OXFORD
INTERNATIONAL
AQA EXAMINATIONS

INTERNATIONAL AS-LEVEL PHYSICS

(9630)

Outline Schemes of Work

For teaching from September 2016 onwards
For AS exams in June 2017 onwards

Introduction

This Scheme of Work has been prepared by teachers for teachers. We hope you will find it a useful starting point for producing your own schemes.

The Scheme of Work is designed to be a flexible medium term plan for the teaching of content and development of the skills that will be assessed. It covers the needs of the specification for the International AS units of Physics 9630.

The teaching of investigative and practical skills is embedded within the specification. We are producing a Practical Handbook that provides further guidance on this. There are also opportunities in this scheme of work, such as the inclusion of rich questions.

We have provided links to some resources. These are illustrative and in no way an exhaustive list. We would encourage teachers to make use of any existing resources, as well as resources provided by Oxford International AQA Examinations and new textbooks written to support the specification. Please note there maybe access restrictions to certain websites from certain countries.

Prior knowledge noted below comprises knowledge from the current double science (ie Core and Additional Science) International GCSE specifications. Students who studied the separate International Science GCSE courses will have this knowledge but may also have been introduced to other topics which are relevant to the International A-level content. Topics only found in separate sciences are not included in the prior knowledge section.

We know that teaching times vary from school to school. In this scheme of work we have made the assumption that it will be taught over about 30 weeks with 4½ to 5 hours of contact time per week. Teachers will need to fine tune the timings to suite their own students and the time available. It could also be taught by one teacher or by more than teacher with topics being taught concurrently.

The **assessment opportunities** column details AQA past paper questions that have been mapped to this new Oxford International AQA qualification and are available through the international Exampro from early 2016. Of course there are also Sample Assessment Materials for download at oxfordaqaexams.org.uk/9630

3.1 Measurements and their errors

Content in this section is a continuing study for a student of physics. A working knowledge of the specified fundamental (base) units of measurement is vital. Likewise, practical work in the subject needs to be underpinned by an awareness of the nature of measurement errors and of their numerical treatment. The ability to carry through reasonable estimations is a skill that is required throughout the course and beyond.

3.1.1 Use of SI units and their prefixes

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Fundamental (base) units. Use of mass, length, time, amount of substance, 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 use the prefixes: T, G, M, k, c, m, μ, n, p, f Students should be able to convert between different units of the same quantity, eg J and eV, J and kW h.	0.5 weeks	• Students know that base units are needed in a system of measurement. • Students demonstrate that they can convert between different units of the same quantity, eg J and eV, J and kW h.	Use of dimensional analysis to predict relationships between quantities, e.g. the speed of a wave, *v*, in water in terms of depth, *d*, and *g*.	Exampro/SAMs AS and A-level Q on same topic.	http://www.npl.co.uk/educate-explore/

3.1.2 Limitation of physical measurements

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Identification and suggestions for removal of random and systematic errors. Precision, repeatability, reproducibility, resolution and accuracy. Use of absolute, fractional and percentage uncertainties to represent uncertainty in the final answer for a quantity. Combination of absolute and percentage uncertainties where measurements are added, subtracted, multiplied, divided, or raised to powers. Representation of uncertainty in a data point on a graph using error bars.	1.0 weeks	• Students explain the difference between precision and accuracy. • Students explain the difference between repeatability and reproducibility. • Students can estimate uncertainties in measurements. • Students are able to calculate percentage uncertainties from absolute uncertainties. • Students are able to combine absolute and percentage uncertainties.	Practical: investigate the relationship between time period and length for a pendulum. Give students the opportunity to estimate uncertainties in the measurement of length and time.		https://www.youtube.com/watch?v=1dTn2pt5PuA

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Determine the uncertainties in the gradient and intercept of a straight-line graph for graphs with or without associated error bars. In practical work students should understand the link between the number of significant figures in the value of a quantity and its associated uncertainty.		• Students can use error bars on graphs to estimate uncertainties in gradients and intercepts.			

3.1.3 Estimation of Physical Quantities

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Estimation of approximate values of physical quantities to the nearest order of magnitude. Use of these estimates together with their knowledge of physics to produce further derived estimates also to the nearest order of magnitude.	0.5 weeks	Students are able to make order of magnitude estimates.	Students participate in group learning by designing their own order of magnitude estimates.	Extend to estimates outside physics, e.g. estimate how many piano tuners there are in Chicago.	http://physics.info/orders-magnitude/problems.shtml http://powersof10.com/film

3.2 Mechanics and materials

Introduction

Vectors and their treatment are introduced followed by development of the student's knowledge and understanding of forces, energy and momentum. A study of materials is considered in terms of their bulk properties including elastic and plastic behaviour, the Young modulus and tensile strength.

