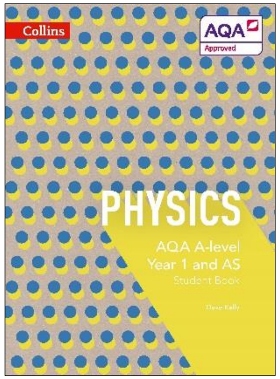
Collins

AQA A-level Physics Year 1 and AS

Scheme of Work



Scheme of Work
AQA A-level Physics Year 1 and AS

This course covers the requirements of the first year of the AQA AS and A-level Physics specification. These schemes of work are designed to accompany the use of Collins' AQA A-level Physics Year 1 and AS Student Book, and references to sections in that book are given for each lesson.

We have assumed that 120 one-hour lessons are taught during the year. Each lesson is matched to the Specification Content. Learning outcomes for each lesson are listed, as are the key Mathematical Skills, Practical Skills, and Apparatus and Techniques Skills that the lesson provides opportunities to practise. It is suggested in which lessons the six Required Practicals may be carried out, to help you plan for these and the sourcing of necessary equipment.

The schemes suggested are of course flexible, and editable, to correspond with your timetabling and to enable you to plan your own route through the course.

KEY

The codes in the 'skills covered' column refer to the skills in the AQA specification.
MS - Mathematical Skills
PS - Practical Skills
AT- Apparatus and Techniques Skills

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 1 – Measuring the Universe (8 hours)					
1 The scale of the Universe Students work with orders of magnitude and standard form to get a sense of the size of various objects in the Universe.	• Develop confidence with powers of 10 and standard form • Appreciate the scale of various objects in our Universe • Practise using prefixes	3.1.1 Fundamental (base) units Knowledge and use of the SI prefixes, values and standard form Students should be able to use the prefixes: T, G, M, k, c, m, μ, n, p, f 3.1.3 Orders of magnitude Estimation of approximate values of physical quantities	MS 0.1 Recognise and make use of appropriate units in calculations MS 0.2 Recognise and use expressions in decimal and standard form MS 1.4 Estimate approximate values of physical quantities to the nearest order of magnitude	1.2	
2 Making measurements Students make a range of measurements with a range of measuring devices.	• Take measurements using stopwatches, balances, micrometers, rulers and vernier callipers • Understand the meanings of random error, systematic error, precision and accuracy, and be able to identify examples of where each is relevant • Learn which are SI base or derived units	3.1.1 Use of mass, length, time, quantity of matter, temperature, electric current and their associated SI units SI units derived Knowledge and use of the SI prefixes, values and standard form Students should be able to convert between different units of the same quantity, e.g. J and eV, J and kW h 3.1.2 Random and systematic errors	PS 2.3 Identify random and systematic errors and suggest ways to reduce or remove them ATd Use stopwatch or light gates for timing ATe Use callipers and micrometers for small distances, using digital or vernier scales	1.2, 1.3	

		Precision, repeatability, reproducibility, resolution and accuracy			
3 Estimating the size of an atom from an oil drop Students carry out an experiment to estimate the size of an oil drop.	• Set up an experiment independently using given instructions • Interpret experimental results using prefixes, SI base units and scientific notation	3.1.3 Estimation of approximate values of physical quantities	MS 0.4 Estimate results PS 1.1 Solve problems set in practical contexts PS 3.2 Process and analyse data using appropriate mathematical skills	1.2	
4 How sure are we about our oil drop experiment? Students calculate the uncertainties in their experiment.	• Understand the difference between and significance of absolute, fractional and percentage uncertainties • Determine uncertainties in their own measurements and calculations	3.1.2 Uncertainty: Absolute, fractional and percentage uncertainties represent uncertainty in the final answer for a quantity	MS 1.1, MS 1.5 Understand the link between the number of significant figures in the value of a quantity and its associated uncertainty, and determine uncertainty when data are combined PS 3.3 Consider margins of error, accuracy and precision of data	1.3, 1.4	
5 Headlines on science and estimations Students learn how to critically review the science articles they read, and how to be confident that an answer is roughly what they estimated it to be.	• Comment on experimental design and evaluate scientific methods • Spot errors in the manipulation of uncertainties • Estimate approximate values of physical quantities to the nearest order of magnitude • Use estimates, together with their own knowledge of physics, to produce further derived estimates to the nearest order of magnitude	3.1.3 Estimation of approximate values of physical quantities	MS 1.4 Estimate approximate values of physical quantities to the nearest order of magnitude PS 2.1 Comment on experimental design and evaluate scientific methods	1.2, 1.3, 1.6	
6 What graph shall I plot and what does it mean?	• Plot two variables from experimental or other data		MS 3.2 Plot two variables from experimental or other data	1.5	

Students learn how to relate equations to analysing the properties of straight-line graphs.	• Understand that $y = mx + c$ represents a linear relationship • Determine the slope and intercept of a linear graph		MS 3.3 Understand that $y = mx + c$ represents a linear relationship MS 3.4 Determine the slope and intercept of a linear graph		
7 Planning for a density investigation Students bring together what they have learnt about errors to plan an accurate experiment.	• Understand the difference between random and systematic errors • Understand and use the terms 'precision', 'repeatability', 'reproducibility', 'resolution' and 'accuracy' • Design an investigation that incorporates these considerations	3.1.2 Random and systematic errors Precision, repeatability, reproducibility, resolution and accuracy	PS 1.2 Apply scientific knowledge to practical contexts PS 3.3 Consider margins of error, accuracy and precision of data	1.2	
8 Carrying out a density investigation and analysing the results Students practise more independently the theory they have learnt about analysing graphs and calculating uncertainties.	• Carry out an investigation they have planned • Apply what they have learnt about graphs and uncertainties to their own results	3.1.2 Random and systematic errors Precision, repeatability, reproducibility, resolution and accuracy Combination of absolute and percentage uncertainties Represent uncertainty in a data point on a graph using error bars Determine the uncertainties in the gradient and intercept of a straight-line graph Individual points on the graph may or may not have error bars	MS 1.5 Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are added, subtracted, multiplied, divided or raised to powers PS 3.1 Plot and interpret graphs PS 3.3 Consider margins of error, accuracy and precision of data	1.2, 1.4, 1.5	
One hour lessons	**Learning Outcomes**	**Specification Content**	**Skills Covered**	**Student Book Section**	**Required Practicals**
CHAPTER 2 – Inside the atom (8 hours)					

1 The discovery of the electron Students observe a demonstration of an electron tube, such as a Maltese cross tube.	• Describe Thomson's plum pudding model of the atom • Know the properties of the electron • Explain why acceptance of the discovery of the electron was so difficult for scientists in 1900 • Appreciate that our knowledge and understanding has developed over time through application of the scientific method	3.2.1.1 Simple model of the atom, including the proton, neutron and electron	PS 1.2 Apply scientific knowledge of the properties of electrons to the practical context of the Maltese cross tube	2.1	
2 The specific charge of the electron Students analyse data from a demonstration to calculate the specific charge on an electron.	• Explain what is meant by 'specific charge' • Describe how the electric force on a beam of moving electrons can be balanced by the magnetic force • Interpret an equation that describes this and substitute in experimental values • Estimate and comment on uncertainties in measurements	3.2.1.1 Specific charge of the electron	MS 1.5 Determine the uncertainty in a calculated value PS 3.2 Analyse data produced by the electron deflection tube demonstration PS 2.3 Evaluate results and draw conclusions with reference to measurement of uncertainties	2.1	
3 The nuclear model of the atom Students consider the implications of the nuclear model of the atom.	• Describe quantitatively the relative dimensions of the atom and its nucleus • Know that the charge and mass are concentrated in the nucleus • Appreciate how Ernest Rutherford concluded that the nucleus existed • Appreciate that our knowledge and understanding have developed through use of	3.2.1.1 Simple model of the atom, including the proton, neutron and electron	MS 0.4 Estimate the size of objects	2.2	

	theories, models and analysis of experimental results				
4 The strong nuclear force Students look at the properties of the strong nuclear force in relation to the electrostatic force.	• Explain why a strong force is needed in the nuclear model • Describe the way the force between two protons changes as they are brought closer together • Interpret force–distance graphs for the nuclear and electrostatic forces in relation to nucleon separation	3.2.1.2 The strong nuclear force; its role in keeping the nucleus stable; short-range attraction up to approximately 3 fm, very-short-range repulsion closer than approximately 0.5 fm	MS 0.1 Recognise and use unit prefixes for small and large distance measurements PS 3.1 Interpret the graph depicting the range and sign of the strong nuclear force compared to the electrostatic force	2.3	
5 The neutron and isotopes The discovery of the neutron and ways to represent the properties of nucleons are considered.	• Understand the reasons for the late discovery of the neutron • Know what is meant by an isotope • Interpret and use standard nuclide notation $^{A}_{Z}X$	3.2.1.1 Simple model of the atom, including the proton, neutron and electron Charge and mass of the proton, neutron and electron in SI units and relative units Specific charge of the proton and the electron, and of nuclei and ions Proton number *Z*, nucleon number *A*, nuclide notation Students should be familiar with the $^{A}_{Z}X$ notation Meaning of isotopes and the use of isotopic data		2.3	
6 Radioactivity, alpha particles and detectors Students see demonstrations of how radioactivity can be detected.	• Explain that radioactivity is a result of the decay of unstable nuclei • Understand that unstable nuclei may emit alpha particles, producing nuclei of greater stability	3.2.1.2 Unstable nuclei; alpha and beta decay	ATl Demonstration of the range of alpha particles using a cloud chamber, spark counter or Geiger counter	2.4	

