

OXFORD

INTERNATIONAL
AQA EXAMINATIONS

INTERNATIONAL GCSE PHYSICS

(9203)

Outline Schemes of Work

For teaching from September 2016 onward

For International GCSE exams in June 2018 onwards

This scheme of work suggests possible teaching and learning activities for each section of the specification. There are far more activities suggested than it would be possible to teach. It is intended that teachers should select activities appropriate to their students and the curriculum time available. The first two columns summarise the specification references, whilst the Learning Outcomes indicate what most students should be able to achieve after the work is completed. The Resources column indicates resources commonly available to schools, and other references that may be helpful. The timings are only suggested, as are the Possible Teaching and Learning Activities, which include references to experimental work. Resources are only given in brief and risk assessments should be carried out.

Spec Reference	Summary of the Specification Content	Learning Outcomes <i>What most students should be able to do</i>	Suggested timing (lessons)	Possible Teaching and Learning Activities <i>Homework</i>	Resource	Examination 'hints and tips' <i>Students should:</i>
3.1 Forces and their effects						
3.1.1 Forces and their interactions						
3.1.1a	Objects interact by non-contact (field) forces (including gravity, electrostatics, magnetism) and by contact forces (including friction, air resistance, tension and normal contact force).	<p>Recall and describe the effects of forces in terms of changing the shape and/or motion of objects.</p> <p>Give examples of contact and non-contact forces.</p> <p>Describe examples of contact forces explaining how the force is produced.</p> <p>Describe examples of non-contact forces and state how the force is produced, eg gravitational force caused by two objects with mass exerting an attractive force on each other.</p>	0.5	<p>Activity: Investigate contact and non-contact forces. This can include magnets, friction along a surface eg when a shoe is pulled along it. You can change the surface to explore how this changes the amount of force required to move the shoe. You could also add a lubricant eg water/oil to the surface.</p> <p>Activity: To illustrate static electricity as a non-contact force pupils could rub a polythene rod with a duster and then use the charged rod to attract small pieces of paper (eg from a hole punch) or bend water.</p>		
3.1.1b	Friction is a force between two surfaces, which impedes motion and may result in heating. Air resistance is a form	<p>Recall the meaning of friction.</p> <p>Explain the effect of friction on objects.</p>	1	<p>Activity: Make parachutes of different sizes, eg 10x10cm and one 50x50cm, and then drop it from a height.</p> <p>Activity: Time how long it takes to fall and then discuss the change in</p>		

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3.1.1c	of friction. Pairs of objects interact to produce a force on each other, which can be represented as vectors.		1	forces. Activity: Measuring the size of a force using a Newtonmeter. Activity: Sort quantities into vectors and scalars. Activity Draw vector diagrams for vectors where the size and direction of the arrow represents the size and direction of the vector.		
3.1.1d	Scalars are quantities that have magnitude only. Vectors are quantities that have direction as well as a magnitude. A vector quantity may be represented by an arrow. The length of the arrow represents the magnitude and the direction of the arrow represents the direction of the vector quantity.	Understand the difference between scalar and vector quantities and give examples of both. Students should be aware that distance, speed and time are examples of scalars and displacement; velocity, acceleration, force and momentum are examples of vectors.		Activity: Pupils could model displacement vectors by sketching a scale drawing for displacement vectors, eg 3m East followed by 5m North in the playground. Then back in the classroom get them to draw a scale diagram (ie 1m = 1cm) of this using the arrow notation.		Know some examples of both scalars and vectors.

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3.1.1e	<p>Weight is the force acting on an object due to gravity. The weight of an object depends on the gravitational field strength at the point where the object is.</p> <p>The weight of an object can be calculated using the equation: Weight (N) = mass (kg) × gravitational field strength (N/kg) $W = m \times g$</p>	<p>Recall weight is the force acting on an object due to gravity. The force of gravity close to the Earth is due to the gravitational field around the Earth.</p> <p>Understand the difference between mass and weight.</p> <p>Apply the formula to calculate weight.</p>	1	<p>Activity: Discuss how weight of a mass on different planets varies.</p> <p>Activity: Pupils can model what a 1kg mass would weigh on different planets using tin cans filled with sand.</p> <p>Activity: Show that a feather and coin fall at the same rate in an evacuated tube.</p>		
3.1.1f	<p>When more than one force is applied to an object they may cause a change in the shape of the object, by stretching, bending or compressing.</p>	<p>Explain how forces can change an objects shape.</p>		<p>Activity: Discuss why deforming a material can only occur if more than one force is acting on the object. If only one force was acting the object would just move in the direction of the force.</p> <p>Activity: Give examples of objects being stretched, bent or</p>		<p>Rearrange formula, convert units, carry out calculations.</p>

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3.1.1g	<p>After elastic distortions an object returns to its original shape when the forces are removed. After inelastic distortions an object does not return to its original shape.</p> <p>A force applied to an elastic object such as a spring will result in the object stretching and storing elastic potential energy.</p>	<p>Recall the effect of applying force to a spring.</p> <p>Investigate what makes the best catapult.</p>	2	<p>compressed by forces. Draw force diagrams to show how the forces are acting on the object and how the stretching, bending or compressing occurs.</p> <p>Activity: Investigate the effect of forces on the extension of a spring.</p> <p>Demonstration: Stretch warm strip of toffee to show inelastic distortion.</p> <p>Practical and enquiry skills: Investigate the effect of stretching elastic band catapults by different amounts on the distance a fired paper pellet travels.</p> <p>Homework: Students research toys they have had that have worked using stored potential energy, eg pull back 'motor' cars.</p>		
3.1.1h	<p>For an object behaving elastically, the extension is directly</p>	<p>Know the relationship between the force, F, and the extension, e.</p>		<p>Activity: Investigate the effect of loading and unloading springs</p>		<p>Rearrange formula, convert units, carry out</p>

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	<p>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:</p> $F = k \times e$ <p>where k is a constant.</p>			<p>stretched up to and beyond their elastic limits. Add a force of 1N (100g mass) at a time and measure the extension of the spring. Continue until the spring is clearly stretched beyond its elastic limit and then remove 1N at a time, recording the extension each time.</p> <p>Activity: Find the spring constant of a spring by experiment.</p> <p>Activity: Sketch and describe the force and extension curve of an elastic material (eg elastic band or spring) when not stretched beyond its elastic limit.</p> <p>Activity: Sketch and describe the force and extension curve of an elastic material when stretched beyond its elastic limit.</p> <p>Activity: Interpret data from an investigation of the relationship between force and extension. Describe the difference between a linear and non-linear relationship.</p> <p>Research: uses of springs in compression and tension.</p>		<p>calculations.</p>

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3.1.1i	Required practical: Students should investigate the relationship between force and extension for a spring.					
3.1.2 Motion						
3.1.2a	If an object moves in a straight line, its distance from a certain point can be represented by a distance–time graph.	Be able to construct and interpret distance-time graphs for an object moving in a straight line when the body is stationary or moving with constant speed.	1	<p>Practical and enquiry skills: Datalogging equipment to graph distance and time.</p> <p>Scientific communication skills and activities: Drawing and interpreting distance-time graphs and using them to determine speed.</p> <p>Use of train timetables to build distance-time graphs to compare fast and slow trains.</p> <p>Students sketch a distance-time graph of their journey to school.</p>	Interactive motion graph can be found at http://www.nuffieldfoundation.org/practical-physics/simple-motion-experiments-datalogger	
3.1.2b	The speed of the object can be calculated from the gradient of a distance–time graph	Know how to calculate the speed of an object from the gradient of a distance-time graph.				
3.1.2c	The velocity, v , of an object is its speed in a given direction and is given by the equation: $v = \frac{s}{t}$	Know how to calculate the velocity of an object from the equation.	1	<p>Activity: Carry out calculations using $v = \frac{s}{t}$</p> <p>Homework: Students sketch a distance-time graph of their journey to school.</p>		

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3.1.2d	<p>where s is the displacement and t is the time taken.</p> <p>This equation can also be used to calculate the average speed of objects undergoing non-uniform motion.</p>					
3.1.3 Resultant forces						
3.1.3a	Whenever two objects interact, the forces they exert on each other are equal in magnitude and opposite in direction. This is Newton's Third Law.	<p>Understand that forces occur in pairs, acting on different objects.</p> <p>Understand the term 'resultant force' and be able to determine the resultant of opposite or parallel forces acting in a straight line.</p>	1	Using model cars / trolleys investigate effect of forces on motion.		
3.1.3b	A number of forces acting on an object may be replaced by a single force that has the same effect on the motion as all the	Understand that a 'resultant force' acting on an object may affect its motion.		Determine the resultant of opposite or parallel forces acting in a straight line and the resultant of two coplanar forces by scale drawing.		

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3.1.3c	<p>original forces acting together. This single force is called the resultant force.</p> <p>A non-zero resultant force acting on an object causes it to accelerate.</p>					
3.1.3d	<p>Acceleration is the rate of change of velocity. An object can accelerate by changing its direction even if it is going at a constant speed. Deceleration is a negative acceleration.</p> <p>The average acceleration a of an object is given by the equation: $a = \frac{\Delta v}{t}$ where Δv is the</p>	Recall the definition and calculation of acceleration.	2	<p>Calculate the acceleration of a vehicle when given the initial and final speed and the time taken for the change in speed to occur. Rearrange the equation to find other unknown quantities.</p> <p>Compare the accelerations of different vehicles.</p> <p>Explain how the acceleration of a vehicle can be determined experimentally.</p> <p>Activity: Carry out calculations using</p>		

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3.1.3e	<p>change in velocity and t is the time taken for the object to accelerate.</p> <p>The acceleration of an object can be calculated from the gradient of the velocity–time graph.</p>	<p>Draw velocity – time graph.</p> <p>Be able to calculate acceleration from the gradient of a velocity – time graph.</p>		<p>$a = \frac{\Delta v}{t}$</p> <p>Activity: View interactive software to show velocity-time graphs.</p> <p>Activity: Drawing and interpreting graphs and calculating acceleration and distance.</p> <p>Explain how the acceleration of an object can be found from a velocity – time graph.</p> <p>Compare the acceleration of a vehicle at different points of a velocity – time graph from the gradients of the lines.</p> <p>Calculate the distance travelled using the area under the line on a velocity – time graph.</p>		
3.1.3f	<p>The distance travelled by an object can be calculated from the area under a velocity–time graph.</p>	<p>Be able to draw and calculated the distance travelled by an object from the area under a velocity – time graph.</p>				
3.1.3g	<p>If the resultant force acting on an object is zero:</p>	<p>Recall Newton's First Law.</p>	1	<p>State Newton's First Law. Describe the effect of having no resultant</p>		

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3.1.3h	<ul style="list-style-type: none"> a moving object will continue to move at the same velocity a stationary object will remain at rest. This is Newton's First Law. <p>If the resultant force on an object is not zero, the object will accelerate in the direction of the resultant force. The relationship between the resultant force, F, acting on an object, its mass, m, and the acceleration caused, a, is: $F = m \times a$</p> <p>This is Newton's Second Law.</p>	<p>Investigate how force and mass affect the rate of acceleration.</p> <p>Be able to use the equation relating force, mass and acceleration.</p>		<p>force on:</p> <ul style="list-style-type: none"> a stationary object an object moving at a constant velocity. <p>Explain that for an object travelling at terminal velocity the driving force(s) must equal the resistive force(s) acting on the object.</p> <p>Define Newton's Second Law.</p> <p>Demo: Demonstration of datalogging equipment to measure force and acceleration of a trolley on a friction-compensated runway.</p> <p>Calculate the resultant force acting on an object using the equation.</p> <p>$F = m a$. Rearrange the equation to find any other unknown quantity.</p> <p>Analyse data on vehicles to determine the acceleration when given the driving force and mass of the vehicle.</p>		

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				<p>Explain why two identical cars that have different loads will have different accelerations.</p> <p>Explain why heavier vehicles have greater stopping distances than light vehicles, assuming the same braking force.</p>		
3.1.4 Momentum						
3.1.4a	All moving objects have momentum. The relationship between momentum, p , mass, m , and velocity, v , is: $p = m \times v$	Know how to calculate the momentum of a moving object.	2	<p>Activity: Make measurements to determine the momentum of moving objects.</p> <p>Activity: Carry out calculations using $p = m \times v$</p>	<p>Colliding trolleys equipment; method of measuring velocities, eg datalogging, light gates and timers etc.</p> <p>Information on momentum can be found on the BBC GCSE Bitesize website at http://www.bbc.co.uk/schools/gcsebitesize/science/add_aq_a/forces/</p>	Know the terms in the equation and their units. Be able to perform calculations for collision and explosions. Remember that momentum has a direction.
3.1.4b	In a closed system the total momentum before an interaction is equal to the total momentum after the interaction.	Understand that momentum is conserved in collisions and explosions. Complete calculations involving two objects colliding or exploding.		<p>Demo: Demonstration of simple colliding system, eg moving trolley colliding with and adhering to a stationary trolley; measuring masses and velocities to calculate momentum before and after the collision.</p>		

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3.1.4c	<p>This is called conservation of momentum.</p> <p>The relationship between force, F, change in momentum, Δp, and time, t, is: $F = \frac{\Delta p}{t}$ ie the force equals the rate of change of momentum.</p>	<p>Use this relationship to explain qualitatively car safety features such as air bags, seat belts, side impact bars, crumple zones. Also gymnasium crash mats, cushioned surfaces for playgrounds and cycle helmets.</p>		<p>Demo: Demonstration of simple exploding system, eg two stationary trolleys joined by a compressed spring, and then released; measuring masses and velocities to calculate momentum after the collision, having started at rest.</p> <p>Activity: Carry out calculations using</p> $F = \frac{\Delta p}{t}$ <p>Discuss: Discussion of use of jet packs for moving in space, and rocket travel. Work done by external force changing momentum of a body, eg work done by force changing shape of car in crumple zones. Importance of time during which work is done reducing the force involved.</p>		
3.1.5 Safety in public transport						
3.1.5a	When a vehicle travels at a steady	Recall that when a vehicle travels at a steady speed the	3	Activity: Measurement of reaction times using stopwatches or falling	Stopwatches and rulers.	