3.2.1 Scalars and vectors

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The nature of scalar and vector quantities. Addition of vectors by calculation or scale drawing. The resolution of vectors into two components. The conditions for equilibrium for two or three coplanar forces acting at a point.	0.5 weeks	• Students can distinguish between scalar and vector quantities including velocity/speed, mass, force/weight, acceleration, displacement/distance. • Students can add two vectors by constructing an appropriate scale drawing. • Calculate the sum of two vectors. • Resolve a vector into two perpendicular components. • Recognise the conditions for two or three coplanar forces acting at a point to be in equilibrium.	**Learning Activity:** • Provide a list of scalar and vector quantities. • Investigate the parallelogram law for combining vectors using three masses, string and pulleys. • Practise calculations combining vectors using vector triangles. • Practical investigation into resolving forces using a fan cart or rolling cars down a slope at various angles. • Construct free body diagrams to show equilibrium when two or three coplanar forces act at a point.	PHYA1 Jan 2013 Q2 PHYA1 Jan 2012 Q1 PHYA1 May 2012 Q1	http://ed.ted.com/lessons/football-physics-scalars-and-vectors-michelle-buchanan

		• Apply the conditions for equilibrium in the context of an object at rest or moving at constant velocity.	**Skills developed by learning activities:** Demonstration of knowledge and understanding of vector and scalar quantities. Apply knowledge and understanding of how vectors can be combined. Apply knowledge and understanding of how vectors can be resolved. Mathematical skills: Use of calculators to handle sine and cosine when resolving vectors. Mathematical skills: 2D representation of coplanar forces. Mathematical skills: Use of sin and cos in problems involving the resolution of vectors.		

3.2.2 Moments

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Definition of the moment of a force about a point. A couple as a pair of equal and opposite coplanar forces. The equation for the moment of a couple. The principle of moments. The centre of mass and its position in a uniform regular solid.	0.5 weeks	• Define and calculate the moment of a force. • Describe a couple and calculate the moment of a couple. • State the principle of moments • Apply and use the principle to analyse the forces acting on a body in equilibrium. • Explain what is meant by the centre of mass.	**Learning Activity:** • Explain what is meant by the moment of a force and a couple. • Practise calculations of moments of a force. • Calculations involving couples produced by coplanar forces. • Experimental investigation of the principle of moments. • Give examples of centre of mass of regular solids. • Determine the centre of gravity and hence the centre of mass by using pieces of card and a plumb line. **Skills developed by learning activities:** Demonstration of knowledge and understanding of the moment of a force and a couple. Apply knowledge and understanding of the moment	PHYA1 May 2014 Q3 PHYA1 Jan 2013 Q3 PHYA1 May 2012 Q3 PHYA1 Jan 2012 Q3 PHYA1 May 2011 Q4	http://www.schoolphysics.co.uk/age16-19/Mechanics/Statics/text/Equilibrium_/index.html Rich question: Are the centre of mass and centre of gravity of a body always in the same position?

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			equation by using in calculations. Apply knowledge and understanding of the principle of moments in calculations. Mathematical skills: Use algebraic equations for moments, couples and the principle of moments.		

3.2.3 Motion along a straight line

Prior knowledge: Motion graphs, the acceleration due to gravity.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Definitions of displacement, speed, velocity, acceleration. 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. The equations for uniform acceleration. $v = u + at$ $s = \left(\frac{u+v}{t}\right)t$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$ The acceleration due to gravity, *g*.	1.5 weeks	• Define displacement, speed, velocity and acceleration. • Distinguish between velocity and speed. • Calculate velocities and accelerations. • Calculate both instantaneous and average velocities. • Draw graphs to represent motion. • Recognise the significance of the areas of velocity – time and acceleration – time graphs. • Recognise the significance of the gradients of displacement-time and velocity-time graphs.	**Learning Activity:** • Practise calculations using the definitions of displacement, speed, velocity and acceleration. • Use light gates to obtain data from a trolley rolling down a slope or a glider on an air track to generate displacement-time and velocity-time graphs. • Practise plotting and analysing motion graphs. • Highlight the link between displacement-time, velocity-time and acceleration-time graphs. • Practise calculations using the equations of uniform acceleration. • Practical to determine *g* using a free fall method.	PHYA1 May 2013 Q2 Q3 PHYA1 May 2012 Q2 PHYA1 Jan 2012 Q3(b) PHYA1 May 2011 Q1, Q2 PHYA1 Jan 2011 Q5	http://hyperphysics.phy-astr.gsu.edu/hbase/mechanics/motgraph.html http://www.grc.nasa.gov/WWW/k-12/airplane/mofall.html Rich Question: What is the average velocity of a cyclist who cycles at a constant speed of 20 m s^{-1}, around a circular track of circumference 400 m when they are a quarter of the way around the track?

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
		• Recall the equations of uniform acceleration and can apply them in calculations. Involving motion in straight lines. • Analyse experiments to determine the acceleration due to gravity using a graphical method.	**Required practical 1** Determination of *g* by a freefall. Procedures should include determination of *g* from graph (eg/from graph of *s* against t^2) **Skills developed by learning activities:** Demonstration of knowledge and understanding of displacement, speed, velocity and acceleration. Apply knowledge and understanding of displacement, speed, velocity and acceleration in calculations. Mathematical skills: Distinguish between instantaneous velocity and average velocity. Practical skills: Solve motion problems in a practical context. Demonstration of knowledge and		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			understanding of motion graphs. Apply knowledge and understanding in the analysis of motion graphs. Mathematical skills: Calculate rate of change from motion graphs showing a linear relationship. Mathematical skills: Draw and use the slope of a tangent to a curve in motion graphs. Apply knowledge and understanding of the equations for uniform acceleration. Mathematical skills: Use calculators to find powers. Mathematical skills: Change the subject of the equations of uniform acceleration. Mathematical skills: Substitute into and solve equations for uniform acceleration.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Apply knowledge and understanding of motion graphs and the equations of uniform acceleration to determine *g*. Mathematical skills: Find arithmetic means from data from the determination of *g*. Mathematical skills: Apply the concepts underlying calculus by solving equations involving rates of change in the experiment to determine *g*.		