	• Know the meaning of ionisation • Understand that detectors of radioactivity detect the ionisation it causes, and know how an electroscope works				
7 Equations for alpha, beta and gamma decay Students learn the need for charge to be conserved in decays.	• Use isotopic data • Construct balanced nuclear decay equations using the $^{A}_{Z}X$ notation • Understand how society makes decisions about scientific issues	3.2.1.2 Equations for alpha decay, β^- decay		2.5	
8 Fundamental interactions Students compare the properties of the four fundamental forces.	• Describe the four fundamental interactions • Appreciate the attempt to unify the forces of nature, from a historical and a future perspective • Relate the four interactions to the way in which matter behaves	3.2.1.4 Four fundamental interactions: gravity, electromagnetic, weak nuclear, strong nuclear		2.5	

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 3 – Antimatter and neutrinos (5 hours)					
1 Why is there matter in the Universe? Students are introduced to the concept of antiparticles and their properties.	• Understand that, for every type of particle, there is a corresponding antiparticle • Compare particle and antiparticle masses, charge and rest energy in MeV • Know that the positron, antiproton, antineutron and antineutrino are the antiparticles of the electron, proton, neutron and neutrino, respectively • Understand that matter and antimatter should be present in equal quantities according to the Big Bang theory, so the imbalance in our Universe is a mystery	3.2.1.3 For every type of particle, there is a corresponding antiparticle Comparison of particle and antiparticle masses, charge and rest energy in MeV Students should know that the positron, antiproton, antineutron and antineutrino are the antiparticles of the electron, proton, neutron and neutrino, respectively		3.1, 3.2	
2 What is a neutrino? Students are introduced to this particle and its properties in the context of the history of its discovery.	• Understand the need for neutrinos in the theory of beta decay using the idea of the conservation of energy • Understand how neutrinos are detected and how they may point to an answer about the matter–antimatter imbalance in the Universe • Appreciate that this as an example of theory coming before experimental confirmation	3.2.1.2 The existence of the neutrino was hypothesised to account for the conservation of energy in beta decay		3.5	

3 Annihilation, pair production and light as a particle Students are expected to calculate photon energies produced and required in annihilation and pair production.	• Understand the photon model of electromagnetic radiation, including the use of the Planck constant and the formula relating the energy of a photon to its wavelength: $E = hf = \frac{hc}{\lambda}$ • Know about the processes of annihilation and pair production and the energies involved • Determine the frequency and wavelength of the two gamma photons produced when a 'slow' electron and a 'slow' positron annihilate each other • Consider and research the application of matter–antimatter annihilation in positron emission tomography	3.2.1.3 Photon model of electromagnetic radiation, the Planck constant $E = hf = \frac{hc}{\lambda}$ Knowledge of annihilation and pair production and the energies involved The use of $E = mc^2$ is not required for calculations	MS 0.1 Convert between different units and prefixes MS 2.2 Change the subject of an equation	3.3, 3.4	
4 The particle zoo (part 1) Leptons and their properties are introduced as a group of fundamental particles.	• Know that leptons include: electron, muon, neutrino (electron and muon types only) and their antiparticles • Know that muons decay into electrons • Know that leptons are subject to the weak interaction	3.2.1.5 Leptons are subject to the weak interaction Leptons: electron, muon, neutrino (electron and muon types only) and their antiparticles The muon as a particle that decays into an electron		3.6	
5 Funding CERN Students research and debate the funding of high-energy particle physics.	• Engage with a debate about funding scientific research, in particular applied to CERN • Research specific examples to build up evidence for an argument			3.6	

	• Communicate ideas and listen to others' ideas				

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 4 – The standard model (6 hours)					
1 The particle zoo (part 2) The properties of hadrons are covered here, including the concept of strangeness.	• Know that hadrons are subject to the strong interaction and that there are two classes: baryons and mesons • Assign baryons and antibaryons with a baryon number as a quantum number • Understand lepton number as a quantum number • Understand strangeness as a quantum number	3.2.1.5 Hadrons are subject to the strong interaction The two classes of hadrons: • baryons (proton, neutron) and antibaryons (antiproton and antineutron) • mesons (pion, kaon) Baryon number as a quantum number The proton is the only stable baryon into which other baryons eventually decay The kaon as a particle that can decay into pions Lepton number as a quantum number Strange particles Strangeness (symbol *S*) as a quantum number		4.1	

2 Which particle will interact with which others? Hadron interactions and the conservation laws are introduced and applied	• Know that baryon number has to be conserved in all particle interactions, and strangeness has to be conserved in strong interactions • Know that strange particles are produced through the strong interaction and decay through the weak interaction • Understand that strangeness conservation means strange particles are always created in pairs • Know that strangeness can change by 0, +1 or −1 in weak interactions	3.2.1.5 Conservation of baryon number Strange particles as particles that are produced through the strong interaction and decay through the weak interaction (e.g. kaons) Strangeness (symbol *S*) as a quantum number to reflect the fact that strange particles are always created in pairs Conservation of strangeness in strong interactions Strangeness can change by 0, +1 or −1 in weak interactions 3.2.1.7 Application of the conservation laws for charge, baryon number and strangeness to particle interactions. The necessary data will be provided in questions for particles outside those specified Students should recognise that energy and momentum are conserved in interactions		4.2	
3 Looking at more particle interactions Lepton number conservation is applied in determining whether an interaction is allowed, as well as hadron conservation laws.	• Know that lepton number has to be conserved separately for muon leptons and for electron leptons	3.2.1.5 Conservation of lepton number for muon leptons and for electron leptons 3.2.1.7 Application of the conservation laws for charge, baryon number, lepton number and strangeness to particle interactions. The necessary data will be provided in questions for particles outside those specified		4.2, 4.3	

		Students should recognise that energy and momentum are conserved in interactions			
4 What are the smallest building blocks of the Universe? Quarks and their properties are introduced.	• Know the properties of up (u), down (d) and strange (s) quarks and antiquarks: charge, baryon number and strangeness • Know the combinations of quarks and antiquarks required for baryons (proton and neutron only), antibaryons (antiproton and antineutron only) and mesons (pion and kaon only) • Understand the nature of neutron decay in terms of change of quark flavour	3.2.1.6 Properties of quarks and antiquarks: charge, baryon number and strangeness Combinations of quarks and antiquarks required for baryons (proton and neutron only), antibaryons (antiproton and antineutron only) and mesons (pion and kaon only) Only knowledge of up (u), down (d) and strange (s) quarks and their antiquarks will be tested The decay of the neutron should be known 3.2.1.7 Change of quark character in β^- decay		4.4, 4.5	
5 How do forces actually act between particles? The concept and properties of exchange particles are discussed here.	• Name the four fundamental interactions • Use the concept of exchange particles to describe forces between particles • Know that virtual photons are the exchange particle for the electromagnetic force • Know and that W^+ and W^- are exchange particles in weak interactions	3.2.1.4 Four fundamental interactions: gravity, electromagnetic, weak nuclear, strong nuclear. (The strong nuclear force may be referred to as the strong interaction) The concept of exchange particles to explain forces between elementary particles Knowledge of the gluon, Z^0 and graviton will not be tested The electromagnetic force; virtual photons as the exchange particle		4.5	

	• Know that the pion is the exchange particle of the strong nuclear force • Construct simple (Feynman) diagrams to represent interactions • Appreciate the analogy of momentum transfer of a heavy ball thrown from one person to another	The weak interaction limited to β^- and β^+ decay, electron capture and electron-proton collisions; W^+ and W^- as the exchange particles Simple diagrams to represent the above reactions or interactions in terms on incoming and outgoing particles and exchange particles 3.2.1.7 Change of quark character in β^- and in β^+ decay 3.2.1.5 The pion as the exchange particle of the strong nuclear force			
6 Collisions at CERN ICT is used to analyse collisions at CERN.	• Appreciate that particle physics relies on the collaborative efforts of large teams of scientists and engineers • Use computer simulations to understand the sort of results that are acquired at CERN	3.2.1.5 Appreciation that particle physics relies on the collaborative efforts of large teams of scientists and engineers to validate new knowledge	ATk Use of computer simulations of particle collisions	Introduction, 4.5	