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3.1.5b	<p>speed in a straight line the resistive forces are balancing the driving force.</p> <p>The greater the speed of a vehicle the greater the braking force needed to stop it in a certain distance. The greater the braking force the greater the deceleration of the vehicle. Large decelerations may lead to brakes overheating and/or loss of control. For a given braking force, the greater the speed, the greater the stopping distance.</p>	<p>resistive forces balance the driving force.</p> <p>Be able to describe and explain stopping distance and the factors that affect it:</p> <ol style="list-style-type: none"> 1. distractions which may affect a driver's ability to react and know the factors which could affect a driver's reaction time. 2. conditions that affect braking distance. 		<p>rulers.</p> <p>Define:</p> <ul style="list-style-type: none"> • thinking distance • braking distance • stopping distance. <p>State that the overall stopping distance of a vehicle is made up of the thinking distance plus the braking distance.</p> <p>Discuss: Small group discussion about factors affecting stopping distance.</p> <p>Video: Watch video clips on speed and stopping distance, and distractions and driving.</p> <p>Homework: Research stopping distances at different speeds; design a poster about factors affecting thinking distance.</p> <p>Research: Research which markings on roads are used to try to make drivers think about stopping distances and those which are to try and make drivers reduce</p>	<p>Video clips about speed and stopping distance can be found at http://www.seattle-duiattorney.com/media/dui-videos.php</p> <p>Video clips about distractions and driving can be found at http://think.direct.gov.uk/index.html</p>	

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3.1.5c	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). A driver's reaction time can be affected by tiredness, distractions, drugs and alcohol.			<p>their speed.</p> <p>Describe and explain the energy changes involved in stopping a vehicle.</p> <p>Explain why vehicles travelling faster have larger braking distances.</p> <p>Find patterns between the speed of a vehicle and the braking distance, eg what would be the effect of doubling the speed on the braking distance and why?</p> <p>Find patterns between the speed of a vehicle and the thinking distance, eg what would be the effect of doubling the speed on the thinking distance and why?</p>		
3.1.5d	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			<p>Explain why stopping from high speed can cause the brake pads to overheat and the brake disks to warp.</p>		

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3.1.5e	brakes increases. A vehicle's braking distance can be affected by adverse road and weather conditions and poor condition of the vehicle.					
3.1.6 Forces and terminal velocity						
3.1.6a	An object moving through a fluid experiences friction. The faster the object moves, the greater the frictional forces (drag) acting on it.	Know which forces act on an object moving through a fluid.	2	Demo: Demonstrate streamlined and non-streamlined shapes falling through water/washing-up liquid. Video: Watch videos on skydiving.	Long glass tubes containing water or washing-up liquid, plasticine shapes, stopwatch, electric balances, force-meters, sheets of paper, cotton, masses, stopwatches. Paper cake cases, available in various sizes, are very effective.	
3.1.6b	An object falling through a fluid will initially accelerate due to the force of gravity and the drag forces increase as the velocity increases. Eventually the resultant force will be zero and the	Be able to describe and explain how the velocity of an object falling through a fluid changes as it falls.		Activity: Investigating the relationship between mass and weight, eg weighing objects on an electric balance and a force-meter. Activity: Investigate the effect of area of a paper parachute on a falling mass. Draw and interpret velocity-time graphs for objects that reach terminal velocity by considering the forces acting on the object.		

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3.1.6c	object will move at its terminal velocity. Parachutes are designed to increase the drag force on a parachutist so that the terminal velocity is reduced.	Understand why the use of a parachute reduces the parachutist's terminal velocity.		Describe how the streamlining of a shark (an adaptation) or a car (a design feature) reduces the drag force and the object.	Video clips of skydiving can be found at http://science.discovery.com/videos/head-rush-terminal-velocity.html	Understand why the use of a parachute reduces the parachutist's terminal velocity. Know the terms in the equation and their units.
3.1.6d	Streamlining reduces the drag force on an object so that its maximum velocity is increased.					
3.1.7 Centre of Mass						
3.1.7a	The centre of mass of an object is the point at which the mass of the object may be thought to be concentrated.	Describe how to find the centre of mass of a thin, irregular sheet of a material. Suggest an appropriate position for the centre of mass of different objects.	2	Activity: Investigations to find the centre of mass of both regular and irregular pieces of flat card.	Card shapes, plumb lines and pins in corks to suspend card.	Be able to suggest an appropriate position for the centre of mass of different objects.
3.1.7b	If freely suspended, an object will come to rest with its					

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3.1.7c	<p>centre of mass directly below the point of suspension.</p> <p>The centre of mass of a symmetrical object is along the axis of symmetry. The position of the centre of mass affects the stability of objects.</p>					
3.1.8 Moments and levers						
3.1.8a	<p>The turning effect of a force is called the moment.</p> <p>The relationship between the moment M, turning force F and perpendicular distance d from the point where the force is applied to the pivot is: $M = F \times d$</p>	<p>Understand the concept of a turning moment and use the equation.</p> <p>Perform calculations involving moments and balanced objects.</p> <p>Investigate the relationship between force and distance to understand the law of moments.</p>	3	<p>Demo: Situations where force and distance combine to produce a moment, eg opening a door, using a spanner etc.</p> <p>Activity: Suspended rulers and hanging weights to verify the law of moments.</p> <p>Activity: Class experiment to find the weight of an object using the law of moments.</p>	<p>Suitable demonstration objects.</p> <p>Suspended rulers, hanging weights.</p>	<p>Know how to calculate the moment of a force.</p> <p>Know how to use the law of moments to calculate a force or distance needed for balance.</p>

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3.1.8b	If an object is not turning, the total clockwise moment must be exactly balanced by the total anticlockwise moment about any pivot.			Homework: Carry out moments calculations.		
3.1.8c	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. Demo: Stable objects, eg Bunsen burner and unstable objects, eg tall thin vase. Homework: Research the design of objects for stability, eg racing cars etc.		Be able to calculate the size of a force, or its distance from a pivot, acting on an object that is balanced.
3.1.8d	Simple levers can be used as force multipliers.	Explain how a simple lever can be used to transmit the rotational effects of forces.		Explain why a longer spanner is used to undo a wheel nut if it is stuck rather than a shorter spanner, eg putting a pole over the spanner to increase the distance from the pivot will increase the moment of the force. Explain why jumping on the spanner undoing a wheel nut will also increase the moment of the	A video clip of levers can be found on www.youtube.com by searching for 'The Lever, a Simple Machine'.	

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				<p>force.</p> <p>Video: Watch video clips or view images of levers.</p> <p>Homework: Design a poster showing how different levers work.</p>		
3.2 Energy						
3.2.1 Forces and energy						
3.2.1a	<p>Work is done when a force causes an object to move through a distance. The relationship between work done, W, force, F, and distance, d, moved in the direction of the force is:</p> $W = F \times d$	Know how to calculate the work done on an object and the power developed.	3	<p>Activity: Calculating students' work done and power output in different situations, eg running up stairs, lifting sandbags onto a table etc.</p> <p>Calculate the work done in stretching or compressing a spring when given the mass or weight applied to the spring.</p>	Bathroom scales, rulers, stopwatches, falling object, light gate and timer.	Know the terms in the equations and their units.
3.2.1b	Energy is transferred when work is done. Work done against frictional forces causes energy transfer by heating					

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3.2.1c	The amount of elastic potential energy stored in a stretched spring (assuming the limit of proportionality has not been exceeded) can be calculated using the equation: $E_e = \frac{1}{2} k e^2$			Explain what is meant by the limit of proportionality. Identify the limit of proportionality on a graph showing the force applied against extension.		
3.2.1d	An object gains gravitational potential energy when it is raised vertically because work is done against the gravitational force. The relationship between gravitational potential energy, E_p , mass, m , gravitational field strength, g , and height, h , is:	Understand that when an object is raised vertically, work is done against gravitational force and the object gains gravitational potential energy. Know how to calculate the change in gravitational potential energy of an object. Understand the transfer of kinetic energy in particular situations, such as space shuttle re-entry or meteorites burning up in the atmosphere.		Recap students understanding of gravitational potential energy. Explain what gravitational field strength is. Recap with students what is meant by kinetic energy. Activity: Measurement of initial gravitational potential energy (GPE) and final kinetic energy (KE) of a falling object, eg using a light gate and timer. Provide students with opportunities to apply the formula		Be able to convert from g to kg.

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3.2.1e	$E_p = m \times g \times h$ <p>The kinetic energy of a moving object depends on its mass and its velocity. The relationship between kinetic energy, E_k, mass, m and velocity, v, is:</p> $E_k = \frac{1}{2} \times m \times v^2$	Know how to calculate the kinetic energy of a moving object.		$E_p = m \times g \times h$ <p>Provide students with opportunities to apply the formula</p> $E_k = \frac{1}{2} \times m \times v^2$ <p>Demo: Motor lifting a mass, and calculation of work and power.</p> <p>Activity: Carry out calculations using</p> $W = F \times d$ $P = \frac{W}{t}$ <p>Homework: Calculations using the different equations.</p>		
3.2.1f	<p>Power is the rate at which energy is transferred or the rate at which work is done. The relationship between power, P, work done, W, or energy transferred, E, and time, t, is:</p> $P = \frac{E}{t}$ <p>and</p>					

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	$P = \frac{W}{t}$					
2.2 Energy transfer, conservation and dissipation of energy						
3.2.2a	When a system changes, energy is transferred. A system is an object or group of objects.	Describe the energy transfers and the main energy wastages that occur in a range of situations or appliances. . For example: <ul style="list-style-type: none"> • an object projected upwards • an object accelerated by a constant force • a vehicle slowing down • an electric kettle boiling water. 	2	<p>Activity: Circus of energy transfer devices. Ask students to explore questions such as:</p> <ul style="list-style-type: none"> • Why are some kitchen appliances given higher energy ratings than others? • Why do the wheels of a bike get very hot when braking hard? • Which type of car is more efficient – petrol or electric? <p>Describe the changes in energy stores that take place in simple machines and simple systems. Examples could include:</p> <ul style="list-style-type: none"> • petrol and electric cars • vehicle braking systems (such as bike brakes) • a ball being thrown upwards • electrical items such as kettles and radios. 	Energy transfer devices, eg battery operated electric bell, wind-up toy etc.	

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3.2.2b	A simple pendulum is an example of oscillating motion and energy is transferred between kinetic energy and gravitational potential energy.	Describe and explain energy transfer for a pendulum.		Use this opportunity of investigating the variables that might effect a pendulum to plan and carry out an investigation .		
3.2.2c	Energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.	Recall that energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed. Describe examples where there are energy transfers in a closed system, that there is no net change to the total energy.		Ask students to explore questions such as: <ul style="list-style-type: none"> • Can energy be created or destroyed? • What happens to energy that is lost? • How can we reduce the amount of energy being wasted by a machine? • What is the best way to reduce heat loss in the home? 	Useful information on 'Heat transfer and efficiency' can be found on the BBC website at http://www.bbc.co.uk/schools/gcsebitesize/science/aqa/energyefficiency/	
3.2.2d	When energy is transferred only part of it may be usefully transferred; the rest is dissipated so that it is stored in less useful ways. This energy is often described as being	Unwanted energy transfers can be reduced in a number of ways, for example, through lubrication and the use of thermal insulation. Students should investigate ways of reducing the unwanted energy transfers in a system.		Presenting and writing descriptions and explanations: Describe what happens to the electrical energy that goes into an appliance, such as a radio – in terms of energy stores and how the amount of energy in each store.		

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3.2.2e	<p>"wasted".</p> <p>Friction and air resistance are forces that dissipate energy by heating the surroundings</p>					Understand why a device or process can never be greater than 100% efficient.
3.2.2f	<p>The efficiency of a device can be calculated using $\text{efficiency} = \frac{\text{useful energy out}}{\text{total energy in}}$</p> <p>and</p> <p>$\text{efficiency} = \frac{\text{useful power out}}{\text{total power in}}$</p>	<p>Understand the concept of efficiency and why an efficiency can never be greater than 100%.</p> <p>Use the equations to calculate efficiency as a decimal or percentage.</p>	1	<p>Ask students to explore questions such as:</p> <ul style="list-style-type: none"> Which type of power station is the most efficient? Which type of light bulb would cost the least amount of money to use? <p>Research different types of power station to find out if combustion based power stations are less efficient than either nuclear or wind. Investigate ways of increasing the efficiency of a coal fired power station.</p>		Know how to use the efficiency equations to calculate the efficiency either as a decimal or as a percentage.
3.2.2g	The energy flow in a system can be represented using Sankey diagrams.	Interpret and draw a Sankey diagram.		or Prepare a presentation on different		Be able to draw and interpret Sankey

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				<p>types of light bulb. Find out the cost of buying and running the light bulbs in a home for one year. Determine whether energy saving light bulbs will save money over incandescent light bulbs.</p> <p>State the equation used to find efficiency.</p> <p>Calculate the efficiency of a machine as either a decimal or a percentage. Rearrange the equation to determine the total energy put into the machine or the useful energy output.</p> <p>Students may have to analyse data to determine the useful energy output if they are told the energy input and the amount of wasted energy.</p> <p>Interpret data on efficiencies of different machines.</p> <p>Activity: Draw Sankey diagrams, having identified major sources of wasted energy.</p> <p>Homework: Use retail catalogues eg. for washing machines and</p>		diagrams.

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				fridges, to see how manufacturers are aware of the need for efficiency, and how it may influence the choice of appliance by consumers.		
3.2.3 Energy resources						
3.2.3a	Fuels are a useful store of energy; different fuels are suitable for different situations and are selected according to a range of factors, such as ease of storage, energy content and safety.	Compare the ways that different energy resources are used. The uses to include transport, electricity generation and heating.	1	<p>Activity: Compare the use of different fuels in the generation of electricity, heating homes and transport. What are the safety concerns?</p> <p>Activity: Determine the most suitable fuel for a particular use depending on the characteristics of the fuel.</p>		
3.2.3b	When a fuel is used, some energy is transferred to the surroundings. Some fuels are more efficient than others.	Investigate the efficiency of different fuels.		<p>Demo or practical: Burn different fuels to heat a beaker of water. Measure temperature change.</p>	Spirit burners, various fuels, eg methanol, ethanol, propan-1-ol, butan-1-ol, beakers of water, thermometers.	
3.2.3c	There is a range of energy sources used on a national and	Describe the main energy resources available for use on Earth. These include: <ul style="list-style-type: none"> • fossil fuels (coal, oil and 	2	<p>Research: the different types of energy resources that are available to generate electricity. For each type of energy resource</p>		

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3.2.3d	<p>global scale. Their use has implications for society in terms of factors including renewability and the environmental impacts of extraction, use and disposal.</p> <p>A range of technologies have been developed to provide energy in a renewable way, such as wave power, solar power and geothermal</p>	<p>gas)</p> <ul style="list-style-type: none"> • nuclear fuel • bio-fuel • wind • hydro-electricity • geothermal • the tides • the Sun • water waves. <p>Explain the advantages and disadvantages of each type of energy resource with respect to other sources, eg the advantages and disadvantages of oil over nuclear power. Explain why each type of energy resource is used to generate electricity even though it does have these environmental impacts.</p> <p>Distinguish between energy resources that are renewable and energy resources that are non-renewable.</p>		<p>find the environmental impacts.</p> <p>Activity: For a given location determine the best way of generating electricity. Role-play a meeting between a group of local politicians, local environmental groups and electricity companies trying to get a new power station built. Which type of power station would each group want? How persuasive are each group in getting their choice? Evaluate the use of different energy resources for a given situation, eg generating electricity in remote locations. The evaluation should include ethical and environmental issues.</p> <p>Define renewable energy resource and give examples of them. Define non-renewable energy resource and give examples of them.</p>		

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	power.					
Spec Reference	Summary of the Specification Content	Learning Outcomes <i>What most students should be able to do</i>	Suggested timing (lessons)	Possible teaching and Learning Activities <i>Homework</i>	Resource	Examination 'hints and tips' <i>Students should:</i>
3.3 Waves						
3.3.1 General properties of waves						
3.3.1a	A wave is a disturbance caused by an oscillating source that transfers energy and information in the direction of wave travel, without transferring matter.		3	Demo: Demonstration of transverse and longitudinal waves using slinky springs or other equipment. Discuss the differences between transverse and longitudinal waves. Explain the changes in air pressure caused by longitudinal waves in regions of compression and rarefaction.	Slinky springs, wave machine equipment and computer access. A useful interactive video clip can be found on BBC GCSE Bitesize 'An Introduction to waves' at http://www.bbc.co.uk/schools/gcsebitesize/science/aqa/waves/	Be able to explain the difference between transverse and longitudinal waves.
3.3.1b	In a transverse wave the oscillations are perpendicular to the direction of energy transfer.	Understand that in a transverse wave the oscillations are perpendicular to the direction of energy transfer.		Demo: Demonstration of reflection, refraction and diffraction of waves using a ripple tank if available If a ripple tank isn't available, show the following two clips from Open University .		

