Edexcel GCSE (9–1) Combined Science - Physics
2-year scheme of work

This document provides a scheme of work for teaching the Physics content from the Pearson Edexcel GCSE (9-1) Combined Science specification in 2 years.

Bold text indicates that the content is for Higher Tier only. An asterisk indicates that you may have covered the specification point if you have been using our transition materials.

The document currently contains exemplar teaching activities and notes on differentiation, but not for all topics. We will update it with this level of detail for the remainder of the course over the coming months. The suggested length for each lesson is indicated next to the title.

Not all of the suggested practicals from the specification have been covered in this scheme of work. Alternative suggested practicals could be substituted into the lessons given here.

P1 Motion				
Lesson CP1a: Vectors and scalars (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P2.1: Explain that a scalar quantity has magnitude (size) but no specific direction • P2.2: Explain that a vector quantity has both magnitude (size) and a specific direction • P2.3: Explain the difference between vector and scalar quantities • P2.4: Recall vector and scalar quantities including: a) displacement / distance b) velocity / speed c) acceleration d) force e) weight / mass f) momentum g) energy • *P2.5: Recall that velocity is speed in a stated direction	*Starter* Ask students to work in groups to list 5 or 10 things we measure in physics, e.g. time, length, area, weight, speed. *Exploring* Complete a card sort activity about an athletics event to reinforce understanding of the differences between scalars and vectors. *Explaining* Place a small 50 ml beaker inside a large beaker (4 l) and fill the large beaker with water to near the top. Then challenge a student to drop a coin into the small beaker. Ask students to work in pairs to write descriptions of the different ways in which the coins move, including the words speed, velocity, distance, displacement.	*Exploring* Support: Discuss with students the placements of labels and any other things they need to add to the drawing (such as lines showing distances). Stretch: Challenge students to find one or more images from the internet and annotate them to illustrate the differences between scalar and vector quantities, writing their own labels. *Explaining* Support: Rather than asking students to write descriptions, elicit their ideas about differences between distance and displacement, speed and velocity, by questioning. Stretch: Ask students to describe the movement of the coins in terms of energy (e.g. losing potential energy and gaining kinetic energy as they accelerate).	• Visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects	n/a

Lesson CP1b: Distance/time graphs (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *P2.6: Recall and use the equations: a) (average) speed (metre per second, m/s) = distance (metre, m) ÷ time (s) b) distance travelled (metre, m) = average speed (metre per second, m/s) × time (s) • *P2.7: Analyse distance/time graphs including determination of speed from the gradient • *P2.12: Recall some typical speeds encountered in everyday experience for wind and sound, and for walking, running, cycling and other transportation systems • P2.11: Describe a range of laboratory methods for determining the speeds of objects such as the use of light gates	*Starter* Show students a video clip (from the Internet) of a supersonic car. Ask students to suggest how fast the speed of sound is, and how this compares to the speeds of cars on the roads. *Exploring* Students carry out their own research into typical speeds for different forms of transport. *Explaining* Use a ramp with a small slope and a dynamics trolley to demonstrate the difference between instantaneous speed and average speed.	*Exploring* Support: Help students to convert their researched speeds to metres per second. Stretch: Students use their own experience or bus timetables and online mapping programs to work out the average speed for a bus journey, and compare this to some of the instantaneous speeds that are likely to occur on the journey (e.g. 30 mph in towns etc.). *Explaining* Support: Reinforce the difference between instantaneous speed and mean speed, and discuss how the average speed can be calculated. Stretch: Ask students to write one or two sentences to explain why the average speed for a journey is always less than the maximum speed during the journey.	• Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Translate information between graphical and numeric form • Plot two variables from experimental or other data • Determine the slope and intercept of a linear graph	Use a ramp with a small slope and a dynamics trolley to demonstrate the difference between instantaneous speed and average speed. (See *Explaining*.)

Lesson CP1c: Acceleration (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *P2.8: Recall and use the equation: acceleration (metre per second squared, m/s^2) = change in velocity (metre per second, m/s) / time taken (second, s) $a = (v - u)/t$ • P2.9: Use the equation: (final velocity)^2 ((metre/second)^2, $(m/s)^2$) – (initial velocity)^2 ((metre/second)^2, $(m/s)^2$) = 2 × acceleration (metre per second squared, m/s^2) × distance (metre, m) $v^2 - u^2 = 2 \times a \times x$ • P2.13: Recall that the acceleration, *g*, in free fall is 10 m/s^2 and be able to estimate the magnitudes of everyday accelerations	*Starter* Ask students to work in groups to think about how you work out different quantities that describe motion and the units they are measured in. *Exploring* Use light gates to measure the acceleration of a card in free fall. (*Suggested practical*.) *Explaining* Guide students through using the two formulae involving acceleration.	*Exploring* Support: Helping students to calculate the acceleration for each drop will give them practice using the formula. Stretch: Calculate the acceleration from a multi-flash image of a falling ball. *Explaining* Support: Work through some calculations with students. Stretch: Ask students to use the acceleration values of 12.64 m/s^2 for a sports car and 1.5 m/s^2 for a family car to calculate the time it would take for each type of car to accelerate from 0 to 30 m/s.	• Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	*Suggested practical:* Investigate the acceleration, *g*, in free fall and the magnitudes of everyday accelerations. (See *Exploring*.)

Lesson CP1d: Velocity/time graphs (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *P2.10: Analyse velocity/time graphs to: a) compare acceleration from gradients qualitatively b) calculate the acceleration from the gradient (for uniform acceleration only) c) determine the distance travelled using the area between the graph line and the time axis (for uniform acceleration only)	*Starter* On the board sketch two distance–time graphs, one with a horizontal line and one with the line sloping upwards. Label the axes of each and ask the class what these show (staying still, moving at a steady speed). Now change the label on the vertical axis to read 'Velocity'. Ask what the horizontal line now shows. *Exploring* Give students a copy of a shooting script for a car chase in an action film. Students work out missing information about velocity and time, and use this to draw a velocity/time graph. *Explaining* Explain why the gradient and area under a velocity–time graph give the acceleration and distance respectively.	*Exploring* Support: Ask students to explain the different slopes of their graph. Stretch: Ask students to think about how they would amend the table and draw the velocity/time graph if the car reversed at some points in the chase. *Explaining* Support: Ask students to suggest next steps in calculating acceleration and distance from the graphs.	• Translate information between graphical and numeric form • Plot two variables from experimental or other data • Determine the slope and intercept of a linear graph • Understand the physical significance of area between a curve and the *x*-axis and measure it by counting squares as appropriate.	n/a

P2 Forces and motion				
Lesson CP2a: Resultant forces (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P2.14: Recall Newton's First Law and use it in the following situations: a) where the resultant force on a body is zero, i.e. the body is moving at a constant velocity or is at rest b) where the resultant force is not zero, i.e. the speed and/or direction of the body changes	*Starter* Students work in groups to write down five things they remember about forces and their effects. *Exploring* Flick a coin off a bench at the same time as dropping one, to demonstrate that the time to reach the ground is not affected by the horizontal component of its velocity and so horizontal and vertical forces on an object can be discussed independently of each other. *Explaining* Use images of objects stationary and in motion, asking students to describe the types of forces acting on the objects and the directions in which they are acting.	*Exploring* Support: Demonstrate the activity for students. Stretch: Ask students to suggest why flicking a coin harder makes it go further. *Explaining* Support: Use questioning to help students to identify the types of forces involved. Stretch: Include images such as skiers going downhill, and elicit the idea that the weight force acting vertically downwards can be thought of as partly pulling the skier down the hill along the surface of the snow, and partly pressing them into the snow at right angles to the surface.	• Recognise and use expressions in decimal form • Make estimates of the results of simple calculations • Use an appropriate number of significant figures	Demonstrate that horizontal and vertical forces on an object can be discussed independently of each other. (See *Exploring*.)

Lesson CP2b: Newton's First law (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P2.14: Recall Newton's First Law and use it in the following situations: a) where the resultant force on a body is zero i.e. the body is moving at a constant velocity or is at rest b) where the resultant force is not zero i.e. the speed and/or direction of the body change(s) • **P2.20: Explain that an object moving in a circular orbit at constant speed has a changing velocity (qualitative only)** • **P2.21: Explain that for motion in a circle there must be a resultant force known as a centripetal force that acts towards the centre of the circle**	*Starter* Fill a balloon with helium and tether it to a weight. Ask students to work in pairs to describe the forces on the balloon while it is tethered, and to describe what would happen if the balloon were released. *Exploring* Give students a selection of statements about motion and why things move. They discuss the statements in groups and separate them into piles: true, false, not sure. *Explaining* Use an air track to demonstrate the effects of friction on moving objects by showing the movement of gliders/pucks with the air on and with the air off.	Exploring Support: Provide students with some additional true statements to help with reasoning. Stretch: Ask students to develop some more cards of their own for others to work from, together with extra information cards. Explaining Support: Help students to write a couple of sentences to summarise what they have seen and the reasons for it. Stretch: Show students a video clip (from the Internet) of hovercraft manoeuvring and ask them to explain why hovercraft appear to skid around a turn.	• Recognise and use expressions in decimal form • Make estimates of the results of simple calculations • Use an appropriate number of significant figures • Visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects	Use an air track to demonstrate the effects of friction on moving objects. (See *Explaining*.)

Lesson CP2c: Mass and weight (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *P2.16: Define weight, recall and use the equation: weight (newton, N) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg), $W = m \times g$ • P2.17: Describe how weight is measured • P2.18: Describe the relationship between the weight of a body and the gravitational field strength	*Starter* Challenge students to write down two statements about mass and weight that are true, and one that is false. The rest of the class have to decide whether the statement is true or false. *Exploring* Provide a selection of objects with their masses shown. Students weigh the objects and draw a scatter graph of weight against mass. Draw a line of best fit, identify the type of correlation, and calculate the value of *g* from the gradient of the line. (*Suggested practical*.) *Explaining* Find images on the Internet of the Saturn V rocket that launched the Apollo spacecraft, and also of the lunar module ascent stage taking off. Ask students to think of as many reasons as they can why the two spacecraft are so different.	*Exploring* Support: Provide masses in 0.1 kg intervals. Stretch: Provide students with masses marked in a variety of units. *Explaining* Support: Help students by asking specific questions, such as what is the difference in gravitational field strengths between Earth and Moon? Stretch: Explain that the Saturn V rocket used three stages to get the Apollo spacecraft into orbit, each stage containing fuel and rocket engine(s). Each stage was thrown away when the fuel was used up. Ask students to work in pairs to write a short paragraph to explain why this was done.	• Use ratios, fractions and percentages • Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	*Suggested practical:* Investigate the relationship between mass and weight. (See *Exploring*.)

Lesson CP2d: Newton's Second Law (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P2.15: Recall and use Newton's Second Law as force (newton, N) = mass (kilogram, kg) × acceleration (metre per second squared, m/s^2) $F = m \times a$ • **P2.22: Explain that inertial mass is a measure of how difficult it is to change the velocity of an object (including from rest) and know that it is defined as the ratio of force over acceleration.** • *P2.19: Core Practical: Investigate the relationship between force, mass and acceleration by varying the masses added to trolleys*	*Starter* Kick a number of different sized objects (e.g. balls) along the floor with (approximately) the same force. The aim is to get across a sense of how fast the balls are moving away. *Exploring* Investigate the effects of mass on acceleration with a constant force using gliders/trolleys on an airtrack/ramp. (*Core practical*.) *Explaining* Use an airtrack, two gliders and some repelling magnets to demonstrate $F = m \times a$ and recap on action and reaction forces. (*Core practical*.)	*Exploring* Support: The practical could be simplified by asking them to time how long it takes the trolley from release to the end of the ramp. Stretch: Ask students to plan their own method to investigate the effects of force and mass on acceleration *Explaining* Support: Give students pairs of disc magnets so they can feel the repelling force. Stretch: Ask students to predict what would happen if one glider was three times the mass of the other one.	• Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	*Core Practical: Investigate the relationship between force, mass and acceleration by varying the masses added to trolleys.* (See *Exploring* and *Explaining*.)