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 5 – Waves (8 hours)					
1 What is polarisation? This phenomenon is presented as evidence for light being a transverse wave.	• Understand the nature of transverse waves • Understand polarisation as evidence for transverse waves • Know applications of polarisers	3.3.1.2 Nature of transverse waves Polarisation as evidence for the nature of transverse waves Applications of polarisers to include Polaroid material and the alignment of aerials for transmission and reception	MS 4.2 Visualise and represent 2D and 3D forms PS 1.2 Apply scientific knowledge to practical contexts	5.1, 5.4	
2 How do longitudinal waves provide warning for earthquakes? The properties of longitudinal waves are recapped and applied to the context of earthquakes.	• Understand the nature of mechanical waves in terms of the oscillation of the particles of the medium • Apply the properties of waves and the relationships between amplitude, frequency, wavelength and speed • Understand the nature of longitudinal waves	3.3.1.1 Oscillation of the particles of the medium Amplitude, frequency, wavelength, speed, $c = f\lambda$, $f = \frac{1}{T}$ 3.3.1.2 Nature of longitudinal waves Students will be expected to know the direction of displacement of particles/fields relative to the direction of energy propagation	MS 3.1 Translate information between graphical and numerical forms	5.1, 5.2, 5.3	
3 How does the intensity of waves vary? Students carry out an experiment into how the intensity of a source varies with distance from it.	• Design and execute an accurate investigation to verify the inverse square law • Record and analyse findings appropriately		MS 2.1 Recognise the significance of $\propto$ to mean proportional MS 3.3 Compare $I \propto \frac{1}{r^2}$ to the relationship for a linear graph PS 2.2 Design a results table	1.5	

4 Changing the speed of a wave Students determine the speed of sound in air, and investigate how water waves change speed, and extend this to considering how the speed of other waves can change.	• Understand that all electromagnetic waves travel at the same speed in a vacuum • Carry out an experiment to determine the speed of sound in free air, and consider the uncertainties in the results • Investigate the factors that determine the speed of a water wave	3.3.1.2 Students will be expected to know that all electromagnetic waves travel at the same speed in a vacuum	MS 1.2 Find arithmetic means MS 1.5 Identify uncertainties in measurements and in data combined by division of readings MS 3.2 Plot two variables from experimental data PS 2.4 Identify variables, including those that must be controlled PS 2.2, 2.3, 3.2, 3.3 Present data in appropriate ways, evaluate results and draw conclusions with reference to measurement uncertainties and errors, and process and analyse data, considering margins of error ATa, b Use appropriate analogue and digital apparatus and instruments to record a range of measurements ATi Generate and measure waves	5.3, 5.6	
5 Wave amplitude cycles Students learn about phase difference and the superposition of waves.	• Understand the terms ‘phase’ and ‘phase difference’ • Be able to state phase difference as an angle (radians and degrees) or as a fraction of a cycle • Understand what is meant by the superposition of waves	3.3.1.1 Phase, phase difference Phase difference may be measured as angles (radians and degrees) or as fractions of a cycle 3.3.1.2 Examples to include: sound, electromagnetic waves	MS 4.7 Understand the relationship between degrees and radians and translate from one to the other	5.2, 5.5	
6 How can a wave be stationary? Students apply the ideas of superposition to stationary waves.	• Explain how stationary waves are formed by two waves of the same frequency travelling in opposite directions	3.3.1.2 Examples to include: waves on a string 3.3.1.3 Stationary waves Nodes and antinodes on strings	MS 3.1 Translate information between graphical and numerical forms ATk Use computer modelling to collect data	5.6	

	• Be confident with understanding the formation of waves on a string • Understand what is meant by nodes and antinodes on strings	The formation of stationary waves by two waves of the same frequency travelling in opposite directions A graphical explanation of formation of stationary waves will be expected Stationary waves on strings will be described in terms of harmonics. The terms fundamental (for first harmonic) and overtone will **not** be used			
7 Using stationary waves to measure *c* Students observe a demonstration with a microwave oven and consider the stationary waves within it to measure the speed of light from the wavelength and frequency	• Understand that stationary waves can be produced with microwaves and sound waves • Use the principle of stationary waves and microwaves to measure the speed of light	3.3.1.3 Stationary waves formed on a string and those produced with microwaves and sound waves should be considered	PS 1.2 Apply scientific knowledge to practical contexts PS 3.3 Consider margins of error, accuracy and precision of data ATi Generate and measure microwaves	5.6	
8 Stationary waves on a string Students complete a Required Practical to investigate the effect of different variables on the stationary waves set up on a stretched string.	Demonstrate mastery of the following practical competencies: • Follows written procedures • Applies investigative approaches and methods when using instruments and equipment • Safely uses a range of practical equipment and materials • Makes and records observations	3.3.1.3 Stationary waves Nodes and antinodes on strings $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ for first harmonic	MS 3.2, 3.3 Plot two variables from experimental data and understand that $y = mx + c$ represents a linear relationship PS 2.1 Comment on experimental design and evaluate scientific methods PS 2.4 Identify variables, including those that must be controlled PS 4.1 Know and understand how to use a wide range of experimental and practical	5.6	Required Practical 1: Investigation into the variation of the frequency of stationary waves on a string with length, tension and mass per unit length of the string

			instruments, equipment and techniques ATa, b Use appropriate analogue and digital apparatus and instruments to record a range of measurements ATc Use methods to increase accuracy of measurements ATh, i Use a signal generator, generate and measure waves		

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 6 – Diffraction and interference (7 hours)					
1 The outcomes of the superposition of waves The effects of superposition from two sources of water waves and sound waves are observed and discussed.	• Understand the meanings of path difference and coherence • Explain why interference patterns are produced from two coherent sources	3.3.2.1 Path difference. Coherence Students will be expected to describe and explain interference produced with sound waves	PS 1.2 Apply scientific knowledge to practical contexts ATi Generate and measure waves	6.1	
2 Interference of light Students learn about double-slit interference of laser light and microwaves.	• Observe and explain interference using a laser as a source of monochromatic light • Observe and explain the interference pattern using white light • Investigate two-source interference with microwave radiation • Understand and use the equation for fringe spacing, $w = \frac{\lambda D}{s}$ • Appreciate that knowledge and understanding of the nature of electromagnetic radiation has changed over time	3.3.2.1 Interference using a laser as a source of monochromatic light Fringe spacing, $w = \frac{\lambda D}{s}$ Students will be expected to describe and explain interference produced with electromagnetic waves Production of interference pattern using white light	MS 2.2, 2.3 Change the subject of an equation, and substitute numerical values using appropriate units PS 3.2 Process and analyse data using appropriate mathematical skills PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques ATi Generate and measure waves	6.1	
3 Young's slits Students carry out and analyse the results of Young's double-slit experiment. This is part of a Required Practical.	Demonstrate mastery of the following practical competencies: • Follows written procedures • Applies investigative approaches and methods when	3.3.2.1 Young's double-slit experiment: the use of two coherent sources or the use of a single source with double slits to produce an interference pattern	MS 0.6, 4.5 Use sin and tan in physical problems, and use calculators to handle sin *x* and tan *x* PS 2.3 Evaluate results and draw conclusions with reference to	6.1, 6.2	Required Practical 2 (Part 1): Investigation of interference effects to include the

	using instruments and equipment • Safely uses a range of practical equipment and materials • Makes and records observations	Students are expected to show awareness of safety issues associated with using lasers Students will not be required to describe how a laser works	measurement uncertainties and errors ATa Use appropriate analogue apparatus ATc Use methods to increase accuracy ATe Use callipers to measure small distances, using vernier scales ATj Use a laser to investigate characteristics of light, including interference		Young's slit experiment
4 Diffraction through a single slit Students qualitatively analyse the diffraction pattern produced when light is passed through a single slit.	• Be familiar with the appearance of the diffraction pattern from a single slit using monochromatic and white light • Qualitatively describe the variation of the width of the central diffraction maximum with wavelength and slit width	3.3.2.2 Appearance of the diffraction pattern from a single slit using monochromatic and white light Qualitative treatment of the variation of the width of the central diffraction maximum with wavelength and slit width. The graph of intensity against angular separation is not required		6.2	
5 The diffraction grating Students analyse the effect of a diffraction grating on light and begin to consider its uses, in particular for determining the composition of stars.	• Understand the behaviour of light transmitted through a diffraction grating at normal incidence Know the derivation of $d\sin\theta = n\lambda$ • Know an application of diffraction gratings	3.3.2.2 Plane transmission diffraction grating at normal incidence Derivation of $d\sin\theta = n\lambda$ Use of the spectrometer will not be tested Applications of diffraction gratings	MS 0.2 Recognise and use expressions in decimal and standard form MS 4.1, 4.5 Use angles in regular 2D structures, and use sin to derive the diffraction grating formula	6.2	
6 More uses of diffraction Students consider further applications of diffraction.	• Appreciate that knowledge and understanding of the nature of	3.3.2.1 Appreciation of how knowledge and understanding of		6.2	

	electromagnetic radiation has changed over time • Know some applications of diffraction gratings • Be prepared for Required Practical 2 (Part 2): Interference by a diffraction grating	nature of electromagnetic radiation has changed over time 3.3.2.2 Applications of diffraction gratings			
7 Using a diffraction grating Students find the wavelength of laser light using a diffraction grating. This is part of a Required Practical.	Demonstrate mastery of the following practical competencies: • Follows written procedures • Applies investigative approaches and methods when using instruments and equipment • Safely uses a range of practical equipment and materials • Makes and records observations	3.3.2.1 Diffraction using a laser as a source of monochromatic light	MS 3.2, 3.3, 3.4 Plot two variables from experimental data, understand that $y = mx + c$ represents a linear relationship, and determine the slope of a linear graph PS 2.1 Comment on experimental design PS 2.3, 3.3, Evaluate results and draw conclusions, considering margins of error, accuracy and precision of data ATc Use methods to increase accuracy ATe Use callipers to measure small distances, using vernier scales ATj Use a laser to investigate characteristics of light, including diffraction	6.2	Required Practical 2 (Part 2): Investigation of interference effects to include interference by a diffraction grating

