operation of a transformer.* *Knowledge of laminations and eddy currents in the core are* ***not*** *required.*
c)	In a step-up transformer the potential difference across the secondary coil is greater than the potential difference across the primary coil.
d)	In a step-down transformer the potential difference across the secondary coil is less than the potential difference across the primary coil.
e)	The potential differences across the primary and secondary coils of a transformer V_p and V_s are related to the number of turns on the coils n_p and n_s by: $\frac{V_p}{V_s} = \frac{n_p}{n_s}$
f)	If transformers are assumed to be 100% efficient, the electrical power output would equal the electrical power input. $V_p \times I_p = V_s \times I_s$ Where V_p and I_p are power input (primary coil) and V_s and I_s are power output (secondary coil). *Candidates should be aware that the input to a transformer is determined by the required output.*
g)	Switch mode transformers are transformers that: - operate at a high frequency, often between 50 kHz and 200 kHz. - are much lighter and smaller than traditional transformers that work from a 50 Hz mains supply, making them useful for applications such as mobile phone chargers - use very little power when they are switched on but no load is applied.

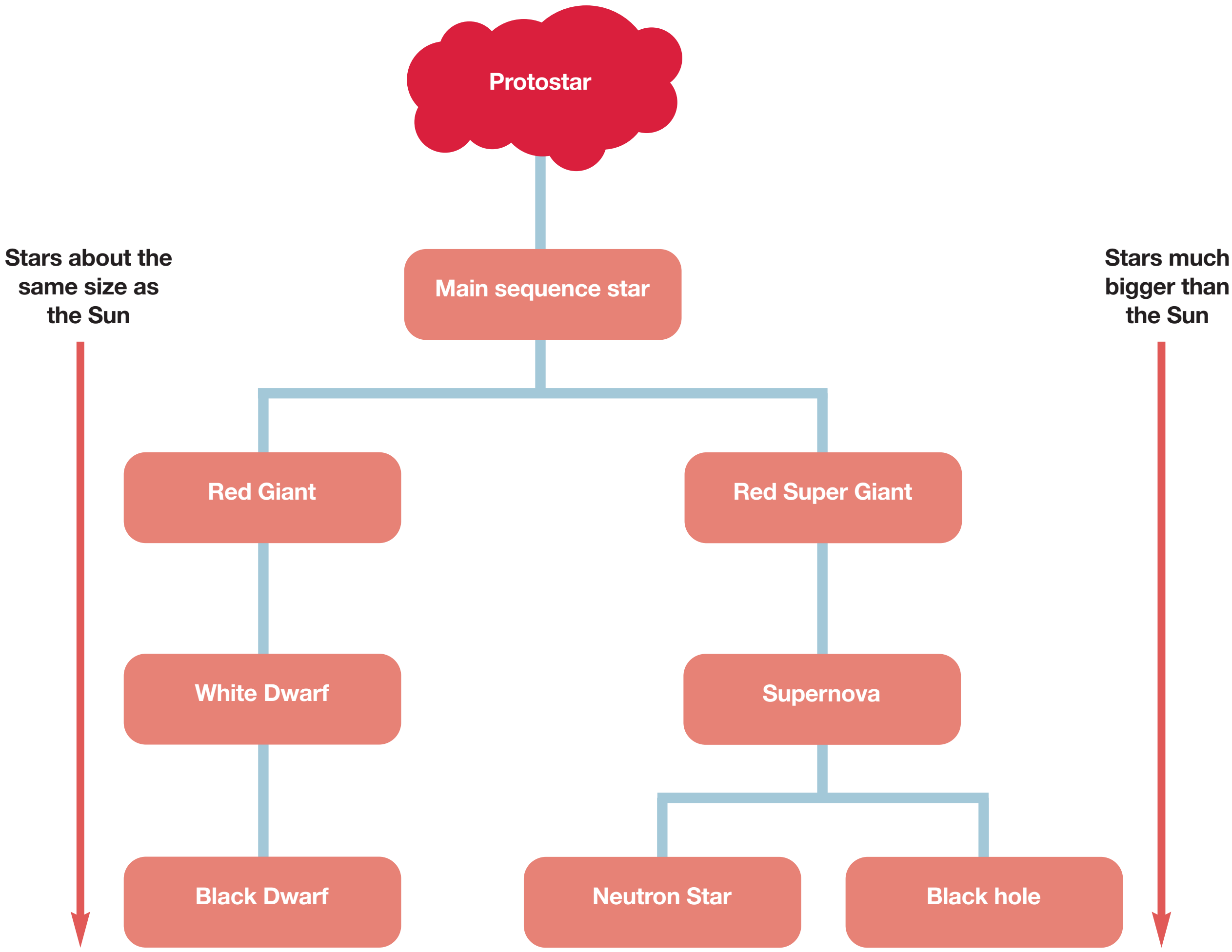
6 Nuclear physics

6.1	**Atomic structure**
a)	The basic structure of an atom is a small central nucleus composed of protons and neutrons surrounded by electrons.
b)	The relative masses and relative electric charges of protons, neutrons and electrons are as follows:

	Relative mass	Relative charge
proton	1	1
neutron	1	0
electron	Very small	–1

c)	In an atom the number of electrons is equal to the number of protons in the nucleus. The atom has no overall electrical charge.
d)	Atoms may lose or gain electrons to form charged particles called ions.