Lesson CP2e: Newton's Third Law (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P2.23: Recall and apply Newton's Third Law… to equilibrium situations… • **P2.23: Recall and apply Newton's Third Law… to collision interactions…**	*Starter* Set up a spring in a clamp and stand with a mass hanging on the end. Discuss the forces on the mass and elicit the idea that the mass is not moving because these forces are balanced. *Exploring* Provide a cut-up set of force labels, and ask students to add the labels to a selection of images where forces are involved. Students add further annotations. *Explaining* Find images of equilibrium situations from the Internet and ask students to identify the forces. Elicit descriptions of both action–reaction pairs and balanced forces, and ask students to explain the difference.	*Exploring* Support: Project the large picture of one image and use it to help students to identify where to place the various labels via class discussion. Stretch: Ask students to identify the forces on the images without using the labels.	• Use an appropriate number of significant figures • Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	n/a

Lesson CP2f: Momentum (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **P2.23: Recall and apply Newton's Third Law… to collision interactions and relate it to the conservation of momentum in collisions** • **P2.24: Define momentum, recall and use the equation: momentum (kilogram metre per second, kg m/s) = mass (kilogram, kg) × velocity (metre per second, m/s)** $p = m \times v$ • **P2.25: Describe examples of momentum in collisions** • **P2.26: Use Newton's Second Law as: force (newton, N) = change in momentum (kilogram metre per second, kg m/s) ÷ time (second, s)** $F = (mv - mu)/t$	*Starter* Set up an air track with two gliders. Ask students to predict what will happen if a moving glider collides with a stationary one and if two moving gliders collide, then show them what happens. Repeat the process using different masses and for changes in velocity. (*Suggested practical.*) *Exploring* Investigate conservation of momentum during collisions, using a ramp and trolley. (*Suggested practical*.) *Explaining* Rearrange the acceleration formula to show that $F \times t = (mv - mu)$, and as $F \times t$ is the same for both objects then the change in momentum must be the same for both.	*Exploring* Support: In pairs, calculate either the momentum of the first trolley, or the momentum of both joined after the collision. Stretch: Ask students to predict what would happen if the trolleys did not join together and the collision caused the first trolley to stop completely. *Explaining* Support: Ask students what the letter symbols mean before looking at the equation itself. Stretch: Challenge students to show how the formula for force, in terms of a change in momentum over time, is derived.	• Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	*Suggested practical:* Investigate conservation of momentum during collisions. (See *Exploring*.) *Suggested practical:* Investigate inelastic collisions with the two objects remaining together after the collision and also 'near' elastic collisions. (*See Starter*.)

Lesson CP2g: Stopping distances (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P2.27: Explain methods of measuring human reaction times and recall typical results • P2.28: Recall that the stopping distance of a vehicle is made up of the sum of the thinking distance and the braking distance • P2.29: Explain that the stopping distance of a vehicle is affected by a range of factors including: a) the mass of the vehicle b) the speed of the vehicle c) the driver's reaction time d) the state of the vehicle's brakes e) the state of the road f) the amount of friction between the tyre and the road surface • P2.30: Describe the factors affecting a driver's reaction time including drugs and distractions	*Starter* Display the Highway Code's chart of increasing stopping distances with speed. Ask students to write down what they think braking distance and thinking distance might be and how each changes with the speed. *Exploring* Students work together in pairs or small groups to produce a poster, leaflet or computer presentation about road safety. *Explaining* Ask students to compare the thinking distances at 20 mph and 40 mph, and then to compare 20 mph and 60 mph – elicit the idea that the thinking distance is directly proportional to the speed. Then ask students to compare the braking distances at these speeds.	*Exploring* Support: Students concentrate on the factors affecting thinking and braking distances. Stretch: Students should include other factors such as visibility, likelihood of children running into the road, etc. in their presentations. *Explaining* Support: Remind students of the meaning of direct proportion. Stretch: Ask students to work out the thinking and braking distances (in metres) at 25 and 55 mph by plotting a graph of thinking and braking distances against speed.	• Make estimates of the results of simple calculations • Find arithmetic means • Construct and interpret frequency tables and diagrams, bar charts and histograms • Use a scatter diagram to identify a correlation between two variables	n/a

Lesson CP2h: Crash hazards (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P2.31: Explain the dangers caused by large decelerations **and estimate the forces involved in typical situations on a public road** • **P2.26: Use Newton's Second Law as: force (newton, N) = change in momentum (kilogram metre per second, kg m/s) ÷ time (second, s)** $F = (mv - mu)/t$	*Starter* Ask students to suggest different causes of crashes. What determines the amount of damage and what safety features are built into cars to mitigate dangers to people? *Exploring* Investigate how crumple zones can be used to reduce the forces in collisions. (*Suggested practical*.) *Explaining* Show students these two statements and give them a few minutes to discuss which of the two statements is correct. • If two vehicles, both travelling at 60 mph, collide head-on, the crash is much worse than a car travelling at 60 mph hitting a wall. • It's only worse because there are two lots of people to be injured and two cars to be damaged. The forces on the car are just the same.	*Exploring* Support: Help students to design a simple crumple zone. Stretch: Students plan their own investigation to test a hypothesis. *Explaining* Support: Use a couple of model cars to help students to visualise the discussion. Stretch: Ask students to consider the case where one vehicle has more mass than the other, or one is moving much faster than the other, and to explain why the faster-moving/more massive vehicle is likely to sustain less damage than the other, in terms of changes in momentum.	• Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	*Suggested practical:* Investigate how crumple zones can be used to reduce the forces in collisions. (See *Exploring*.)

P3 Conservation of energy				
Lesson CP3a: Energy stores and transfers (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P3.6: Explain that where there are energy transfers in a closed system there is no net change to the total energy in that system • P3.5: Analyse the changes involved in the way energy is stored when a system changes, including: a) an object projected upwards or up a slope b) a moving object hitting an obstacle c) an object being accelerated by a constant force d) a vehicle slowing down e) bringing water to a boil in an electric kettle • P3.3: Draw and interpret diagrams to represent energy transfers • P3.4: Explain what is meant by conservation of energy • P3.8: Explain, using examples, how in all system changes energy is dissipated so that it is stored in less useful ways	*Starter* Ask students to write a short story to illustrate different energy stores and transfers. *Exploring* Investigation to observe a series of energy transfers from one store to another. (*Suggested practical*.) *Explaining* Show students two or three examples of energy dissipation. In all cases, elicit ideas about the energy stores and transfers involved, particularly the final energy stores.	*Exploring* Support: Give students a list of the different energy stores and ways of transferring energy. Stretch: Ask students to draw energy transfer diagrams showing the relative amounts of energy transferred by each process or device. *Explaining* Support: Help students to draw simple flow charts to represent the energy stores and transfers for a pendulum and bouncing ball. Stretch: Show students the demonstrations without discussion or questioning and ask them to write a short description of the energy stores and transfers involved, and to explain where the energy originally stored ends up.	n/a	*Suggested practical:* Investigate conservation of energy. (See *Exploring*.) Show a range of energy dissipation demonstrations, such as a simple swinging pendulum, a bouncing ball, or heating caused by drilling. (See *Explaining*.)

Lesson CP3b: Energy efficiency (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **P3.12: Explain how efficiency can be increased** • P3.11: Recall and use the equation: efficiency = (useful energy transferred by the device) / (total energy supplied to the device) • P3.7: Explain that mechanical processes become wasteful when they cause a rise in temperature so dissipating energy in heating the surroundings • P3.9: Explain ways of reducing unwanted energy transfer, including through lubrication…	*Starter* Draw two Sankey diagrams on the board for similar appliances with the same energy inputs but different proportions of useful and wasted energies output. Ask students to describe what the two diagrams show, elicit ideas about the differences between the energies transferred by the two objects, and discuss what could be used as the measure of energy wasted. *Exploring* Students sort a selection of cards on energy efficiency into five rows (picture; useful and wasted energies; energy conversion diagram; efficiency). Students then use the pictorial and diagrammatic information to explain which device is most efficient, orally or in writing. *Explaining* Find one or more news reports on the internet from 2014 when an upper limit on the power of new vacuum cleaners. Ask for suggestions why this was done and whether the limit says anything about the efficiency of the machines.	*Exploring* Support: Set out the working for the first row in a structured way for students to copy and check the calculations. Stretch: Students could set up their own spreadsheet formulae to calculate efficiencies. *Explaining* Support: Use structured questioning to help students to take part in the discussion. Stretch: Ask students to suggest why a higher-powered kettle would actually be more efficient than a lower-powered kettle of the same design.	• Recognise and use expressions in decimal form • Use ratios, fractions and percentages • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	n/a

Lesson CP3c: Keeping warm (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P3.9: Explain ways of reducing unwanted energy transfer, including through… thermal insulation… • P3.10: Describe the effects of the thickness and thermal conductivity of the walls of a building on its rate of cooling qualitatively	*Starter* Show students some images of energy-efficient houses, ask them to explain what it means to refer to a house as 'energy-efficient', and the features of the house that help with this. *Exploring* Ask students to research the thermal conductivities of various traditional and modern building materials and to look at how the design of a building is adapted to local weather conditions. *Explaining* Remind students of the energy transfer processes with two demonstrations. 1) Wood v metal: wrap a piece of paper around the junction between the wood and metal in a wood and metal bar. Gently play a Bunsen burner flame on the paper. The paper over the wood will scorch; the paper over the metal will not. 2) Smoke box: use 'convection in air' apparatus (a glass-fronted metal box with two chimneys) to demonstrate convection.	*Exploring* Support: Find some websites that are suitable for students to access and give them the links, or get students to work in mixed ability groups. Stretch: Students research the ways in which spacecraft and potential Moon/Mars bases may be insulated. For spacecraft, the problem is often being too hot because of the heating from electrical equipment. A Moon base would have to cope with two weeks of sunlight followed by two weeks of darkness. *Explaining* Support: Use questioning to help students recall prior learning. Stretch: Ask students to list two situations in which conduction is useful and two in which it is not, then do the same for convection.	n/a	Demonstrations of energy transfer processes. (See *Explaining*.)