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 7 – Refraction and optical fibres (6 hours)					
1 A reminder of reflection and refraction Students observe demonstrations and qualitatively explain them.	• Recall the law of reflection • Know and understand the definition for the refractive index of a substance, $n = \frac{c}{c_s}$ • Know that the refractive index of air can be taken to be 1	3.3.2.3 Refractive index of a substance, $n = \frac{c}{c_s}$ Students should recall that the refractive index of air is approximately 1	MS 0.3 Use ratios	7.1, 7.2, 7.3	
2 What is the mystery material? Students use Snell's law to work out the refractive index of a substance using the results from an investigation.	• Recall and use Snell's law of refraction for a boundary, $n_1 \sin\theta_1 = n_2 \sin\theta_2$ • Carry out an investigation and work out the uncertainties in measurements	3.3.2.3 Snell's law of refraction for a boundary, $n_1 \sin\theta_1 = n_2 \sin\theta_2$	MS 0.6, 4.5 Use sin in problems involving Snell's law MS 1.5 Identify uncertainties in measurements and determine uncertainty when data are combined PS 1.1 Solve problems set in practical contexts PS 1.2 Apply scientific knowledge to practical contexts PS 2.3 Evaluate results and draw conclusions with reference to measurement uncertainties and errors	7.3	
3 Predicting the path of light Total internal reflection is covered and students decide on whether rays of light will reflect or refract.	• Understand the concept of total internal reflection • Use and understand the equation for the critical angle in total internal reflection, $\sin\theta_c = \frac{n_2}{n_1}$	3.3.2.3 Total internal reflection, $\sin\theta_c = \frac{n_2}{n_1}$	MS 4.2 Visualise and represent 2D and 3D forms, including two-dimensional representations of 3D objects MS 0.6, 4.5 Use sin in physical problems	7.4, 7.5	

	• Understand how an optical fibre works				
4 Controlling the path of light Optical fibres, how they work and their functions are introduced.	• Describe the core–cladding construction of a step-index optical fibre • Apply the law of reflection, rules for total internal reflection and the critical angle formula to light in optical fibres • Understand that light rays at different angles in an optical fibre have different path lengths and hence different arrival times at the other end	3.3.2.3 Simple treatment of fibre optics including the function of the cladding Optical fibres will be limited to step index only		7.4, 7.5	
5 Optical fibre communications The practicalities of sending light through optical fibres are discussed.	• Understand how modal dispersion results in pulse broadening, which can lead to distortion of the transmitted data • Explain that pulse broadening caused by modal dispersion can be reduced by having only a small difference in the refractive indices of the core and the cladding • Describe material dispersion as the broadening of a light pulse caused by different wavelengths of light travelling at different speeds in the optical fibre, resulting in different arrival times • Describe attenuation as the reduction in the amplitude of a light pulse travelling along an optical fibre and that it is	3.3.2.3 Material and modal dispersion Students are expected to understand the principles and consequences of pulse broadening and absorption	MS 0.3 Use ratios	7.6	

	caused by scattering, absorption and bending of the fibre				
6 Writing good questions Students consolidate their learning from the last three chapters and think about the material in a new way by writing their own exam-style question for a peer to complete, along with a mark scheme.	• Consolidate knowledge gained from Chapters 5, 6 and 7 • Understand how to apply knowledge to exam questions				

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 8 – Spectra, photons and wave–particle duality (10 hours)					
1 Problems with light as a wave The photoelectric effect is demonstrated and the UV catastrophe is described, as evidence for the need of a new model of light.	• Understand why the photoelectric effect demonstrates that light does not always behave as a wave • Explain the terms 'threshold frequency' and 'work function' • Appreciate that line spectra are also evidence for a particle model of light	3.2.2.1 Threshold frequency; photon explanation of threshold frequency Work function ϕ	ATj Use a light source to investigate the diffraction of light	8.1, 8.3, 8.4	
2 Determining the Planck constant Students carry out an experiment to determine the Planck constant using the voltage that just turns on an LED.	• Convert between eV and J • Carry out an investigation and work out the uncertainties in measurements • Decide on the most sensible graph to plot	3.2.2.2 The electronvolt Students will be expected to be able to convert eV into J and vice versa.	MS 0.1, 2.3 Substitute numerical values into calculations using appropriate units MS 0.2 Recognise and use expressions in decimal and standard form PS 3.2 Process and analyse data using appropriate mathematical skills ATf Correctly construct circuits where polarity is important	8.3	
3 The photoelectric equation Students use the photoelectric equation and consider how the kinetic energy of the photoelectrons can be found.	• Understand the photoelectric equation, $hf = \phi + E_{k(max)}$ • Understand what is meant by a stopping potential in a photoelectric experiment and the usefulness of it • Observe a photoelectric experiment using a photocell	3.2.2.1 Photoelectric equation: $hf = \phi + E_{k(max)}$ $E_{k\,(max)}$ is the maximum kinetic energy of the photoelectrons Stopping potential	MS 2.2 Change the subject of an equation MS 3.1 Translate information between graphical, numerical and algebraic forms MS 3.4 Determine the slope and intercept of a linear graph	8.4	
4 Another way to find the Planck constant					

Students determine the Planck constant using stopping potential data, which may be onbtained from a demonstration using a photocell.			PS 1.2 Apply scientific knowledge to practical contexts PS 3.1, 3.2 Plot and interpret graphs using appropriate mathematical skills		
5 Bohr's hydrogen atom Students consider excitation, ionisation and de-excitation of hydrogen, assuming discrete energy levels.	• Understand the concepts of ionisation and excitation, by both electrons and photons • Understand the Bohr model of discrete energy levels and how this relates to the photon model of light • Be able to use the equation $hf = E_1 - E_2$ • Be comfortable with energy values *E* being quoted in eV or J	3.2.2.2 Ionisation and excitation 3.2.2.3 $hf = E_1 - E_2$ In questions, energy levels may be quoted in J or eV	MS 0.1 Recognise and make use of appropriate units in calculations	8.2	
6 Absorption and emission of photons by hydrogen Students observe hydrogen spectra, and consider the effect of photons on the electron in a hydrogen atom and the consequences for the incident light.	• Understand how ionisation and excitation lead to absorption spectra • Understand what emission spectra are	3.2.2.3 Line spectra (e.g. of atomic hydrogen) as evidence for transitions between discrete energy levels in atoms	PS 1.2 Apply scientific knowledge to practical contexts ATj Observe line spectra using a diffraction grating ATk Use computer modelling to collect data	8.1, 8.2, 8.3	
7 De-excitation of other elements Line spectra of various elements are analysed, and the function of a fluorescent tube is studied.	• Understand how ionisation and excitation occur in elements other than hydrogen • Understand the application of ionisation and excitation in the action of a fluorescent tube	3.2.2.2 Understanding of ionisation and excitation in the fluorescent tube	PS 1.2 Apply scientific knowledge to practical contexts	8.3	
8 Wave–particle duality	• Know that electron diffraction suggests that particles possess wave properties and that the	3.2.2.4 Students should know that electron diffraction suggests that particles possess wave properties	MS 0.4 Estimate the effect of changing experimental parameters on measurable values	8.5	