Ref	Content
e)	The atoms of an element always have the same number of protons, but have a different number of neutrons for each isotope. The total number of protons in an atom is called its proton number or atomic number. The total number of protons and neutrons in an atom is called its mass number. Atoms can be represented as shown: (Mass number) 23 Na (Atomic number) 11
6.2	**Atoms and radiation**
a)	Some substances give out radiation from the nuclei of their atoms all the time, whatever is done to them. These substances are said to be radioactive. *Candidates should be aware of the random nature of radioactive decay.*
b)	Background radiation is around us all of the time. It comes from: ▪ natural sources such as rocks and cosmic rays from space ▪ man-made sources such as the fallout from nuclear weapons testing and nuclear accidents.
c)	An alpha particle consists of two neutrons and two protons, the same as a helium nucleus. A beta particle is an electron from the nucleus. Gamma radiation is electromagnetic radiation from the nucleus.
d)	Nuclear equations may be used to show single alpha and beta decay. *Candidates will be required to balance such equations, limited to the completion of atomic number and mass number. The identification of daughter elements from such decays is* ***not*** *required.*
e)	Alpha and beta radiations are deflected by both electric and magnetic fields but gamma radiation is not. *Candidates should know that alpha particles are deflected less than beta particles and in an opposite direction. Candidates should be able to explain this in terms of the relative mass and charge of each particle.* *Properties of the alpha, beta and gamma radiations are limited to their relative ionising power, their penetration through materials and their range in air.*
f)	Gamma radiation is not deflected by electric or magnetic fields.
g)	There are uses and dangers associated with each type of nuclear radiation. *Candidates should be able to describe the dangers and some uses of each type of radiation.*
h)	The half-life of a radioactive isotope is: ▪ either the average time it takes for the number of nuclei of the isotope in a sample to halve ▪ or the time it takes for the count rate from a sample containing the isotope to fall to half its initial level.
6.3	**Nuclear fission**
a)	Nuclear fission is the splitting of an atomic nucleus.
b)	There are two fissionable substances in common use in nuclear reactors, uranium-235 and plutonium-239. *Candidates should be aware that the majority of nuclear reactors use uranium-235.*
c)	For fission to occur the uranium-235 or plutonium-239 nucleus must first absorb a neutron.
d)	The nucleus undergoing fission splits into two smaller nuclei, releasing two or three neutrons and energy.
e)	These neutrons may go on to start a chain reaction. *Candidates should be able to sketch or complete a labelled diagram to illustrate how a chain reaction may occur.*

Ref	Content
6.4	**Nuclear fusion**
a)	Nuclear fusion is the joining of two atomic nuclei to form a larger one.
b)	Nuclear fusion is the process by which energy is released in stars.
c)	Stars form when enough dust and gas from space is pulled together by gravitational attraction. Smaller masses may also form and be attracted by a larger mass to become planets.
d)	During the 'main sequence' period of its life cycle a star is stable because the forces within it are balanced. *The term 'radiation pressure' will **not** be required.*
e)	A star goes through a life cycle. This life cycle is determined by the size of the star.  *Candidates should be familiar with the chart that shows the life cycles of stars.*
f)	Fusion processes in stars produce all of the naturally occurring elements. These elements may be distributed throughout the Universe by the explosion of a massive star (supernova) at the end of its life. *Candidates should be able to explain how stars are able to maintain their energy output for millions of years.* *Candidates should be able to explain why the early Universe contained only hydrogen but now contains a large variety of different elements.* *Candidates should know that elements heavier than iron are formed in a supernova.*

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3d Experimental and investigative skills

During this course, students should be encouraged to develop their understanding of the scientific process and the skills associated with scientific enquiry. In Paper 2, students will be assessed on aspects of the skills listed below, and may be required to read and interpret information from scales given in diagrams and charts, present data in appropriate formats, design investigations and evaluate information that is presented to them.

a) Design a practical procedure to answer a question, solve a problem or test a hypothesis.

b) Comment on/evaluate plans for practical procedures.

c) Select suitable apparatus for carrying out experiments accurately and safely.

d) Appreciate that, unless certain variables are controlled, experimental results may not be valid.