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3.3.1c	In a longitudinal wave the oscillations are parallel to the direction of energy transfer. Longitudinal waves have areas of compression and rarefaction.	Understand that in a longitudinal wave the oscillations are parallel to the direction of energy transfer. Understand the terms 'compression' and 'rarefaction'.		Activities listed on Institute of Physics website Episode 309 Demonstrate a non-Newtonian fluid (corn starch) on a speaker cone or show clip		
3.3.1d	Electromagnetic waves and water waves are transverse, sound waves are longitudinal and mechanical waves may be either transverse or longitudinal.	To know examples of the different types of waves.		Discuss different examples of longitudinal and transverse waves.		
3.3.1e	Waves can be reflected, transmitted or absorbed (or a combination of these) at the boundary between two different	Investigate how waves behave at different wave boundaries.	1		Ripple tank and accessories.	

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3.3.1f	materials. Waves can undergo refraction due to a change in velocity and diffraction through a narrow gap or at an edge.	Understand the circumstances where a wave is reflected, refracted or diffracted. Be able to complete wavefront diagrams for reflection, refraction and diffraction. Be able to complete diagrams to illustrate interference.		Demo: reflected, refracted or diffracted using a ripple tank , Demo: 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. Students draw diagram to illustrate the phenomena and then explain the wave pattern.		
3.3.1g	Wave motion can be described in terms of their frequency, wavelength, period, amplitude and wavefront.	Understand the terms 'frequency', 'wavelength' and 'amplitude' and be able to annotate a diagram to show these terms.	2	Define: <ul style="list-style-type: none"> • Wavelength • Amplitude • Frequency • Peak • Trough • Period. The amplitude of a wave is the maximum displacement of a point on a wave away from its undisturbed position. The wavelength of a wave is the distance from a point on one wave to the equivalent point on the	Demonstrate what effect does increasing the amplitude/ frequency of a sound wave have using a loudspeaker and signal generator connected to an oscilloscope. Vary the frequency and then the amplitude on the signal generator – what is observed?	Know the terms in the equation and their units.

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3.3.1h	The relationship between wave speed, frequency and wavelength is $v=f\lambda$	Know that: All waves obey the wave equation: $wave\ speed = frequency \times wavelength$		adjacent wave. The frequency of a wave is the number of waves passing a point each second. $Period [T] = \frac{1}{f}$ period, T , in seconds, s frequency, f , in Hertz, Hz. The period of a wave is how long it takes for one wave to pass a point. The wave speed is the speed at which the energy is transferred (or the wave moves) through the medium Calculate the wavelength of a wave from a labelled diagram of a wave. Calculate the frequency of a wave given the number of waves (possibly from interpreting a diagram) and the time. Calculate the speed of a wave. Rearrange the equation to find any unknown given the other two values.	Demonstrate that changing the frequency of a transverse wave on a length of rope changes the wavelength. Pupils could investigate how to accurately measure the period of a wave ie time a fixed number, say 10 and then divide the time by this number.	

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				Show that when sound waves travel from one medium to another the changes in velocity, frequency and wavelength are inter-related.		
3.3.2 The electromagnetic spectrum						
3.3.2a	Electromagnetic waves are transverse waves that transfer energy from the source of the waves to an absorber.		2	Describe the properties of all electromagnetic waves. State that electromagnetic waves transfer energy from one place to an absorber of that energy.		
3.3.2b	Electromagnetic waves form a continuous spectrum and all types of electromagnetic wave travel at the same speed through a vacuum (space).	<p>Know the names and order of electromagnetic waves within the spectrum, in terms of energy, frequency and wavelength.</p> <p>Understand the wavelengths of the electromagnetic spectrum range from 10^{-15} to 10^4 and beyond.</p> <p>Know situations in which waves are typically used for communication.</p> <p>Give examples of the uses of</p>		<p>Name the seven electromagnetic waves, in the correct order from shortest to longest wavelength.</p> <p>State the range of wavelengths is approximately $10^{-15}\text{m} - 10^4\text{m}$</p> <p>State that electromagnetic waves can travel through a vacuum at the speed of light, $3.0 \times 10^8 \text{m/s}$.</p> <p>Research: Group research into properties and uses of electromagnetic waves, and the hazards of electromagnetic waves and appropriate precautions.</p>	<p>'Sending Information' can be found on BBC GCSE Bitesize at http://www.bbc.co.uk/schools/gcsebitesize/science/aqa/waves/</p> <p>Computer access, microwave transmitter and detector apparatus. Computer or reference book access.</p>	<p>Know the order of the electromagnetic waves within the spectrum in terms of energy, frequency and wavelength.</p>

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3.3.2c	Visible light is the part of the electromagnetic spectrum that is detected by our eyes; we see different wavelengths as colours.	<p>each part of the electromagnetic spectrum.</p> <p>Give examples of the hazards associated with each part of the electromagnetic spectrum.</p> <p>Recall that visible light is the part of the electromagnetic spectrum that allows us to see it.</p>		<p>Discuss: The concerns surrounding possible risks related to mobile phone use.</p> <p>State that the only part of the electromagnetic spectrum that is visible to us is visible light.</p>		
3.3.2d	All objects emit and absorb infrared radiation. Objects emit infrared radiation because of the motion of their particles. The amount and frequency of emitted radiation depends on the temperature and surface of the	<p>Recall that, no matter what temperature, objects emit and absorb infra-red radiation. The hotter an object is the more infra-red radiation it radiates in a given time.</p> <p>Explain why some objects emit more heat /infrared than others.</p>	1	<p>Describe and explain the factors that affect the rate of cooling of an object.</p> <p>Explain how the rate of cooling of a black object depends on the temperature that the object is at.</p> <p>Why does a black car get hotter than a white car in the summer?</p> <p>Why does a hot drink cool quickly but a warm bath stays warm for a</p>	<p>BBC Bitesize – Energy transfer by heating</p> <p>Heat radiation – Infrared radiation</p> <p>Heat (thermal) energy and heat transfer</p>	

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3.3.2e	<p>object. The hotter an object is the more infrared radiation it radiates in a given time.</p> <p>As an object heats up it radiates more and more infrared and radiation at higher frequencies.</p>			<p>long time?</p> <p>Investigate the rate of cooling by measuring 200 ml of boiling water and taking the temperature every 30 seconds using a temperature sensor. Plot a graph of temperature against time.</p> <p>Use a Lesley cube to investigate the emission of infra-red radiation by objects of different colour. Opportunity to use data loggers and temperature sensors attached to each of the four sides of the Leslie cube.</p>		
3.3.2f	<p>Black-body radiation is the range of electromagnetic radiation emitted by an object at a particular temperature.</p>	<p>A perfect black body is an object that absorbs the entire radiation incident on it. The object does not reflect or transmit any radiation. Since a good absorber is also a good emitter a perfect black body would be the best possible emitter.</p>	1	<p>Define what is meant by a black body in terms of radiation.</p> <p>Describe and explain why black would be the best colour for a radiator and suggest why most radiators are painted white.</p> <p>Explain what is meant by black body radiation.</p> <p>Plan an experiment to see if black T-shirts would keep you cooler in</p>	<p>Perfect black body and its spectrum</p>	

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3.3.2g	Radio waves, microwaves, infrared and visible light can be used for communication.	Describe uses of each wave in the electromagnetic spectrum.	1	<p>the summer than white T-shirts.</p> <p>Alternatively plan and investigate whether a black or silver cup can keeps water hotter for longer.</p>	Investigate the range of Bluetooth communications between mobile phones.	
3.3.2h	Electromagnetic waves have many practical applications.	Explain the suitability of each wave for its practical application.		<p>Electromagnetic waves have many practical applications. For example:</p> <ul style="list-style-type: none"> • radio waves – television and radio (including Bluetooth) • microwaves – satellite communications, cooking food • infrared – electrical heaters, cooking food, infra-red cameras • visible light – fibre optic communications • ultraviolet – energy efficient lamps, sun tanning • X-rays – medical imaging and treatments • Gamma rays – sterilising surgical instruments and killing harmful bacteria in food. 	<p>Research the use of laser light in barcodes and in reading CDs.</p> <p>Demonstrate an optical fibre showing total internal reflection.</p> <p>Demonstrate a use of UV by shining a UV light onto a bank note, through tonic water or writing a message using a security marker and then holding a UV light over the message.</p> <p>BBC Bitesize: The electromagnetic spectrum</p>	Know the uses and dangers of medical X-rays.

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3.3.2i	Excessive exposure of the human body to electromagnetic waves can be hazardous. Low energy waves have a heating effect and higher energy waves have enough energy to cause ionisation.	Describe and explain how and why electromagnetic waves can be harmful to the human body, eg <ul style="list-style-type: none"> • microwave – heating of body tissue • infrared – skin burns • ultraviolet – skin cancer and blindness • X-rays – high doses kill cells • gamma rays – genetic mutations. 	1	Describe how ultraviolet radiation from the sun can affect the body and in particular the skin. Explain what ionisation is and how X-rays may cause it. Draw conclusions from given data about the risks and consequences of exposure to radiation. Students will not need to recall the unit of radiation dose.	Cyber Physics: The electromagnetic spectrum	
3.3.2j	X-rays are part of the electromagnetic spectrum. They have a very short wavelength, high energy and cause ionisation.					
3.3.2k	Properties of X-rays include: <ul style="list-style-type: none"> • they affect a photographic film in the same 	Know that X-rays affect a photographic film in the same way as light, are absorbed by metal and bone but are transmitted by soft tissue.	1	Activity: view images of X-rays Using some X rays explain how they work in order for us to see images of our bones.	An interesting article on X-ray images, 'Artist's X-ray images seek beauty underneath', can be found at	

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3.3.2l 3.3.2m	<p>way as light</p> <ul style="list-style-type: none"> • they are absorbed strongly by metal and bone • they are transmitted by healthy tissue. <p>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.</p> <p>The use of high energy ionising radiation can be dangerous, and precautions need to be taken to monitor</p>	<p>Understand that X-rays can be used for diagnosis of bone fractures and dental problems, in computerised tomography (CT) scans, and in treatment by killing cancer cells.</p> <p>Know that the use of CCDs allows images to be formed electronically.</p> <p>Give examples of the precautions that need to be taken to monitor and minimise the levels of radiation that people who work with it are exposed to.</p>		<p>Discuss the uses of x rays</p> <p>Discuss how we minimise the risks associated with radiation for the people who work with it</p>	<p>http://www.msnbc.msn.com/id/24792453</p> <p>At the bottom of this article is a video about Nick Veasey's work.</p> <p>A video clip on the medical uses of X-rays can be found on the BBC website at http://www.bbc.co.uk/learningzone/clips/medical-uses-of-x-rays-the-electromagnetic-spectrum/1455.html</p>	

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	and minimise the levels of radiation that people who work with it are exposed to.					
3.3.3 Sound and ultrasound						
3.3.3a	Sound waves are longitudinal waves and cause vibrations in a medium, which are detected as sound. The range of human hearing is about 20 Hz to 20 000 Hz.	Know how sound waves are produced. Know that the range is about 20 Hz to 20 000 Hz.	3	Demo: Properties of sound using signal generator, loudspeaker and cathode ray oscilloscope (CRO). Demo: 'Electric bell in bell jar' type apparatus to show the need for a medium.	Signal generator, loudspeaker, CRO. Bell in bell jar apparatus.	Know the relationships between pitch and frequency, loudness and amplitude.
3.3.3b	The pitch of a sound is determined by the frequency of vibrations of the source. Its loudness is related to the size of the amplitude of the disturbance.	Understand the relationship between the pitch of a sound and the frequency of the sound wave.				

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3.3.3c	Sound waves can be reflected (echoes) and diffracted.	Understand how echoes are formed.		Demo: Demonstration of echoes from an outside wall.	A useful video clip on echoes and their use in sonar can be found on the BBC website at http://www.bbc.co.uk/learningzone/clips/echoes-and-their-use-in-sonar/14.html	
3.3.3d	Ultrasound is acoustic (sound) energy, in the form of waves with a frequency above the human hearing range.	Know that sound waves of higher frequencies than 20 000 Hz are referred to as ultrasound.	1	Demo: Demonstration of limit of human hearing using signal generator and loudspeaker. Homework: Research what happens to the range of audible sounds as a person ages.	Signal generator and loudspeaker. A video clip and news article on 3D ultrasounds can be found on the Northwest Cable News website at http://www.nwcn.com/news/health/Ultrasound-shows-babies-in-3D-100278289.html	Know the definition of 'ultrasound'. Know some examples of the medical uses of ultrasound.
3.3.3e	Electronic systems can be used to produce ultrasound waves, which have a frequency higher than the upper limit of hearing for humans.					
3.3.3f	Ultrasound waves are partially reflected when they meet a boundary between two different media. The time taken for	Understand the principle of ultrasound echoes.				Remember that in calculations involving ultrasound echoes the ultrasound has travelled

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3.3.3g	<p>the reflections to reach a detector can be used to determine how far away such a boundary is.</p> <p>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.</p>	Calculations involving distance between interfaces using $s = v \times t$.	1	<p>Use the equation to calculate distances between interfaces and use data from diagrams of oscilloscope traces.</p> <p>Evaluate the medical use of ultrasound and X-rays, including an understanding that some of the differences in use are because ultrasound waves are non-ionising and X-rays are ionising.</p>		from the transducer to the reflecting surface and back.
3.3.3h	<p>Ultrasound waves can be used in medicine. Examples include pre-natal scanning and the removal of kidney stones.</p>	Recall some uses of ultrasound.		<p>Compare the advantages and disadvantages of using ultrasound, X-rays or CT scans in terms of safety issues and the quality of image formed.</p> <p>Know examples of the use of ultrasound in medicine for diagnosis, pre-natal scanning and treatment eg the removal of kidney stones.</p>		

Spec Reference	Summary of the Specification Content	Learning Outcomes <i>What most students should be able to do</i>	Suggested timing (lessons)	Possible Teaching and Learning Activities <i>Homework</i>	Resource	Examination 'hints and tips' <i>Students should:</i>
3.3.4 Reflection						
3.3.4a	When waves are reflected the angle of incidence is equal to the angle of reflection.	Be able to draw diagrams showing rays of light being reflected from a plane mirror, labeling incident and reflected rays, angles of incidence and reflection, and the 'normal'.	2	<p>Investigate into the reflection of light at different angles from a plane mirror.</p> <p>Using a plane mirror recap the nature of the image produced – virtual, upright and laterally inverted.</p> <p>Construct labelled ray diagrams to illustrate the reflection of a wave at a surface.</p> <p>State the law of reflection.</p> <p>Describe and explain the effect of a wave moving from one medium into another.</p> <p>Investigate the law of reflection using a plane mirror and ray box. Pupils measure the angles of incidence and reflection.</p> <p>Demonstrate/investigate refraction of light using a straw in a glass of water, or use of a ray box and rectangular prisms. Pupils measure angles of incidence and refraction.</p>		Be able to construct a ray diagram to show the image formed in a plane mirror.