Electron diffraction is witnessed and the de Broglie wavelength used.	photoelectric effect suggests that electromagnetic waves have a particulate nature • Know that the de Broglie wavelength is given by $\lambda = \frac{h}{mv}$ • Explain how and why the amount of diffraction changes when the momentum *mv* of the particle is changed • Be confident in the use of prefixes when expressing wavelength values	and the photoelectric effect suggests that electromagnetic waves have a particulate nature Details of particular methods of particle diffraction are not expected de Broglie wavelength $\lambda = \frac{h}{mv}$ where *mv* is the momentum Students should be able to explain how and why the amount of diffraction changes when the momentum of the particle is changed	MS 1.1 Use an appropriate number of significant figures MS 2.3 Substitute numerical values into algebraic equations using appropriate units for wavelengths PS 2.1 Evaluate scientific methods PS 3.3 Consider accuracy and precision of data		
9 The story of quantum physics Students research the development of ideas in quantum physics, and the applications of the understanding of line spectra.	• Know some applications of quantum physics • Appreciate that knowledge and understanding of the nature of matter develop over time • Appreciate that new knowledge needs to be evaluated and validated by the scientific community	3.2.2.4 Appreciation of how knowledge and understanding of the nature of matter changes over time Appreciation that such changes need to be evaluated through peer review and validated by the scientific community	Practical competency 5: Researches, references and reports	8.4	
10 Presenting research Students present a short lesson to peers based on their research.	• Use knowledge, understanding, theories, models and ideas to develop and present scientific explanations clearly • Listen well to peers				

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 9 – The equations of motion (12 hours)					
1 Vectors and scalars The nature of vectors and scalars and the way they can be represented is covered.	• Understand the difference between vectors and scalars • Give examples of vector and scalar quantities • Know how vectors are represented • Define average speed and average velocity	3.4.1.1 Nature of scalars and vectors Examples should include: velocity/speed, mass, force/weight, acceleration, displacement/distance 3.4.1.3 Displacement, speed, velocity	MS 2.1 Understand and use the symbol Δ	9.1	
2 Vector arithmetic Addition of vectors and resolving vectors into two components is covered.	• Add vectors at any angle by scale drawing • Add vectors at angles of 90° by calculation • Resolve a vector into two perpendicular components	3.4.1.1 Addition of vectors by calculation or scale drawing Calculations will be limited to two vectors at right angles. Scale drawings may involve vectors at angles other than 90° Resolution of vectors into two components at right angles to each other	MS 4.1 Use angles in 2D triangles to resolve vectors MS 4.5 Use sin, cos and tan in physical problems	9.2	
3 Motion graphs 1 A set of motion data is presented and it is analysed in terms of its distance–time graph.	• Understand how motion is represented by various distance–time, speed–time, displacement–time and velocity–time graphs • Use the gradient of motion graphs to work out other quantities • Know the difference between instantaneous and average speeds and velocities	3.4.1.3 Displacement, speed, velocity, acceleration $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$ Calculations may include average and instantaneous speeds and velocities	MS 3.1 Translate information between graphical, numerical and algebraic forms MS 3.5 Calculate rate of change from a graph showing a linear relationship	9.3, 9.4	

4 Motion graphs 2 The properties of displacement–time, velocity–time and acceleration–time graphs, and how they relate to one another, is covered.	• Sketch the shape of a motion graph from a description of the motion • Analyse motion graphs in terms of other quantities not directly represented by them	Representation by graphical methods of uniform and non-uniform acceleration Significance of areas of velocity–time and acceleration–time graphs and gradients of displacement–time and velocity–time graphs for uniform and non-uniform acceleration, e.g. graphs for motion of bouncing ball	MS 3.6 Draw and use the slope of a tangent to a curve as a measure of rate of change MS 3.7 Distinguish between instantaneous rate of change and average rate of change PS 1.1 Solve problems set in practical contexts PS 3.1 Plot and interpret graphs		
5 Equations for uniform acceleration Students use a velocity–time graph to derive the equations of constant acceleration for themselves.	• Know when to use the equations of motion • Appreciate how the equations are derived from motion graphs • Begin to use the equations to work out unknown quantities	3.4.1.3 Equations for uniform acceleration: $v = u + at$ $s = \left(\frac{u+v}{2}\right)t$ $s = ut + \frac{at^2}{2}$ $v^2 = u^2 + 2as$	MS 0.5 Use calculators to find and use power MS 2.2 Change the subject of an equation, including non-linear equations MS 2.4 Solve algebraic equations MS 3.8 Understand the physical significance of the area between a velocity–time line and the *x*-axis PS 2.1 Comment on experimental design and evaluate scientific methods PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques ATk Use a data logger with a motion sensor to collect data	9.5	
6 Applying the equations for uniform acceleration Students use the equations of constant acceleration in problems involving motion in a straight line.	• Use the equations for uniform acceleration to work out unknown quantities • Be able to measure the quantities used in the equations to verify the relationships				
7 Terminal speed The reasons for terminal speed being reached and the	• Understand why acceleration reduces, eventually to zero, when an object falls through a fluid	3.4.1.4 Terminal speed Knowledge that air resistance increases with speed		9.6	

corresponding motion graphs are discussed.	• Relate this phenomenon to motion graphs depicting it				
8 What is the terminal speed of a cupcake case? Students carry out a practical to analyse the effect that changing mass has on terminal speed.	• Investigate how acceleration reduces, eventually to zero, when an object falls through a fluid • Obtain data to determine how the terminal speed varies with mass		PS 2.1 Comment on experimental design and evaluate scientific methods PS 2.2 Present data in appropriate ways PS 2.3 Evaluate results and draw conclusions with reference to measurement uncertainties and errors		
9 Measuring *g* Students complete a Required Practical to determine *g* by a free fall method.	Demonstrate mastery of the following practical competencies: • Follows written procedures • Applies investigative approaches and methods when using instruments and equipment • Safely uses a range of practical equipment and materials • Makes and records observations	3.4.1.3 Acceleration due to gravity, *g*	Ata, b Use appropriate analogue and digital apparatus to record a range of measurements ATc Use methods to increase accuracy of measurements ATd Use stopwatch or light gates for timing ATk Use ICT such as a data logger to collect data	9.6	Required Practical 3: Determination of *g* by a free fall method
10 Analysis of the results of measuring *g* Students analyse their results to work out *g*.			MS 1.1 Use an appropriate number of significant figures MS 1.2 Find arithmetic means MS 3.9 Determine *g* from a graph PS 2.1 Comment on ways to remove or reduce random and systematic errors PS 2.3 Evaluate results and draw conclusions with reference to the errors in the experiment		

11 Maximising the range of a projectile Students learn how to solve constant acceleration problems in two dimensions.	• Understand the independent effect of motion in horizontal and vertical directions of a uniform gravitational field • Use the equations for uniform acceleration to work out the motion of a projectile given certain initial conditions	3.4.1.4 Independent effect of motion in horizontal and vertical directions of a uniform gravitational field. Problems will be solvable using the equations of uniform acceleration Qualitative understanding of the effect of air resistance on the trajectory of a projectile	MS 3.1 Translate information between graphical, numerical and algebraic forms	9.7	
12 Investigating projectile motion Students apply their knowledge of two-dimensional problems to a set of practical results.	• Apply understanding of projectile motion to practical phenomena		MS 1.2 Find arithmetic means PS 1.2 Apply scientific knowledge to practical contexts PS 2.1 Comment on experimental design ATc Use methods to increase accuracy of measurements		

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 10 – Forces in balance (10 hours)					
1 Forces Students observe a range of phenomena and identify the forces involved and their relative size.	• Understand the difference between contact and non-contact forces • Identify the forces acting in a variety of situations	3.4.1.1 Nature of scalars and vectors Examples should include mass, force/weight Qualitative treatment of friction Distinctions between static and dynamic friction will not be tested Qualitative treatment of lift and drag forces	PS 1.2 Apply scientific knowledge to the demonstration of phenomena	10.1, 10.2	
2 Is there upthrust on a plane? Students look in detail at the difference between upthrust and lift, and consider drag, through a variety of observations.	• Understand the difference between upthrust and lift • Understand what is meant by drag		PS 1.1 Solve problems set in practical contexts	10.2	
3 Equilibrium in a plane Students set up a situation with three measurable forces in equilibrium in a plane, and produce a scale drawing.	• Resolve vectors into their components • Appreciate the concept of a closed triangle of vector forces in cases where an object is in equilibrium • Relate experimental values of force to scale drawings of vectors	3.4.1.1 Conditions for equilibrium for two or three coplanar forces acting at a point. Appreciation of the meaning of equilibrium in the context of an object at rest or moving with constant velocity	MS 0.6 Use calculators to handle sin *x*, cos *x*, tan *x* MS 4.1 Use angles in regular 2D and 3D structures PS 1.2 Apply scientific knowledge to practical contexts PS 2.3 Evaluate results and draw conclusions with reference to uncertainties and errors	10.3	
4 Resolving forces Students practise resolving forces by calculation in the case where they are acting to produce equilibrium.	• Resolve vectors into their components • Equate horizontal and vertical components for objects in equilibrium to find an unknown quantity	3.4.1.1 Addition of vectors by calculation or scale drawing Resolution of vectors into two components at right angles to each other	MS 0.6 Use calculators to handle sin *x*, cos *x*, tan *x* MS 4.1 Interpret force diagrams to solve problems MS 4.4 Use Pythagoras' theorem	10.3	