Lesson CP3d: Stored energies – please note that this lesson has recently been updated so differentiation notes are tbc (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P3.1: Recall and use the equation to calculate the change in gravitational PE when an object is raised above the ground: change in gravitational potential energy (joule, J) = mass (kilogram, kg) × gravitational field strength (newton per kilogram, N/kg) × change in vertical height (metre, m) $\Delta GPE = m \times g \times \Delta h$ • P3.2: Recall and use the equation to calculate the amounts of energy associated with a moving object: kinetic energy (joule, J) = ½ × mass (kilogram, kg) × (speed)^2 ((metre/second)^2, (m/s)^2) $KE = ½ \times m \times v$	*Starter* Demonstrate a pendulum and elicit ideas about energy changes. *Exploring* Research activity on how GPE stores are useful (e.g. pumped storage, pile drivers, counterweights). *Explaining* Activity on rearranging formulae	tbc	• Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	n/a

Lesson CP3e: Non-renewable resources (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P3.13: Describe the main energy sources available for use on Earth (including fossil fuels, nuclear fuel…), and compare the ways in which both renewable and non-renewable sources are used • P3.14: Explain patterns and trends in the use of energy resources	*Starter* Ask students to suggest why the phrase 'NIMBY' is often used when talking about people who are protesting against a new wind farm or other renewable ways of generating electricity. *Exploring* Look at a case study of small-scale wind energy generation in the UK, such as the electricity supply on Fair Isle. *Explaining* Discuss what happens to the demand for electricity when a very popular TV programme finishes or when there is an advert break.	*Exploring* Support: Review the data associated with the case study in question with students, supporting them in answering questions about the study. Stretch: Ask students to find out about the wind farm that was proposed in 2004 for the Isle of Lewis (in the Outer Hebrides), why Lewis was suggested as a location and why the application was eventually rejected by the Scottish Government in 2008. They could also be asked to contrast this with the situation on Fair Isle. *Explaining* Support: Write some phrases on the board that students can use in a written explanation of why power engineers need to know when breaks occur in TV schedules. Stretch: Ask students to find out what 'pumped storage' power stations are and why they are necessary.	• Use a scatter diagram to identify a correlation between two variables • Construct and interpret frequency tables and diagrams, bar charts and histograms	n/a

Lesson CP3f: Renewable resources (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P3.13: Describe the main energy sources available for use on Earth (including… bio-fuel, wind, hydro-electricity, the tides and the Sun), and compare the ways in which both renewable and non-renewable sources are used • P3.14: Explain patterns and trends in the use of energy resources	*Starter* Tell students that a new power station is needed to make sure there is enough electricity for everyone in the country. Ask them which kind of fuel they would choose for their power station and why. *Exploring* Provide students with a range of tables and charts showing the changes in energy use since 1970. Students need to interpret the charts and draw a bar chart. *Explaining* Use a model steam engine to demonstrate one way in which the energy stored in a fuel is transferred to motion.	*Exploring* Support: Give students pre-prepared axes for their bar charts or help them to draw the axes and draw the bars. Stretch: Ask students to work in pairs to write a short paragraph evaluating the different ways in which data has been presented during this activity. *Explaining* Support: Give students a list of the energy stores and transfers occurring in the demonstration. Stretch: Ask students to research and write a short paragraph describing the similarities and differences in propulsion systems between early steamships (1850-1900) and modern nuclear-powered vessels.	• Construct and interpret frequency tables and diagrams, bar charts and histograms • Use a scatter diagram to identify a correlation between two variables	Demonstrate how energy from fuel is transferred into motion using a steam engine. (See *Explaining*.)

P4 Waves				
Lesson CP4a: Describing waves (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P4.1: Recall that waves transfer energy and information without transferring matter • P4.2: Describe evidence that with water and sound waves it is the wave and not the water or air itself that travels • P4.3: Define and use the terms frequency and wavelength as applied to waves • P4.4: Use the terms, amplitude, period and wave velocity as applied to waves • P4.5: Describe the difference between longitudinal and transverse waves by referring to sound, electromagnetic, seismic and water waves	*Starter* Use a 'slinky' spring to demonstrate longitudinal and transverse waves. Ask students to describe the differences between the two types of wave, and also ask them to describe what is moving and how it is moving. *Exploring* Show students how a microphone connected to an oscilloscope can be used to represent the characteristics of a sound wave. *Explaining* Set up a ripple tank with illumination. Use a straight dipper to illustrate plane waves. Measure the frequency and wavelength of the waves.	*Exploring* Support: Ensure that students understand that the transverse wave-form shown on the oscilloscope screen is just a way of representing the sound waves. Stretch: Ask students to consider the benefits and drawbacks of using flashing lights to send messages between ships in wartime. *Explaining* Support: Discuss with students the reason for using 10 waves or 10 seconds for measuring period and frequency. Stretch: Ask students to explain what causes the standing wave, using ideas about reflection and superposition.	n/a	Demonstrate longitudinal and transverse waves. (See *Starter*.) Demonstrate the characteristics of a sound wave using an oscilloscope. (See *Exploring*.) Use a ripple tank to illustrate plane waves, and calculate frequency and wavelength. (See *Explaining*.)

Lesson CP4b: Wave velocity (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P4.6: Recall and use both the equations below for all waves: wave speed (metre/second, m/s) = frequency (hertz, Hz) × wavelength (metre, m) $v = f \times \lambda$ wave speed (metre/second, m/s) = distance (metre, m) ÷ time (second, s) $v = x/t$ • P4.7: Describe how to measure the velocity of sound in air and ripples on water surfaces • *P4.17: Core Practical: Investigate the suitability of equipment to measure the speed, frequency and wavelength of a wave in a solid and a fluid*	*Starter* Tell students that a train is 216 metres long and takes 5 seconds to pass a point on the track. Ask them to calculate the velocity of the train. Now tell students that railway carriages are 24 metres long, and 9 of them go past in 5 seconds. Ask them what the frequency of carriages passing is, and ask them to suggest how to use this and the carriage length to work out the speed of the train. *Exploring* Investigate the suitability of equipment to measure the speed, frequency and wavelength of a wave in a solid and a fluid. *(Core practical.)* *Explaining* Search the internet using 'volcano shock wave' to find a video taken by tourists off Papua New Guinea when the Tavurvur volcano erupted. Ask students to time how long the shock wave takes to arrive, and to use this and the speed of sound in air (330 m/s) to work out the distance of the boat from the volcano.	*Exploring* Support: Demonstrate the speed of sound in a solid practical to them first, and then allow them to take several different readings and help them to plot a graph. Stretch: For the speed of sound in a solid, ask students to plot distance against time for their repeated measurements, draw a line of best fit through the points and work out the velocity from the gradient of the line. *Explaining* Support: Work through some calculations with students to ensure they can use the formulae. Stretch: A rule of thumb for working out the distance to a lightning strike is to divide the time for the thunder to arrive by 3 to give the distance in kilometres. Ask students to explain why this works, and why we do not bother to take the speed of light into account in such estimates.	• Recognise and use expressions in standard form • Use a scatter diagram to identify a correlation between two variables • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	*Core Practical: Investigate the suitability of equipment to measure the speed, frequency and wavelength of a wave in a solid and a fluid* (See *Exploring.*)

Lesson CP4c: Refraction (3 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P4.10: Explain how waves will be refracted at a boundary in terms of the change of direction **and speed** • **P4.11: Recall that different substances may absorb, transmit, refract, or reflect waves in ways that vary with wavelength** • P4.6: Recall and use both the equations below for all waves: wave speed (metre/second, m/s) = frequency (hertz, Hz) × wavelength (metre, m) $v = f \times \lambda$ wave speed (metre/second, m/s) = distance (metre, m) ÷ time (second, s) t $v = x/t$	*Starter* Demonstrate some of the more common optical illusions that result from refraction. *Exploring* Investigate the way in which a ray of light is bent when it enters and leaves Perspex or glass blocks. (*Suggested practical*.) *Explaining* Use a ripple tank to demonstrate refraction occurring when waves move into a different depth of water.	*Exploring* Support: Provide students with ready-made outlines of the blocks with the incident rays marked. Stretch: Students could investigate how the angle of incidence and angle of refraction are connected. *Explaining* Support: Students could be provided with ready-made outlines of the angles to be demonstrated. Stretch: Remind students of the formula linking wave velocity, frequency and wavelength, and ask them to suggest whether it is the wavelength or the frequency that changes when the wave speed changes.	• Use ratios, fractions and percentages • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects	Demonstrate some of the more common optical illusions that result from refraction. (See *Starter*.) *Suggested practical:* Investigate models to show refraction, such as toy cars travelling into a region of sand. Use a ripple tank to demonstrate refraction occurring when waves move into a different depth of water. (See *Explaining*.)

P5 Light and the electromagnetic spectrum				
Lesson CP5a: Electromagnetic waves (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P5.7: Recall that all electromagnetic waves are transverse, that they travel at the same speed in a vacuum • P5.8: Explain, with examples, that all electromagnetic waves transfer energy from source to observer • P5.12: Recall that our eyes can only detect a limited range of frequencies of electromagnetic radiation • P5.14: Explain the effects of differences in the velocities of electromagnetic waves in different substances • *P5.9: Core practical: Investigate refraction in rectangular glass blocks in terms of the interaction of electromagnetic waves with matter*	*Starter* Ask students to write down a list of examples that show waves transferring energy. *Exploring* Conduct an investigation into the refraction of light when travelling from air to glass, and glass to air. (*Core practical.*) *Explaining* Demonstrate Johann Ritter's experiment that led to the discovery of ultraviolet radiation. (*Suggested practical.*)	*Exploring* Support: Help students with measuring the angles by providing them with a printed protractor. Stretch: Extend the investigation to include transitions between additional materials. *Explaining* Support: Ask students to write messages on paper with a security marker pen and view them under ultraviolet light. Stretch: Students plan a systematic experiment to test the responses of silver chloride to different parts of the EM spectrum.	• Recognise and use expressions in decimal form • Use a scatter diagram to identify a correlation between two variables.	*Core practical: Investigate refraction in rectangular glass blocks in terms of the interaction of electromagnetic waves with matter. (*See *Exploring)* *Suggested practical:* Investigate the areas beyond the visible spectrum, such as the work of Herschel and Ritter in discovering IR and UV respectively. (See *Explaining*)

Lesson CP5b: The electromagnetic spectrum (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P5.10: Recall the main groupings of the continuous electromagnetic spectrum including (in order) radio waves, microwaves, infrared, visible (including the colours of the visible spectrum), ultraviolet, X-rays and gamma rays • P5.11: Describe the electromagnetic spectrum as continuous from radio waves to gamma rays and that the radiations within it can be grouped in order of decreasing wavelength and increasing frequency • **P5.13: Recall that different substances may absorb, transmit, refract or reflect electromagnetic waves in ways that vary with wavelength**	*Starter* Challenge students to put the areas of the electromagnetic spectrum in order of wavelength or frequency, and to explain their reasoning. *Exploring* Students build a spectrometer and use it to look at the spectra of a variety of different light sources. (*Suggested practical.*) *Explaining* Ask students to sketch a diagram of the electromagnetic spectrum, labelling the wavelengths and seven regions.	*Exploring* Support: Help students with the construction of the spectrometer. Stretch: Ask students to find out why the sky appears blue during the day and looks more red at sunset. *Explaining* Support: Remind students that mnemonics can help them to recall the order of the areas in the EM spectrum. Stretch: Students could convert the wavelengths of different areas in the EM spectrum into 'prefixed' SI units, e.g. km, mm, nm.	• Recognise and use expressions in standard and decimal forms • Use ratios, fractions and percentages • Substitute numerical values into algebraic equations using appropriate units for physical quantities	*Suggested practical:* Construct a simple spectrometer, from a CD or DVD, and use it to analyse common light sources. (See *Exploring*)