3.2.4 Projectile motion

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Independent effect of motion in horizontal and vertical directions of a uniform gravitational field. A qualitative treatment of friction. Qualitative treatments of lift and drag forces. A qualitative treatment of the effects of air resistance on the trajectory of a projectile. The factors affecting the maximum speed of a vehicle.	1.0 weeks	• Explain how the motion of a projectile can be analysed by treating its horizontal and vertical motion independently. • Analyse the motion of a projectile by considering the effect of gravity on horizontal and vertical motion. • Describe friction quantitatively. • Explain the nature of lift and drag forces. • Describe the effects of air resistance on the trajectory of a projectile. • Explain why falling objects can reach a terminal speed. • Discuss the factors that affect the maximum speed of a vehicle.	**Learning Activity:** • Practise examples of projectile motion. • Demonstrate the monkey and hunter experiment. • Consider the effects of air resistance on the horizontal and vertical motion of a projectile. • Experiment to investigate air resistance and terminal velocity using different numbers of stacked coffee filters or cupcake cases. • Investigate the motion of different shaped objects through a tall column of viscous fluid. • Outline the nature of lift and drag forces. • Model the effects of air resistance on the motion of projectiles using a spread sheet.	PHYA1 May 2014 Q2 PHYA1 Jan 2011 Q2	http://phet.colorado.edu/sims/projectile-motion/projectile-motion_en.html http://www.nationalstemcentre.org.uk/elibrary/resource/2084/monkey-and-hunter http://www.instructables.com/id/MONKEY-HUNTER-PHYSICS/

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Skills developed by learning activities: Demonstration of knowledge and understanding of projectile motion. Apply knowledge and understanding of the independence of horizontal and vertical motion when considering projectiles. Mathematical skills: Use of sine and cos and 2D diagrams to represent projectile motion. Practical skills: Evaluate results from the motion of an object through a fluid. Analyse, interpret and evaluate evidence from motion in a fluid experiments. Demonstration of knowledge and understanding of the nature of frictional forces. Apply knowledge and understanding of the effects of frictional forces on projectile motion.		

3.2.5 Newton's laws of motion

Prior knowledge: Force = mass × acceleration

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Knowledge and application of the three laws of motion. Use of the equation *F = ma*.	1.0 Weeks	• Recall the three laws of motion and apply them in appropriate situations. • Construct and use free-body diagrams. • Use the equation linking force and acceleration in calculations. • Recognise that the equation can only be used in situations where the mass is constant.	**Learning Activity:** • Give examples of Newton's first and second law. • Practise examples of free-body diagrams and relate these to Newton's first and second law. • Investigate Newton's Second law using trollies or an air track. • Practise examples using the equation *F=ma*. • Investigate situations where mass is changing, e.g. rocket motion. • Model the motion of a rocket using a spreadsheet. • Give examples of Newton's third law. **Skills developed by learning activities:** Demonstration of knowledge and understanding of Newton's Laws of motion.	PHYA1 May 2013 Q1 PHYA1 May 2011 Q3	http://hyperphysics.phy-astr.gsu.edu/hbase/newt.html Rich Question: How is the equation, *F=ma*, modified when mass is changing?

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Apply knowledge and understanding of Newton's laws in practical situations. Mathematical skills: substitute values into equation linking force, mass and acceleration. Practical skills: Knowledge and understanding of practical instruments needed to investigate Newton's Second law. Analyse, interpret and evaluate evidence from investigation of Newton's Second Law. Mathematical skills: Use 2D representation of forces in a free-body diagram. Practical skills: Use ICT to model motion of rocket.		

