3.3 Unit 1: Physics 1

P1.1 The transfer of energy by heating processes and the factors that affect the rate at which that energy is transferred

Energy can be transferred from one place to another by work or by heating processes. We need to know how this energy is transferred and which heating processes are most important in a particular situation.

Candidates should use their skills, knowledge and understanding to:	**Additional guidance:**
■ compare ways in which energy is transferred in and out of objects by heating and ways in which the rates of these transfers can be varied	Examples should include the design of a vacuum flask, how to reduce the energy transfer from a building and how humans and animals cope with low temperatures.
■ evaluate the design of everyday appliances that transfer energy by heating, including economic considerations	Examples include radiators and heat sinks.
■ evaluate the effectiveness of different types of material used for insulation, including U-values and economic factors including payback time	Examples include loft insulation and cavity wall insulation.
■ evaluate different materials according to their specific heat capacities.	Examples include the use of water, which has a very high specific heat capacity, oil-filled radiators and electric storage heaters containing concrete or bricks.

P1.1.1 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.

P1.1.2 Kinetic theory

	Additional guidance:
a) The use of kinetic theory 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.	An understanding of specific latent heat is **not** required.

P1.1.3 Energy transfer by heating

	Additional guidance:
a) The transfer of energy by conduction, convection, evaporation and condensation involves particles, and how this transfer takes place.	Candidates should understand in simple terms how the arrangement and movement of particles determine whether a material is a conductor or an insulator. Candidates should 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) The factors that affect the rate of 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 explain the design of devices in terms of energy transfer, for example, cooling fins.
c) The rate at which an object transfers energy by heating depends on: ■ 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 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.	

P1.1.4 Heating and insulating buildings

a) U-values measure how effective a material is as an insulator.

Additional guidance:

Knowledge of the U-values of specific materials is **not** required, nor is the equation that defines a U-value.

b) The lower the U-value, the better the material is as an insulator.

c) 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.

d) 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.

$$E = m \times c \times \theta$$

Additional guidance:

E is energy transferred in joules, J

m is mass in kilograms, kg

θ is temperature change in degrees Celsius, °C

c is specific heat capacity in J / kg °C

Suggested ideas for practical work to develop skills and understanding include the following:

- passing white light through a prism and detecting the infrared radiation with a thermometer
- demonstration using balls in a tray to show the behaviour of particles in substances in different states
- measuring the cooling effect produced by evaporation; putting wet cotton wool over the bulb of a thermometer or temperature probe
- plan and carry out an investigation into factors that affect the rate of cooling of a can of water, eg shape, volume, and colour of can
- using Leslie's cube to demonstrate the effect on radiation of altering the nature of the surface
- plan and carry out an investigation using immersion heaters in a metal block to measure specific heat capacity
- investigating thermal conduction using rods of different materials.

P1.2 Energy and efficiency

Appliances transfer energy but they rarely transfer all of the energy to the place we want. We need to know the efficiency of appliances so that we can choose between them, including how cost effective they are, and try to improve them.

Candidates should use their skills, knowledge and understanding to:	**Additional guidance:**
■ compare the efficiency and cost effectiveness of methods used to reduce 'energy consumption'	The term 'pay-back time' should be understood. Given relevant data, candidates should be able to make judgements about the cost effectiveness of different methods of reducing energy consumption over a set period of time. This is **not** restricted to a consideration of building insulation but may include: ■ low energy light bulbs and LED lighting ■ replacing old appliances with energy efficient ones ■ ways in which 'waste' energy can be useful, eg heat exchangers.
■ describe the energy transfers and the main energy wastages that occur with a range of appliances	Common electrical appliances found in the home will be examined. Examples will **not** be limited to electrical appliances; however, in this case all the information would be given in the question.
■ interpret and draw a Sankey diagram.	Candidates should be able to use a Sankey diagram to calculate the efficiency of an appliance.

P1.2.1 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. The wasted energy becomes increasingly spread out and so becomes less useful.

d) To calculate the efficiency of a device using:

$$\text{efficiency} = \frac{\text{useful energy out}}{\text{total energy in}} \ (\times 100\%)$$

$$\text{efficiency} = \frac{\text{useful power out}}{\text{total power in}} \ (\times 100\%)$$

Additional guidance:

Candidates may be required to calculate efficiency as a decimal or as a percentage.

Suggested ideas for practical work to develop skills and understanding include the following:

- an energy 'circus' to demonstrate various energy transfers
- plan and carry out an investigation by constructing a model house, using sensors and data logger to measure temperatures with and without various types of insulation.

P1.3 The usefulness of electrical appliances

We often use electrical appliances because they transfer energy at the flick of a switch. We can calculate how much energy is transferred by an appliance and how much the appliance costs to run.

Candidates should use their skills, knowledge and understanding to:

- compare the advantages and disadvantages of using different electrical appliances for a particular application
- consider the implications of instances when electricity is not available.

Additional guidance:

Candidates will be required to compare different electrical appliances, using data provided.

P1.3.1 Transferring electrical energy

a) Examples of energy transfers that everyday electrical appliances are designed to bring about.

b) The amount of energy an appliance transfers depends on how long the appliance is switched on and its power.

c) To calculate the amount of energy transferred from the mains using:

$E = P \times t$

Additional guidance:

Candidates will **not** be required to convert between kilowatt-hours and joules.

E is energy transferred in kilowatt-hours, kWh

P is power in kilowatts, kW

t is time in hours, h

This equation may also be used when:

E is energy transferred in joules, J

P is power in watts, W

t is time in seconds, s

d) To calculate the cost of mains electricity given the cost per kilowatt-hour.

Additional guidance:

This includes both the cost of using individual appliances and the interpretation of electricity meter readings to calculate total cost over a period of time.

Suggested ideas for practical work to develop skills and understanding include the following:

- candidates reading the electricity meter at home on a daily or weekly basis. They could then look for trends in usage and try to explain these, eg in terms of weather conditions
- plan and carry out an investigation using an electrical joulemeter to measure the energy transferred by low voltage bulbs of different powers, low voltage motors and low voltage immersion heaters.

P1.4 Methods we use to generate electricity

Various energy sources can be used to generate the electricity we need. We must carefully consider the advantages and disadvantages of using each energy source before deciding which energy source(s) it would be best to use in any particular situation. Electricity is distributed via the National Grid.