		Problems may be solved either by the use of resolved forces or the use of a closed triangle	MS 4.5 Use sin, cos and tan in physical problems		
5 Determining the coefficient of friction Students carry out an experiment that considers the limits to equilibrium on a slope.	• Resolve vectors into their components • Consider problems relating to the inclined plane	3.4.1.1 Resolution of vectors into two components at right angles to each other Examples should include components of forces along and perpendicular to an inclined plane	MS 0.6 Use calculators to handle sin *x*, cos *x*, tan *x* MS 1.2 Find arithmetic means PS 1.1 Solve problems set in practical contexts PS 2.1 Comment on experimental design and evaluate scientific methods	10.3	
6 Modelling slope problems Students use mathematics software (e.g. GeoGebra) to analyse slope problems.	• Resolve vectors into their components • Consider problems relating to the inclined plane • Use ICT to model situations		ATk Use computer modelling software to process data	10.3	
7 Turning effect of a force Students are introduced to the principle of moments and to couples, and apply these to problems.	• Know the definitions for a moment and a couple • Understand the principle of moments	3.4.1.2 Moment of a force about a point Moment defined as force × perpendicular distance from the point to the line of action of the force Couple as a pair of equal and opposite coplanar forces Moment of couple defined as force × perpendicular distance between the lines of action of the forces Principle of moments	MS 0.1 Recognise and make use of appropriate units in calculations MS 1.1 Use an appropriate number of significant figures	10.4	
8 Determining the centre of mass of an object	• Understand what is meant by the centre of mass	3.4.1.2 Centre of mass		10.1, 10.4	

Students carry out an experiment to determine the position of the centre of mass of an object.	• Know how to find the centre of mass of an object • Understand why this is a useful concept	Knowledge that the position of the centre of mass of uniform regular solid is at its centre	PS 1.1 Solve problems set in practical contexts PS 3.2 Process data using appropriate mathematical skills		
9 Equilibrium Students bring together all they know about both forces and moments in equilibrium to solve problems.	• Use the principle of moments and their knowledge of forces to solve problems about objects in equilibrium	3.4.1.2 Principle of moments		10.5	
10 Balancing moments to find the density of a fluid Students carry out an experiment using moments to find the density of a fluid.	• Use the principle of moments in a practical context to determine density		MS 0.1, 1.1, 1.5 Use appropriate units and appropriate significant figures in calculations based on measurements, and determine the uncertainty in measurements PS 1.1, 2.3, 3.2, 3.3 Apply the physics of moments to determine density, and analyse and evaluate the results	10.5	

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 11 – Forces and motion (10 hours)					
1 Newton's laws of motion Students discuss the first law and the difficulties of observing it directly on Earth, and use/observe an air track experiment to verify the law. They then go on to consider the second law and apply it to situations where a resultant force acts on an object, and the third law.	• Understand that a resultant force is needed to change motion rather than maintain it • Understand the concept of inertial mass • Understand that the forces referred to in Newton's third law act on different bodies	3.4.1.5 Knowledge and application of the three laws of motion in appropriate situations	MS 2.1 Understand and use the symbols $\propto$, Δ	11.1	
2 Verification of Newton's second law Students carry out an experiment to verify the second law.	• Understand how resistive forces may be reduced in the laboratory by the use of an air track • Use light gates linked to a computer to measure and record timings, and understand how these can be used to calculate velocity and acceleration • Identify sources of experimental error and consider how they may be reduced	3.4.1.5 $F = ma$ for situations where the mass is constant	MS 1.5 Identify uncertainties in measurements MS 3.2, 3.3, 3.4 Plot two variables from experimental or other data, understand that $y = mx + c$ represents a linear relationship, and determine the slope and intercept of a linear graph PS 2.3 Evaluate results and draw conclusions with reference to measurement uncertainties and errors PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques ATa, b, d Use appropriate analogue and digital apparatus	11.1	

			and instruments, including light gates		
3 Conservation of momentum Students define momentum and look at examples of colliding objects coalescing or both continuing in the same direction.	• Understand the concept of momentum • Appreciate that $F = ma$ is a special case of $F = \frac{\Delta(mv)}{\Delta t}$ • Understand how the conservation of momentum arises from Newton's third law • Apply the conservation of momentum to problems, including collisions	3.4.1.6 Momentum = mass × velocity Conservation of linear momentum Principle applied quantitatively to problems in one dimension Force as the rate of change of momentum, $F = \frac{\Delta(mv)}{\Delta t}$	MS 2.2, 2.3, 2.4 Change the subject of an equation, substitute numerical values into equations using appropriate units, and solve algebraic equations	11.1, 11.2	
4 Analysing collisions Students analyse experimental data from trolley collisions and consider inelastic and elastic collisions.	• Understand the difference between elastic and inelastic collisions, and appreciate that conservation of momentum applies to both • Apply the conservation of momentum and conservation of energy to problems other than straightforward collisions, e.g. emission of alpha particles and rockets	3.4.1.6 Conservation of linear momentum Principle applied quantitatively to problems in one dimension Elastic and inelastic collisions; explosions	PS 1.1 Solve problems set in practical contexts PS 1.2 Apply scientific knowledge to practical contexts PS 2.4 Identify variables, including those that must be controlled PS 3.2 Process and analyse data using appropriate mathematical skills	11.2, 11.4	
5 Impulse Students define impulse and analyse data from impacts to see the usefulness of force–time graphs.	• Be able to define impulse • Apply the concept of impulse quantitatively to practical situations	3.4.1.6 Impulse = change in momentum $F\Delta t = \Delta(mv)$, where F is constant Significance of the area under a force–time graph Quantitative questions may be set on forces that vary with time. Impact forces are related to contact times (e.g. kicking a	MS 3.1 Translate information between graphical, numerical and algebraic forms MS 3.8 Understand the physical significance of the area between a curve and the *x*-axis and calculate it or estimate it by graphical methods as appropriate	11.3	
6 Crumple zone challenge Students apply what they have learnt to a design challenge.	• Understand that in a car crash the impulse is determined by the mass of the vehicle and its original speed, so the force on the car and passengers can only				

	be reduced by extending the time of the collision • Apply this idea to explain how safety features (airbags, seat belts, crumple zones) help to reduce injury in collisions	football, crumple zones, packaging) Appreciation of momentum conservation issues in the context of ethical transport design	PS 1.1, 1.2 Use ideas about momentum and impulse to solve a practical problem		
7 Work and energy Students practise analysing situations where energy is transferred.	• Be able to define work and calculate the work done in situations where the force and displacement are not parallel • Apply the principle of conservation of energy to simple situations such as a bicycle freewheeling down a hill: loss of E_p = gain in E_k + work done against resistive forces	3.4.1.7 Energy transferred $W = Fs\cos\theta$ 3.4.1.8 Principle of conservation of energy $\Delta E_p = mg\Delta h$ and $E_k = \frac{1}{2}mv^2$ Quantitative and qualitative application of energy conservation to examples involving gravitational potential energy, kinetic energy, and work done against resistive forces	MS 2.2, 2.3, 2.4 Change the subject of an equation, substitute numerical values into equations using appropriate units, and solve algebraic equations	11.4, 11.5	
8 Power Students consider mechanical power and apply it to situations where the force may vary.	• Be able to derive the formula $P = \frac{\Delta W}{\Delta t} = Fv$ from the definition of work • Calculate the instantaneous power in simple situations • Calculate the work done from a graph of force versus distance and so calculate the average power in a case where force varies	3.4.1.7 Rate of doing work = rate of energy transfer, $P = \frac{\Delta W}{\Delta t} = Fv$ Quantitative questions may be set on variable forces. Significance of the area under a force–displacement graph 3.4.1.4 Qualitative understanding of the effect of air resistance on the factors that affect the maximum speed of a vehicle	MS 3.1 Translate information between graphical, numerical and algebraic forms MS 3.8 Understand the physical significance of the area between a curve and the *x*-axis and calculate it or estimate it by graphical methods as appropriate	11.5	
9 Efficiency	• Define efficiency in terms of work or power		MS 0.3 Use ratios, fractions and percentages	11.6	

Students analyse the work done and efficiency in pulley systems.	• Calculate the efficiency of energy transfer in problems • Carry out an experiment to measure the efficiency of a pulley system		ATc Use methods to increase accuracy of measurements		
10 Efficiency Students investigate the efficiency of an electric motor being used to raise a mass through a measured height.	• Design and carry out an experiment to measure the efficiency of an electric motor • Identify sources of experimental errors and suggest ways of reducing the errors • Write an experimental report	3.4.1.7 $\text{Efficiency} = \frac{\text{useful output power}}{\text{input power}}$ Efficiency can be expressed as a percentage	MS 1.5 Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined PS 2.1 Comment on experimental design and evaluate scientific methods PS 2.3, 3.3 Evaluate results and draw conclusions with reference to measurement uncertainties and errors, and consider accuracy and precision of data PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques ATa, b, f Use appropriate analogue and digital apparatus and instruments, including electric circuits		