3.2.6 Momentum

Prior knowledge: Safety features in cars such as crumple zones.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Define momentum The conservation of linear momentum in one dimension. Force as rate of change of momentum. Define impulse and its relationship to the area under a force-time graph. The relationship between impact forces and contact time. Distinguish between elastic an inelastic collisions. Apply the conservation of momentum to explosions.	1.0 week	• define momentum and recall the unit for momentum. • discuss the conservation of linear momentum and apply it in calculations involving collisions in one dimension. • relate force to rate of change of momentum. • define impulse. • deduce the effect on impact forces of contact times. • distinguish between elastic and inelastic collisions. • apply momentum conservation to explosions.	**Learning Activity:** • Give the definition of momentum and state the principle of the conservation of momentum. • Practise examples involving the conservation of momentum. • Investigate momentum using colliding trollies or gliders on an air track. • Link rate of change of momentum to Newton's Second Law and demonstrate how this leads to *F=ma*. • Give examples of impulse and link this to the relationship between impact forces and contact time.		http://hyperphysics.phy-astr.gsu.edu/hbase/elacol.html http://hyperphysics.phy-astr.gsu.edu/hbase/inecol4.html http://www.animations.physics.unsw.edu.au/jw/momentum.html Rich Question: Prove that an object of mass, *m*, must be stationary after an elastic collision with a stationary object also of mass *m*.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			• Explain the difference between elastic and inelastic collisions and investigate inelastic collisions by dropping different balls from the same height and measuring the height of rebound. • Practise examples using the conservation of momentum in explosions. **Skills developed by learning activities:** Demonstration of knowledge and understanding of momentum. Apply knowledge and understanding of the conservation of momentum in the analysis of collisions. Practical skills: Evaluate results from conservation of momentum experiments and draw conclusions. Practical skills: Process and analyse data from conservation of momentum experiments.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Demonstration of knowledge and understanding of impulse. Apply knowledge and understanding of impulse and relate this to the area under a force-time graph. Apply knowledge and understanding of the relationship between impact force and contact time. Demonstration of knowledge and understanding elastic and inelastic collisions. Mathematical skills: Substitute numerical values into a conservation of momentum equation and change the subject of the equation.		

3.2.7 Work, energy and power

Prior knowledge: Calculating work and power.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The relationship between energy transferred and work done $W = Fs\cos\theta$ Rate of doing work is equal to the rate of energy transfer $P = \frac{\Delta W}{\Delta t} = Fv$ The significance of the area under a force displacement graph. Efficiency as the ratio of useful output power to input power.	1.0 week	• Recognise that when work is done energy is transferred. • Calculate the work done including situations where the force is not acting in the direction of displacement. • Calculate the rate of doing work. • Analyse situations in which the force acting is variable. • Recall that the work done or energy transferred is equal to the area under a force displacement graph. • Calculate efficiency as a ratio and as a percentage.	**Learning Activity:** • Review the relationship between work and energy transfer from GCSE. • Practise calculations for work done including situations where force and displacement do not act in the same direction. • Derive the equation linking power, force and velocity. • Construct force displacement graphs and work out the area under the graph. • Investigate the power developed by the body by doing step ups or lifting masses. • Define efficiency and practice calculations for efficiency in practical situations, e.g. using pulley systems. • Investigate the efficiency of an electric motor.	PHYA1 Jan 2013 Q1 PHYA1 Jan 2012 Q1, Q2	http://hyperphysics.phy-astr.gsu.edu/hbase/work.html https://phet.colorado.edu/en/simulations/category/physics/work-energy-and-power

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Skills developed by learning activities: Demonstration of knowledge and understanding the relationship between work done and energy transfer. Apply knowledge and understanding of work done using the appropriate equation. Mathematical skills: Use ratios, fractions and percentages in efficiency calculations. Practical skills: Consider precision and accuracy of data in efficiency experiments. Practical skills: Know and understand the use of a wide range of experimental and practical instruments, equipment and techniques in efficiency experiments.		

3.2.8 Conservation of energy

Prior knowledge: Energy is always conserved**.**

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The principle of conservation of energy. Kinetic energy and gravitational potential energy. Quantitative and qualitative applications of energy conservation.	0.5 weeks	• Recall the principle of the conservation of energy. • Calculate kinetic and gravitational potential energy. • Describe energy changes involving kinetic, gravitational potential energy and work done against friction.	**Learning Activity:** • Review the principle of conservation of energy. • Practise calculations using gravitational potential energy and kinetic energy. • Investigate energy changes in a bouncing ball. • Estimate the energy that can be derived from food consumption. **Skills developed by learning activities:** Demonstration of knowledge and understanding of the principle of conservation of energy. Apply knowledge and understanding of the formulae for gravitational potential energy and kinetic energy.	PHYA1 Jan 2012 Q2 PHYA1 Jan 2013 Q1 PHYA1 May 2014 Q1	http://hyperphysics.phy-astr.gsu.edu/hbase/conser.html http://www.nuffieldfoundation.org/node/1842

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Practical skills: Use analogue apparatus to measure heights and heights of rebound for a bouncing ball. Mathematical skills: Estimate energies derived from food consumption. Mathematical skills: Change the subject of equations calculating gravitational potential energy and kinetic energy.		