Candidates should use their skills, knowledge and understanding to:

- evaluate different methods of generating electricity

Additional guidance:

Candidates should be able to evaluate different methods of generating electricity given data including start-up times, costs of electricity generation and the total cost of generating electricity when factors such as building and decommissioning are taken into account. The reliability of different methods should also be understood.

Knowledge of the actual values of start-up times and why they are different is **not** needed, but the implications of such differences are important.

- evaluate ways of matching supply with demand, either by increasing supply or decreasing demand

Candidates should be aware of the fact that, of the fossil fuel power stations, gas-fired have the shortest start-up time. They should also be aware of the advantages of pumped storage systems in order to meet peak demand, and as a means of storing energy for later use.

- compare the advantages and disadvantages of overhead power lines and underground cables.

P1.4.1 Generating electricity

a) In some power stations an energy source is used to heat water. The steam produced drives a turbine that is coupled to an electrical generator.

Energy sources include:

- the fossil fuels (coal, oil and gas) which are burned to heat water or air
- uranium and plutonium, when energy from nuclear fission is used to heat water
- biofuels that can be burned to heat water.

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	Additional guidance:
b) Water and wind can be used to drive turbines directly.	Energy sources used in this way include, but are not limited to, wind, waves, tides and the falling of water in hydroelectric schemes.
c) Electricity can be produced directly from the Sun's radiation.	Candidates should know that solar cells can be used to generate electricity and should be able to describe the advantages and disadvantages of their use.

d) In some volcanic areas hot water and steam rise to the surface. The steam can be tapped and used to drive turbines. This is known as geothermal energy.

	Additional guidance:
e) Small-scale production of electricity may be useful in some areas and for some uses, eg hydroelectricity in remote areas and solar cells for roadside signs.	Candidates should understand that while small-scale production can be locally useful it is sometimes uneconomic to connect such generation to the National Grid.
f) Using different energy resources has different effects on the environment. These effects include: ■ the release of substances into the atmosphere ■ the production of waste materials ■ noise and visual pollution ■ the destruction of wildlife habitats.	Candidates should understand that carbon capture and storage is a rapidly evolving technology. To prevent carbon dioxide building up in the atmosphere we can catch and store it. Some of the best natural containers are old oil and gas fields, such as those under the North Sea.

P1.4.2 The National Grid

	Additional guidance:
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 and this reduces the energy losses in the cables.	Candidates should know why transformers are an essential part of the National Grid.
c) The uses of step-up and step-down transformers in the National Grid.	Details of the structure of a transformer and how a transformer works are **not** required.

Suggested ideas for practical work to develop skills and understanding include the following:

- investigating the effect of changing different variables on the output of solar cells, eg distance from the light source, the use of different coloured filters and the area of the solar cells
- planning and carrying out an investigation into the effect of changing different variables on the output of model wind turbines, eg the number or pitch of the blades, the wind velocity
- demonstrating a model water turbine linked to a generator
- modelling the National Grid.

P1.5 The use of waves for communication and to provide evidence that the universe is expanding

Electromagnetic radiations travel as waves and move energy from one place to another. They can all travel through a vacuum and do so at the same speed. The waves cover a continuous range of wavelengths called the electromagnetic spectrum.

Sound waves and some mechanical waves are longitudinal, and cannot travel through a vacuum.

Current evidence suggests that the universe is expanding and that matter and space expanded violently and rapidly from a very small initial 'point', ie the universe began with a 'big bang'.

Candidates should use their skills, knowledge and understanding to:	Additional guidance:
■ compare the use of different types of waves for communication	Knowledge and understanding of waves used for communication is limited to sound, light, microwaves, radio waves and infrared waves.
■ evaluate the possible risks involving the use of mobile phones	
■ consider the limitations of the model that scientists use to explain how the universe began and why the universe continues to expand.	

P1.5.1 General properties of waves

	Additional guidance:
a) Waves transfer energy.	
b) Waves may be either transverse or longitudinal.	Candidates should understand that in a transverse wave the oscillations are perpendicular to the direction of energy transfer. In a longitudinal wave the oscillations are parallel to the direction of energy transfer.
c) Electromagnetic waves are transverse, sound waves are longitudinal and mechanical waves may be either transverse or longitudinal.	
d) All types of electromagnetic waves travel at the same speed through a vacuum (space).	
e) Electromagnetic waves form a continuous spectrum.	Candidates should know the order of electromagnetic waves within the spectrum, in terms of energy, frequency and wavelength. Candidates should appreciate that the wavelengths vary from about 10^{-15} metres to more than 10^4 metres.
f) Longitudinal waves show areas of compression and rarefaction.	

Specification	Additional guidance
g) Waves can be reflected, refracted and diffracted.	**Additional guidance:** Candidates should appreciate that significant diffraction only occurs when the wavelength of the wave is of the same order of magnitude as the size of the gap or obstacle.
h) Waves undergo a change of direction when they are refracted at an interface.	Waves are not refracted if travelling along the normal. Snell's law and the reason why waves are refracted are **not** required.
i) The terms frequency, wavelength and amplitude.	
j) All waves obey the wave equation: $v = f \times \lambda$	**Additional guidance:** v is speed in metres per second, m/s f is frequency in hertz, Hz λ is wavelength in metres, m Candidates are **not** required to recall the value of the speed of electromagnetic waves through a vacuum.
k) Radio waves, microwaves, infrared and visible light can be used for communication.	Candidates will be expected to be familiar with situations in which such waves are typically used and any associated hazards, eg: ■ radio waves – television, and radio (including diffraction effects) ■ microwaves – mobile phones and satellite television ■ infrared – remote controls ■ visible light – photography.

P1.5.2 Reflection

Specification	Additional guidance
a) The normal is a construction line perpendicular to the reflecting surface at the point of incidence.	
b) The angle of incidence is equal to the angle of reflection.	
c) The image produced in a plane mirror is virtual.	**Additional guidance:** Candidates will be expected to be able to construct ray diagrams.

P1.5.3 Sound

Specification	Additional guidance
a) Sound waves are longitudinal waves and cause vibrations in a medium, which are detected as sound.	**Additional guidance:** Sound is limited to human hearing and **no** details of the structure of the ear are required.

b) The pitch of a sound is determined by its frequency and loudness by its amplitude.

c) Echoes are reflections of sounds.