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 12 – The strength of materials (8 hours)					
1 Measuring density Students make calculations of the density of various materials from different states of matter from their own measurements.	• Define density and calculate it for uniform, regular solids given the dimensions and mass • Use appropriate units for density and convert between units • Use standard lab equipment to measure volume and mass • Quantify the uncertainty in measurements and in the calculated value of density	3.4.2.1 Density, $\rho = \frac{m}{v}$	MS 0.4 Estimate the volume of an object, leading to an estimate of its density MS 4.3 Calculate volumes PS 3.3 Consider margins of error, accuracy and precision of data PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques ATe Use callipers and micrometers for small distances, using digital or vernier scales	12.1	
2 Investigating the behaviour of materials Students plan and carry out an experiment to determine the properties of springs and elastic bands.	• Understand Hooke's law and appreciate the conditions in which it applies • Define the spring constant and calculate it from a graph of experimental results • Construct a table of results and plot an appropriate graph	3.4.2.1 Hooke's law, elastic limit $F = k\Delta l$, k as stiffness and spring constant	MS 2.1 Understand and use the symbols $\propto$, Δ PS 1.1 Solve problems set in practical contexts PS 2.1 Comment on experimental design and evaluate scientific methods PS 2.2 Present data in appropriate ways PS 2.4 Identify variables, including those that must be controlled	12.1, 12.2, 12.4	
3 Defining stress and strain Students analyse their data from the previous lesson and	• Know the definitions of stress and strain	3.4.2.1 Tensile strain and tensile stress	PS 3.2 Process and analyse data using appropriate mathematical skills	12.1, 12.2	

use this to define stress and strain.	• Know why stress and strain are used in preference to force and extension				
4 Energy stored in materials Students consider elastic strain energy and how this is represented in force–extension graphs.	• Know that work equals force × distance and understand how this can be applied for a varying force • Derive the equation $E = \frac{1}{2}k(\Delta l)^2$ for the energy stored in a spring • Apply this equation to the solution of problems involving the conservation of energy	3.4.2.1 Elastic strain energy, breaking stress Energy stored $= \frac{1}{2}F\Delta l =$ area under force–extension graph Quantitative and qualitative application of energy conservation to examples involving elastic strain energy and energy to deform Spring energy transformed into kinetic and gravitational potential energy	MS 0.5 Use calculators to find and use power MS 2.2 Change the subject of an equation MS 2.4 Solve algebraic equations MS 3.8 Understand the physical significance of the area between a curve and the *x*-axis and calculate it or estimate it by graphical methods	12.2, 12.4	
5 Analysing stress–strain graphs Students carry out measurements to produce stress–strain graphs, analyse stress–strain graphs and define the Young modulus.	• Design and carry out simple experiments to produce stress–strain graphs for various materials • Analyse the results graphically • Describe the behaviour of each material and explain it in terms of molecular structure • Identify sources of error and quantify uncertainties in measurements	3.4.2.1 Interpretation of simple stress–strain curves Description of plastic behaviour, fracture and brittle behaviour liked to force–extension graphs 3.4.2.2 Young modulus $= \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{Fl}{A\Delta l}$ Use of stress–strain graphs to find the Young modulus	MS 3.1 Translate information between graphical, numerical and algebraic forms	12.1, 12.3	
6 Measuring the Young modulus Students carry out a Required Practical to	Demonstrate mastery of the following practical competencies: • Follows written procedures • Applies investigative approaches and methods when	3.4.2.2 Young modulus $= \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{Fl}{A\Delta l}$	MS 1.2 Find arithmetic means MS 3.1, 3.2, 3.3, 3.4, PS 3.1 Plot and interpret linear graphs	12.3	Required Practical 4: Determination of the Young modulus by a simple method

measure the Young modulus of a material.	using instruments and equipment • Safely uses a range of practical equipment and materials • Makes and records observations • Researches, references and reports	Use of stress–strain graphs to find the Young modulus	PS 3.2 Process and analyse data using appropriate mathematical skills PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques Ata, e Use appropriate analogue apparatus, including callipers and micrometers, to record a range of measurements ATc Use methods to increase accuracy		
7 Research into 21st century materials Students carry out research.	• Appreciate that scientific knowledge develops over time • Research applications of modern materials science		Practical competency 5: Researches, references and reports	Introduction	
8 Presenting research Students present their research.	• Communicate ideas and listen to others' ideas				

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 13 – Electricity 1 (11 hours)					
1 Electrical power and energy Students discuss power and energy in the context of electric lighting, comparing LED lighting with filament light bulbs, and carry out calculations of energy demand, efficiency and pay-back period.	• Use the definitions of power and efficiency in calculations of energy demand • Use the correct units of joules, watts and kilowatt-hours, and convert between them	3.4.1.7 $\text{Efficiency} = \frac{\text{useful output power}}{\text{input power}}$	MS 0.1, 0.2 Convert between J and kW h and use prefixes such as MJ confidently	13.1	
2 Charge and current Students observe electrostatic phenomena (e.g. Van de Graaff generator) and demonstrations of moving charges (e.g. sparks/a pith-ball shuttling charge), discuss the concept of electric current and use ammeters to measure current.	• Understand what is meant by electric charge • Understand that current is the rate of flow of charge • Apply the equation $I = \frac{\Delta Q}{\Delta t}$ in calculations, using the correct units • Be able to use an ammeter correctly, and understand why an ammeter has a low resistance	3.5.1.1 Electric current as the rate of flow of charge $I = \frac{\Delta Q}{\Delta t}$ 3.5.1.2 Unless specifically stated in questions, ammeters should be treated as ideal (having zero resistance)	PS 1.2 Apply scientific knowledge to a practical circuit PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques ATa,b Use appropriate analogue and digital apparatus and instruments ATf Correctly construct circuits with a range of circuit components	13.2, 13.3	
3 Potential difference (pd) Students discuss the concept of potential difference, compare sources of pd, use a voltmeter to measure pds, and learn how pd is related to current and power.	• Be able to use a voltmeter correctly and understand why a voltmeter has a high resistance • Use the definitions of potential difference and current to derive an expression for electrical power, $P = IV$	3.5.1.1 Potential difference as work done per unit charge $V = \frac{W}{Q}$ 3.5.1.2 Unless specifically stated in questions, voltmeters should be			

		treated as ideal (having infinite resistance) 3.5.1.4 Energy and power equations: $E = IVt$ and $P = IV$			
4 Kirchhoff's laws Students construct simple series and parallel circuits including cells, bulbs, switches, resistors and meters, to investigate how the current and the pds vary around these circuits.	• Construct circuits with various component configurations and measure currents and potential differences • Understand the conservation of charge and the conservation of energy as applied to simple series and parallel circuits	3.5.1.4 Conservation of charge and conservation of energy in dc circuits			
5 Resistance and Ohm's law Students investigate how the pd applied to a circuit component affects the current that flows through it, and plot an I–V graph for a length of metal wire at constant temperature (an ohmic conductor).	• Understand what electrical resistance is and how it arises in metals • Use the definition of resistance, $R = \frac{V}{I}$, and be able to define the ohm • Know Ohm's law as a special case where I is proportional to V under constant conditions • Understand what is meant by an ohmic conductor	3.5.1.1 Resistance defined as $R = \frac{V}{I}$ 3.5.1.2 Ohm's law as a special case where $I \propto V$ under constant physical conditions Current–voltage characteristics for an ohmic conductor Questions can be set where either I or V is on the horizontal axis of the characteristic graph	MS 3.1, 3.2, 3.3, 3.4, PS 3.1 Plot and interpret linear graphs PS 3.2, 3.3 Process and analyse data, considering margins of error ATf Correctly construct circuits	13.4, 13.5	
6 I–V characteristics Students learn about the characteristic behaviour of semiconductor diodes and filament lamps, and plan an experiment to obtain I–V data for these components.	• Describe and explain the behaviour of a metal wire, a filament bulb and a semiconductor diode	3.5.1.2 Current–voltage characteristics for a semiconductor diode and filament lamp Questions can be set where either I or V is on the horizontal axis of the characteristic graph	ATg Design circuits	13.5	