3.2.9 Bulk properties of solids

Prior knowledge: The definition of density. Investigation of Hooke's law using springs.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The definition of density. Hooke's law and the elastic limit. The force extension equation: $F = k\Delta l$ Definitions of tensile stress and tensile strain. The meaning of breaking stress. Elastic strain energy $energy\ stored = \frac{1}{2}F\Delta l$ Description of plastic behaviour, fracture and brittle behaviour related to force-extension graphs. Interpretation of stress – strain curves. Application of energy	1.0 week	• Define density and do calculations using the density equation. • State Hooke's law and explain what is meant by the elastic limit. • Apply the force extension equation and recognise that the constant, k, is known as the stiffness or the spring constant. • Demonstrate that they recognise the meanings of tensile stress and tensile strain. • Explain what breaking stress means. • Calculate elastic strain energy. • Recognise that the energy stored is equal to the area under a force-extension graph.	**Learning Activity:** • Practise calculations including those involving composite materials. • Determine the density of different objects. • Investigate the elastic behaviour of various materials such as metals in the form of wires and springs and rubber in the form of elastic bands. • Review Hooke's Law and elastic limit. • Give definitions of tensile stress and tensile strain and practice using both these quantities in calculations. • Explain what is meant by elastic strain energy. • Illustrate plastic behaviour, elastic behaviour, fracture and brittle behaviour using a variety of stress strain graphs for a variety of materials.	PHYA1 May 2013 Q4 PHYA1 May 2012 Q5 PHYA1 Jan 2012 Q4 PHYA1 Jan 2011 Q1	https://depts.washington.edu/bonebio/ASBMRed/biomecha/bio.swf http://www-tc.pbskids.org/zoom/printables/activities/pdfs/eggbungeejump.pdf

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
conservation to examples involving elastic strain energy and energy to deform. The transformation of spring energy to kinetic and gravitational potential energy. Appreciation of energy conservation issues in the context of ethical transport design		• Explain what is meant by plastic behaviour, fracture and brittle behaviour. • Analyse stress – strain curves. • Apply energy conservation to examples involving elastic strain energy and energy to deform. • Analyse the energy changes taking place in an oscillating spring. • Appreciate the importance of energy conservation in transport design.	• Practise calculations involving energy conservation involving elastic strain energy and energy to deform. • Describe the energy changes that take place when a mass is attached to a vibrating spring. • Consider energy conservation issues in the context of ethical transport design. **Skills developed by learning activities:** Demonstration of knowledge and understanding of the meaning of density. Apply knowledge and understanding of density in calculations. Mathematical skills: Use of ratios in density calculations. Mathematical skills: Calculate volumes of regular solids.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Demonstration of knowledge and understanding of Hooke's Law and elastic limit. Mathematical skills: Translate information between graphical, numerical and algebraic form when investigating elastic behaviour. Demonstration of knowledge and understanding of tensile stress and tensile strain. Mathematical skills: Understand the significance of the area between the curve and the *x-axis* on a force extension graph. Demonstration of knowledge and understanding of plastic behaviour, fracture and brittle behaviour. Apply knowledge and understanding of plastic behaviour, fracture and brittle behaviour when relating them to force extension graphs.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Apply knowledge and understanding in the interpretation of stress strain graphs. Apply knowledge and understanding in the description of the energy changes in masses attached to vibrating springs. Analyse, interpret and evaluate evidence when considering energy conservation in the context of ethical transport design.		

3.2.10 The Young modulus

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The definition of the Young modulus. Experiment to determine the Young modulus using a stress – strain graph.	0.5 week	• Define the Young modulus and use it in calculations. • Describe a method to determine the Young modulus.	**Learning Activity:** • Define the Young modulus and practice using this property in calculations. • Carry out an experiment to determine the Young modulus of the metal in a wire. **Required practical 2** Investigation of load-extension graph for a wire and determination of the Young modulus for the material of the wire. Demonstration of knowledge and understanding of the Young modulus. Apply knowledge and understanding of the Young modulus in calculations. Mathematical skills: Translate information between graphical, numerical and algebraic form when investigating the Young modulus.	SAM Q6 PHYA1 May 2014 Q4 PHYA1 Jan 2013 Q4 PHYA1 May 2011 Q6 PHYA1 Jan 2011 Q6	https://www.tes.co.uk/teaching-resource/Young-Modulus-AS-Physics-6130086/ http://tap.iop.org/mechanics/materials/228/page_46520.html

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Mathematical skills: Calculate cross sectional areas of wires. Practical skills: Use appropriate analogue apparatus in the Young modulus experiment. Practical skills: Use methods to increase accuracy in the Young modulus experiment. Practical skills: use micrometer to measure the diameters of wires. Practical skills: Present data from the Young modulus experiment in appropriate ways. Mathematical skills: Determine the slope of a stress strain graph to find the Young modulus.		

3.3 Particles, radiation and radioactivity

In this section students will study microscopic nature of matter and the basics of radioactive decay. They will gain an appreciation of the range of elementary particles and their interactions.

3.3.1 Constituents of the atom

Prior knowledge:

GCSE Double Award Science
- simple atomic model
- isotopes

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Simple model of the atom, including the proton, neutron and electron. Charge and mass of the proton, neutron and electron in SI and relative units. Specific charge of the proton and the electron and of nuclei and ions. Proton number, Z, nucleon number, A, nuclide notation ($^A_Z X$). Meaning of isotopes and the use of isotopic data.	0.5 Weeks	• Describe a model of the atom including protons, neutrons and electrons. • Identify the charge and mass of the proton, neutron and electron in SI and relative units. • Define specific charge and calculate the specific charges of the proton and the electron and of nuclei and ions.	**Learning activities:** • Present pictures of atomic models and ask students to identify the neutrons, protons and electrons. • Compare the charges and masses of protons, neutrons and electrons in SI and relative units. • Introduce specific charge and practice calculations involving the specific charges of protons and electrons	Past exam paper materials: PHYA1 May 2013 Q1 PHYA1 January 2013 Q1 (a) PHYA1 June 2012 Q 2 (a) PHYA1 June 2012 Q2 (b) PHYA1 May 2014 Q Q2 (a) (i) (ii) (iii)	http://phet.colorado.edu/en/simulation/build-an-atom Rich questions: - Why was specific charge important in the discovery of the electron by J.J. Thomson?