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3.3.4b	The normal is a construction line perpendicular to the reflecting surface at the point of incidence.					
3.3.4c	The image produced in a plane mirror.	State how an image is formed by a plane mirror, and why it is virtual.			Plane mirrors, rayboxes and protractors. Reflection of waves: BBC Bitesize: General properties of waves Cyber Physics: Reflection	
3.3.5 Refraction and total internal reflection						
3.3.5a	The velocity of waves is affected by the medium they are travelling through. The speed changes. Unless the wave enters at 90° to the surface (along the normal)	Describe and explain how light behaves as it travels from one medium to another.	2	Activity: Class experiment to measure angles 'i' and 'r' for light passing through a rectangular glass block. Demo: Interactive demonstration of refraction.		

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3.3.5b	the direction also changes. This is called refraction. Light waves are refracted at an interface.					
3.3.5c	Refraction by a prism can lead to dispersion of light waves and the formation of a spectrum.	Observe and explain what happens to light passing through a prism.		Students investigate how light behaves as it is passed through a prism. Explain their observations <ul style="list-style-type: none"> • 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 a change of speed. 	Rectangular glass blocks, rayboxes and protractors. An interactive demonstration of refraction can be found at http://www.upscale.utoronto.ca/PVB/Harrison/Flash/Optics/Refraction/Refraction.html	Know the direction in which light is refracted in different situations.
3.3.5d	Refractive index can be defined in terms of wave speed. (see equation)	Know that the refractive index of a medium, n , is defined as $n = \frac{\text{speed of light in vacuum}}{\text{speed of light in the medium}}$ and $n = \frac{\sin i}{\sin r}$	1	Explain what is meant by refractive index and the critical angle. Activity: Investigation using semi-circular blocks to observe total internal reflection and to measure the critical angle.		

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3.3.5e	The relationship between refractive index, n , angle of incidence, i , and angle of refraction, r , is: $n = \frac{\sin i}{\sin r}$	Explain the concept of critical angle.		Activity: Carry out calculations using the equation $n = \frac{\sin i}{\sin r}$ Demo: Observation of light passing through optical fibres. Demo: Demonstration of total internal reflection by laser focused on jet of water coming from a pierced carbonated drinks bottle.		
3.3.5f	Required practical:	Investigate refraction of light by different substances.	1	Use different types of blocks to investigate how light rays pass through them.	Plastic and glass blocks, ray boxes, protractors.	
3.3.5g	The relationship between refractive index, n , and critical angle, c , is $n = \frac{1}{\sin c}$		1	Explain the relationship between refractive index, n , and critical angle, c Carry out calculations using the equations $n = \frac{1}{\sin c}$ and $n = \frac{v_1}{v_2}$		

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3.3.5h	Total internal reflection is a special case of refraction, which occurs if the angle of incidence within the denser medium is greater than the critical angle.	Recall what total internal reflection is. Recall how light and infra-red are transmitted through optical fibres.		Explain that 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. Demo: how optical fibres work. Homework: Research what a laser is and what its medical uses are.	A computer simulation of total internal reflection can be found at http://www.upscale.utoronto.ca/PVB/Harrison/Flash/Optics/Refraction/Refraction.html	Remember that total internal reflection only occurs when the light is passing from a more dense to a less dense medium and the angle of incidence is greater than the critical angle.
3.3.5i	Visible light and infra-red can be transmitted through optical fibres by total internal reflection.					

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3.3.6 Lenses and the eye						
3.3.6a	A lens forms an image by refracting light.	<p>Understand how a lens refracts light.</p> <p>Understand the terms associated with lenses, which include 'convex', 'converging' and 'concave', 'diverging', 'principal focus' and 'focal length'.</p> <p>Understand the terms associated with images, which include 'upright' and 'inverted', 'real' and 'virtual', 'enlarged' and 'diminished'.</p>	4	<p>Describe the key features of a ray diagram where light passes through a lens. Students should be able to identify the:</p> <ul style="list-style-type: none"> • Principal axis • Focal point • Focal length. <p>Activity: Observing images of objects at different distances from converging and diverging lenses of different focal lengths.</p> <p>Activity: Observe passing parallel rays of light through converging and diverging lenses of different focal lengths.</p>	Converging and diverging lenses of different focal lengths, ray boxes.	<p>Draw ray diagrams neatly using a ruler.</p> <p>Know the meaning of the terms 'convex', 'converging', 'concave', 'diverging', 'principal focus' and 'focal length'.</p> <p>Make sure you recognise the symbols that represent converging and diverging lenses.</p>
3.3.6b	In a convex lens, parallel rays of light are brought to a focus at the principal focus.					
3.3.6c	In a concave (diverging) lens, parallel rays of light diverge as if coming from the principal focus.					

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3.3.6d	The distance from the lens to the principal focus is called the focal length.			<p>Activity: Measurement of the focal length of a converging lens by focusing a distant object on a screen.</p> <p>Construct ray diagrams to show how light travels through concave and convex lenses.</p> <p>Homework: Research uses of lenses.</p>	Pre-drawn outlines on graph paper showing the object and the lens, for students to complete.	
3.3.6e	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.	Explain the difference between real and virtual images.		Investigate the nature of the images formed by a converging lens when the object is at different distances from the lens, and the images formed by a diverging lens.	Lenses (of different focal lengths) and holders, metre rules, ray boxes, screens with cross-wires.	
3.3.6f	Ray diagrams are used to show the formation of images by convex and concave lenses.			Draw diagrams to show the nature of the images formed by a converging lens when the object is at different distances from the lens, and the images formed by a diverging lens.		

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3.3.6g	The magnification produced by a lens may be calculated using the equation Magnification = $\frac{\text{image height}}{\text{object height}}$	Use the focal length equation. Use the magnification equation. Use the power of a lens equation. Be able to apply the equation Magnification = $\frac{\text{image height}}{\text{object height}}$ to work out the magnification of some objects.		Calculate the magnification of a lens using the magnification equation. Activity: Draw ray diagrams to show image formation by converging and diverging lenses. Use the diagrams to work out magnification. Using some simple examples apply the equation Magnification = $\frac{\text{image height}}{\text{object height}}$		
3.3.6h	The structure of the eye.		2	Using a model of the eye, eg biological model in sections, describe the function of parts of the eye: retina, lens, cornea, pupil/iris, ciliary muscle and suspensory ligaments. 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.	Biological model eye.	Know the function of the parts of the eye.

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3.3.6i	The near point and the far point of the human eye. The range of vision.			<p>Know that the near point is approximately 25cm and the far point is infinity. Understand that the distance between these two points is the range of vision.</p> <p>Activity: Test the eye sight of some students using a standard eye test.</p>		
3.3.6j	Lenses can be used to correct defects of vision.			<p>Research: What causes short sight and long sight and how they are corrected.</p> <p>Demo: Demonstration of model eye with short and long sight and the use of lenses to correct these defects.</p>	Model of eye with defects, lenses to correct.	
3.3.6k	Lasers are a concentrated source of light and can be used for cutting, cauterising and burning.	Be aware of uses of lasers such as in eye surgery.		Discuss the benefits /disadvantages of laser eye correction over wearing glasses		

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3.3.6l	Comparison between the structure of the eye and the camera.	Be aware that the film in a camera or the Charge-coupled devices (CCDs) in a digital camera is the equivalent of the retina in the eye.		Using a camera show students the similarities and differences between a camera and the eye.		Be able to give examples of similarities and differences between a camera and the eye.
3.3.4 Particle model of matter						
3.4.1 Kinetic theory						
3.4.1a	Kinetic theory can be used to explain the different states of matter.	Describe and explain the differences between the 3 states of matter.	3	<p>Draw simple diagrams to model the difference between solids, liquids and gases.</p> <p>Explain the states of matter in terms of the energy of their particles.</p> <p>If you have a kinetic model, you can use it to demonstrate the motion of particles in a liquid/gas. If you don't have a model, use a tray filled with ping-pong balls and shake it. You can vary the number of ping-pong balls to demonstrate the three states.</p>	<p>Access to computers; interactive kinetic theory modelling programme. Useful information can be found at http://www.preparatorychemistry.com/Bishop_KMT_frames.htm</p> <p>BBC Bitesize – Kinetic theory</p> <p>Cyberphysics – The Particle Theory – states of matter</p>	Be able to describe the arrangement and movement of particles in solids, liquids and gases.

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3.4.1b	<p>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.</p> <p>The relationship between energy, mass, specific heat capacity and temperature</p>	<p>Understand the meaning of specific heat capacity.</p> <p>Evaluate different materials according to their specific heat capacities.</p>		<p>Describe and explain the limitations of the particle model of matter, in particular that the particles within the substance are not solid spheres and that the forces between the particles are not represented.</p> <p>Activity: Individual/class demonstration of interactive kinetic theory modelling computer programme.</p> <p>Plan a practical to investigate the rate of heating of various metals using a joulemeter to determine the energy input. If no joulemeter is available, use an ammeter, I, a voltmeter, V, and heat the material for a fixed amount of time, t. Calculate the energy transferred, E, using:</p> $E = I \times t \times V$ <p>Determine the specific heat capacity of water by experiment. Conclude that the specific heat</p>	<p>Specific heat capacity apparatus, eg immersion heater, voltmeter, ammeter, stopwatch, metal blocks, top pan balance, thermometer.</p> <p>BBC Bitesize – Changing state</p> <p>BBC Bitesize – Heating ice to observe changes in state</p>	<p>Know the units of each of the quantities in the specific heat capacity equation; know how to convert grams to kilograms and joules to kilojoules.</p> <p>Understand</p>

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3.4.1c	<p>change is $E=mc\Delta\theta$</p> <p>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.</p> <p>The relationship between energy,</p>	Understand the meaning of specific latent heat of vaporisation.		<p>capacity of a substance is the amount of energy required to raise the temperature of one kilogram of the substance by one degree Celsius.</p> <p>Evaluate different materials according to their specific heat capacities, eg hot water, which has a very high specific heat capacity, oil-filled radiators and electric storage heaters containing concrete.</p> <p>Define specific latent heat.</p> <p>Draw heating and cooling graphs for a substance including a change of state.</p> <p>Interpret a heating or cooling graph to explain what is happening at each stage of the graph.</p>		that while a substance is changing state there is no change in temperature.

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3.4.1d	<p>mass and specific latent heat of vaporisation is</p> $E = m \times L_v$ <p>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.</p> <p>The relationship between energy, mass and specific latent heat of fusion is</p> $E = m \times L_f$	<p>Understand the meaning of specific latent heat of fusion.</p> <p>If a change of state happens:</p> <p>The energy needed for a substance to change state is called latent heat. When a change of state occurs, the energy supplied changes the energy stored (internal energy), but not the temperature.</p> <p>The specific latent heat of a substance is the amount of energy required to change the state of one kilogram of the substance with no change in temperature:</p> <p><i>energy for a change of state = mass x specific latent heat</i></p> $[E = m L]$		<p>Explain why a block of ice at 0°C that is being heated does not increase in temperature initially.</p> <p>Calculate the energy for a change of state, mass or specific latent heat of a substance given the other values.</p> <p>Students will be expected to convert to SI units and use standard form where required.</p> <p>Evaluate the use of different coolants used in fridges in terms of the specific latent heat of the coolant and the boiling point of the coolant.</p> <p>Research the use of coolants in fridges.</p> <p>Define specific latent heat of fusion and vaporisation.</p> <p>Explain why the specific latent heat of vaporisation is greater than the</p>	<p>Specific latent heat apparatus, eg immersion heater, voltmeter, ammeter, hot water, ice, stopwatch, top pan balance</p> <p>Plan and carry out an investigation to find the specific latent heat of fusion of water.</p> <p>Investigate the heating curve for water by heating some ice in a beaker until the water evaporates. Use temperature sensors/data loggers to record the temperature at fixed intervals, eg 30 seconds. A graph can be plotted of temperature against time.</p> <p>Instead of the above carry out the Institute of Physics</p>	

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3.4.1e	The melting point of a solid and the boiling point of a liquid are affected by impurities.	energy, E , in joules, J mass, m , in kilograms, kg specific latent heat, L , in joules per kilogram, J/kg Specific latent heat of fusion – change of state from solid to liquid. Specific latent heat of vaporisation – change of state from liquid to vapour.		specific latent heat of fusion for a given material in terms of the increase in separation of the particles. Why is more energy required to vaporise 1 kg of water than to melt 1 kg of ice?	investigation from Episode 608-2: The specific latent heat of fusion of ice	
3.4.1f	Required practical: Carry out the investigation about the cooling curve of stearic acid.					
3.4.2 Energy transfer and particle motion						
3.4.2a	Energy may be transferred by conduction and convection.	Explain in terms of particles arrangement and movement why things are conductors or insulators. Be able to explain the role of	4	Demo: Demonstrations of conduction, eg heating a metal bar with tacks stuck on with wax; rods of different materials held in a flame etc; heating rods on heat sensitive paper.	Conduction demonstrations kits. Containers of hot water wrapped in different materials.	Know that air is an excellent insulator and examples of insulation

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		<p>free electrons in conduction through a metal.</p> <p>Explain simple applications of convection.</p>		<p>Explain in terms of how the arrangement and movement of particles determine whether a material is a conductor or an insulator.</p> <p>Explain the role of free electrons in conduction of metals.</p> <p>Demo: Demonstrations of convection, eg paper coil held above heat source, tracing convection currents in water etc. Use of jumbo black bag lifted by convection to sky.</p>	<p>Convection demonstration kits.</p> <p>Product of Hawkin's Bazaar, Science museum shop.</p>	<p>materials using trapped air.</p>
3.4.2b	Energy may be transferred by evaporation and condensation.	Explain evaporation and the cooling effect this causes using the kinetic theory.		Activity: Individual use/class demonstration of interactive kinetic theory modelling computer programme to explain evaporation and condensation.	A video clip on heat transfer can be found on the BBC website at http://www.bbc.co.uk/learningzone/clips/frying-an-egg-with-a-paper-pan/8762.html	Be able to explain why evaporation causes the surroundings to cool.
3.4.2c	The rate at which an object transfers energy by heating depends on a number of factors.	<p>Know that the rate at which an object transfers energy by heating depends on:</p> <ul style="list-style-type: none"> • surface area and volume • the material from which 		<p>Discuss: Summary of the factors affecting the rate at which an object transfers energy by heating.</p> <p>Activity: In small groups, students</p>	Access to computers, interactive kinetic theory modelling programme.	Be able to apply knowledge of the factors that affect the

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3.4.2d	The bigger the temperature difference between an object and its surroundings, the faster the rate at which energy is transferred by heating.	<p>the object is made</p> <ul style="list-style-type: none"> the nature of the surface with which the object is in contact the temperature difference between the object and its surroundings. <p>Be able to explain the design of devices in terms of energy transfer, eg cooling fins.</p>		prepare a presentation on a topic to present to the class, eg animal adaptations in terms of energy transfer, how each of the factors affects the rate at which an object transfers energy by heating and an application of this etc.		rate of energy transfer to different practical situations.
3.4.2e	Most substances expand when heated.	Explain in terms of particles what happens what materials expand.		Demo: Demonstration of expanding on heating, eg ball and hoop, bi-metallic strip.	Ball and hoop, bi-metallic strip, Bunsen burner.	