P1.5.4 Red-shift

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.

Additional guidance:

The following should be included:

- 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 are, the faster they are moving, and the bigger the observed increase in wavelength. This effect is called red-shift.

c) How 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).

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.

Suggested ideas for practical work to develop skills and understanding include the following:

- reflecting light off a plane mirror at different angles
- using a class set of skipping ropes to investigate frequency and wavelength
- demonstrating transverse and longitudinal waves with a slinky spring
- carrying out refraction investigations using a glass block
- carrying out investigations using ripple tanks, including the relationship between depth of water and speed of wave
- investigating the range of Bluetooth or infrared communications between mobile phones and laptops
- demonstrating the Doppler effect for sound.

3.4 Unit 2: Physics 2

P2.1 Forces and their effects

Forces can cause changes to the shape or motion of an object. Objects can move in a straight line at a constant speed. They can also change their speed and / or direction (accelerate or decelerate). Graphs can help us to describe the movement of an object. These may be distance-time graphs or velocity-time graphs.

Candidates should use their skills, knowledge and understanding to:

- interpret data from tables and graphs relating to speed, velocity and acceleration
- evaluate the effects of alcohol and drugs on stopping distances
- evaluate how the shape and power of a vehicle can be altered to increase the vehicle's top speed
- draw and interpret velocity-time graphs for objects that reach terminal velocity, including a consideration of the forces acting on the object.

P2.1.1 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.

c) A resultant force acting on an object may cause a change in its state of rest or motion.

Additional guidance:

Candidates should be able to determine the resultant of opposite or parallel forces acting in a straight line.

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.

P2.1.2 Forces and motion

	Additional guidance:
a) The acceleration of an object is determined by the resultant force acting on the object and the mass of the object. $a = \frac{F}{m}$ or $F = m \times a$	F is the resultant force in newtons, N m is the mass in kilograms, kg a is the acceleration in metres per second squared, m/s^2
b) The gradient of a distance–time graph represents speed.	Candidates should be able to construct distance–time graphs for an object moving in a straight line when the body is stationary or moving with a constant speed.
c) **Calculation of the speed of an object from the gradient of a distance–time graph.**	**HT only**
d) The velocity of an object is its speed in a given direction.	

	Additional guidance:
e) The acceleration of an object is given by the equation: $a = \frac{v - u}{t}$	a is the acceleration in metres per second squared, m/s^2 v is the final velocity in metres per second, m/s u is the initial velocity in metres per second, m/s t is the time taken in seconds, s
f) The gradient of a velocity–time graph represents acceleration.	

	Additional guidance:
g) **Calculation of the acceleration of an object from the gradient of a velocity–time graph.**	**HT only**
h) **Calculation of the distance travelled by an object from a velocity–time graph.**	**HT only**

P2.1.3 Forces and braking

	Additional guidance:
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.

Additional guidance:

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 increase.

f) A vehicle's braking distance can be affected by adverse road and weather conditions and poor condition of the vehicle.

Additional guidance:

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.

P2.1.4 Forces and terminal velocity

a) The faster an object moves through a fluid the greater the frictional force that 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).

Additional guidance:

Candidates should understand why the use of a parachute reduces the parachutist's terminal velocity.

c) Draw and interpret velocity-time graphs for objects that reach terminal velocity, including a consideration of the forces acting on the object.

d) Calculate the weight of an object using the force exerted on it by a gravitational force:

$$W = m \times g$$

Additional guidance:

W is the weight in newtons, N

m is the mass in kilograms, kg

g is the gravitational field strength in newtons per kilogram, N/kg

P2.1.5 Forces and elasticity

a) A force acting on an object may cause a change in shape of the object.

b) A force applied to an elastic object such as a spring will result in the object stretching and storing elastic potential energy.

Additional guidance:

Calculation of the energy stored when stretching an elastic material is **not** required.

c) For an object that is able to recover its original shape, elastic potential energy is stored in the object when work is done on the object to change its shape.

d) The extension of an elastic object is directly proportional to the force applied, provided that the limit of proportionality is not exceeded:

$F = k \times e$

Additional guidance:

F is the force in newtons, N

k is the spring constant in newtons per metre, N/m

e is the extension in metres, m

Suggested ideas for practical work to develop skills and understanding include the following:

- dropping a penny and a feather in a vacuum and through the air to show the effect of air resistance
- plan and carry out an investigation into Hooke's law
- catapult practicals to compare stored energy
- measurement of acceleration of trolleys using known forces and masses
- timing objects falling through a liquid, eg wallpaper paste or glycerine, using light gates or stop clocks
- plan and carry out an investigation to measure the effects of air resistance on parachutes, paper spinners, cones or bun cases
- measuring reaction time with and without distractions, eg iPod off and then on.

P2.2 The kinetic energy of objects speeding up or slowing down

When an object speeds up or slows down, its kinetic energy increases or decreases. The forces which cause the change in speed do so by doing work. The momentum of an object is the product of the object's mass and velocity.

Candidates should use their skills, knowledge and understanding to:

- evaluate the benefits of different types of braking system, such as regenerative braking
- evaluate the benefits of air bags, crumple zones, seat belts and side impact bars in cars.

Additional guidance:

This should include ideas of both energy changes and momentum changes.

P2.2.1 Forces and energy

a) When a force causes an object to move through a distance work is done.

b) Work done, force and distance are related by the equation:

$W = F \times d$

Additional guidance:

W is the work done in joules, J

F is the force applied in newtons, N

d is the distance moved in the direction of the force in metres, m

	Additional guidance:
c) Energy is transferred when work is done.	Candidates should be able to discuss the transfer of kinetic energy in particular situations. Examples might include shuttle re-entry or meteorites burning up in the atmosphere.
d) Work done against frictional forces.	

	Additional guidance:
e) Power is the work done or energy transferred in a given time. $P = \frac{E}{t}$	P is the power in watts, W E is the energy transferred in joules, J t is the time taken in seconds, s
f) Gravitational potential energy is the energy that an object has by virtue of its position in a gravitational field. $E_p = m \times g \times h$	Candidates should understand that when an object is raised vertically work is done against gravitational force and the object gains gravitational potential energy. E_p is the change in gravitational potential energy in joules, J m is the mass in kilograms, kg g is the gravitational field strength in newtons per kilogram, N/kg h is the change in height in metres, m
g) The kinetic energy of an object depends on its mass and its speed. $E_k = \frac{1}{2} \times m \times v^2$	E_k is the kinetic energy in joules, J m is the mass in kilograms, kg v is the speed in metres per second, m/s

P2.2.2 Momentum

	Additional guidance:
a) Momentum is a property of moving objects. $p = m \times v$	p is momentum in kilograms metres per second, kg m/s m is the mass in kilograms, kg v is the velocity in metres per second, m/s
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.