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
		• Identify the unit of specific charge. • Define proton number and nucleon number and recognise nuclear notation. • Explain the meaning of isotopes. • Analyse isotopic data.	and of nuclei and ions. • Review atomic number and nucleon number and practice using nuclide notation. • Review isotopes and practise analysing isotopic data to deduce neutron number. **Skills developed by learning activities:** Demonstration of knowledge of simple models of the atom. Practical skills: Present masses in SI and relative units. Mathematical skills: Substitute numerical values into algebraic equations to calculate specific charge.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Mathematical skills: Solve algebraic equations involving masses and charges of nuclei and ions. AO2: Demonstrate knowledge and understanding isotopes and analyse isotope data.		

3.3.2 Elementary Particles

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
For every type of particle there is a corresponding antiparticle. Knowledge of particle antiparticle pairs and a comparison of their properties. The mechanisms of annihilation of matter and antimatter and pair production. Comparison of particle and antiparticle masses, charge and rest energy in MeV.	0.5 weeks	• Recall that every particle has a corresponding antiparticle. • Contrast the properties of particles and antiparticles. • Give examples of particle antiparticle pairs. • Calculate the energy of photons from wavelength and frequency. • Describe the processes of annihilation and pair production.	**Learning Activity:** • Show table which compares properties of particles and antiparticles. • Highlight similarities (rest mass) and differences (quantum numbers). • Look at examples of annihilation of matter and antimatter. • Calculations linking the frequencies of photons produced in the annihilation of matter and antimatter. • Look at examples of pair production. • Calculations on the energy of photons necessary for pair production.	PHYA1 January 2013 Q2 PHYA1 May 2013 Q4(b)	QED – Richard Feynman Rich Question: How is annihilation of matter and antimatter used in forming a PET scan?

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Skills developed by learning activities: Demonstration of knowledge of matter and antimatter. Apply knowledge and understanding of the factors affecting the energy of photons. Mathematical skills: Substitute numerical values into algebraic equations to calculate energies of photons using frequency and wavelength. Mathematical skills: Solve algebraic equations to calculate energy of photons from frequency and wavelength. Demonstration of knowledge of the process of pair production.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Mathematical skills: Substitute numerical values into algebraic equations to calculate the frequencies of photons required for pair production. Demonstration of knowledge of the process of annihilation. Mathematical skills: Solve algebraic equations to calculate the frequency of the photons released during annihilation.		

3.3.3 Radioactivity

Prior knowledge:

GCSE Dual Award Science
– unstable nuclei

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Possible decay modes of unstable nuclei including α, β^-, β^+ The existence of the neutrino was hypothesised to account for conservation of energy in beta decay. Equations for α, β^- and β^+ decays including neutrinos and antineutrinos. The decay of a free neutron should be known. Half-life; Determination of half-life from graphical decay data including decay; simple calculations involving times that are whole numbers of the half-life.	1.0 weeks	• Describe alpha decay and beta decay. • Illustrate alpha beta decay using equations. • Deduce why the neutrino is necessary in beta decay. • Determine the half-life of an isotope using a graphical method. • Recognise that nuclei can be in excited states and emit γ rays when they lose energy. • Know how technetium-99m can be used in medicine.	**Learning activities:** • Explain what is meant by unstable nuclei and contrast alpha and beta decay. • Demonstrate alpha and beta tracks in a cloud chamber. • Demonstrate the difference in absorption properties of alpha and beta. • Practise writing equations to represent alpha and beta decay. • Compare the energy of alpha particles with beta particles and discuss why this led to the existence of neutrinos being	Past exam paper materials: PHYA1 May 2011 Q2 PHYA1 May 2010 Q2 (b) (c)	http://www.walter-fendt.de/ph14e/decayseries.htm Rich question: Identify a radioactive decay series and analyse the types of decay taking place that lead to the series.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Existence of nuclear excited states; γ ray emission; application, e.g. use of technetium-99m as a source in medical diagnosis. Properties of α, β, and γ radiation and experimental identification of these using simple absorption experiments; applications, eg to relative hazards of exposure to humans. Applications also include thickness measurements of aluminium foil paper and steel. Inverse-square law for γ radiation: $\boldsymbol{I} = \frac{I_0}{r^2}$ Experimental verification of inverse-square law. Applications, eg to safe handling of radioactive		• Describe properties of α, β, and γ radiation and use these to deduce the radiation present by analysing results from absorption experiments. • Describe uses of α, β, and γ radiation such as thickness measurement. • Understand the inverse square law for gamma radiation. • Describe experiments that verify the inverse square law. • Describe the nature of background radiation.	hypothesised. • Measure the half-life of an isotope. • Investigate the inverse square law for gamma radiation. • Measure the average background radiation in various locations and at various times of the day. **Skills developed by learning activities:** Apply knowledge and understanding of scientific ideas, processes, techniques and procedures when handling quantitative data. Apply knowledge and understanding of alpha and beta decay to analyse and complete equations representing the decay.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Background radiation; examples of its origins and experimental elimination from calculations.			Apply knowledge and understanding of half-life Apply knowledge and understanding of the inverse square law. Know the main causes of background radiation.		