Lesson CP5c: Using the long wavelengths (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P5.22: Describe some uses of electromagnetic radiation a) radio waves: including broadcasting, communications and satellite transmissions b) microwaves: including cooking, communications and satellite transmissions c) infrared: including cooking, thermal imaging, short range communications, optical fibres, television remote controls and security systems d) visible light: including vision, photography and illumination … • **P5.23: Recall that radio waves can be produced by, or can themselves induce, oscillations in electrical circuits** • **P5.13: Recall that different substances may absorb, transmit, refract, or reflect EM waves in ways that vary with wavelength** • P5.14: Explain the effects of differences in the velocities of EM waves in different substances	*Starter* Demonstrate to students that infrared radiation can be reflected and focused in a similar way to light using a concave mirror. *Exploring* Show students the ranges of mobile phone masts of various heights, and ask them to calculate the range each. *Explaining* Show students a photo of a TV satellite dish or images of radio telescopes, and ask questions about how the dish works.	*Exploring* Support: Work through the calculations with students. Stretch: Ask students to work out how tall a mast would have to be to have a range of 50 km. *Explaining* Support: Remind students of the relative wavelengths of waves in different parts of EM spectrum. Stretch: Draw a diagram to explain how a reflecting telescope works.	• Recognise and use expressions in standard and decimal form • Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities	Demonstrate the reflection and focusing of IR. (See *Starter*)

Lesson CP5d: Using the short wavelengths (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P5.22: Describe some uses of electromagnetic radiation … e) ultraviolet: including security marking, fluorescent lamps, detecting forged bank notes and disinfecting water f) X-rays: including observing the internal structure of objects, airport security scanners and medical X-rays g) gamma rays: including sterilising food and medical equipment, and the detection of cancer and its treatment • **P5.13: Recall that different substances may absorb, transmit, refract, or reflect electromagnetic waves in ways that vary with wavelength** • P5.14: Explain the effects of differences in the velocities of electromagnetic waves in different substances	*Starter* Use a video from the Bank of England website to demonstrate how forged notes are detected *Exploring* Students undertake a series of brief practical investigations to familiarise themselves with parts of the electromagnetic spectrum not visible to the naked eye. *Explaining* Demonstrate the cyanotype process for printing monochrome photographs using ultraviolet light.	*Exploring* Support: Use peer-to-peer learning, pairing students during the investigation. Stretch: Ask students additional questions to elicit the idea that the spectrum is continuous. *Explaining* Support: Help students to link the different optical properties of the materials you use with the different materials in the body and their transmission or absorption of X-rays. Stretch: Ask students to find out what blueprints are and why this process was used for making them instead of just copying drawings.	n/a	Investigations into the non-visible sections of the EM spectrum. (See *Exploring*) Demonstrate the cyanotype process. (See *Explaining*)

Lesson CP5e: EM radiation dangers (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P5.21: Describe the harmful effects on people of excessive exposure to electromagnetic radiation, including: a) microwaves: internal heating of body cells b) infrared: skin burns c) ultraviolet: damage to surface cells and eyes, leading to skin cancer and eye conditions d) X-rays and gamma rays: mutation or damage to cells in the body • P5.20: Recall that the potential danger associated with an electromagnetic wave increases with increasing frequency • P5.24: Recall that changes in atoms and nuclei can a) generate radiations over a wide frequency range b) be caused by absorption of a range of radiations	*Starter* Ask students to make a concept map of the electromagnetic spectrum. *Exploring* In groups, research and conduct a debate about whether there are health hazards associated with mobile phones. *Explaining* Students should compare the safety features of conventional and microwave ovens.	*Exploring* Support: Give students basic instructions for conducting an accurate investigation. Stretch: Show students the equipment, then ask them to plan and conduct their own fair tests.	n/a	n/a

P6 Radioactivity				
Lesson CP6a: Atomic models (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P6.1: Describe an atom as a positively charged nucleus surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atom and with almost all of the mass in the nucleus • P6.2: Recall the typical size (order of magnitude) of atoms and small molecules • P6.17: Describe how and why the atomic model has changed over time including reference to the plum pudding model and Rutherford alpha particle scattering leading to the Bohr model	*Starter* Show students a beach ball labelled 'proton' and ask them to guess where an electron would be in this scale model of a hydrogen atom and what it would look like. (It would be a small seed about 0.5 mm across and it would be about 25 km away). *Exploring* Students build a simple model of an atom to give them an idea of the size of a proton compared to the size of a whole atom. *Explaining* Present and discuss the different atomic models suggested by J.J. Thomson, Ernest Rutherford and Niels Bohr.	*Exploring* Stretch: Students look up the sizes of larger atoms and compare these to the size of a hydrogen atom/proton by working out ratios of diameters. *Explaining* Stretch: Ask students to research and produce a timeline of ideas about atoms and what is inside them. They could go back to the Greek ideas and Dalton.	• Recognise and use expressions in decimal form • Recognise and use expressions in standard form • Visualise and represent 2D and 3D forms including two dimensional representations of 3D objects	Build a simple model of an atom. (See *Exploring*.)

Lesson CP6b: Inside atoms (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P6.3: Describe the structure of nuclei of isotopes using the terms atomic (proton) number and mass (nucleon) number and using symbols in the format $^{13}_{6}C$ • P6.4: Recall that the nucleus of each element has a characteristic positive charge, but that elements differ in mass by having different numbers of neutrons • P6.5: Recall the relative masses and relative electric charges of protons, neutrons, electrons and positrons • P6.6: Recall that in an atom the number of protons equals the number of electrons and is therefore neutral	*Starter* Write the words 'protons', 'neutrons' and 'mass number' on the board. Ask students to work in pairs to write a sentence connecting all three words. *Exploring* Ask students to make models of atomic nuclei. They could use polystyrene balls, which they colour and stick together to make atomic nuclei, and then produce posters to show the names and neutron/proton configurations of their elements. *Explaining* Show students the notation for isotopes of Be, B, C and N, their mass and atomic number, and ask them to sketch diagrams for each.	*Exploring* Support: Tell students that they will be making models of simple atoms such as lithium-6 or lithium-7 and tell them how many protons and neutrons they need for each nucleus. Stretch: Ask students to make models of at least two nuclei, which should be isotopes of the same element. *Explaining* Support: Work through the first couple of examples with students. Stretch: Show students a copy of a periodic table that gives the mass number of copper as 63.5 and the mass number of chlorine as 35.5, and ask them to suggest reasons for this.	n/a	Build simple models of atomic nuclei. (See *Exploring*.)

Lesson CP6c: Electrons and orbits (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P6.7: Recall that in each atom its electrons orbit the nucleus at different set distances from the nucleus • P6.8: Explain that electrons change orbit when there is absorption or emission of electromagnetic radiation • P6.9: Explain how atoms may form positive ions by losing outer electrons • P6.17: Describe how and why the atomic model has changed over time including reference to the plum pudding model and Rutherford alpha particle scattering leading to the Bohr model	*Starter* Ask students to suggest what evidence there is that electrons are in different arrangements in the atoms of different elements. *Exploring* Create a set of cards for students to use to help them to summarise the material in this and the last two topics. The cards provide sentence halves which need to be matched up and then arranged in a suitable order to form a summary. *Explaining* Show students some examples of fluorescence or phosphorescence, such as glow in the dark paint, security markings on banknotes, or some of the materials suggested in the equipment list. Ask students to work in pairs to write a few sentences to describe what is happening in one or two of the examples shown.	*Explaining* Support: Help students to write their sentences by using questioning. Stretch: Ask students to find out about three examples of fluorescence in nature, and write a couple of sentences about each one.	• Visualise and represent 2D and 3D forms including two dimensional representations of 3D objects	n/a

Lesson CP6d: Background radiation (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P6.12: Explain what is meant by background radiation • P6.13: Describe the origins of background radiation from Earth and space • P6.14: Describe methods for measuring and detecting radioactivity limited to photographic film and a Geiger–Müller tube	*Starter* Show students before and after videos of background noise from the Prelinger Archives. Ask students what differences there are. *Exploring* Provide students with a diagram of a GM tube and a set of labels and statements for students to sort and sequence to explain how it works. *Explaining* Demonstrate an analogy for a GM tube, e.g. using a beaker full of distilled water with two electrodes, a lamp and power supply. Demonstrate that the bulb does not light up when the electrodes are in distilled water. Add a spatula of salt to the water and show that the bulb lights.	*Exploring* Support: Remind students of the units (counts per minute) and emphasise that even with an 'object' there is still a background count. Stretch: Ask students what the advantage of taking an average is and why it is best to measure counts over as long a time period as possible. *Explaining* Support: Reinforce the idea that adding salt produced ions which allowed a current to flow. Stretch: Ask students to write a short paragraph evaluating the demonstration as a model of how a GM tube works.	n/a	Demonstrate how a GM tube works via an analogous set-up. (See *Explaining*.)

Lesson CP6e: Types of radiation (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P6.5: Recall the relative masses and relative electric charges of protons, neutrons, electrons and positrons • P6.15: Recall that an alpha particle is equivalent to a helium nucleus, a beta particle is an electron emitted from the nucleus and a gamma ray is electromagnetic radiation • P6.16: Compare alpha, beta and gamma radiations in terms of their abilities to penetrate and ionise • P6.10: Recall that alpha, β− (beta minus), β+ (positron), gamma rays and neutron radiation are emitted from unstable nuclei in a random process • P6.11: Recall that alpha, β− (beta minus), β+ (positron) and gamma rays are ionising radiations	*Starter* Revise the nature of protons, neutrons and electrons by asking students to work in pairs to write down three facts about each of these three particles. *Exploring* Students should research how a radiation badge works. They should make an A4 poster summarising their findings, with an emphasis on the penetration properties of the three types of radiation. *Explaining* Use a Geiger–Müller tube and alpha, beta and gamma sources to demonstrate how they can be blocked by different materials. Alternatively, you can show students a video clip that explores what materials the three types of radiation are blocked by.	*Exploring* Support: Provide students with three pieces of plastic of different thicknesses and ask them to suggest how these would affect the amount of radiation penetrating each one to reach a detector. Stretch: Ask students to list the potential advantages of an electronic dosimeter where data could be recorded on a memory card. *Explaining* Support: Ask students to identify the material that is the 'most useful' for stopping radiation and to justify their answer using evidence from the demonstration. Stretch: Ask students why the clicks they can hear from the count rate are not 'smooth'.	n/a	Demonstrate how alpha, beta and gamma radiation can be blocked by different materials. (See *Explaining*.)