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		Understand that the expansion of substances on heating may be a hazard or useful.		Homework: Research examples where the expansion of substances on heating is a hazard eg, roofs and bridges and where it is useful eg, the bi-metallic strip.		
3.3.5 Electricity and magnetism						
3.5.1 Electrical circuits						
3.5.1a 3.5.1b	Electrical charges can move easily through some substances, for example metals. There may be an imbalance of charge in an object or area; this is known as static electricity. The charge has no conducting route to travel along. If such a route is provided, the result is a discharge.		2	State the name of the particle that usually carries the electrical charge round a circuit. Define potential difference. Ask questions such as: <ul style="list-style-type: none"> • What is an electric current? • Which particle moves in an electric current? What makes the particle move? Demonstrate models of electricity and discuss what each part of the model represents and what makes the particles move. Examples could include the rope model, sweets model, water flow model, etc.		

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3.5.1c	<p>Electric current is the rate of flow of electric charge. Charge flow, current, and time are linked by the equation</p> $I = \frac{Q}{t}$	<p>Recall that a flow of electrical charge constitutes a current.</p> <p>Use the equation relating current, charge and time.</p>		<p>Define an electric current.</p> <p>Describe and explain why an electric current will flow in a circuit.</p> <p>Describe different models of electricity including:</p> <ul style="list-style-type: none"> • marbles moving down a ramp with masses placed on the ramp to represent atoms • rope models of electricity with knots or marks on the rope to represent electrons • pupils modelling the electrons taking energy (sweets) from the battery (teacher) to a component (cup held by a pupil). <p>Evaluate the benefits and drawbacks of each model.</p> <p>Calculate the charge flow, current or time when given the other two values. State the units used for each quantity.</p> <p>Carry out calculations using the equation</p> $I = \frac{Q}{t}$	<p>Video clips or computer simulations of current as a flow of charge can be found at http://phet.colorado.edu/en/simulation/circuit-construction-kit-dc</p> <p>Model the flow of an electric current using various models and also video clips available on YouTube, eg Modelling electric current</p> <p>Nuffield Foundation Models of electric circuits</p> <p>Pass My Exams – Electric Current</p> <p>Cyberphysics – Electric Current</p>	

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3.5.1d	The voltage of a source is the energy supplied by a source in driving charges round a complete circuit and is measured in volts.	Draw and interpret circuit diagrams.	2	Activity: Translating real circuits into circuit diagrams. Teacher 'dictates' circuits which students draw.	Equipment for setting up simple circuits, eg battery packs, small value resistors, ammeters, low voltage light bulbs, variable resistors etc. Small white boards for showing circuits.	Be able to recognise and draw the electrical circuit symbols.
3.5.1e	Potential difference across a component measures the energy transfer by charges and is measured in volts.	Use the equation relating potential difference, energy transferred and charge.		Activity: Set up simple circuits and using an ammeter to measure current and a voltmeter to measure p.d. Explain what Potential difference is and the voltage of a source. Carry out calculations that link potential difference, energy transferred and charge.		
3.5.1f	The relationship between potential difference, energy transferred and charge is $V = \frac{E}{Q}$					
3.5.1g	Circuit diagrams use standard symbols.	Know the standard circuit symbols as shown in the specification.		Learn circuit symbols.		

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3.5.1h	<p>Components resist the flow of charge through them. The greater the resistance the smaller the current for a given potential difference across the component.</p> $V = I \times R$	<p>Use the equation relating current, potential difference and resistance.</p> <p>Understand that the greater the resistance the smaller the current for a given potential difference across a component.</p>	3	<p>Using a rheostat investigate the relationship between current, potential difference and resistance.</p> <p>How can the resistance of a component be calculated using the current and potential difference?</p> <p>Why does increasing the voltage in a circuit also increase the current flowing through it?</p> <p>What is meant by resistance?</p> <p>Carry out calculations using the equation $V = I \times R$</p>	<p>There are a huge number of downloadable experiments from the Practical Physics website, which can be found at http://www.nuffieldfoundation.org/practical-physics/water-circuit-modelling-current-and-potential-difference</p> <p>Electric circuits apparatus, eg battery packs, low value resistors, ammeters, voltmeters, filament light bulbs, diodes, LEDs etc.</p>	<p>Know the shapes of the current – potential difference graphs for different components and be able to explain them.</p>
3.5.1i	<p>The current through a resistor (at a constant temperature) is directly proportional to the potential difference across the resistor.</p>	<p>Know and explain the features of current-potential difference graphs for a resistor, a filament bulb and a diode.</p>		<p>Find the resistance of some electrical components using current and potential difference readings.</p> <p>Draw graphs of experimental results to illustrate the proportionality of the relationship.</p>		

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3.5.1j	The resistance of components such as lamps, diodes, thermistors and LDRs is not constant; it changes with the current through the component			Investigate the resistance of component, eg lamps, diodes, thermistors and LDRs. Activity: bserve the effect of light intensity on the resistance of a LDR.		
3.5.1k	The resistance of a thermistor decreases as the temperature increases.			Activity: Observe the effect of how a thermistor decreases as the temperature increases.		
3.5.1l	The resistance of an LDR decreases as light intensity increases.			Activity: Draw and explain the graphs of current-potential difference graphs for a resistor, a filament bulb and a diode.		
3.5.1m	The resistance of a filament bulb increases as the temperature of the filament increases.			Activity: Class investigation measuring current through and potential difference across, a filament light bulb, as the current is varied.		

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3.5.1n	The 'forward' resistance is low in a diode and the 'reverse' resistance is very high. The current through a diode flows in one direction only.			Activity: Class investigation measuring current through and potential difference across a diode, as the current is varied. Above practical's		
3.5.1o	Required Practical: Investigate the V-I characteristics of a filament bulb, a diode and a resistor at constant temperature.					
3.5.1p	An LED emits light when a current flows through it in the forward direction.			Activity: Class investigation observing the effect of current direction on the output of an LED.		
3.5.1q	The combined voltage of several sources in series is their sum.	Know how to work out total potential difference in a circuit.	3	Recap combined voltage of several sources in series is their sum. Work out the potential difference provided by a number of cells in series, taking in to account the direction in which they are connected.	Electric circuits apparatus, eg battery packs, low value resistors, ammeters, voltmeters, filament bulbs.	

Spec Reference	Summary of the Specification Content	Learning Outcomes <i>What most students should be able to do</i>	Suggested timing (lessons)	Possible Teaching and Learning Activities <i>Homework</i>	Resource	Examination 'hints and tips' <i>Students should:</i>
3.5.1r	There are two ways of joining electrical components: in series and in parallel. Some circuits include both series and parallel parts.			<p>Investigate series and parallel circuits:</p> <ol style="list-style-type: none"> 1. make a simple circuit containing a switch, power supply and a bulb 2. add more bulbs – both in series and then in parallel 3. note the effect on the brightness of the bulbs. <p>Current and potential difference across each bulb can also be measured to get numerical values and see the effect of adding more bulbs.</p> <p>Describe the differences between series and parallel circuits.</p> <p>Draw circuit diagrams for components connected in series and in parallel.</p> <p>Describe how ammeters and voltmeters are connected into a circuit.</p> <p>Why does adding light bulbs in series make them all dimmer?</p>	Useful information and activities can be found at www.hyperstaffs.info/work/physics/child/main.html And www.what2learn.com	Know the properties of the current and potential difference in series and parallel circuits.

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3.5.1s	For components connected in series how the resistance, current and potential difference are affected.	Be able to recall that for components connected in series how the resistance, current and potential difference are affected.		Activity: Measuring current at different places in a series circuit. Summaries that <ul style="list-style-type: none"> 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. 		
3.5.1t	For components connected in parallel how the current and potential difference are affected.	Be able to recall that for components connected in parallel how the current and potential difference are affected.		Activity: Measuring potential difference across each resistor and the battery in a parallel circuit. Summaries that for components in parallel <ul style="list-style-type: none"> 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. 		
3.5.1u	When an electrical charge flows through a resistor, the resistor gets hot.	Understand that a lot of energy is wasted in filament bulbs by heating. Less energy is wasted in power saving lamps such as				

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		Compact Fluorescent Lamps (CFLs).				
3.5.2 Magnetism and electromagnetism						
3.5.2a	Magnetic forces are strongest at the poles of a magnet. When two magnets are brought close together they exert a force on each other. Two like poles repel each other and two unlike poles attract. Attraction and repulsion between two magnetic poles are examples of non-contact forces.	Recall the features of a magnet.	3	Using different magnets recap the basic information about magnets.	Bar magnets and iron filings in sealed bag or magna probe.	
3.5.2b	The space around a magnet where a force acts on another magnet or on a magnetic material (iron, steel cobalt, nickel) is called a magnetic	Recognise magnetic field patterns using one or two bar magnets. Know how to produce a uniform magnetic field using two bar magnets.		Activity: Investigate and draw the magnetic field patterns produced by one and two permanent bar magnets using plotting compasses or iron filings if this wasn't done in the earlier section.		

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3.5.2c	<p>field. The strength and direction of a magnetic field change from one point to another.</p> <p>An induced magnet is a material that becomes a magnet when it is placed in a magnetic field. Induced magnetism always causes a force of attraction.</p> <p>When removed from the magnetic field an induced magnet loses most/all of its magnetism quickly.</p>	Know how to make a magnet		<p>Make an iron nail into a magnet to illustrate an induced magnet.</p> <p>Describe how an induced magnet is produced.</p> <p>Explain what is meant by a permanent magnet and give examples of materials that can become magnetised.</p>		
3.5.2d	The earth has a magnetic field that is most concentrated at the magnetic north and south poles.	To know that earth has a magnetic field that is most concentrated at the magnetic north and south poles.		<p>Draw the magnetic field pattern of a bar magnet and describe how to plot the magnetic field pattern using a compass.</p> <p>Describe how a compass can be made using a needle floating on a</p>		

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3.5.2e	<p>A magnetic field is produced when an electric current flows through a wire. The magnetic field lines are concentric circles in a plane, perpendicular to the wire.</p> <ul style="list-style-type: none"> the field is stronger closer to the wire increasing the current makes the magnetic field stronger reversing the current reverses the direction of the magnetic field 	<p>Describe how the magnetic effect of a current can be demonstrated.</p> <p>Use the 'right hand thumb rule' to draw the magnetic field pattern of a wire carrying an electric current.</p> <p>Describe the effect on the magnetic field of changing the direction of the electric current.</p>	2	<p>leaf once it has been magnetised by a permanent magnet.</p> <p>Explain how the behaviour of a magnetic compass is related to evidence that the core of the Earth must be magnetic.</p> <p>Demonstrate what happens when a foil strip with a current flowing through it is placed in a strong magnetic field. What happens if the direction of the current is reversed?</p> <p>Use the 'right hand thumb rule' to draw the magnetic field pattern of a wire carrying an electric current.</p> <p>Try to demonstrate the shape by placing a wire through a piece of card with iron filings sprinkled near it. Apply a current through the wire.</p> <p>Explain when a current flows through a conducting 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</p>		

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3.5.2f	<p>lines.</p> <p>Shaping a wire to form a solenoid increases the strength of the magnetic field created by a current through the wire. The magnetic field inside a solenoid is strong and uniform.</p>	<p>Does shaping the wire improve the strength of the magnetic field?</p>		<p>depends on the direction of the current. The strength of the magnetic field depends on the current through the wire and the distance from the wire.</p> <p>Plan an experiment to see if a coil of wire has a stronger magnetic field than a straight wire when both carry the same electric current. What are the control variables in this experiment?</p> <p>Find the magnetic field pattern of a solenoid using iron filings or a plotting compass. How can the shape of the magnetic field inside the solenoid be determined?</p>	<p>Demonstration equipment for magnetic field around a wire and solenoid.</p>	
3.5.2g	<p>The magnetic field around a solenoid has a similar shape to that of a bar magnet. Adding an iron core increases the magnetic field strength. An electromagnet consists of a</p>	<p>Describe ways of increasing the magnetic field strength of a solenoid.</p> <p>Explain how an electromagnet can be made from a solenoid.</p>				

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	solenoid with an iron core.					
3.5.2h	Required practical: Investigate the factors that determine the strength of an electromagnet. Construct a hypothesis to test which identifies the factors that determine the strength of an electromagnet, plan and carry out an investigation to collect reliable data to test your hypothesis.					
3.3.6 Generating and distributing electricity and household use						
3.6.1	Generating electricity					
3.6.1a	<p>A potential difference is induced across the ends of a conductor when:</p> <ul style="list-style-type: none"> the conductor moves relative to a magnetic field the conductor is in a changing magnetic field. <p>This is called the generator effect.</p>	Understand the principle of electromagnetic induction.	2	<p>Demo: Demonstration of electromagnetic induction.</p> <p>Discuss: Discussion of the differences between the motor effect and electromagnetic induction.</p> <p>Describe what a generator does. Describe and explain:</p> <ul style="list-style-type: none"> how a generator induces a potential difference across the ends of a conductor if the conductor is part of a complete circuit a current will also be induced. <p>Apply the principles of the generator effect in a given context.</p>	<p>Magnets, sensitive voltmeters, insulated wire.</p> <p>YouTube: GCSE Physics P3 Revision: Motor and generator effect</p> <p>Cyberphysics – Electromagnetic Induction</p> <p>BBC Bitesize – Electromagnets and motors</p>	Know how an electric current can be generated in a wire.
3.6.1b	A potential difference is induced across the ends of a coil of					