Suggested ideas for practical work to develop skills and understanding include the following:

- investigating the transfer of E_p to E_k by dropping a card through a light gate
- plan and carry out an investigation to measure velocity using trolleys and ramps
- running upstairs and calculating work done and power, lifting weights to measure power
- a motor lifting a load to show how power changes with load
- stretching different materials before using as catapults to show the different amounts of energy transferred, indicated by speed reached by the object or distance travelled.

P2.3 Currents in electrical circuits

The current in an electric circuit depends on the resistance of the components and the supply.

Candidates should use their skills, knowledge and understanding to:

- apply the principles of basic electrical circuits to practical situations

- evaluate the use of different forms of lighting, in terms of cost and energy efficiency.

Additional guidance:

Examples might include filament bulbs, fluorescent bulbs and light-emitting diodes (LEDs).

P2.3.1 Static electricity

a) When certain insulating materials are rubbed against each other they become electrically charged. Negatively charged electrons are rubbed off one material and onto the other.

b) The material that gains electrons becomes negatively charged. The material that loses electrons is left with an equal positive charge.

c) When two electrically charged objects are brought together they exert a force on each other.

d) Two objects that carry the same type of charge repel. Two objects that carry different types of charge attract.

e) Electrical charges can move easily through some substances, eg metals.

P2.3.2 Electrical circuits

Additional guidance:

a) Electric current is a flow of electric charge. The size of the electric current is the rate of flow of electric charge. The size of the current is given by the equation:

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

Additional guidance:

I is the current in amperes (amps), A

Q is the charge in coulombs, C

t is the time in seconds, s

b) The potential difference (voltage) between two points in an electric circuit is the work done (energy transferred) per coulomb of charge that passes between the points.

$$V = \frac{W}{Q}$$

Additional guidance:

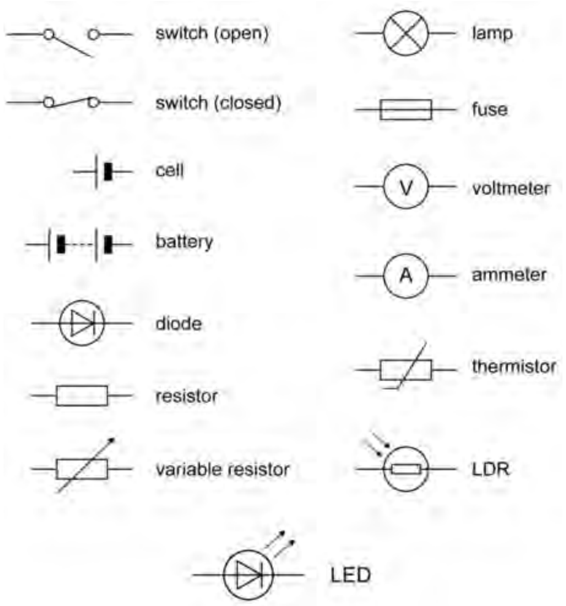
Teachers can use either of the terms potential difference or voltage. Questions will be set using the term potential difference. Candidates will gain credit for the correct use of either term.

V is the potential difference in volts, V

W is the work done in joules, J

Q is the charge in coulombs, C

c) Circuit diagrams using standard symbols. The following standard symbols should be known:



Additional guidance:

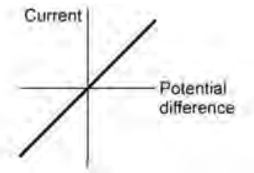
Candidates will be required to interpret and draw circuit diagrams.

Knowledge and understanding of the use of thermistors in circuits, eg thermostats is required.

Knowledge and understanding of the applications of light-dependent resistors (LDRs) is required, eg switching lights on when it gets dark.

d) Current–potential difference graphs are used to show how the current through a component varies with the potential difference across it.

e) The current–potential difference graphs for a resistor at constant temperature.



f) The resistance of a component can be found by measuring the current through, and potential difference across, the component.

g) The current through a resistor (at a constant temperature) is directly proportional to the potential difference across the resistor.

h) Calculate current, potential difference or resistance using the equation:

$V = I \times R$

Additional guidance:

V is the potential difference in volts, V

I is the current in amperes (amps), A

R is the resistance in ohms, Ω

i) 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.

j) 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).

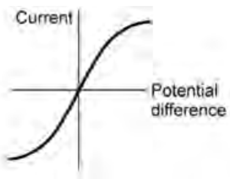
k) For components connected in series:

- 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.

l) 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.

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

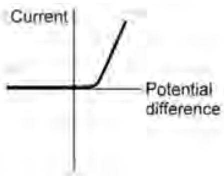


Additional guidance:

HT only

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

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



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

Additional guidance:

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

p) The resistance of a light-dependent resistor (LDR) decreases as light intensity increases.

q) The resistance of a thermistor decreases as the temperature increases.

Additional guidance:

Knowledge of a negative temperature coefficient thermistor only is required.

Suggested ideas for practical work to develop skills and understanding include the following:

- using filament bulbs and resistors to investigate potential difference/current characteristics
- investigating potential difference/current characteristics for LDRs and thermistors
- setting up series and parallel circuits to investigate current and potential difference
- plan and carry out an investigation to find the relationship between the resistance of thermistors and their temperature
- investigating the change of resistance of LDRs with light intensity.

P2.4 Using mains electricity safely and the power of electrical appliances

Mains electricity is useful but can be very dangerous. It is important to know how to use it safely.

Electrical appliances transfer energy. The power of an electrical appliance is the rate at which it transforms energy. Most appliances have their power and the potential difference of the supply they need printed on them. From this we can calculate their current and the fuse they need.

Candidates should use their skills, knowledge and understanding to:

- understand the principles of safe practice and recognise dangerous practice in the use of mains electricity
- compare the uses of fuses and circuit breakers
- evaluate and explain the need to use different cables for different appliances
- consider the factors involved when making a choice of electrical appliances.