Lesson CP6f: Radioactive decay (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P6.18: Describe the process of β^- decay (a neutron becomes a proton plus an electron) • P6.19: Describe the process of β^+ decay (a proton becomes a neutron plus a positron) • P6.20: Explain the effects on the atomic (proton) number and mass (nucleon) number of radioactive decays (α, β, γ and neutron emission) • P6.21: Recall that nuclei that have undergone radioactive decay often undergo nuclear rearrangement with a loss of energy as gamma radiation • P6.22: Use given data to balance nuclear equations in terms of mass and charge	*Starter* Hold a quick-fire question session naming a property of alpha or beta particles, and have students say which particle(s) it applies to. *Exploring* Tell students that there is a radioactive form of carbon (carbon-14) that is used to date old artefacts that include organic matter. Ask them to make a series of models to illustrate the beta-decay of carbon-13, or to draw a cartoon showing what happens. Students could also be asked to model alpha decay in a similar way. *Explaining* Show students the symbols used in nuclear equations and how to balance them. Worked through some examples to model the process of balancing equations.	*Explaining* Stretch: Tell students that naturally occurring uranium-235 is the beginning of a 'decay' chain, where the product of a decay is itself radioactive and decays to form yet another element. Tell them that the first five decays are: α, β^-, α, β^{--}, α. Ask them to write nuclear equations for each of these decays, using the periodic table on the skills sheet to work out what the subsequent elements are.	• Recognise and use expressions in standard form • Use ratios, fractions and percentages • Substitute numerical values into algebraic equations using appropriate units for physical quantities	n/a

Lesson CP6g: Half-life (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P6.23: Describe how the activity of a radioactive source decreases over a period of time • P6.24: Recall that the unit of activity of a radioactive isotope is the Becquerel, Bq • P6.25: Explain that the half-life of a radioactive isotope is the time taken for half the undecayed nuclei to decay or the activity of a source to decay by half • P6.26: Explain that it cannot be predicted when a particular nucleus will decay but half-life enables the activity of a very large number of nuclei to be predicted during the decay process • P6.27: Use the concept of half-life to carry out simple calculations on the decay of a radioactive isotope, including graphical representations	*Starter* Ask all students to stand up. Then ask a series of questions that is likely to apply to only half those standing. Only the students who the question applies to remain standing. Plot the number of students standing at the beginning and then after each question on a graph. Explain to students that this is a model for radioactive decay. (*Suggested practical*.) Exploring Model radioactive decay using sets of cubes with 3 marked sides. Roll 50 cubes repeatedly, each time removing ones with the marked face uppermost, until they have no cubes left. Students repeat this, and then repeat it with 100 cubes. (*Suggested practical*.) *Explaining* Demonstrate radioactive decay using a commercially available protactinium generator. The GM tube should be connected to a datalogger, as otherwise taking enough readings to calculate half-life from a graph requires some planning.	*Exploring* Support: Help students to plot their graphs and work out the fraction of cubes remaining. Stretch: Ask students to suggest what would be different about their results if each cube had two marked faces, and what this change to the model would represent in real life. *Explaining* Support: Ask students to describe the main features of the decay curve produced from the demonstration – mark off values for the starting count rate and for half of the starting count rate and mark the time taken for the count rate to halve. Stretch: Ask students why the graph produced by a datalogger is not a smooth curve, and how you could make the calculations of half-life more reproducible.	• Use ratios, fractions and percentages • Make estimates of the results of simple calculations • Use a scatter diagram to identify a correlation between two variables	*Suggested practical:* Investigate models which simulate radioactive decay. (See *Starter* and *Exploring*.) Demonstrate radioactive decay using a protactinium generator. (See *Explaining*.)

Lesson CP6h: Dangers of radioactivity (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P6.29: Describe the dangers of ionising radiation in terms of tissue damage and possible mutations and relate this to the precautions needed • P6.31: Explain the precautions taken to ensure the safety of people exposed to radiation, including limiting the dose for patients and the risks to medical personnel • P6.32: Describe the differences between contamination and irradiation effects and compare the hazards associated with these two	*Starter* Tell students that some people have to work with radioactive sources. Ask half the class to write down one safety precaution, and the other half of the class to write down one way of stopping ionising radiation reaching someone. Try to match up at least three precautions with their explanations as to why they would work. *Exploring* Create a set of cards which show examples of 'bad' and 'good' practice. Students match up pairs of cards that show a safe and unsafe way of doing something, then ask them to write their own explanations for the precautions. *Explaining* Show a video of some of the precautions taken in hospitals to reduce any potential harm to users and patients from radioactive sources.	*Exploring* Stretch: Ask students to write a set of bullet points to be made into a poster for the wall of a science lab, describing and explaining the precautions that should be taken. *Explaining* Support: Summarise the safety precautions as ways of minimising exposure, and check that students understand the difference between irradiation and contamination. Stretch: Ask students to explain why using a GM tube near the surface of soil may not give a reliable indication of whether the soil has been contaminated.	n/a	n/a

P7 Energy – forces doing work				
Lesson CP7a Work and power (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P8.4: Identify the different ways that the energy of a system can be changed a) through work done by forces b) in electrical equipment c) in heating • P8.5: Describe how to measure the work done by a force and understand that energy transferred (joule, J) is equal to work done (joule, J) • *P8.6: Recall and use the equation: • work done (joule, J) = force (newton, N) × distance moved in the direction of the force (metre, m) • $E = F \times d$ • *P8.7: Describe and calculate the changes in energy involved when a system is changed by work done by forces • P8.12: Define power as the rate at which energy is transferred and use examples to explain this definition • P8.13: Recall and use the equation: • power (watt, W) = work done (joule, J) ÷ time taken (second, s) • $P = E/T$ • P8.14: Recall that one watt is equal to one joule per second, J/s • P9.10 Explain ways of reducing unwanted energy transfer through lubrication	*Starter* Ask students, in small groups, to write down any equations or definitions they already know for forces and/or energy, and their units. The groups should classify their ideas into 'definitely correct' and 'hopefully correct but we're not 100% certain'. *Exploring* In this experiment, students calculate their own work done and power in a simple timed lifting exercise. Students lift the object and return it to the floor 20 times, to allow a reasonable period for timing purposes. *Explaining* Fasten a small electric motor to the edge of the bench so that its shaft sticks over the edge. Fasten string with hanging masses on the end to the shaft so that the string winds around the shaft when the motor runs. Show the motor lifting a mass, and ask students what they need to measure to calculate the power of the motor. Ask for a couple of volunteers to take these measurements, and then work through the calculations with the class. Change the setting on the power supply and ask students to calculate the power of the motor when a higher or lower voltage supply is used.	*Exploring* Support: Take students needing more support through the calculations one by one. Stretch: Ask students to explain why the instructions ask them to time how long it takes for 20 lifts. *Explaining* Support: Start by asking students how to calculate the work done in lifting the weight, and calculate that before asking how to use the work done to calculate the power. Stretch: Ask students to explain why the power supplied to the motor is greater than the power calculated using measurements of the time taken to lift the masses a certain distance.	• Make estimates of the results of simple calculations • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations • Understand the physical significance of area between a curve and the *x*-axis and measure it by counting squares as appropriate	*Suggested practical:* Investigate work and power by running up the stairs or lifting objects of different weights.

P8 Forces and their effects				
Lesson CP8a Objects affecting each other (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *P9.1: Describe, with examples, how objects can interact a) at a distance without contact, linking these to the gravitational, electrostatic and magnetic fields involved b) by contact, including normal contact force and friction c) producing pairs of forces which can be represented as vectors • P9.2: Explain the difference between vector and scalar quantities using examples • P9.10: Explain ways of reducing unwanted energy transfer through lubrication	*Starter* Write some of the key words for this topic on the board (e.g. force field, electrostatic, magnetism, vector) and ask students to work in groups to write glossary entries for them. Discuss any misconceptions. *Exploring* Set up a circus of simple demonstrations of the effects of force fields. *Explaining* Carry out simple demonstrations with a Van de Graaff generator to illustrate some effects of an electric field.	*Exploring* Support: Show students how to suspend magnets or rods in the paper stirrups provided. Allow students to do all the practicals, then discuss the questions with them and help them to formulate verbal answers. Stretch: Ask students to sketch the shape of the gravitational field around the Earth and of the electric field around a charge of static electricity. *Explaining* Support: Emphasise that like charges repel, to explain the effects demonstrated. Stretch: Ask students to draw a diagram to show the electric field around the dome in the final demonstration with the motor running faster.	n/a	n/a

Lesson CP8b Vector diagrams (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **P9.3: Use vector diagrams to illustrate resolution of forces, a net force, and equilibrium situations (scale drawings only)** • **P9.4: Draw and use free body force diagrams** • **P9.5: Explain examples of the forces acting on an isolated solid object or a system where several forces lead to a resultant force on an object and the special case of balanced forces when the resultant force is zero**	*Starter* Show examples of aeroplanes landing in strong cross-winds, ideally clips taken from the end of the runway so it is clear that the aeroplane is not pointing along the runway as it lands. Ask how the landing would look different if the wind was a different strength. *Exploring* In this activity, students link three force meters with string and pull on them in different directions, noting the forces and angles when the forces produce a zero net force. This is a way of introducing the idea of scale drawings to find a resultant. *Explaining* Provide example questions so that students can practice vector diagrams. Build up the diagrams step by step on the board to explain the processes involved.	*Exploring* Support: Show students how to use a ruler and set square to draw parallel lines. Some students may need help working out a suitable scale for their scale drawings. Stretch: Groups could repeat the exercise using four force meters linked together. They can find the overall resultant by finding the resultants of two pairs of forces before showing that the overall resultant is zero. *Explaining* Stretch: Tie a piece of string between two clamp stands and hang a small mass in the middle so that the string makes a V shape. Ask students to explain, using diagrams if they wish, why the force in each side of the string is greater than half the weight of the hanging mass.	• Translate information between graphical and numeric form • Use angular measures in degrees • Visualise and represent 2D and 3D forms, including two dimensional representatio ns of 3D objects	*Suggested practical:* Use scale drawings to work out the resultant of forces at different angles (see *Exploring*)

P9 Electricity and circuits				
Lesson CP9a: Electric circuits (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P10.1: Describe the structure of the atom, limited to the position, mass and charge of protons, neutrons and electrons • *P10.2: Draw and use electric circuit diagrams representing them with the conventions of positive and negative terminals, and the symbols that represent cells, including batteries, switches, voltmeters, ammeters, resistors, variable resistors, lamps, motors, diodes, thermistors, LDRs and LEDs • P10.3: Describe the differences between series and parallel circuits	*Starter* Give students a torch bulb (not in a holder), one piece of wire and a cell that is not in a holder, and challenge them to make the bulb light up. *Exploring* Students investigate the different brightness of lamps in series and parallel circuits, as a reminder of the differences between series and parallel circuits. Afterwards, they can experiment with placing the switch at different points in the circuit. *Explaining* Demonstrate different series and parallel circuits asking students to predict the brightness of bulbs and whether they will light up at all, before switching them on to confirm. This is a good opportunity to add a large number of cells and lamps to show a real difference in brightness.	*Exploring* Support: Remind students of what series (e.g. TV series) and parallel (e.g. Programs at the same time on different channels) mean… Stretch: Give students two-way switches to investigate. Challenge them to wire up a circuit in which the two switches can both switch one lamp on and off. *Explaining* Support: Demonstrate real circuits where possible, such as lamps in the classroom or school hall, if you have switches that switch rows off independently. Stretch: Ask students to predict what will happen each time they make a change to a circuit, before they switch it on, and also to explain their prediction.	• Visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects	*Suggested practical*: Complete a circuit with only one wire (see *Starter*) *Suggested practical*: Investigate the different brightness of lamps in series and parallel circuits (see *Exploring*)

Lesson CP9b: Current and potential difference (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *P10.4: Recall that a voltmeter is connected in parallel with a component to measure the potential difference (voltage), in volts, across it • *P10.7: Recall that an ammeter is connected in series with a component to measure the current, in amps, in the component • P10.10: Describe that when a closed circuit includes a source of potential difference there will be a current in the circuit • P10.11:Recall that current is conserved at a junction in a circuit	*Starter* Show students how to use a voltmeter to measure the voltage of a cell. Explain the concept of potential difference using a ramp and a ball (i.e. g.p.e. needs to be different at each end of the ramp for the ball to roll & the greater the difference, the faster the ball rolls). *Exploring* Students set up a toy marble run to visualise how current flows in a circuit. Students should decide what the marbles, tubes, paddle wheel and person lifting the marbles represent. What's wrong the model? (i.e. when marbles are no longer lifted, they end up at the bottom). A central heating system is another useful model. *Explaining* Explain that a neon or compact fluorescent tube requires a potential difference across its ends in order to illuminate. Demonstrate this using an electric circuit. Then use a Van de Graaff generator to show that a potential difference causes current to flow. Hold the contacts of a neon bulb or fluorescent bulb near the dome and show the small flashes of light when sparks jump from the dome.	*Exploring* Support: Discuss the effect of increasing the height (making the balls travel faster) and compare this with increasing potential difference increasing the current. Stretch: Challenge students to think of ways the models fail, e.g. in the marble model marbles would fall out of a hole in the tube, whereas current does not flow out of a broken wire *Explaining* Support: Recap what is meant by potential difference before starting the demonstration. Stretch: Explain to students that charge collects on the dome of the Van de Graaff generator, and that it is discharged by the charges flowing through anything that comes close to it. Ask students to think what is happening to make the tube light up.	• Visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects	n/a