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3.6.1c	<p>wire when:</p> <ul style="list-style-type: none"> • a permanent magnet is moved into or out of the coil • the coil is moved relative to the magnet. <p>If the conductor is part of a complete circuit, a current flows in the wire. The magnetic field produced by the induced current opposes the field of the permanent magnet.</p>	Describe how inducing a current in a conductor generates a magnetic field that opposes the original change (motion or magnetic field).		<p>Research to find how the generator in a power station differs from a simple generator (coil of wire spinning between two magnets).</p> <p>Research to find out why radial magnets are used in Generator Homework: Poster describing electromagnetic induction.</p> <p>Investigate the opposing forces in a generator by spinning the coil of wire without the magnets present and then with the magnets present. It is harder to turn due to the opposing forces.</p> <p>Explain that an induced current generates a magnetic field that opposes the original change, either the movement of the conductor or the change in magnetic field.</p>		Be able to sketch graphs of potential difference against time for an a.c. generator and a d.c. generator.
3.6.1d	If the direction of motion, or the polarity of the magnet, is reversed, the polarity of the induced potential difference and direction of flow of any induced current	<p>Describe the effect on the induced potential difference, and induced current, of reversing the direction of motion of the conductor in a magnetic field.</p> <p>Describe the effect on the induced potential difference, and induced current, of reversing the polarity of the</p>		<p>Investigate the effect on the induced potential difference, and induced current, of reversing the magnetic poles of a generator.</p> <p>Investigate the effect on the induced potential difference, and induced current, of reversing the direction that the coil of wire spins</p>		

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3.6.1e	<p>are reversed.</p> <p>The size of the induced potential difference increases when:</p> <ul style="list-style-type: none"> • 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. 	<p>magnets in a generator.</p> <p>Describe ways of increasing the size of the induced potential difference of a generator.</p> <p>Explain how these methods of increasing the induced potential difference work.</p>	2	<p>in a simple generator. Explain that if the direction of motion of the conductor or the polarity of the magnetic field is reversed, the direction of the induced potential difference and any induced current is reversed.</p> <p>Investigate the factors that affect the size of the induced current in a generator by using stronger magnets eg neodymium and ordinary magnets or by using a solenoid with more/less turns on.</p>	<p>Generator kits.</p> <p>BBC Bitesize – Generators</p> <p>Cyberphysics – Electromagnetic Induction</p>	
3.6.1f	<p>Power stations use turbines to turn wire coils between magnets to generate electricity.</p>	<p>Recall the names and function of the different parts of a power station.</p>		<p>Research how electricity is generated in a power station.</p> <p>Explain the stages involved in generating electricity in the power station.</p>		

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3.6.2 Electrical transmission and distribution						
3.6.2a	Electricity is distributed from power stations to consumers along transmission cables with transformers at both ends.	Explain how electricity is transmitted safely and efficiently using transformers.	4	<p>Discuss how electricity is transmitted over long distances.</p> <p>Model an electricity grid showing the step-up transformer at the power station, the power cables and the step-down transformer before it reaches the consumer.</p>	<p>Cyberphysics – The Transformer</p> <p>Antonine Education – Magnetic Fields Tutorial 7 – Transformers</p> <p>BBC Bitesize – Dynamos and transformers</p>	
3.6.2b	For a given power rating, a high distribution voltage reduces the current flowing, therefore reducing energy losses due to heating and making the system more efficient.	Understand why transformers are needed.		Discuss why electricity needs to be transmitted at high voltages.		
3.6.2c	A basic transformer consists of a primary coil and a secondary coil wound on a soft iron core. An alternating current in the primary coil of a transformer	<p>Understand the basic structure of the transformer.</p> <p>Explain how a transformer works.</p>		<p>Demonstrate a transformer and show the effect of changing the number of turns of wire on both the primary and secondary coils. If you have the equipment you can use the instructions from Institute of Physics: Episode 416 – Generators and transformers</p> <p>A basic transformer consists of a</p>	<p>Iron C-cores, insulated wire, demonstration transformer.</p> <p>An experiment that shows the basic principle of any transformer can be found at http://www.nuffieldfoundation.org/practical-physics/model-transformer</p>	Know the components of a transformer and be able to describe how it works.

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3.6.2d	<p>produces a changing magnetic field in the iron core and hence in the secondary coil. This induces a changing potential difference across the ends of the secondary coil and an alternating current flows.</p> <p>Step-up and step-down transformers are used to increase the voltage before the distribution lines and reduce it at the end to produce a safer voltage for local consumers.</p>	<p>Understand the difference between a step-up transformer and a step-down transformer.</p> <p>Use the transformer equations.</p>		<p>primary coil and a secondary coil wound on an iron core.</p> <p>Activity: Class experiments making a simple transformer using C-cores and insulated wire – observing the effect of d.c. and a.c. inputs, observing the effect of different coil ratios.</p> <p>Demo: Demonstration transformer – measuring voltages.</p> <p>Investigate the effect of changing the number of turns of wire on the primary and secondary coils and measure the input and output potential difference. Do the values measured agree with the transformer equation? How can you account for any discrepancies in the results?</p>	<p>BBC Bitesize – Transformers – Higher tier</p> <p>Cyberphysics – The Transformer</p> <p>BBC Bitesize – Transformers – Higher Tier</p>	
3.6.2e	<p>The potential differences across the primary and secondary coils of a transformer, V_p and V_s, are related to</p>			<p>Perform calculations to determine the potential difference on the primary or secondary coil or the number of turns on the primary or secondary coil when given the other value. Students should be able to</p>		

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3.6.2f	<p>the number of turns on the coils, n_p and n_s, by:</p> $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ <p>For a 100% efficient transformer, the electrical power output would equal the electrical power input.</p>	<p>If transformers were 100% efficient, the electrical power output would equal the electrical power input: $V_s \times I_s = V_p \times I_p$ Where $V_s \times I_s$ is the power</p>		<p>use simple ratios or the equation: $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ to calculate any unknown value.</p> <p>Describe how a step-up transformer and a step-down transformer affect the potential difference on the secondary coil compared to the primary coil.</p> <p>The ratio of the potential differences across the primary and secondary coils of a transformer V_p and V_s depends on the ratio of the number of turns on each coil n_p and n_s:</p> $\frac{V_p}{V_s} = \frac{n_p}{n_s}$ <p>potential difference, V_p and V_s in volts, V</p> <p>In a step-up transformer $V_s > V_p$ In a step-down transformer $V_s < V_p$</p> <p>Explain how a step-up transformer will increase the potential difference in the secondary coil compared to the primary coil but it will also decrease the current. This happens as the electrical power on both</p>		

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3.6.2g	Switch mode transformers.	<p>output (secondary coil) and $V_p \times I_p$ is the power input (primary coil).</p> <p>Power input and output, in watts, W.</p> <p>Power is transmitted at high voltages along the National Grid.</p> <p>Understand the difference between a switch mode transformer and a conventional transformer. Know the advantages and uses of switch mode transformers.</p>		<p>primary and secondary coils remains the same so:</p> $V_s \times I_s = V_p \times I_p$ <p>However, this only works if the transformer is 100% efficient so it is classed as an ideal case.</p> <p>What are the drawbacks of using transformers?</p> <p>Calculate the current drawn from the input supply to provide a particular power output.</p> <p>Explain the reason why the p.d. across the power cables is increased only to decrease at the other side of the cables.</p>		

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3.6.3	Using electricity in the home					
3.6.3a	Cells and batteries supply current that always passes in the same direction. This is called direct current (d.c.).	Understand the difference between direct current and alternating current. Describe the flow of electrons in a d.c. circuit as being in one direction only. State some common sources of a direct current including cells, batteries and solar cells.	3	Demo: Demonstration of cathode ray oscilloscope (CRO) traces of d.c. and a.c. and effect of increasing the p.d. and the frequency on the shape of the trace; measurement of p.d. and frequency from the trace. Cells and batteries supply current that always passes in the same direction. This is called direct current (d.c.).	CRO, variable voltage d.c. supplies and variable frequency a.c. supply, eg, signal generator, diodes, three-pin plugs, cable, wire cutters, screwdrivers, fuse wire, ammeter, RCCB.	Know how to calculate the potential differences of d.c. supplies and peak potential differences of a.c. supplies from oscilloscope traces. Know how to calculate the period and frequency of a supply from oscilloscope traces.
3.6.3b	An alternating current (a.c.) is one that is constantly changing direction.			An alternating current (a.c.) is one that changes direction. Mains electricity is an a.c. supply. In the UK it has a frequency of 50 Hz and is about 230 V.		
3.6.3c	Mains electricity is an a.c. supply. Which has a set frequency and voltage .	Describe the flow of electrons in an a.c. circuit as moving backwards and forwards.				
3.6.3d	There are a number of safety features that can be incorporated in electrical systems	Understand the purpose and the action of the fuse and the earth wire. Know that an RCCB		Describe and explain how a fuse prevents a current that is too large flowing.		

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3.6.3e	<p>and appliances. One of these is earthing.</p> <p>If an electrical fault causes too great a current to flow, a fuse or a circuit breaker in the live wire disconnects the circuit.</p>	<p>operates much faster than a fuse.</p> <p>Know that RCCBs operate by detecting a difference in the current between the live and neutral wires.</p>		<p>Describe situations where circuit breakers are used.</p> <p>Find out why circuit breakers are better at preventing electrocution than the fuse in a plug.</p>	<p>Cyberphysics – Earthing</p> <p>Pass My Exam – Mains Electricity</p>	
3.6.3f	<p>Appliances with metal cases are usually earthed. If a fault develops a large current flows from the live wire to earth.</p>	<p>Know that some appliances are double insulated, and therefore have no earth wire connection.</p>		<p>Describe what double insulated means and give examples of materials that an appliance case can be made out of to make it double insulated.</p> <p>Find out why double insulated appliances use two core electrical cables rather than three core electrical cables.</p>		

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3.6.4 The motor effect						
3.6.4a	Recall that a current carrying conductor has a magnetic field around the wire. When a current carrying conductor is placed in a magnetic field so that it cuts lines of magnetic force, the magnet and conductor exert a force on each other. This is called the motor effect. The conductor will not experience a force if it is parallel to the magnetic field.	To understand the motor effect.	3	<p>Demo: Demonstration of the motor effect.</p> <p>Explain what is meant by the motor effect. When a conductor carrying a current is placed in a magnetic field the magnet producing the field and the conductor exert a force on each other.</p> <p>Explain why a motor spins with respect to the magnetic field produced by a wire carrying an electric current and the magnetic field of the permanent magnets in the motor interacting.</p> <p>Make an electric motor (available from Winchester Kits) and investigate how the speed and direction of rotation can be changed.</p>		
3.6.4b	The size of the force can be increased by: <ul style="list-style-type: none"> • increasing the strength of the magnetic field • increasing the 	To investigate the factors that affect the size of the force on a conductor.		Investigate both the size and direction of the force on a conductor in a magnetic field. This can be done when making simple motors by wrapping more wire around, increasing the p.d. or using stronger magnets.		Be able to use Fleming's Left-hand Rule to identify the direction of the force on a

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3.6.4c	<p>size of the current</p> <ul style="list-style-type: none"> increasing the length of the conductor in the magnetic field. <p>The direction of the force is reversed if either the direction of the current or the direction of the magnetic field is reversed.</p>	<p>Explain why changing the direction of the electric current in an electric motor changes the direction of rotation.</p> <p>Explain why changing the polarity of the permanent magnets in the electric motor will change the direction of rotation.</p>		<p>Investigate the effect of changing the direction of the current or changing the direction of the magnetic field on the rotation of a motor.</p> <p>The direction of the force on the conductor is reversed if either the direction of the current or the direction of the magnetic field is reversed.</p>		current carrying conductor.
3.6.4d	<p>A coil of wire carrying a current in a magnetic field tends to rotate. This is the basis of an electric motor.</p>	<p>Understand the principle of the motor effect and know how to use Fleming's Left-hand Rule to identify the direction of the force.</p>		<p>Activity: Students make simple motors from kits.</p> <p>Research: Students research the structure and action of a motor.</p> <p>Homework: Applying Fleming's left-hand rule to different situations.</p>	<p>Demonstration equipment for the motor effect and motor kits.</p>	

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3.6.5 Transferring electrical energy						
3.6.5a	Electrical appliances are designed to transfer energy.	Give examples of electrical appliances and the energy transfers they are designed to bring about.	4	Define power. State the equation that links power, potential difference and current. Activity: Class experiment to measure the power of a low voltage light bulb and the energy transferred by measuring current, potential difference and time. Demo: Demonstration of measuring the energy transferred to a low voltage motor as it lifts a load (and compare to the gravitational potential energy gained by the load).	Electric circuits apparatus, eg battery packs, low value resistors, ammeters, voltmeters, filament light bulbs etc. Low voltage motor set up to lift a load.	
3.6.5b	The rate at which energy is transferred by an appliance is called the power. The relationship between power, energy transferred and time is $P = \frac{E}{t}$	Use the equation connecting power with energy transferred and time.				
3.6.5c	The power transfer, P , in any device is related to the current, I , flowing through it and potential difference, V , across it: $P = I \times V$	Use the equation connecting power with current and potential difference. Calculate the current through an appliance from its power and the p.d. of the supply and from this determine the size of fuse needed.		Calculate the power of an electrical appliance given the potential difference and the current. Why is a 7 W energy efficient light bulb cheaper to run than a 100 W incandescent light bulb? Activity: Calculate the current through an appliance from its power and the p.d. of the supply and from		

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3.6.5d	<p>The relationship between energy transferred, potential difference and charge is</p> $E = V \times Q$	<p>Describe the energy changes that are taking place in a given electrical appliance.</p> <p>Use the equation connecting energy with potential difference and charge.</p>		<p>this determine the size of fuse needed.</p> <p>What energy changes take place in electrical appliances?</p> <p>Describe the energy changes that are taking place in a given electrical appliance – stating which energy transfers are useful and which are wasted. Electrical appliances may be either battery or mains operated and may involve motors or heating elements.</p>		
3.6.5e	<p>The amount of energy an appliance transfers depends on how long the appliance is switched on for and its power rating.</p>	<p>Describe how the amount of electrical energy transferred depends on the time the appliance is on for and the power of the appliance.</p>		<p>Investigate a number of electrical appliances, either around the lab or well-known devices, eg a TV, to look at the energy transfers that occur within them.</p> <p>Investigate how the amount of energy transferred to an electrical appliance depends on the amount of time that it is on for by connecting the appliance up to a joulemeter.</p> <p>Activity: Carry out calculations using the equations</p> $P = \frac{E}{t}$ <p>And</p>		