Additional guidance:

Candidates should consider the efficiency and power of the appliance.

P2.4.1 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.

Additional guidance:

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.

Higher Tier candidates should be able to determine the period and hence the frequency of a supply 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) Most electrical appliances are connected to the mains using cable and a three-pin plug.

e) The structure of electrical cable.

Additional guidance:

Candidates should be familiar with both two-core and three-core cable.

f) 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.

g) If an electrical fault causes too great a current, the circuit is disconnected by a fuse or a circuit breaker in the live wire.	
h) When the current in a fuse wire exceeds the rating of the fuse it will melt, breaking the circuit.	
	Additional guidance:
i) Some circuits are protected by Residual Current Circuit Breakers (RCCBs).	Candidates should realise that RCCBs operate by detecting a difference in the current between the live and neutral wires. Knowledge of how the devices do this is **not** required. Candidates should be aware of the fact that this device operates much faster than a fuse.
j) Appliances with metal cases are usually earthed.	Candidates should be aware that some appliances are double insulated, and therefore have no earth wire connection.
k) The earth wire and fuse together protect the wiring of the circuit.	Candidates should have an understanding of the link between cable thickness and fuse value.

P2.4.2 Current, charge and power

	Additional guidance:
a) 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.
b) The rate at which energy is transferred by an appliance is called the power. $P = \frac{E}{t}$	P is power in watts, W E is energy in joules, J t is time in seconds, s
c) Power, potential difference and current are related by the equation: $P = I \times V$	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. P is power in watts, W I is current in amperes (amps), A V is potential difference in volts, V

d) **Energy transferred, potential difference and charge are related by the equation:**

$$E = V \times Q$$

Additional guidance:

HT only

E **is energy in joules, J**

V **is potential difference in volts, V**

Q **is charge in coulombs, C**

Suggested ideas for practical work to develop skills and understanding include the following:

- measuring oscilloscope traces
- demonstrating the action of fuse wires
- using fluctuations in light intensity measurements from filament bulbs to determine the frequency of a.c.
- measuring the power of 12 V appliances by measuring energy transferred (using a joulemeter or ammeter and voltmeter) in a set time.

P2.5 What happens when radioactive substances decay, and the uses and dangers of their emissions

Radioactive substances emit radiation from the nuclei of their atoms all the time. These nuclear radiations can be very useful but may also be very dangerous. It is important to understand the properties of different types of nuclear radiation. To understand what happens to radioactive substances when they decay we need to understand the structure of the atoms from which they are made. The use of radioactive sources depends on their penetrating power and half-life.

Candidates should use their skills, knowledge and understanding to:

- evaluate the effect of occupation and/or location on the level of background radiation and radiation dose
- evaluate the possible hazards associated with the use of different types of nuclear radiation
- evaluate measures that can be taken to reduce exposure to nuclear radiations
- evaluate the appropriateness of radioactive sources for particular uses, including as tracers, in terms of the type(s) of radiation emitted and their half-lives
- explain how results from the Rutherford and Marsden scattering experiments led to the ‘plum pudding’ model being replaced by the nuclear model.

Additional guidance:

Candidates should realise that new evidence can cause a theory to be re-evaluated.

Candidates should realise that, according to the nuclear model, most of the atom is empty space.

P2.5.1 Atomic structure

	Additional guidance:
a) The basic structure of an atom is a small central nucleus composed of protons and neutrons surrounded by electrons.	Candidates should appreciate the relative size of the nucleus compared to the size of the atom.
b) The relative masses and relative electric charges of protons, neutrons and electrons.	
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.	
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 atomic number. The total number of protons and neutrons in an atom is called its mass number.	

P2.5.2 Atoms and radiation

	Additional guidance:
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) The origins of background radiation.	Knowledge and understanding should include both natural sources, such as rocks and cosmic rays from space, and man-made sources such as the fallout from nuclear weapons tests and nuclear accidents.
c) Identification of an alpha particle as two neutrons and two protons, the same as a helium nucleus, a beta particle as an electron from the nucleus and gamma radiation as electromagnetic radiation.	
d) **Nuclear equations to show single alpha and beta decay.**	**Additional guidance:** **HT only** **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) Properties of the alpha, beta and gamma radiations limited to their relative ionising power, their penetration through materials and their range in air.	

f) Alpha and beta radiations are deflected by both electric and magnetic fields but gamma radiation is not.

Additional guidance:

All candidates should know that alpha particles are deflected less than beta particles and in an opposite direction.

Higher Tier candidates should be able to explain this in terms of the relative mass and charge of each particle.

g) The uses of and the dangers associated with each type of nuclear radiation.

h) The half-life of a radioactive isotope is 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.

Suggested ideas for practical work to develop skills and understanding include the following:

- using hot-cross buns to show the 'plum pudding' model
- using dice to demonstrate probabilities involved in half-life
- using Geiger counters to measure the penetration and range in air of the radiation from different sources.

P2.6 Nuclear fission and nuclear fusion

During the process of nuclear fission atomic nuclei split. This process releases energy, which can be used to heat water and turn it into steam. The steam drives a turbine, which is connected to a generator and generates electricity.

Nuclear fusion is the joining together of atomic nuclei and is the process by which energy is released in stars.

Candidates should use their skills, knowledge and understanding to:

- compare the uses of nuclear fusion and nuclear fission.

Additional guidance:

Limited to the generation of electricity.

P2.6.1 Nuclear fission

a) There are two fissionable substances in common use in nuclear reactors: uranium-235 and plutonium-239.

Additional guidance:

The majority of nuclear reactors use uranium-235.

b) Nuclear fission is the splitting of an atomic nucleus.

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 and two or three neutrons and energy is released.

e) The neutrons may go on to start a chain reaction.

Additional guidance:

Candidates should be able to sketch or complete a labelled diagram to illustrate how a chain reaction may occur.

P2.6.2 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.