Lesson CP9c: Current, charge and energy (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P10.5: Explain that potential difference (voltage) is the energy transferred per unit charge passed and hence that the volt is a joule per coulomb • P10.6: Recall and use the equation: • energy transferred (joule, J) = charge moved (coulomb, C) × potential difference (volt, V) • $E = Q \times V$ • P10.8: Explain that an electric current as the rate of flow of charge and the current in metals is a flow of electrons • P10.9: Recall and use the equation: • charge (coulomb, C) = current (ampere, A) × time (second, s) • $Q = I \times t$	*Starter* Show an electrical circuit set up with a battery, a switch and a lamp, and another circuit with a battery, a switch and a motor. Remind students of the energy model, in which we talk about energy stores and transfers (or pathways). Students should work in groups or pairs to decide how the energy is stored at the start, before the circuit is switched on, and how it is stored at the end. *Exploring* One student is the 'cell' and moves a looped rope (2-3m) by pushing and pulling the two sides so that the loop moves around the group. The others hold it lightly so that as the rope slips through their hands, the friction makes their hands warmer. These students represent the components, which transfer energy by heating. (There may be intermediate transfers, e.g. for lamps, by lighting.) *Explaining* Set students questions that involve using equations for charge (i.e. Q=It, E=QV).	*Exploring* Support: Remind students about potential difference, which can be thought of as a 'push'. The rope is pushed in one direction and pulled in the other – in the same way that electrons are attracted to the positive terminal but also repelled from the negative terminal. Stretch: Ask students to think about the usefulness of the model and its limitations, and to write a paragraph evaluating the model. *Explaining* Support: Consider breaking this up and doing one equation in one lesson and the other in a subsequent lesson. Stretch: Tell students that mobile phone batteries are often given a capacity in milliampere hours (mAh). A 1000 mAh battery can theoretically give a current of 1000 mA for 1 hour, or 500 mA for 2 hours or 100 mA for 10 hours. Ask students to work out the theoretical amount of charge stored in their phones or in other common batteries.	• Use an appropriate number of significant figures • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	n/a

Lesson CP9d: Resistance (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P10.12: Explain how changing the resistance in a circuit changes the current and how this can be achieved using a variable resistor • *P10.13: Recall and use the equation: • potential difference (volt, V) = current (ampere, A) × resistance (ohm, Ω) • $V = I \times R$ • P10.14: Explain why, if two resistors are in series, the net resistance is increased, whereas with two in parallel the net resistance is decreased • *P10.15: Calculate the currents, potential differences and resistances in series circuits • P10.16: Explain the design and construction of series circuits for testing and measuring	*Starter* Give students a sheet of A4 paper and ask them to draw on the left-hand side all the circuit symbols they can remember and the names of the relevant components on the right-hand side. Go through a master list on the board, and encourage students to amend or add to their answers as necessary. *Exploring* Students investigate fixed resistors by building a simple circuit with a resistor connected to a power supply, a voltmeter across the resistor and an ammeter in series. They change the potential difference in even steps and record the current, and then again for a 2nd resistor. They use $V = I \times R$ for each resistor to calculate the resistance and verify that their value of R corresponds to the given value. Elicit that the higher the resistance the lower the current. The same is true for potential difference. *Explaining* Demonstrate series and parallel circuits, calculating the resistance of resistors in series and parallel. Consider traffic flow as a model of resistance.	*Exploring* Support: Ask students to look at the circuit diagram and tell you how they will connect the components before they build the circuit. Stretch: Give students a resistor, or resistors, with unknown resistance, and ask them to find out their resistance. If students plot V against I the gradient will give the resistance. *Explaining* Support: Consolidate the idea of resistances in series adding together; by measuring and adding a third resistor in series. Stretch: Students do not need to calculate the total resistance of resistors in parallel, but explain that it is possible to do this for two resistors.	• Recognise and use expressions in decimal form. • Use an appropriate number of significant figures. • Understand and use the symbols: =, <, <, >>, >, ☐, ~ • Substitute numerical values into algebraic equations using appropriate units for physical quantities. • Solve simple algebraic equations.	*Suggested practical*: Investigate fixed resistors

Lesson CP9e: More about resistance (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P10.18: Explain how current varies with potential difference for the following devices and how this relates to resistance a) filament lamps b) diodes c) fixed resistors • P10.19: Describe how the resistance of a light-dependent resistor (LDR) varies with light intensity • P10.20: Describe how the resistance of a thermistor varies with change of temperature (negative temperature coefficient thermistors only) • P10.21: Explain how the design and use of circuits can be used to explore the variation of resistance in the following devices a) filament lamps b) diodes c) thermistors d) LDRs • **P10.17: Core Practical: Construct electrical circuits to:* • *a) investigate the relationship between potential difference, current and resistance for a resistor and a filament lamp* • *b) test series and parallel circuits using resistors and filament lamps*	*Starter* Set up an alarm with a light-emitting diode (LED) or infrared LED to create a beam, and an LDR to detect when the beam is broken. This should then trigger an alarm. The circuit could be set up before the lesson so that students do not know it is there, and when they walk through the beam they set it off. *Exploring* Core practical: Investigating the relationship between potential difference, current and resistance for a resistor or filament lamp, and testing series and parallel circuits using resistors and filament lamps. *Explaining* Set up a demonstration with a thermistor and a temperature probe (connected to a suitable datalogger interface) in a beaker of water. Heat the water and display the graph of resistance against temperature on a computer. Discuss the fact that the resistance falls as the temperature rises. This may be counterintuitive as filament lamps and hot wires have increased resistance.	*Exploring* Support: Give students tables for students to record their results, and exemplify calculating resistance using P.D. and current. Stretch: Students carry out the practical with resistors as well as filament lamps. *Explaining* Support: To emphasise the fact that the resistance is changing, show the same experiments with a fixed resistor and show that the resistance does not change. Stretch: Explain that the thermistor is made of a material where electrons can move more easily when they have more thermal energy – so this lowers the resistance	• Recognise and use expressions in standard form. • Use a scatter diagram to identify a correlation between two variables. • Change the subject of an equation. • Substitute numerical values into algebraic equations using appropriate units for physical quantities. • Translate information between graphical and numeric form. • Plot two variables from experimental or other data. • Determine the slope and intercept of a linear graph	*Core Practical: Construct electrical circuits to:* *a) investigate the relationship between potential difference, current and resistance for a resistor and a filament lamp* *b) test series and parallel circuits using resistors and filament lamps*

Lesson CP9f: Transferring energy (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P10.22: Recall that, when there is an electric current in a resistor, there is an energy transfer which heats the resistor • P10.23: Explain that electrical energy is dissipated as thermal energy in the surroundings when an electrical current does work against electrical resistance • P10.24: Explain the energy transfer (in 10.22 above) as the result of collisions between electrons and the ions in the lattice • P20.25: Explain ways of reducing unwanted energy transfer through low resistance wires • P10.26: Describe the advantages and disadvantages of the heating effect of an electric current • P10.27: Use the equation: • energy transferred (joule, J) = current (ampere, A) × potential difference (volt, V) × time (second, s) • $E = I \times V \times t$	*Starter* Demonstrate the transfer of energy using wire wool. *Exploring* Students work in small groups to think of electrical appliances that make use of the heating effect of current. To encourage them to focus, ask them to describe the useful heating effect that the appliance is producing and think about how this could be done without electricity. *Explaining* An effective demonstration can be done in the school hall or outside if students stand with their backs to some other students holding basketballs. The students roll the basketballs through the standing students and then repeat when the students are moving from side to side. Count the number of basketballs that get through each time. Ask students to think about why wires, filament lamps and resistors have resistance to electric current passing through them. Draw together their ideas and elicit the model of a lattice of positive ions with electrons moving through the lattice.	*Exploring* Support: You may wish to limit the number of examples. Stretch: Ask students to think of their own examples for both advantages and disadvantages. *Explaining* Support: Add in further analogies for the electrons moving through a lattice. An example is trying to cross a crowded dance floor if everyone is standing still or dancing. Stretch: Consider the effect of cooling the wires (reducing the vibrations will reduce the resistance). Ask students to think of examples where wires are cooled; they may be interested to know that MRI machines in hospitals, for example, have large coils to provide the magnetic fields and that these have to be cooled or they would melt.	• Use an appropriate number of significant figures • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	n/a

Lesson CP9g: Power (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P10.28: Describe power as the energy transferred per second and recall that it is measured in watts • P10.29: Recall and use the equation: • power (watt, W) = energy transferred (joule, J) ÷ time taken (second, s) • $P = E/t$ • P10.30: Explain how the power transfer in any circuit device is related to the potential difference across it and the current in it • P10.31: Recall and use the equations: • electrical power (watt, W) = current (ampere, A) × potential difference (volt, V) • $P = I \times V$ • electrical power (watt, W) = current squared (ampere^2, A^2) × resistance (ohms, Ω) • $P = I^2 \times R$	*Starter* Students work in small groups to produce a list of all the electrical appliances they use during a normal day. Then ask them to rank them in order of how much energy they use. *Exploring* Set a number of different appliances around the room for students to examine the rating plates. Ask students to work in groups to discuss how long an item is likely to be switched on for and enter this in the table. They can then work out the typical energy use for each appliance. *Explaining* There are a number of equations that students must not only learn, but be able to select and use as appropriate. To help students, work through these slowly, making links between them. Introduce the idea of power being energy transfer per second, and show why this is relevant by using two appliances, one low power and one high. A good example would be a fast boil kettle and a travel kettle.	*Exploring* Support: Show students some power rating backing plates and point out the information they are looking for. Make sure students understand that power will be in W or kW and voltage/potential difference will be in V. Stretch: Introduce the idea of input power and output power. *Explaining* Support: Break the explanation into two parts. Stop after the $P = I \times V$, and resume after another activity, recapping and continuing to show $P = I \times (I \times R) = I^2 \times R$. Stretch: Challenge students to consider why overhead transmission lines are high voltage.	• Use an appropriate number of significant figures • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	*Suggested practical:* Investigate the power consumption of low-voltage electrical items.