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3.6.5f	<p>The relationship between energy transferred from the mains and time is: $E(kWh) = P(kW) \times t(h)$</p>	<p>Describe how work is done when a charge flows in a circuit.</p> <p>Describe, with examples, the relationship between the power ratings for domestic electrical appliances and the changes in stored energy when they are in use.</p> <p>Calculate the energy transferred by an electrical appliance and rearrange the equation $E = P t$ to find the other two values.</p> <p>Use the equation $E = Q V$ including rearranging the equation to find any quantity given the other two.</p>		<p>$E = V \times Q$</p> <p>Work is done when charge flows in a circuit.</p> <p>The amount of energy transferred by electrical work can be calculated using the equation:</p> <p><i>energy transferred = power x time</i> $[E = P t]$</p> <p><i>energy transferred = charge flow x potential difference</i> $[E = Q V]$</p> <p>energy transferred, E, in joules, J power, P, in watts, W time, t, in seconds, s charge flow, Q, in coulombs, C potential difference, V, in volts, V.</p> <p>Carry out examples to calculate energy transfer.</p>		<p>Know the terms in the equation and their units; be able to convert from hours and minutes into seconds.</p>

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3.3.7 Nuclear physics						
3.7.1 atomic structure						
3.7.1a	Atoms are very small, having a radius of about 10^{-10} metres. The simple model of an atom is a small central positively charged nucleus composed of protons and neutrons, surrounded by electrons. The radius of the nucleus is much smaller than that of the atom with almost all of the mass in the nucleus.	Describe the structure of an atom. Describe the relative sizes and charges of the parts of an atom.	3	How big is an atom? What particles are in an atom? Where is each particle found within the atom? State the size of the atom in standard form. Describe the composition of an atom and draw a fully labelled diagram of an atom showing protons and neutrons in the nucleus with electrons outside the nucleus. Give the charges of all particles within the atom. Calculate the size of an atom given the size of the nucleus and the scale of the nucleus compared to the atom. Describe how the concentration of mass of an atom is not uniform but concentrated on the nucleus of the atom. Describe how electrons are arranged within an atom.	Coloured plasticine. Video clips of atomic structure can be found on www.youtube.com by searching for 'Nuclear Energy Part 1'. Information on Atoms and Isotopes can be found on BBC GCSE Bitesize at http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/atoms_radiation/ Video clip YouTube: Powers of Ten™ (1977) Cyberphysics – The Atom Pass My Exams – Radioactivity, Atomic Structure, Atomic Number and Atomic Mass BBC Bitesize – Atomic structure and isotopes	

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3.7.1b	The scattering of alpha particles by thin metal foil provides evidence of the distribution of mass in the atom.	<p>Explain how results from the Rutherford and Marsden scattering experiments led to the 'plum pudding' model being replaced by the nuclear model.</p> <p>Understand that new evidence can cause a theory to be re-evaluated.</p>		<p>Describe and explain how electrons can be moved further away from the nucleus of the atom and how they lose energy to move closer to the nucleus.</p> <p>Discuss: Discussion of how results from the Rutherford and Marsden scattering experiments led to the 'plum pudding' model being replaced by the nuclear model.</p>		Learn the relative masses and charges of the particles.
3.7.1c	The relative masses and electric charges of protons, neutrons and electrons.	Understand the terms atomic number and mass number.		Recap the relative masses and electric charges of protons, neutrons and electrons.		
3.7.1d	In an atom the number of electrons is equal to the number of protons in the nucleus. The atom has no overall electrical charge.	Explain why an atom has no overall charge.		<p>Recap why an atom has no overall charge</p> <p>Calculate the number of neutrons for a stated element given the number of protons and the mass number.</p>		

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3.7.1e	In each atom its electrons are arranged at various distances from the nucleus. Atoms may lose or gain outer electrons to form charged particles called ions.	Describe how an ion is formed.		Calculate the mass number for a particular element given the number of protons and neutrons in the atom. Rearrange the equation to find number of protons or number of neutrons and the mass number.		Know the definition of 'isotopes'.
3.7.1f	The atoms of a particular 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	Understand how atoms are represented in terms of their mass number and atomic number, eg (Mass number) 23 Na (Atomic number) 11		Describe an atom in terms of number of protons, neutrons and electrons when given the following representation ${}_{11}^{23}\text{Na}$. What is ionisation? Define isotope. How can an atom be ionised? Why do some elements have isotopes?		

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	protons and neutrons in an atom is called its mass number.			<p>Explain how isotopes of elements, eg hydrogen and uranium, all have the same number of protons but have a different number of neutrons.</p> <p>'Fill in the gaps' exercise relating to the number of protons, neutrons and electrons, atomic number and mass number of atoms of different isotopes.</p>		
3.7.2 Ionizing radiation from the nucleus						
3.7.2a	Some atomic nuclei are unstable. The nucleus emits particles or radiation and the nucleus changes to that of a different element and becomes more stable. This is a random process called radioactive decay.	<p>Describe radioactive decay as a process by which an unstable atom releases radiation.</p> <p>State that the part of the atom, which releases the radiation is the nucleus.</p> <p>Describe how the emission of radiation from a radioactive atom is a random process, but over time the amount of decay can be predicted.</p>	3	<p>Explain that some atomic nuclei are unstable. The nucleus gives out ionising radiation as it changes to become more stable. This is a random process called radioactive decay.</p> <p>Demo: Demonstration of radiation emitted from various sources, eg radioactive rocks, sealed sources, and luminous watch. This is background radiation.</p> <p>Research how nuclear radiation was discovered and who discovered it.</p>	<p>Geiger-Müller (GM) tube and counter or other radioactivity meter, radioactive sources.</p> <p>BBC Bitesize – Radioactive decay</p> <p>Pass My Exams – Stable and Unstable Nuclei</p>	

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3.7.2b	Energy is emitted by changes in the nucleus.			Video: Watch video clips of the discovery of radioactivity.		
3.7.2c	Unstable nuclei emit alpha particles, beta particles, or neutrons, and electromagnetic radiation as gamma waves. Neither chemical nor physical processes affect this behaviour. These substances are said to be radioactive and although the general process follows a pattern this radioactive decay is a random process. It is impossible to predict when a	Describe the composition of each type of radiation and where relevant, give the particle that the type of radiation is identical to, eg an alpha particle is a helium nucleus.		<p>Explain that the nuclear radiation emitted may be:</p> <ul style="list-style-type: none"> • an alpha particle (α) – this consists of two neutrons and two protons, it is identical to a helium nucleus • a beta particle (β) – a high speed electron ejected from the nucleus as a neutron turns into a proton • a gamma ray (γ) – electromagnetic radiation from the nucleus. 	<p>Model alpha, beta, gamma and neutron decay using plasticine and/or stop frame animation. Models should show the atom before and after decay as well as the radiation emitted.</p> <p>Interactive websites showing the nature of each type of nuclear radiation can be found at http://phet.colorado.edu/en/simulation/alpha-decay</p> <p>Nuffield Foundation Nature of ionising radiations</p> <p>Cyberphysics – Radioactivity Index</p> <p>Pass My Exams – Alpha, Beta and Gamma Rays</p>	

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3.7.2d	<p>particular atom might decay.</p> <p>Background radiation is around us all of the time. It comes from a range of sources, such as radioactive substances in the environment, from space or from devices such as X-ray machines in hospitals.</p>	<p>Know what background radiation is, where it comes from.</p>		<p>Background radiation is around us all of the time. It comes from:</p> <ul style="list-style-type: none"> natural sources such as rocks and cosmic rays from space man-made sources such as the fallout from nuclear weapons testing and nuclear accidents. <p>Explain why the level of background radiation is not the same across the planet in terms of altitude, geology and location of nuclear power stations.</p>	<p>BBC Bitesize – Background radiation</p> <p>Cyberphysics –Background Radiation</p> <p>Pass My Exams – Background Radiation</p>	<p>Know the natural and man-made sources of background radiation.</p>
3.7.2e	<p>An alpha particle consists of two neutrons and two protons (i.e. a Helium nucleus). A beta particle is a high speed electron ejected from the nucleus as a neutron turns into a proton. Gamma radiation is</p>	<p>Describe an alpha particle structure.</p> <p>Describe how in beta emission a neutron decays into a proton and an electron, with the electron then being ejected from the nucleus at high speed.</p> <p>Explain gamma rays as being part of the</p>		<p>Describe the effect of nuclear weapons and their testing on the level of background radiation.</p>		

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3.7.2f	<p>electromagnetic radiation from the nucleus.</p> <p>Nuclear equations are used to represent radioactive decay.</p>	<p>electromagnetic spectrum as well as a type of nuclear radiation.</p> <p>Describe what happens to an atom when it undergoes alpha, beta and gamma emission.</p> <p>Calculate how the mass number, the proton number and the number of neutrons in an atom change when it undergoes alpha, beta and gamma emission.</p> <p>State the composition of alpha and beta particles and be able to recall how an alpha, beta, gamma particle can be represented.</p> <p>Complete nuclear decay calculations for alpha and beta decay. The calculations may be in the form of an equation or a table of results showing the same data.</p> <p>Describe in words how the nucleus of an atom changes</p>	1	<p>Nuclear equations are used to represent radioactive decay.</p> <p>In a nuclear equation an alpha particle may be represented by the symbol:</p> ${}^4_2\text{He}$ <p>and a beta particle by the symbol:</p> ${}^0_1\text{e}$ <p>The emission of the different types of ionising radiation may cause a change in the mass and/or the charge of the nucleus. For example:</p> ${}^{219}_{86}\text{radon} \longrightarrow {}^{215}_{84}\text{polonium} + {}^4_2\text{He}$ <p>Alpha decay causes both the mass and charge of the nucleus to decrease.</p> ${}^{14}_6\text{carbon} \longrightarrow {}^{14}_7\text{nitrogen} + {}^0_{-1}\text{e}$ <p>Beta decay does not cause the</p>	<p>HT only Nuclear equations to show single alpha and beta decay.</p> <p>http://phet.colorado.edu/en/simulation/beta-decay</p> <p>Information on Electrostatic model of alpha particle scattering can be found on the Practical Physics website at http://www.nuffieldfoundation.org/practical-physics/electrostatic-model-alpha-particle-scattering</p> <p>Information on radioactive substances can be found on BBC GCSE Bitesize website http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/atoms_radiation/</p>	<p>Be able to balance equations by completing atomic number and mass number.</p> <p>Know the definitions of half-life. Be able to calculate the half-life from a decay curve.</p>

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3.7.2g	Properties of the alpha, beta and gamma radiations are limited to their relative ionising power, their penetration through materials and their range in air.	<p>when it undergoes alpha and beta decay.</p> <p>Describe how the charge of a nucleus changes as it undergoes alpha and beta decay.</p> <p>Properties of alpha particles, beta particles and gamma rays limited to their penetration through materials and their range in air.</p> <p>Know that alpha particles are deflected less than beta particles and in an opposite direction.</p> <p>Explain this in terms of the relative mass and charge of each particle.</p>	2	<p>mass of the nucleus to change, but it does cause the charge of the nucleus to increase.</p> <p>Demo: Demonstrations of the properties of alpha, beta and gamma radiation. Discussion of conclusions (nature, size, speed).</p> <p>Draw a diagram to illustrate the penetration of the different types of nuclear radiation.</p> <p>Evaluate the use of different shielding materials for use when handling radioactive sources when supplied with relevant data.</p> <p>Explain why gamma sources are usually the most harmful when outside the body and alpha are the most dangerous when inside the body in terms of penetration of the radiation.</p>		
3.7.2h	Radioactive decay is random, but with a large enough	Recall the definition of half-life.		How does the activity of a radioactive substance change with time?	Large number of dice or similar.	

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	<p>number of nuclei it is possible to predict how many will decay in a certain amount of time.</p> <p>The half-life of a radioactive isotope is:</p> <ul style="list-style-type: none"> the average time it takes for the number of nuclei of the isotope in a sample to halve the time it takes for the count rate from a sample containing the isotope to fall to half its initial level. 	<p>Understand the shape of a radioactive decay graph and work out the half-life from it.</p> <p>Define the term half-life.</p> <p>Calculate the half-life of a radioactive source from a decay curve of the radioactive element.</p> <p>Calculate the mass of a radioactive substance remaining after a given time when given the half-life of the substance and the initial mass of the radioactive source.</p>		<p>Can you predict, with accuracy, which atoms in a radioactive substance will decay first?</p> <p>Describe the process of radioactive decay as being a random event analogous to flipping lots of coins – not knowing which coins will fall on heads but knowing about half of them will on any given throw.</p> <p>Demonstrate the randomness of the decay of a radioactive substance by throwing six dice and getting a prediction of the number of dice that will land on a six. Alternatively, drop 20 coins and get students to predict the number that will land on a head.</p> <p>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 average time it takes for the count rate from a sample containing the isotope to fall to half of its initial level.</p> <p>Activity: Drawing graphs to show radioactive decay and calculating the half-life from the graph.</p>	<p>S-cool, the revision website – Half life Cyberphysics – Half Life and Rate of Decay Pass My Exams – Radioactive Half Life</p> <p>BBC Bitesize – Handling radioactive materials</p>	

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3.7.2i	<p>Radioactive contamination is the unwanted presence of radioactive atoms on other materials. The hazard from contamination is due to the decay of the contaminating atoms. The type of radiation emitted affects the level of hazard.</p> <p>Irradiation is the process of exposing an object to ionizing radiation. The irradiated object does not become radioactive. Suitable precautions must be taken to protect against the hazards of the radioactive source used in irradiation.</p>	<p>Describe how radioactive contamination can occur.</p> <p>If radiation is dangerous, why is it used in schools?</p> <p>How would a person become contaminated by radiation?</p> <p>Explain how the procedure followed by people dealing with radioactive sources reduces the risk of contamination.</p> <p>If a person gets contaminated by radiation how are they decontaminated?</p>		<p>Radioactive contamination is the unwanted presence of materials containing radioactive atoms on other materials. The hazard from contamination is due to the decay of the contaminating atoms. The type of radiation emitted affects the level of hazard.</p> <p>Compare precautions taken by a teacher handling radioactive sources with those used by, say, in a nuclear power station.</p> <p>Research decontamination techniques for workers exposed to radioactive sources.</p> <p>Describe how decontamination would take place if a person's clothes or skin have been contaminated by a radioactive source.</p> <p>Explain why contamination by a highly active alpha source may be a lot more damaging than a low activity gamma source.</p> <p>Irradiation is the process of exposing an object to ionising radiation. The irradiated object does</p>	<p>YouTube: Food irradiation: Is it safe? Cyberphysics – Radioactivity and Food Pass My Exams – Uses of Radioactivity, Gamma Rays in Sterilisation</p> <p>BBC Bitesize – Hazards from radioactive materials Cyberphysics – Radioactivity – safety</p>	