Additional guidance:

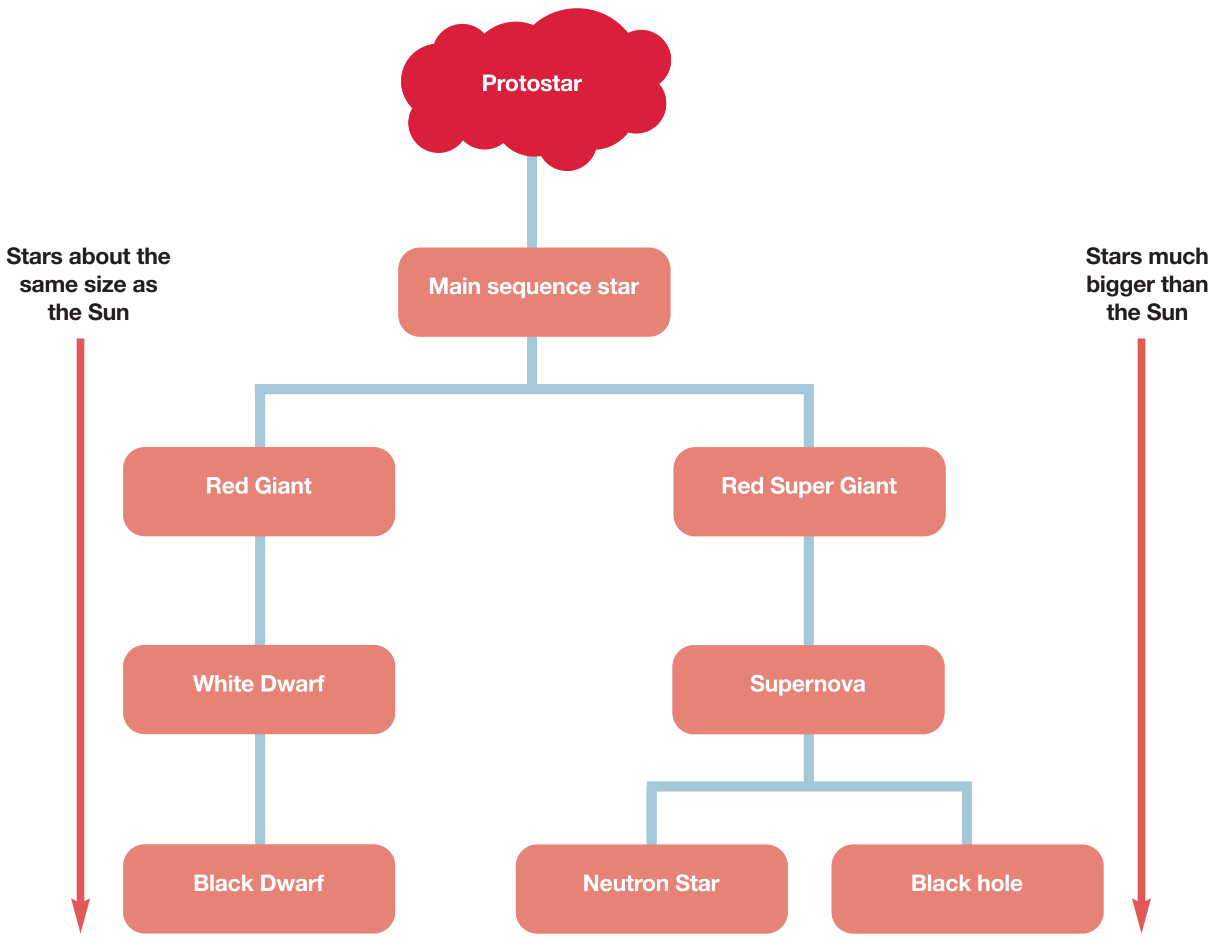
Candidates should be able to explain why the early Universe contained only hydrogen but now contains a large variety of different elements.

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 on the next page 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.

Additional guidance:

Candidates should be able to explain how stars are able to maintain their energy output for millions of years.

Candidates should know that elements up to iron are formed during the stable period of a star. Elements heavier than iron are formed in a supernova.

Suggested ideas for practical work to develop skills and understanding include the following:

- using domino tracks for fission/chain reactions.

3.5 Unit 3: Physics 3

P3.1 Medical applications of physics

Physics has many applications in the field of medicine. These include the uses of X-rays and ultrasound for scanning, and of light for image formation with lenses and endoscopes

Candidates should use their skills, knowledge and understanding to:

- draw and interpret ray diagrams in order to determine the nature of the image

Additional guidance:

In ray diagrams a convex lens will be represented by:

A concave lens will be represented by:

- evaluate the use of different lenses for the correction of defects of vision

- compare the medical use of ultrasound and X rays

Additional guidance:

Candidates should understand that some of the differences in use are because ultrasound waves are non-ionising and X rays are ionising.

- evaluate the advantages and disadvantages of using ultrasound, X-rays and Computerised Tomography (CT) scans.

Limited to safety issues and the quality of image formed.

P3.1.1 X-rays

a) X-rays are part of the electromagnetic spectrum. They have a very short wavelength and cause ionisation.

Additional guidance:

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
- their wavelength is of the same order of magnitude as the diameter of an atom.

b) X-rays can be used to diagnose and treat some medical conditions.

Examples include CT scans, bone fractures, dental problems and killing cancer cells.

The use of charge-coupled devices (CCDs) allows images to be formed electronically.

c) Precautions to be taken when X-ray machines and CT scanners are in use.

P3.1.2 Ultrasound

a) Electronic systems can be used to produce ultrasound waves, which have a frequency higher than the upper limit of hearing for humans.

Additional guidance:

Candidates should know that the range of human hearing is about 20 Hz to 20 000 Hz.

b) 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.

c) Calculation of the distance between interfaces in various media.

$s = v \times t$

Additional guidance:

Candidates may be required to use data from diagrams of oscilloscope traces.

s is distance in metres, m

v is speed in metres per second, m/s

t is time in seconds, s

d) Ultrasound waves can be used in medicine.

Examples include pre-natal scanning and the removal of kidney stones.

P3.1.3 Lenses

a) Refraction is the change of direction of light as it passes from one medium to another.

b) A lens forms an image by refracting light.

c) In a convex or converging lens, parallel rays of light are brought to a focus at the principal focus. The distance from the lens to the principal focus is called the focal length.

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

Additional guidance:

i is the angle of incidence

r is the angle of refraction

d) 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.

e) The nature of the image produced by a converging lens for an object placed at different distances from the lens.

f) The use of a converging lens as a magnifying glass.

g) The nature of the image produced by a concave or diverging lens.

h) The construction of ray diagrams to show the formation of images by converging and diverging lenses.