Lesson CP9h: Transferring energy by electricity (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P10.32: Describe how, in different domestic devices, energy is transferred from batteries and the a.c. mains to the energy of motors and heating devices • P10.33: Explain the difference between direct and alternating voltage • P10.34: Describe direct current (d.c.) as movement of charge in one direction only and recall that cells and batteries supply direct current (d.c.) • P10.35: Describe that in alternating current (a.c.) the movement of charge changes direction • P10.36: Recall that in the UK the domestic supply is a.c., at a frequency of 50 Hz and a voltage of about 230 V • P10.42: Describe, with examples, the relationship between the power ratings for domestic electrical appliances and the changes in stored energy when they are in use	*Starter* Ask students to work in groups to develop bullet points about 'How electricity is generated in the UK'. This should also revise some concepts from CP3e and CP3f. Ask students to include the following terms: mains electricity, national grid, alternating current. *Exploring* Students work in pairs or groups to decide if a series of graphs showing current plotted against time show d.c. or a.c. *Explaining* Use an oscilloscope to demonstrate a.c. and d.c. voltages.	*Exploring* Support: Revise the meaning of the term frequency in more detail, going through a couple of examples, before looking at the graphs Stretch: Ask students to draw some of their own examples. *Explaining* Support: To explain the oscilloscope trace ask students to help you to draw a distance time graph with positive distance from a point in one direction and negative in the other (i.e. a displacement time graph). Stretch: Use the scale of the time base together with the length of one cycle to work out the period of the oscillation (wave) and then 1 ÷ period to work out the frequency of the oscillation that is displayed and show that it is 50 Hz.	• Construct and interpret frequency tables and diagrams, bar charts and histograms	n/a

Lesson CP9i: Electrical safety (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P10.37: Explain the difference in function between the live and the neutral mains input wires • P10.38: Explain the function of an earth wire and of fuses or circuit breakers in ensuring safety • P10.39: Explain why switches and fuses should be connected in the live wire of a domestic circuit • P10.40: Recall the potential differences between the live, neutral and earth mains wires • P10.41: Explain the dangers of providing any connection between the live wire and earth	*Starter* Show students a standard three-pin plug and ask them to make a drawing and label the parts, along with their functions. They can then come back to their drawings as part of a plenary and add to/correct their drawings. *Exploring* Students measure the current that blows different thicknesses of fuse wire and see if thickness affects fuse rating. Worksheet CP9i.1 *Blowing a fuse* gives instructions for students. Make sure students increase the current slowly and realise that they cannot read the ammeter when the fuse wire melts, they must keep watching to see what it is just before the wire melts. *Explaining* Go through a list of electrical faults, and discuss some of the hazards that they present, e.g. Fault: water getting into appliances. Hazard: Water could provide a low resistance conducting path for the electricity so that a user could get a shock (In March 2017 it was reported that a man was electrocuted when charging his phone in the bath). Then discuss ways in which the risk of harm from those hazards is reduced. Introduce the circuit breaker as a fast acting switch that detects a change in current and switches off the electricity.	*Exploring* Support: Demonstrate the first experiment and then allow students to continue with the repeats and the other wires. Stretch: For each wire students can calculate the cross sectional area of the wire and compare this to the maximum current flow. *Explaining* Support: Build up a cartoon strip story with students working together as a group. Stretch: Elicit the idea that the current in the live and neutral wires should be the same. A residual current circuit breaker will detect a difference between the two of 30 mA and switch off the circuit.	• Find arithmetic means. • Change the subject of an equation. • Substitute numerical values into algebraic equations using appropriate units for physical quantities. • Solve simple algebraic equations.	*Suggested practical:* Investigate the current that blows different thicknesses of fuse wire and see if thickness affects fuse rating (see *Exploring*)

P10 Magnetism and the motor effect				
Lesson CP10a: Magnets and magnetic fields (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *P12.1: Recall that unlike magnetic poles attract and like magnetic poles repel • *P12.3: Explain the difference between permanent and induced magnets • P12.2: Describe the uses of permanent and temporary magnetic materials including cobalt, steel, iron and nickel • *P12.4: Describe the shape and direction of the magnetic field around bar magnets and for a uniform field, and relate the strength of the field to the concentration of lines • P12.5: Describe the use of plotting compasses to show the shape and direction of the field of a magnet and the Earth's magnetic field • *P12.6: Explain how the behaviour of a magnetic compass is related to evidence that the core of the Earth must be magnetic	*Starter* Elicit students' existing knowledge about magnets by having a bar magnet suspended in a paper stirrup from a clamp and stand and moving another bar magnet towards it. Also show how temporary magnets can be created using a magnet and paper clips. *Exploring* Students plot magnetic fields using plotting compasses. *Explaining* Use a magnaprobe to demonstrate the three-dimensional nature of the magnetic field around a bar magnet. Students could investigate the shape of the field for themselves if sufficient magnaprobes are available.	*Exploring* Support: Demonstrate the method to students before they attempt their own plotting. Using a web cam plugged into a whiteboard will allow a group of students to see the procedure. Stretch: Students plot the field between two bar magnets, as described in the Extra Challenge section. *Explaining* Support: It may be helpful for such students to find a diagram on the internet to show the three dimensional field. Stretch: Ask students to predict what the magnaprobe will do before demonstrating.	• Visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects	*Suggested practical*: Investigating magnetic fields using plotting compasses (see *Exploring*)

Lesson CP10b: Electromagnetism (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P12.7: Describe how to show that a current can create a magnetic effect and relate the shape and direction of the magnetic field around a long straight conductor to the direction of the current • P12.8: Recall that the strength of the field depends on the size of the current and the distance from the long straight conductor • P12.9: Explain how inside a solenoid (an example of an electromagnet) the fields from individual coils a) add together to form a very strong almost uniform field along the centre of the solenoid b) cancel to give a weaker field outside the solenoid	*Starter* Demonstrate the effect discovered by Hans Christian Ørsted (1777-1851) in 1820. Ørsted was performing a demonstration and noticed that a nearby compass was deflected when the circuit he was using was switched on. *Exploring* Plan an investigation to determine the factors (current in a coil and/or number of turns of wired in a coil) that affect the strength of an electromagnet; including apparatus, measurements, preliminary tests, range/interval of readings, how to ensure fairness, precision and safety. *Explaining* Demonstrate the shape of the magnetic field around a wire using iron filings. Thread a length of insulated wire through a hole in a piece of stiff card. Hold the wire vertical and the card horizontal using clamps and a stand. Shake iron filings onto the card and tap it gently so that the pattern of lines can be seen.	*Exploring* Support: Discuss the method needed with students and help them to write their own plans. Stretch: Show students optional apparatus for measuring the strength of electromagnets and ask them to work out how to use it (e.g. electromagnet above a bar magnet on a measuring balance, electromagnet in a plastic bag above iron filings on a measuring balance). *Explaining* Support: Students need to recall only the main facts that the solenoid has a uniform field inside it and a weaker field outside it, because the fields around each part of the wire interact. Stretch: Ask students to write a short paragraph to explain the shape of the magnetic field of a solenoid	• Visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects	n/a

Lesson CP10c: Magnetic forces (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **P12.10: Recall that a current carrying conductor placed near a magnet experiences a force and that an equal and opposite force acts on the magnet** • **P12.11: Explain that magnetic forces are due to interactions between magnetic fields** • **P12.12: Recall and use Fleming's left-hand rule to represent the relative directions of the force, the current and the magnetic field for cases where they are mutually perpendicular** • **P12.13: Use the equation:** • **force on a conductor at right angles to a magnetic field carrying a current (newton, N) = magnetic flux density (tesla, T, or newton per amp metre, N/A m) × current (ampere, A) × length (metre, m)** $F = B \times I \times l$	*Starter* Demonstrate the motor effect using a horseshoe magnet (or two flat magnets in a steel yoke, ensuring opposite poles are facing each other) and a length of wire or strip of metal foil (the latter may be easier for students to see). *Exploring* Students construct a model electric motor using a standard motor kit. Once students have assembled their motors, encourage them to discuss how a motor works. *Explaining* Show students the way magnetic fields combine to produce a force. The Institute of Physics website has more details on the 'catapult magnetic field'.	*Exploring* Support: Provide students with the kit at least partially assembled, with the ends of the wires already stripped for them. Stretch: Ask students to write a short paragraph explaining how the motor works. *Explaining* Stretch: Ask students to write a short paragraph explaining the catapult effect.	• Recognise and use expressions in decimal form • Recognise and use expressions in standard form • Understand and use the symbols: =, <, <<, >>, >, ∝, ~ • Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations • Visualise and represent 2D and 3D forms, including two dimensional representations of 3D objects	*Suggested practical:* Construct an electric motor (see *Exploring*)

P11 Electromagnetic induction				
Lesson CP11a Transformers (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• **P13.2: Recall the factors that affect the size and direction of an induced potential difference, and describe how the magnetic field produced opposes the original charge** • **P13.5: Explain how an alternating current in one circuit can induce a current in another circuit in a transformer** • **P13.6: Recall that a transformer can change the size of an alternating voltage** • P13.8: Explain why, in the national grid, electrical energy is transferred at high voltages from power stations, and then transferred at lower voltages in each locality for domestic uses as it improves the efficiency by reducing heat loss in transmission lines • P13.9: Explain where and why step-up and step-down transformers are used in the transmission of electricity in the national grid	*Starter* Show students an electric toothbrush and its charger, or a mobile phone and charger that uses charging by induction. Ask students to work in groups for a few minutes to jot down any ideas about how it works. *Exploring* Create a card sort where students match the potential difference and current in the primary coil of a transformer to the combinations of potential difference and current that might exist in the secondary coil of each transformer (students will need to calculate the power transferred to the transformer). *Explaining* Use a demountable transformer (or two C-cores with a clip and insulated wire) to demonstrate various features of transformers. Students are not required to recall the relationship between the turns and voltage ratios, but the demonstration will give them a general understanding of what transformers do.	*Exploring* Support: Tell students which potential difference cards go with each transformer and show them how to divide the power they have calculated by the potential difference to find the current. *Explaining* Support: Students not entered for the Higher tier need only recall that a transformer is used to change the voltage of an a.c. supply, and use the power equation. They will not be asked to explain how a transformer works. Stretch: Ask student to write a set of bullet points that summarises the key points about transformers.	• Recognise and use expressions in decimal form • Understand and use the symbols: =, <, <<, >>, >, ∝, ~ • Change the subject of an equation • Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations	*Suggested practical*: Investigate factors affecting the generation of electric current by induction.