3.4 Electricity

This section builds on and develops earlier study of these phenomena from GCSE. It provides opportunities for the development of practical skills and lays the groundwork for later study of the many electrical applications that are important to society.

3.4.1 Basics of electricity

Prior knowledge:

Electric current as a flow of charge. Definitions of current, potential difference and resistance.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Electric current is the rate of flow of charge. Potential difference is the work done per unit charge. The definition of resistance.	0.5 weeks	• Recognise that current is the rate of flow of charge. • Recognise that potential difference is the work done per unit charge. • Recognise the equation defining resistance and can apply it in calculations.	**Learning Activity:** • Review current as a flow of charge and practice calculations. • Review potential difference is the work done per unit charge and practice calculations. • Practise resistance calculations. **Skills developed by learning activities:** Demonstrate and apply knowledge and understanding of electric current, potential difference and resistance.	PHYA1 May 2012 Q7 PHYA1 Jan 29012 5(a)	http://hyperphysics.phy-astr.gsu.edu/hbase/electric/elecur.html

3.4.2 Current-voltage characteristics

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The current-voltage characteristics for an ohmic conductor, a semiconductor diode and a filament lamp. Ohm's law as a special case where current is directly proportional to voltage under constant physical conditions.	1.5 weeks	• Interpret current-voltage graphs and distinguish between the characteristics for an ohmic conductor, a semiconductor diode and a filament lamp. • Recognise that Ohm's law is a special case for a component with constant resistance.	**Learning Activity:** • Investigate current-voltage graphs for an ohmic conductor, a semiconductor diode and a filament lamp. • Give examples of current-voltage graphs and explain how they should be interpreted. • Explain Ohm's Law and outline why it is a special case. **Skills developed by learning activities:** Demonstration of knowledge and understanding of current-voltage characteristics of various components. Apply knowledge and understanding of current-voltage characteristics. Mathematical skills: Plot current voltage characteristics.		http://hyperphysics.phy-astr.gsu.edu/hbase/electric/ohmlaw.html

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Practical skills: Plot and interpret current-voltage graphs. Practical skills: Use digital meters. Practical skills: Construct and check circuits.		

3.4.3 Resistivity

Prior knowledge: The definition of resistance.

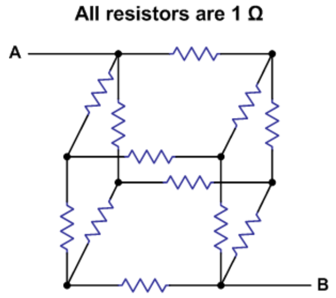
Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Resistivity. Experiment to determine the resistivity of a wire. Description of the qualitative effect of temperature on the resistance of metal conductors. The effect of temperature on a negative temperature coefficient thermistor. Application of thermistors in temperature sensors. Superconductivity as a property of certain materials which have zero resistivity at or below the critical temperature. Applications of superconductors.	1.5 weeks	• Define resistivity and use the resistivity equation in calculations. • Describe an experiment to determine the resistivity of a wire. • Describe the effect of temperature on the resistance of metal conductors. • Describe the effect of temperature on a negative temperature coefficient thermistor. • Describe application of thermistors including temperature sensors. • Explain what is meant by a superconductor.	**Learning Activity:** • Define resistivity and practise using the definition in calculations. • Determine the resistivity of the metal in a wire. • Explain how temperature affects the resistance of metal conductors. • Explain how temperature affects the resistance of a thermistor. • Investigate applications of thermistors. • Explain what is meant by superconductivity and explain the significance of critical temperature. • Investigate some of the uses of superconductors.	PHYA1 May 2014 Q6 PHYA1 Jan 2013 Q7(a) PHYA1 Jan 2012 Q5(b)	http://phet.colorado.edu/en/simulation/resistance-in-a-wire http://hyperphysics.phy-astr.gsu.edu/hbase/electric/resis.html https://teachers.web.cern.ch/teachers/archiv/HST2001/accelerators/superconductivity/superconductivity.htm

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
		• Describe how superconductors can be used to produce strong magnetic fields and to reduce energy losses in the transmission of electric power.	**Skills developed by learning activities:** Demonstration of knowledge and understanding of resistivity. Apply knowledge and understanding of resistivity in calculations. Mathematical skills: Calculate cross-sectional areas of wires. Mathematical skills: Plot a graph of voltage against current. Practical skills: Use micrometers to measure diameters of wires Practical skills: Use multimeters Practical skills: Apply scientific knowledge set in a practical context. Practical skills: Know and use a wide range of practical equipment to determine the resistivity of the metal in a wire.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Demonstration of knowledge and understanding of effect of temperature on the resistance of metal conductors. Demonstration of knowledge and understanding of effect of temperature on a negative temperature coefficient thermistor. Analyse and interpret how thermistors are used in temperature sensors. Demonstration of knowledge and understanding of superconductivity. Analyse and interpret the applications of superconductors.		