Additional guidance:

Candidates may be asked to complete ray diagrams drawn on graph paper.

i) The magnification produced by a lens is calculated using the equation:

$$\text{magnification} = \frac{\text{image height}}{\text{object height}}$$

P3.1.4 The eye

a) The structure of the eye.

The structure of the eye is limited to:

- retina
- lens
- cornea
- pupil / iris
- ciliary muscle
- suspensory ligaments.

Additional guidance:

Candidates should know the function of these named parts.

Candidates should understand how the action of the ciliary muscle causes changes in the shape of the lens, which allows the light to be focused at varying distances.

b) Correction of vision using convex and concave lenses to produce an image on the retina:

- 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.

c) Range of vision. The eye can focus on objects between the near point and the far point.

Additional guidance:

Candidates should know that the near point is approximately 25 cm and the far point is infinity.

d) Comparison between the structure of the eye and the camera.

Candidates should be aware that the film in a camera or the CCDs in a digital camera is the equivalent of the retina in the eye.

e) The power of a lens is given by:

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

Candidates should know that the power of a converging lens is positive and the power of a diverging lens is negative.

P is power in dioptres, D

f is focal length in metres, m

f) 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.

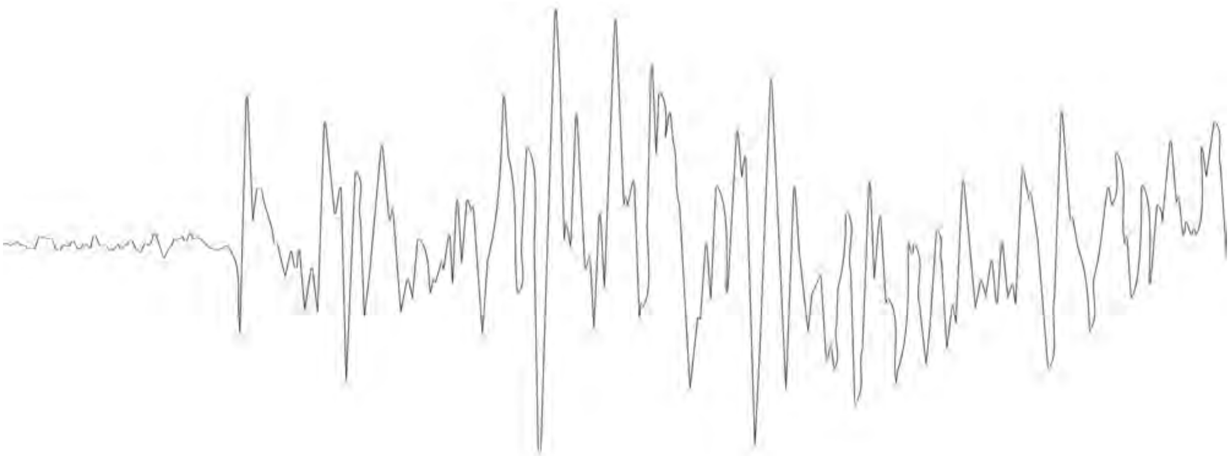
	Additional guidance:
g) **For a given focal length, the greater the refractive index, the flatter the lens. This means that the lens can be manufactured thinner.**	**HT only**

P3.1.5 Other applications using light

	Additional guidance:
a) Total internal reflection and critical angle. **refractive index** $= \frac{1}{\sin c}$	Candidates need to understand the concept of critical angle but knowledge of the values of critical angles is not required. **HT only** ***c* is the critical angle**
b) Visible light can be sent along optical fibres.	Examples of use should include the endoscope for internal imaging.
c) The laser as an energy source for cutting, cauterising and burning.	Knowledge of how lasers work is **not** required. Applications should include use in eye surgery.

Suggested ideas for practical work to develop skills and understanding include the following:

- demonstrating the range of frequencies audible to the human ear, using a signal generator, loudspeaker and oscilloscope
- demonstrating long and short sight by placing a screen, not at the focal point, and rectifying the image through the use of appropriate lenses
- using a round bottom flask filled with a solution of fluorescein to represent the eye
- investigating total internal reflection using a semi-circular glass block.



P3.2 Using physics to make things work

Many things, from simple toys to complex fairground rides, are constructed from basic machines such as the lever. A knowledge of the physics involved in balancing and turning can help us to make these appliances work.

Candidates should use their skills, knowledge and understanding to:	**Additional guidance:**
■ analyse the stability of objects by evaluating their tendency to topple	Candidates should use a range of laboratory equipment to model real-life situations, eg cranes.
■ recognise the factors that affect the stability of an object	Candidates should recognise that objects with a wide base and low centre of mass are more stable than those with a narrow base and a high centre of mass.
■ evaluate how the design of objects affects their stability	
■ interpret and evaluate data on objects moving in circular paths.	**Additional guidance:** Candidates should understand that a centripetal force does not exist in its own right but is always provided by something else such as gravitational force, friction or tension.

P3.2.1 Centre of mass

	Additional guidance:
a) The centre of mass of an object is that 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.	
d) For a simple pendulum: $T = \frac{1}{f}$	**Additional guidance:** T is periodic time in seconds, s f is frequency in hertz, Hz
e) The time period depends on the length of a pendulum.	The equation $T = 2\pi\sqrt{l/g}$ is **not** required. Applications of the pendulum should include simple fairground and playground rides.

P3.2.2 Moments

a) The turning effect of a force is called the moment.	
b) The size of the moment is given by the equation: $M = F \times d$	**Additional guidance:** *M* is the moment of the force in newton-metres, Nm *F* is the force in newtons, N *d* is the perpendicular distance from the line of action of the force to the pivot in metres, m
c) If an object is not turning, the total clockwise moment must be exactly balanced by the total anticlockwise moment about any pivot.	
d) The calculation of the size of a force, or its distance from pivot, acting on an object that is balanced.	**Additional guidance:** **HT only**
e) Ideas of simple levers.	Limited to levers as force multipliers.
f) 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 tend to topple.	**HT only** **Applications should include vehicles and simple balancing toys.**

P3.2.3 Hydraulics

a) Liquids are virtually incompressible, and the pressure in a liquid is transmitted equally in all directions.	**Additional guidance:** 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 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.	
c) The pressure in different parts of a hydraulic system is given by: $P = \frac{F}{A}$	**Additional guidance:** *P* is the pressure in pascals, Pa *F* is the force in newtons, N *A* is the cross-sectional area in metres squared, m^2

P3.2.4 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.