Lesson CP11b: Transformers and energy (1 hour)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P13.10: Use the power equation (for transformers with 100% efficiency): potential difference across primary coil (volt, V) × current in primary coil (ampere, A) = potential difference across secondary coil (volt, V) × current in secondary coil (ampere, A) $V_p \times I_p = V_s \times I_s$	*Starter* Hold a short brainstorming session to elicit words connected with the transmission of electricity around the country (e.g. power station, pylon, cables, substation). Ask students to suggest what these things are for, and then to work in pairs or small groups to write a short paragraph to explain their ideas. *Exploring* Investigate the difference in energy transferred by a bulb connected to a power pack with different lengths of wire. Higher Tier: Investigate some of the factors that affect the generation of electric current by induction. *Explaining* Demonstrate the effect on transmission losses of increasing the voltage of a supply by using a 12 V a.c. supply connected to two metre-long lengths of resistance wire, with a bulb across the supply and another across the ends of the resistance wires. Then use a transformer to increase the voltage to 240V and discuss the brightness of the bulbs in the two demonstrations.	*Exploring* Support: Discuss how students can use the apparatus before they start planning. For example, there is no need to cut the wire, but different amounts of it can be wound onto the cardboard tube to investigate the effects of the number of turns in the coil. Stretch: Ask students to find a diagram of a bicycle dynamo or other device where a magnet spins relative to a coil (as opposed to the magnet being moved towards or away from the coil) and ask them to explain how this works. *Explaining* Stretch: Measure the current and voltage through each bulb in each part of the demonstration, and ask students to calculate the energy being transferred each second by each bulb by multiplying the current and voltage.	• Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations • Visualise and represent 2D and 3D forms, including two dimensional representatio ns of 3D objects	*Suggested practical*: Investigate the difference in energy transferred by a bulb connected to a power pack with different lengths of wire (see *Exploring*) *Suggested practical*: Investigate factors affecting the generation of electric current by induction (see *Exploring*)

P12 Particle model				
Lesson CP12a: Particles and density (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *P14.1: Use a simple kinetic theory model to explain the different states of matter (solids, liquids and gases) in terms of the movement and arrangement of particles • P14.5: Describe that when substances melt, freeze, evaporate, boil, condense or sublimate mass is conserved and that these physical changes differ from some chemical changes because the material recovers its original properties if the change is reversed • *P14.2: Recall and use the equation: • density (kilograms per cubic metre, kg/m^3) = mass (kilograms, kg) ÷ volume (cubic metres, m^3) • $\rho = m/V$ • *P14.4: Explain the differences in density between the different states of matter in terms of the arrangements of the atoms or molecules • *P14.3: Core practical: Investigate the densities of solid and liquids*	*Starter* Pour sand, sugar or salt from one beaker to another, and ask students to explain whether the substance is a solid or a liquid (as it can be poured and takes the shape of its container). *Exploring* Core practical: Investigate the densities of solids and liquids. *Explaining* Demonstrate sublimation by placing some iodine crystals in the bottom of a conical flask and placing a watch glass on the top. Heat gently using a Bunsen burner. Students should be able to see that the crystals have turned into purple vapour without becoming a liquid first. Crystals will form on the underside of the watch glass, demonstrating that the gas can turn back to a solid without first becoming a liquid.	*Exploring* Support: Ensure students know how to set balances to zero with a beaker on them. Some students may need help using the formula. Stretch: Ask students to find the density of expanded polystyrene, and ask them to suggest how they would go about trying to find the density of the polystyrene in it. *Explaining* Support: Write some key words and phrases on the board for students to use in their descriptions, such as fixed arrangement, vibrate, forces of attraction, close together, far apart, moving around. Stretch: Ask students to find out the names of two other substances that sublimate under everyday conditions.	• Substitute numerical values into algebraic equations using appropriate units for physical quantities • Translate information between graphical and numeric form • Plot two variables from experimental or other data	*Core practical: Investigate the densities of solid and liquids*

Lesson CP12b: Energy and changes of state (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P14.6: Explain how heating a system will change the energy stored within the system and raise its temperature or produce changes of state • P14.7: Define the terms specific heat capacity and specific latent heat and explain the differences between them	*Starter* Write word clouds (the jumbled up letters for a word) on the board for words connected with changes of state (melting, boiling, evaporating, condensing, freezing, subliming). Ask students to work in small groups to unscramble the letters and write a definition for each word *Exploring* Investigate how the temperature of ice changes as it melts. This practical can be extended by using other substances, e.g. fatty acids. *Explaining* Show students a model that helps to explain how land and sea breezes form. Heat a shallow tray of sand and one of water using heat lamps. Embed a probe from a digital thermometer in the sand, and place another below the surface of the water.	*Exploring* Support: Students do only the melting ice practical. They may need help with drawing the axes for their graph. Check they understand that the starting temperature of the ice should be recorded against time zero. Stretch: Students produce melting and cooling curves for two of the suggested substances in addition to the melting ice practical, and compare the results. *Explaining* Support: Tell students that the specific heat capacity of water is 4182 J/kg °C and that of sand is 830 J/kg °C. Ask them to explain what specific heat capacity means, to check their understanding, and also elicit their ideas of what the units means. Stretch: Ask students to write a paragraph summarising the demonstration and what it is modelling. Their explanations should include the term specific heat capacity.	• Translate information between graphic and numeric form. • Pot two variables from experimental or other data	*Suggested practical:* Investigate latent heat of vaporisation (see *Exploring*).

Lesson CP12c: Energy calculations (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P14.8: Use the equation: • change in thermal energy (joules, J) = mass (kilogram, kg) × specific heat capacity (joules per kilogram degree celsius, J/kg °C) × change in temperature (degree celsius, °C) • $\Delta Q = m \times c \times \Delta\theta$ • P14.9: Use the equation: • thermal energy for a change of state (joules, J) = mass (kilogram, kg) × specific latent heat (joules per kilogram, J/kg) • $Q = m \times L$ • P14.10 Explain ways of reducing unwanted energy transfer through thermal insulation • *P14.11: Core Practical: Investigate the properties of water by determining the specific heat capacity of water and obtaining a temperature-time graph for melting ice*	*Starter* Find a video or image of a lizard lifting its feet on hot sand (search using 'lizard hot sand'). Ask students to suggest why it is doing this. *Exploring* Core practical: Investigate the properties of water by determining the specific heat capacity of water and obtaining a temperature-time graph for melting ice. *Explaining* Set students questions that require the use of the following equations: change in thermal energy = mass x specific heat capacity x change in temperature, thermal energy needed for a change of state = mass x specific latent heat. For example, students could be asked to complete a table that shows information about heating a range of different substances.	*Exploring* Support: Students do only the practical to find the specific heat capacity of water. If a joulemeter is not available, help students to work out the energy transferred from the current, voltage and time Stretch: Provide students with some insulating material and ask them to repeat the measurements for one of the metal blocks, asking them to compare the values obtained with and without insulation and to explain the difference. *Explaining* Support: Demonstrate worked examples of any questions that involve changing the subject of the equations. Stretch: Provide more demanding exam-style questions or questions where there is an unfamiliar context to consider.	• Substitute numerical values into algebraic equations using appropriate units for physical quantities • Solve simple algebraic equations • Translate information between graphical and numeric form • Plot two variables from experimental or other data • Draw and use the slope of a tangent to a curve as a measure of rate of change	*Core Practical: Investigate the properties of water by determining the specific heat capacity of water and obtaining a temperature-time graph for melting ice* *Suggested practical:* Investigate latent heat of vaporisation.

Lesson CP12d: Gas temperature and pressure (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *P14.12: Explain the pressure of a gas in terms of the motion of its particles • *P14.13: Explain the effect of changing the temperature of a gas on the velocity of its particles and hence on the pressure produced by a fixed mass of gas at constant volume (qualitative only) • *P14.14: Describe the term absolute zero, −273 °C, in terms of the lack of movement of particles • *P14.15: Convert between the kelvin and Celsius scales	*Starter* Put hot water into a conical flask with a neck just smaller than the diameter of a cooked and peeled hard-boiled egg. Heat the flask until the water starts to boil. Remove the heat source and place the egg on the opening. As the water cools, the water vapour in the flask condenses and the egg should get sucked in to the flask. Ask students to suggest why this happens, in terms of the difference in air pressure between the inside and outside the flask *Exploring* Students measure the pressure of a fixed volume of gas at different temperatures and extrapolate their results to work out the temperature (in °C) of absolute zero. *Explaining* Show students a physical model representing the motion of particles and help them to relate this to the motion of particles in the different states of matter. The model can also be used to illustrate pressure increasing with temperature.	*Exploring* Support: Provide students with ready-drawn axes for plotting their graphs or help them to do the graph plotting using a spreadsheet program. Stretch: Ask students to work out the gradient of their line and to use the general equation for a straight line (y = mx + c) to calculate the value of absolute zero from their results. *Explaining* Support: Carry out this demonstration after reminding students about the kinetic theory of matter. Stretch: Point out to students that the number of balls per unit volume is less in the upper part of the tube than the lower. Ask them to explain how this illustrates that the temperature of a gas is represented by the mean speed of the particles.	• Recognise and use expressions in decimal form • Use an appropriate number of significant figures	*Suggested practical:* Investigate the temperature and volume relationship for a gas. *Suggested practical:* Investigate the volume and pressure relationship for a gas.

P13 Forces and matter				
Lesson CP13a: Bending and stretching (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• P15.1: Explain, using springs and other elastic objects, that stretching, bending or compressing an object requires more than one force • P15.2: Describe the difference between elastic and inelastic distortion • P15.5: Describe the difference between linear and non-linear relationships between force and extension	*Starter* Use a range of balls (e.g. a super ball or power ball, a tennis ball, a golf ball and a squash ball) all dropped from 1 metre onto a hard surface. Challenge students to explain why the balls bounce. Follow this up by dropping something inelastic such as sticky putty and ask them to note what happens to it. *Exploring* Students investigate the deformation of a tennis ball with different forces acting on it. *Explaining* Demonstrate the stretching of copper wire, to show students that it is not just springs and obviously 'springy' materials such as rubber bands that deform elastically.	*Exploring* Support: Demonstrate the method to students before they start, including how to calculate the mean height of the board supporting the masses. Stretch: Students could carry out a similar investigation with other balls, to investigate whether the relationship between the force on the ball and its change of shape is common to more than one type of ball. *Explaining* Support: Emphasise that a graph of force against extension would be the same shape for the wire as they have seen for a spring, including reaching a non-linear section after a certain load. Stretch: Ask students to describe the difference in the way forces are applied to the wire in this experiment relative to stretching a spring.	• Plot two variables from experimental or other data • Draw and use the slope of a tangent to a curve as a measure of rate of change	*Suggested practical*: Investigate the deformation of a tennis ball with different forces acting on it (see *Exploring*).

Lesson CP13b: Extension and energy transfers (2 hours)				
Specification points	**Exemplar teaching activities**	**Differentiation**	**Maths skills**	**Practicals**
• *P15.3: Recall and use the equation for linear elastic distortion including calculating the spring constant: • force exerted on a spring (newton, N) = spring constant (newton per metre, N/m) × extension (metres, m) $F = k \times x$ • *P15.4: Use the equation to calculate the work done in stretching a spring: • energy transferred in stretching (joules, J) = 0.5 × spring constant (newton per metre, N/m) × (extension (metres, m))^2 • $E = ½ \times k \times x^2$ • *P15.5: Describe the difference between linear and non-linear relationships between force and extension • *P15.6: Core Practical: Investigate the extension and work done when applying forces to a spring*	*Starter* Draw sketch graphs on the board that show linear and non-linear distortion and ask students to work in small groups to describe the relationships shown. Follow this up by drawing a graph showing force and extension of a spring and asking students to explain where the points would lie if the extension were measured again as the masses were removed from the bottom of the spring. *Exploring* Core Practical: Investigate the extension and work done when applying forces to a spring. *Explaining* Provide a set of results for an investigation into stretching springs. Students are asked to plot the results and calculate the spring constant of each spring by finding the gradient of the line on the graph.	*Exploring* Support: Help students to plot their graphs and work out the gradients of the lines. Remind them that a straight line on the graph shows a linear relationship and that a straight line that goes through the origin indicates a directly proportional relationship. Stretch: Ask students to work out the area under the graph for each of their springs, and compare the values to the calculated values of work done. Ask why this idea is useful if they need to find the work done in stretching a rubber band. *Explaining* Support: Help students to set up formulae to work out the extensions. Students may also need help to get the force plotted on the y-axis and extension on the x-axis.	• Substitute numerical values into algebraic equations using appropriate units for physical quantities • Understand that $y = mx + c$ represents a linear relationship • Plot two variables from experimental or other data • Draw and use the slope of a tangent to a curve as a measure of rate of change • Understand the physical significance of area between a curve and the *x*-axis and measure it by counting squares as appropriate	*Core Practical: Investigate the extension and work done when applying forces to a spring*

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