7 Producing I–V characteristics Students carry out their planned experiment, collect data and plot I–V graphs for a semiconductor diode and a filament lamp.	• Use ammeters and voltmeters (digital and analogue) to collect data to plot I–V characteristics	3.5.1.2 Current–voltage characteristic for a semiconductor diode	PS 2.2 Present data in appropriate ways PS 3.1 Plot and interpret graphs ATf Correctly construct circuits	13.5	
8 Combining resistors Students use multimeters (as resistance meters and/or voltmeters and ammeters) to measure the resistance of various combinations of resistors, and use the equations for combinations of resistors to solve circuit problems.	• Measure the total resistance of a combination of resistors that include series and parallel arrangements • Calculate the total resistance of a combination of resistors that include series and parallel arrangements	3.5.1.4 Resistors: in series, $R_T = R_1 + R_2 + R_3 + \cdots$ in parallel, $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$	MS 2.2, 2.3 Change the subject of an equation and substitute numerical values using appropriate units PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques ATb Use appropriate digital instruments	13.6	
9 Power and resistance Students derive the equations $P = I^2R = \frac{V^2}{R}$ and apply these in solving circuit problems.	• Apply the power equations to the solution of circuit problems	3.5.1.4 Power equations: $P = IV = I^2R = \frac{V^2}{R}$	MS 0.1 Recognise and make use of appropriate units in calculations MS 2.2 Change the subject of an equation, including non-linear equations MS 2.4 Solve algebraic equations	13.7	
10 Resistivity Students learn about the property of resistivity, ρ, use the equation $R = \frac{\rho l}{A}$ and plan an investigation to find the resistivity of a metal wire by measuring its change in	• Understand and apply the equation $R = \frac{\rho l}{A}$ • Design an appropriate circuit to measure the resistivity of a length of metal wire	3.5.1.3 Resistivity $\rho = \frac{RA}{l}$	MS 0.1 Recognise and make use of appropriate units in calculations MS 2.2 Change the subject of an equation, including non-linear equations PS 2.4 Identify variables, including those that must be controlled	13.8	

resistance as its length changes			ATg Design circuits		
11 Finding the resistivity of a wire Students carry out a Required Practical to investigate the change in resistance with changing length of wire and use their results to determine the resistivity of the metal.	Demonstrate mastery of the following practical competencies: • Follows written procedures • Applies investigative approaches and methods when using instruments and equipment • Safely uses a range of practical equipment and materials • Makes and records observations • Researches, references and reports		MS 1.2 Find arithmetic means MS 1.5 Identify uncertainties in measurements MS 4.3 Calculate area of cross-section PS 3.1, 3.2, 3.3 Plot and interpret graphs, process and analyse data, considering margins of error ATa,b,e Use appropriate analogue and digital equipment, including micrometers ATc Take multiple readings to increase accuracy		Required Practical 5: Determination of resistivity of a wire using a micrometer, ammeter and voltmeter

One hour lessons	Learning Outcomes	Specification Content	Skills Covered	Student Book Section	Required Practicals
CHAPTER 14 – Electricity 2 (11 hours)					
1 Internal resistance and emf Students observe that the terminal pd provided by a power supply can vary according to the resistance of the circuit, and are introduced to the equation $V = \mathcal{E} - Ir$.	• Define emf and explain how and why it differs from the terminal potential difference • Use the equation $V = \mathcal{E} - Ir$ to solve circuit problems	3.5.1.6 Electromotive force, $\mathrm{E} = \frac{E}{Q}$, $\mathrm{E} = I(R + r)$ Students will be expected to understand and perform calculations for circuits in which the internal resistance of the supply is not negligible	MS 2.2, 2.3, 2.4 Change the subject of an equation, substitute values using appropriate units and solve equations	14.1	
2 Investigating the emf and internal resistance of a cell Students carry out a Required Practical to investigate the emf and internal resistance of a cell.	Demonstrate mastery of the following practical competencies: • Follows written procedures • Applies investigative approaches and methods when using instruments and equipment • Safely uses a range of practical equipment and materials • Makes and records observations		MS 1.5 Identify uncertainties in readings and combine them appropriately MS 3.4 Determine the slope and intercept of a linear graph PS 3.2 Process and analyse data using appropriate mathematical skills ATb Use digital ammeters and voltmeters ATf Correctly construct circuits	14.1	Required Practical 6: Investigation of the emf and internal resistance of electric cells and batteries by measuring the variation of the terminal pd of the cell with current in it
3 Internal resistance of electrical power supplies Students design and carry out experiments to measure the terminal pd of different types of cells (such as a fruit/vegetable cell, a solar cell, a 12 V lab pack) as the current in the circuit is varied.	• Apply knowledge of a practical technique to find the emf and internal resistance of a power supply • Design an appropriate experiment, specifying the ammeter and voltmeter ranges required • Make an estimate of the uncertainties in the readings		MS 1.5 Identify uncertainties in readings and combine them appropriately PS 1.1, 1.2 Apply knowledge of internal resistance to a practical context PS 3.2 Process and analyse data using appropriate mathematical skills	14.1	

	and combine these to arrive at an overall uncertainty for internal resistance and emf		PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques ATg Design, construct and check circuits		
4 Investigating the efficiency of electrical energy transfer Students carry out an experiment using a power supply of known internal resistance and emf, and/or model the experiment using a spreadsheet, and plot a graph of power transfer to the external circuit versus the value of the external resistance, *R*.	• Design a suitable circuit to carry out an experiment to measure power and resistance • Use a spreadsheet to model a simple electrical circuit • Discuss the accuracy of a theoretical model, compare it with real practical results and adjust the model accordingly		MS 3.6 Draw and use the slope of a tangent to a curve as a measure of rate of change MS 3.9 Apply the concepts underlying calculus PS 3.1 Plot and interpret graphs PS 3.2 Process and analyse data using appropriate mathematical skills ATk Use spreadsheet modelling of a graph of power against resistance to determine where the power is a maximum	14.1	
5 Resistance and temperature Students investigate how the resistance of a metal wire varies with temperature, discuss their results and carry out research to provide a physical explanation for their results.	• Design and carry out an experiment to measure resistance at different temperatures • Explain the cause of resistance in metals and explain how temperature makes a difference	3.5.1.3 Description of the qualitative effect of temperature on the resistance of metal conductors	MS 1.4 Make order of magnitude calculations MS 3.5 Calculate rate of change from a graph PS 2.1 Comment on experimental design and evaluate scientific methods Practical competency 5: Researches, references and reports	14.2	
6 Investigating the current surge through a light bulb	• Use data logging equipment to measure current		ATg Design and construct circuits		

Students use data logging equipment to record the current through a light bulb during the first few seconds after it is turned on.	• Decide on an appropriate rate of data capture and a sensible duration		ATk Use a data logger with sensors to collect data		
7 Semiconductors Students are introduced to semiconductors, in particular the thermistor and its behaviour and applications, then investigate the variation of resistance of a thermistor with temperature.	• Use a digital multimeter to measure the resistance of a thermistor • Identify sources of error and suggest improvements to the experimental method • Plot a suitable graph	3.5.1.3 Description of the qualitative effect of temperature on the resistance of thermistors Only negative temperature coefficient (ntc) thermistors will be considered Applications of thermistors to include temperature sensors and resistance–temperature graphs	PS 1.2 Apply scientific knowledge to practical contexts PS 2.1 Comment on experimental design and evaluate scientific methods PS 2.3 Evaluate results and draw conclusions with reference to measurement uncertainties and errors PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques ATa, b, f, g Use appropriate analogue and digital equipment and correctly construct circuits	14.3	
8 Superconductors Students learn about the physical phenomenon of superconductivity, its initial discovery and subsequent developments, do some further research, and then prepare a presentation on an aspect of superconductivity, such as room-temperature superconductivity or new applications.	• Appreciate that scientific knowledge and understanding develop over time • Appreciate how science contributes to society through applications	3.5.1.3 Superconductivity as a property of certain materials which have zero resistivity at and below a critical temperature which depends on the material Applications of superconductors to include the production of strong magnetic fields and the reduction of energy loss in transmission of electric power Critical field will not be assessed	Practical competency 5: Researches, references and reports	14.4	

9 Presenting research Students complete the preparation of their presentations and then present to their peers.	• Use presentation software to deliver a presentation • Present scientific information clearly and confidently				
10 Potential dividers Students construct potential dividers from individual resistors, use digital multimeters to measure pds, and investigate how the measured pds change when a load resistor is placed across one half of the divider.	• Construct a potential divider • Verify the equation $V_{out} = V_{in}\left(\frac{R_1}{R_1 + R_2}\right)$ • Explain what happens when the potential divider supplies current • Use the equation to solve problems involving potential dividers	3.5.1.5 The potential divider used to supply constant or variable potential difference from a power supply	PS 4.1 Know and understand how to use a wide range of experimental and practical instruments, equipment and techniques ATa, b, f, g Use appropriate analogue and digital equipment and correctly construct circuits	14.5	
11 Sensors in potential divider circuits Students design potential divider circuits that work as automatic switches triggered by changing light levels or changing temperatures.	• Know how the resistance of an LDR changes as incident light intensity changes • Understand how LDRs and thermistors can be used in potential divider circuits • Calculate the value of resistors needed for the potential divider to switch at a given light level or temperature	3.5.1.5 Potential divider: examples should include the use of variable resistors, thermistors, and light dependent resistors (LDR) in the potential divider	ATb, g Design and construct circuits using appropriate digital instruments	14.3, 14.5	