Additional guidance:

Candidates should be able to identify which force(s) provide(s) 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.

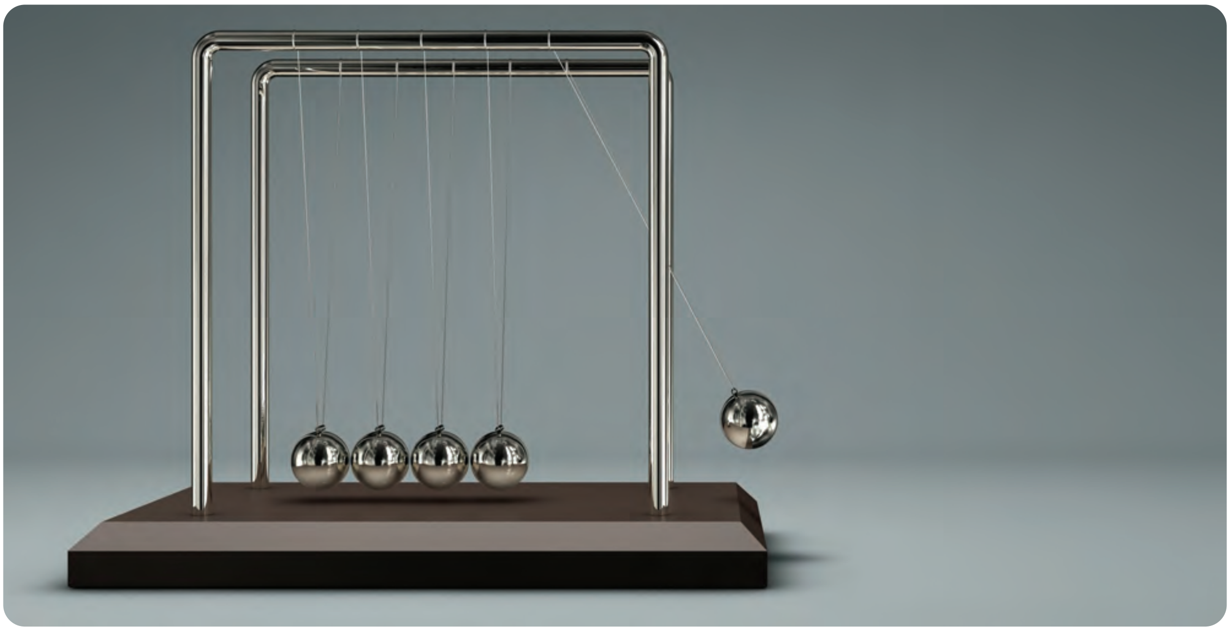
The equation

$$F = \frac{mv^2}{r}$$

is **not** required.

Suggested ideas for practical work to develop skills and understanding include the following:

- demonstrating that pressure in liquids acts in all directions using a circular container with holes around it
- finding the centre of mass of an irregularly shaped card
- using a balanced metre ruler and masses to verify the principle of moments
- plan and carry out an investigation into factors that affect the period of a simple pendulum (mass, length of pendulum, amplitude of swing)
- whirling a bung on the end of a piece of string to demonstrate the factors that affect centripetal force
- investigating objects and slopes to find out the point at which the object topples.



P3.3 Keeping things moving

Electric currents produce magnetic fields. Forces produced in magnetic fields can be used to make things move. This is called the motor effect and is how appliances such as the electric motor create movement.

Many appliances do not use 230 volts mains electricity. Transformers are used to provide the required potential difference.

Candidates should use their skills, knowledge and understanding to:

- interpret diagrams of electromagnetic appliances in order to explain how they work
- compare the use of different types of transformer for a particular application.

Additional guidance:

Examples might include some mobile phone chargers and power supplies for lap top computers.

P3.3.1 The motor effect

	Additional guidance:
a) When a current flows through a wire a magnetic field is produced around the wire.	Applications of electromagnets could include their use on cranes for lifting iron/steel.
b) The motor effect and its use.	Candidates should be able to apply the principles of the motor effect in any given situation.
c) The size of the force can be increased by: ■ increasing the strength of the magnetic field ■ increasing the size of the current.	The equation $F = BIL$ is **not** required.
d) The conductor will not experience a force if it is parallel to the magnetic field.	
e) The direction of the force is reversed if either the direction of the current or the direction of the magnetic field is reversed.	**Additional guidance:** Candidates will be expected to identify the direction of the force using Fleming's left-hand rule.

P3.3.2 Transformers

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.

c) The basic structure of the transformer.

d) An alternating current in the primary coil 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.

Additional guidance:

Knowledge of laminations and eddy currents in the core are **not** required.

e) In a step-up transformer the potential difference across the secondary coil is greater than the potential difference across the primary coil.

f) In a step-down transformer the potential difference across the secondary coil is less than the potential difference across the primary coil.

g) The potential difference across the primary and secondary coils of a transformer are related by the equation:

$$\frac{V_p}{V_s} = \frac{n_p}{n_s}$$

Additional guidance:

V_p is the potential difference across the primary coil in volts, V

V_s is the potential difference across the secondary coil in volts, V

n_p is the number of turns on the primary coil

n_s is the number of turns on the secondary coil

h) If transformers are assumed to be 100% efficient, the electrical power output would equal the electrical power input.

$$V_p \times I_p = V_s \times I_s$$

Candidates should be aware that the input to a transformer is determined by the required output.

V_p is the potential difference across the primary coil in volts, V

I_p is the current in the primary coil in amperes (amps), A

V_s is the potential difference across the secondary coil in volts, V

I_s is the current in the secondary coil in amperes (amps), A

i) Switch mode transformers operate at a high frequency, often between 50 kHz and 200 kHz.

j) Switch mode transformers are much lighter and smaller than traditional transformers working from a 50 Hz mains supply.

Additional guidance:

Candidates should be aware that this makes them useful for applications such as mobile phone chargers.

k) Switch mode transformers use very little power when they are switched on but no load is applied.

Suggested ideas for practical work to develop skills and understanding include the following:

- placing a foil strip with a current going through it in a strong magnetic field
- building a motor
- making a loudspeaker
- making a transformer using C cores and insulated wire
- demonstrating a transformer to show the difference between using d.c. and a.c.