e) Recognise the need to choose appropriate sample sizes, and study control groups where necessary.

f) Identify possible hazards in practical situations, the risks associated with these hazards, and methods of minimising the risks.

g) Make and record observations and measurements with appropriate precision and record data collected in an appropriate format (such as a table, chart or graph).

h) Recognise and identify the cause of anomalous results and suggest what should be done about them.

i) Appreciate when it is appropriate to calculate a mean, calculate a mean from a set of at least three results and recognise when it is appropriate to ignore anomalous results in calculating a mean.

j) Recognise and identify the causes of random errors and systematic errors.

k) Recognise patterns in data, form hypotheses and deduce relationships.

l) Use and interpret tabular and graphical representations of data.

m) Draw conclusions that are consistent with the evidence obtained and support them with scientific explanations.

n) Evaluate data, considering its repeatability, reproducibility and validity in presenting and justifying conclusions.

o) Evaluate methods of data collection and appreciate that the evidence obtained may not allow a conclusion to be made with confidence.

p) Suggest ways of improving an investigation or practical procedure to obtain extra evidence to allow a conclusion to be made.

3e Mathematical and other requirements

Mathematical requirements

This specification provides learners with the opportunity to develop their skills in communication, mathematics and the use of technology in scientific contexts. In order to deliver the mathematical element of this outcome, assessment materials for this specification contain opportunities for candidates to demonstrate scientific knowledge using appropriate mathematical skills.

The areas of mathematics that arise naturally from the science content are listed below. This is not a checklist for each question paper, but assessments reflect these mathematical requirements, covering the full range of mathematical skills over a reasonable period of time.

Candidates are permitted to use calculators in all assessments.

Candidates are expected to use units appropriately. However, not all questions reward the appropriate use of units.

All candidates should be able to:

1 Understand number size and scale and the quantitative relationship between units.

2 Understand when and how to use estimation.

3 Carry out calculations involving +, –, ×, ÷, either singly or in combination, decimals, fractions, percentages and positive whole number powers.

4 Provide answers to calculations to an appropriate number of significant figures.

5 Understand and use the symbols =, <, >, ~.

6 Understand and use direct proportion and simple ratios.

7 Calculate arithmetic means.

8 Understand and use common measures and simple compound measures such as speed.

9 Plot and draw graphs (line graphs, bar charts, pie charts, scatter graphs, histograms) selecting appropriate scales for the axes.

10 Substitute numerical values into simple formulae and equations using appropriate units.

11 Translate information between graphical and numeric form.

12 Extract and interpret information from charts, graphs and tables.

13 Understand the idea of probability.

14 Calculate area, perimeters and volumes of simple shapes.

15 Interpret order and calculate with numbers written in standard form.

16 Carry out calculations involving negative powers (only –1 for rate).

17 Change the subject of an equation.

18 Understand and use inverse proportion.

19 Understand and use percentiles and deciles.

Units, symbols and nomenclature

Units, symbols and nomenclature used in examination papers will normally conform to the recommendations contained in the following:

- *The Language of Measurement: Terminology used in school science investigations.* Association for Science Education (ASE), 2010. ISBN 978 0 86357 424 5.
- *Signs, Symbols and Systematics – the ASE companion to 16–19 Science.* Association for Science Education (ASE), 2000. ISBN 978 0 86357 312 5.
- *Signs, Symbols and Systematics – the ASE companion to 5–16 Science.* Association for Science Education (ASE), 1995. ISBN 0 86357 232 4.

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3f Units of physical quantities

The table gives details of units that candidates are expected to know.

Where a unit is given, eg second (s), candidates should be familiar with relevant subdivisions of the unit, eg millisecond (ms) and microsecond (µs). In addition, where appropriate, candidates should be aware of larger units where the basic unit is given, eg joule (J) and kilojoule (kJ).

What the unit measures	Unit	Symbol
length	metre	m
area	square metre	m^2
volume	cubic metre	m^3
time	second hour	s h
speed velocity	metres per second or kilometres per hour	m/s or km/h
acceleration	metres per second squared	m/s^2
mass	kilogram	kg
weight force	newton	N
moment of a force	newton metre	Nm
momentum	kilogram metre per second	kg m/s
pressure	pascal newtons per square metre	Pa N/m^2
power	watt	W
energy	joule kilowatt-hours	J kWh
current	ampere (amp)	A
charge	coulomb	C
potential difference	volt	V
resistance	ohm	Ω
temperature	degree Celsius	°C
specific heat capacity	joules per kilogram degree Celsius	J/(kg °C)
specific latent heat of vaporisation	joules per kilogram	J/kg
specific latent heat of fusion	joules per kilogram	J/kg
frequency	hertz	Hz
power of a lens	dioptre	D