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3.7.2j	<p>Radioactive isotopes have a very wide range of half-life values.</p> <p>The most unstable nuclei have the shortest half-lives; decay is rapid with a lot of radiation emitted in a short time.</p> <p>The least unstable nuclei have the longest half-lives; they emit little radiation each second but emit radiation for a long time.</p> <p>There are uses and dangers associated with each type of nuclear radiation.</p>	<p>Know that Radioactive isotopes have a very wide range of half-life values.</p>		<p>not become radioactive.</p> <p>How does the activity of a radioactive source affect its half-life?</p> <p>State that the most unstable nuclei have short half-lives as they decay much faster. Radioactive atoms with much longer half-lives are more stable.</p> <p>If some radioactive sources have short half-lives why are they still found on Earth?</p> <p>Evaluate the use of the uranium-lead ratio to determine the age of rocks even though the decay is not straight from uranium into lead. Research how isotopes with long half-lives and short half-lives are used.</p>		

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3.7.3 Nuclear fission						
3.7.3a	Nuclear fission is the splitting of a large and unstable nucleus and the release of energy.	Explain what nuclear fission is.	3	Model nuclear fission of a uranium atom. What happens when you split an atom?	BBC Bitesize – Nuclear fission	
3.7.3b	There are two fissionable substances in common use in nuclear reactors: uranium-235 and plutonium-239.	Recall examples of fissionable substances in common use in nuclear reactors.		Can splitting the atom be done at home? What type of radiation is emitted when an atom splits? Draw a diagram to illustrate the fission process.	Cyberphysics – Fission – The splitting of the atom's nucleus Pass My Exams – What is Nuclear Fission?	
3.7.3c	For fission to occur a uranium-235 or plutonium-239 nucleus must first absorb a neutron to make the nucleus unstable. The nucleus undergoing fission splits into two smaller nuclei, releasing two or three neutrons and energy. The amount of energy	The nucleus undergoing fission splits into two smaller nuclei, roughly equal in size, and emits two or three neutrons plus gamma rays. Energy is released by the fission reaction. All of the fission products have kinetic energy.		Describe what happens to the nucleus of an unstable atom when it undergoes fission. State the products of a fission reaction. What are the by-products of fission? Explain how the products of the fission reaction are still moving very fast and it is this kinetic energy that it transformed into heat energy to boil the water in a nuclear reactor. Describe the fission of uranium as still being a random event and the splitting of the atom can take place in different ways – releasing two or	Video clip YouTube: Nuclear Reactor – Understanding how it works Physics Elearnin	

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3.7.3d	<p>released during nuclear fission is much greater than that released in a chemical reaction involving a similar mass of material.</p> <p>A chain reaction occurs when neutrons from the fission go on to cause further fission.</p> <p>In a nuclear reactor control rods absorb fission neutrons to ensure that on average only one neutron per fission goes on to produce further fission and energy transfer.</p>	<p>Recall that the neutrons may go on to start a chain reaction.</p> <p>Recall that the chain reaction is controlled in a nuclear reactor to control the energy released. The explosion caused by a nuclear weapon is caused by an uncontrolled chain reaction.</p>		<p>three neutrons.</p> <p>What happens to the neutrons that do not go on to split more uranium atoms?</p> <p>How does nuclear fission produce heat?</p> <p>Model chain reactions using dominos or matches. Define the term 'chain reaction'. Explain why all the neutrons emitted by the uranium nucleus do not go to split up more uranium atoms – in terms of some of the neutrons escaping into the reactor vessel itself.</p> <p>If the sequence of number of decays of uranium atoms starts 1, 3, 9, 27 how many uranium atoms would be split on the 25th term of this sequence?</p> <p>Explain how the chain reaction in a nuclear power station is controlled by the use of boron control rods that absorb excess neutrons. Are nuclear power stations safer now or are they more at risk?</p>	<p>BBC Bitesize – Nuclear fission</p> <p>Video clips of nuclear fission and chain reactions can be found at http://phet.colorado.edu/en/simulation/nuclear-fission</p>	<p>Be able to sketch a labelled diagram to illustrate a chain reaction.</p>

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3.7.3e	<p>Nuclear reactions produce waste which may be dangerous due to its radioactive nature and may remain so for a long time, depending upon its half-life and products.</p> <p>The disposal of such waste needs to be managed with care and is a factor that may influence the use of nuclear power for the generation of electricity.</p>	Recall that waste which may be dangerous due to its radioactive nature.		<p>Describe the Chernobyl nuclear disaster as being caused by the control rods being removed from the reactor to test a safety system (that didn't work).</p> <p>Discuss why using nuclear power is dangerous.</p> <p>Set up a debate on the advantages and disadvantages of having nuclear power stations rather than other types of power stations.</p>		

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3.7.4 Nuclear fusion						
3.7.4a	Nuclear fusion is the joining of two light nuclei to form a heavier nucleus.	Understand the process of nuclear fusion.	3	Link to 3.8. on Nuclear fusion in stars.	Information on nuclear fission and fusion can be found on BBC GCSE Bitesize website http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa/atoms_radiation/	
3.7.4b	In this process some of the mass of the smaller nuclei is converted into energy.			Describe the conditions required for nuclear fusion to occur.	S-cool, the revision website – Fusion and Fission	
3.7.4c	The force of repulsion between the two positive nuclei must be overcome for them to get close and fuse and this happens at very high temperatures and pressures.			Describe nuclear fusion as being the joining of two small atoms to make a larger atom and releasing energy in the process. Write simple word or symbol equations for the fusion of two hydrogen atoms or other light elements.	Pass My Exams – What is Nuclear Fusion?	
3.7.4d	Nuclear fusion is the process by which energy is released in stars.				Cyberphysics – Nuclear Power	

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3.8 Space Physics						
3.8.1 Life cycle of a star						
All the following points can be covered as one project to understand and describe the life cycle of a star.						
3.8.1a	Stars form when enough dust and gas (mainly hydrogen and helium) from space are pulled together by gravitational attraction. Smaller masses may form and be attracted by a larger mass to become planets, or even stars.	Describe how a star forms.	3	<p>Describe how a star forms from a cloud of dust and gas called a nebula.</p> <p>State the name of the element that makes up most of the mass of a star.</p> <p>Explain how the star gets bigger by accreting the particles that are attracted to it and how the star gets hotter due to the kinetic energy transferred from the impacting particles to the developing star.</p>	<p>BBC Bitesize – Formation of a Star</p> <p>Cyberphysics – Life cycle of a star</p> <p>Pass My Exams – Life Cycle of Stars</p> <p>YouTube: Supernovas: When Stars Die</p> <p>BBC Bitesize – How are elements made?</p>	Know the stages in the life of large and small stars.
3.8.1b	During the 'main sequence' period of its life cycle, energy is released by the fusion of hydrogen nuclei to make helium nuclei in the core and a star is stable because the forces within it are balanced.	Describe how the star becomes stable in the main sequences of the life cycle.		<p>Explain how the star starts to fuse hydrogen atoms together in a process called nuclear fusion when the temperature of the protostar becomes high enough.</p> <p>Use the Sun as an example of a star in its 'main sequence' period of its lifecycle and is stable. It is stable because the force of gravity acting inwards and trying to collapse the Sun is in equilibrium with outward force due to the fusion energy trying</p>		

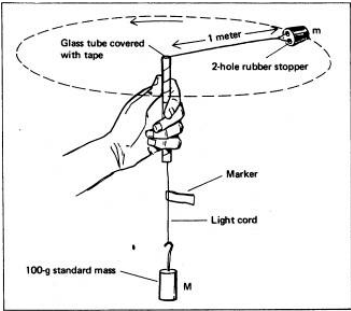
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3.8.1c	The core (centre) of a star is where the temperature and density are greatest and where most nuclear fusion takes place.	Describe the core of the star.		to expand the Sun. A star goes through a life cycle. The life cycle is determined by the size of the star.		
3.8.1d	The more massive a star, the hotter its core and the heavier the nuclei it can create by fusion.					
3.8.1e	Stars change over time; they have a life cycle. This life cycle is determined by the mass of the star.					
3.8.1f	A main sequence star uses nuclear reactions to					

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3.8.1g	<p>produce light and heat. When it runs out of hydrogen, what happens next in its life cycle depends upon its mass.</p> <p>A larger star will swell to become a red supergiant, in which helium nuclei fuse to form carbon, followed by further fusion that produces heavier nuclei such as nitrogen and oxygen. It expands, cools and turns red. The outer layers then blast away as a supernova is formed. The core then collapses and, again depending upon mass, it forms either a neutron star or a black hole.</p>					

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3.8.1h	A smaller star, similar to our sun, follows a different sequence, expanding to become a red giant. It then sheds out layers of gas, exposing the core as a white dwarf and finally cools to become a black dwarf.					
3.8.1i	Fusion processes in stars are the source of energy and 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.					

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3.8.2 Solar system & orbital motion						
3.8.2a	The Earth is one of eight planets orbiting the Sun (a medium sized star), which together with other smaller objects (asteroids, dwarf planets, comets) and moons orbiting several planets, make up the solar system.	Know the structures that make up our solar system.	1	<p>Describe the different objects in our solar system and their location within our solar system.</p> <p>Explain where in the solar system various groups of objects are likely to be found, eg asteroids and comets, the correct order of the planets, rocky dwarf planets and gas giants.</p> <p>Activity: Make a scale model of the solar system.</p> <p>Research: information about the solar system.</p> <p>Describe satellites as objects that orbit around larger objects in space.</p>	<p>Videos on formation of solar system:</p> <p>NASA – Solar System Exploration</p> <p>Cyber physics – The Solar System</p> <p>BBC Bitesize – The solar system</p> <p>Pass My Exams – The Solar System</p> <p>Video clip</p> <p>YouTube: A Tour through our Solar system</p>	
3.8.2b	How the universe is made up. Know the universe is made up of thousands of galaxies, each made up of thousands of stars. Our sun is one of thousands of millions of stars in our galaxy, the Milky Way.					
3.8.2c	Planets orbit the Sun and a moon is	Describe the difference between natural and artificial				

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3.8.2d	<p>a natural satellite of a planet. Artificial satellites orbit the Earth and can be in geostationary or low polar orbits.</p> <p>Gravity provides the centripetal force that keeps planets and satellites (both natural and artificial) in orbit.</p>	<p>satellites.</p> <p>Describe and explain how satellites can orbit the Earth in a (near) circular orbit at a steady speed even though they have a force at right angles accelerating them towards the ground.</p>	2	<p>Activity: Model centripetal force by swirling a bung on a string around your head. You can extend this to show what happens to the force if a heavier mass bung is used.</p> <p>Activity: Draw a diagram to show the forces acting on a satellite in orbit around the Earth.</p> <p>Activity: Evaluate data on the orbital speeds of planets and use</p>	<p>http://www.bbc.co.uk/schools/gcsebitesize/science/triple_ocr_gateway/space_for_reflection/satellites_gravity_circular_motion/revision/2/</p> <p>http://www.bbc.co.uk/education/guides/zk8hvcw/revision/4</p> <p>http://www.physicsclassroom.com/class/circles/Lesson-4/Circular-Motion-Principles-for-Satellites</p>	
3.8.2e	<p>The force of gravity acts towards the centre of the orbit. This unbalanced force causes acceleration towards the centre of the orbit, changing the direction of motion of the body (its velocity) but not its speed.</p>					
3.8.2f	<p>The centripetal force due to gravity</p>					

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3.8.2g	<p>decreases as the separation of orbiting masses increases, resulting in lower orbital speeds.</p> <p>At a particular separation of the masses, the centripetal force results in a particular orbital speed. To stay in a stable orbit at a particular distance, the planet or satellite moves at a particular speed. A change in orbital speed results in a change in orbital radius.</p>	<p>Explain how changing the speed of a satellite affects the orbital radius of the satellite.</p>		<p>this to predict the orbital radius, assuming a circular orbit.</p> <p>To stay in a stable orbit at a particular distance the smaller body, the planet or satellite, must move at a particular speed around the larger body it orbits. If the speed changes then the radius of the orbit must also change. The instantaneous velocity of the orbiting body is at right angle to the direction of the force of gravity.</p>	<p>Investigate circular motion of an object using the set up below.</p> 	
3.8.3 Red-shift and the expanding universe						
3.8.3a	<p>If a wave source is moving relative to an observer there will be a change in</p>	<p>Be able to explain the Doppler effect.</p>	3	<p>Demo: Demonstration of Doppler effect using sound:</p> <ul style="list-style-type: none"> a length of tubing swung in a circle 	<p>Apparatus to demonstrate Doppler effect, eg length of tubing swung in a circle.</p>	<p>Be able to explain the Doppler effect.</p>

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3.8.3b	<p>the observed wavelength and frequency. This is known as the Doppler effect.</p> <p>There is an observed increase in the wavelength of light from most distant galaxies.</p>	<p>Be able to explain the term 'red-shift'.</p> <p>Know that the further away the galaxies are, the faster</p>		<ul style="list-style-type: none"> a sound file of an emergency services siren going towards and away from a stationary observer. <p>Play clip from The Big Bang Theory: YouTube: Doppler Effect, Big Bang Theory Style</p> <p>Why does the pitch of a fire engine siren change as the fire engine comes towards you then moves away from you?</p> <p>Explain how light is shifted towards the red end of the spectrum as the light source is moving away from us as the movement makes the wavelength longer.</p> <p>Link to the Doppler effect. For example, a siren of a police car moving away from you would have a lower pitch and therefore a longer wavelength than one stationary relative to you.</p> <p>Demonstrate distant galaxies getting further away from you by using a balloon with some crosses on to represent galaxies and then inflate it.</p>	<p>The Big Bang – NASA Science</p>	

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	<p>The further away the galaxies, the faster they are moving and the bigger the observed increase in wavelength. This effect is called red-shift. The observed red-shift suggests that space itself is expanding and supports the Big Bang model.</p>	<p>they are moving, and the bigger the observed increase in wavelength.</p> <p>Be able to explain how 'red-shift' provides evidence that the universe is expanding.</p> <p>Know that the 'Big Bang' theory indicates that the universe began from a very small initial point.</p>		<p>Are all galaxies moving away from us at the same speed?</p> <p>Explain why more distant stars would have a greater red-shift than nearby stars in terms of their speed.</p> <p>How does red-shift provide evidence of the Big Bang?</p> <p>Explain how the red-shift of distant stars and galaxies shows that they are moving away from us. This is evidence of the universe starting off from a small point in space and expanding outwards.</p> <p>Why are some stars and galaxies blue-shifted if the universe is expanding?</p> <p>Describe the red-shift of light from distant stars and galaxies as evidence of the stars and galaxies moving away from us as the space between the stars and galaxies is expanding – not as the galaxies themselves getting bigger. The further away the light source is from us, the greater the amount of space between, that is expanding, and the faster the light source is moving</p>	<p>BBC Universe The Big Bang Cyberphysics - Doppler Effect and Red Shift Pass My Exams – Red Shift and the Expanding Universe</p> <p>Video clips of 'red- shift', the 'Big Bang' theory, and CMBR can be found at http://www.pbs.org/wgbh/nova/space/origins-series-overview.html</p>	<p>Be able to explain the term 'red-shift' and the 'Big Bang' theory.</p>