3.4.4 Circuits

Prior knowledge: Combining resistors in series. Energy and power in electric circuits.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Combining resistors in series and in parallel. The relationship between currents, voltages and resistances in series and parallel circuits. Cells in series and identical cells in parallel. The energy and power equations: *E=VIt* $P = VI = I^2R = \frac{V^2}{R}$ The conservation of charge and energy in dc circuits.	1.5 weeks	• Calculate the total resistance for combinations of series and parallel resistors. • Analyse series and parallel circuits. • Analyse circuits involving combinations of cells in series and identical cells in parallel. • Calculate the energy and power in electric circuits. • Explain how energy and charge are conserved in electric circuits.	**Learning Activity** • Explain how resistance in series and resistances in parallel combine. • Explain why the total resistance of a parallel combination of resistors is always less than the smallest resistance resistor in the combination. • Practise calculations involving series and parallel arrangements of components. • Outline how the cells in series and in parallel combine. • Review the power and energy equations and practise calculations involving these. • Demonstrate how energy and charge are conserved in electric circuits.	PHYA May 2014 Q5 PHYA1 Jan 2013 Q6, 7(b) PHYA1 Jan 2012 Q 6 PHYA1 Jun 2012 Q6	http://www.tap.iop.org/electricity/circuits/index.html Rich Question: What is the resistance between A and B? 

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Skills developed by learning activities: Demonstration of knowledge and understanding of series and parallel electric circuits. Apply knowledge and understanding in the analysis of electric circuits. Practical skills: Construct circuits from a range of components. Mathematical skills: Use fractions when combining resistors in parallel. Practical skills: Know and understand how to use a wide range of experimental and practical instruments when investigating circuit. Practical skills: Construct circuits with various component configurations and measure currents and potential differences.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Demonstration of knowledge and understanding of how cells combine in series and in parallel.. Apply knowledge and understanding of the power equations and apply these in the analysis of electric circuits. Mathematical skills: Substitute numerical values into the power equations. Mathematical skills: Change the subject of the power equations. Demonstration of knowledge and understanding of the conservation of energy in electric circuits.		

3.4.5 Potential divider

Prior knowledge: The definition of resistance

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The potential divider used to supply constant or variable potential difference from a power supply. The use of variable resistors, light dependent resistors and thermistors in potential divider circuits.	1.0 weeks	• Demonstrate that they understand how a potential divider can provide a constant or variable potential difference from a power supply. • Describe how variable resistors, light dependent resistors and thermistors can be used in potential divider circuits.	**Learning Activity:** • Investigate potential divider circuits. • Investigate how sensors can be used in potential divider circuits. **Skills developed by learning activities:** Demonstration of knowledge and understanding of the potential divider. Apply knowledge and understanding of using potential dividers in sensing circuits. Mathematical skills Use ratios and fractions when analysing potential divider circuits.	SAM Q5 PHYA1 May 2014 Q7 PHYA1 May 2013 Q7 PHYA1 May 2012 Q7	http://tap.iop.org/electricity/circuits/118/page_46038.html

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Mathematical skills: Substitute numerical values into the potential divider equation. Practical skills: Know and understand how to use a wide range of experimental and practical instruments when investigating potential divider circuits. Practical skills: Correctly design, connect and check circuits.		

3.4.6 Electromotive force and internal resistance

Prior knowledge: The definition of resistance.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
The definition of electromotive force (emf). Circuit equation when cells have appreciable internal resistance. $\in = I(R+r)$ Terminal potential difference.	1.0 weeks	• Define emf with reference to cells. • Understand and perform calculations for circuits in which the internal resistance of the supply is not negligible. • Explain what is meant by terminal pd.	**Learning Activity:** • Explain what is meant by emf, internal resistance and terminal pd. • Practise calculations using the equation $\in = I(R+r)$ • Determine the internal resistance of a cell by measuring the terminal pd when the cell is connected to an external resistor with variable resistance. **Required practical 3:** Investigation of the emf and internal resistance of electric cells and batteries by measuring the variation of the terminal pd of a cell or battery with current.	PHYA1 May 2013 Q6 PHYA1 Jan 2012 Q7	http://www.tap.iop.org/electricity/emf/index.html http://www.nuffieldfoundation.org/practical-physics/internal-resistance-potato-cell Rich Question: Why is it important for car batteries to have very low internal resistances?

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Skills developed by learning activities: Demonstration of knowledge and understanding of emf and internal resistance. Apply knowledge and understanding of emf and internal resistance in circuit calculations. Mathematical skills: Translate data from experiments to determine internal resistance into graphical form. Mathematical skills: Understand that the circuit equation including emf and internal resistance represents a linear relationship. Mathematical skills: Determine the intercept and slope of a linear graph. Practical skills: Present data from experiments to determine internal resistance in appropriate ways.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Practical skills: Plot and interpret the graph from experiments to determine internal resistance. Practical skills: Correctly construct circuits for experiments to determine internal resistance.		

3.5 Oscillations and waves

The earlier study of mechanics is developed further with a study of examples of systems undergoing simple harmonic motion (SHM). This is followed by a study of the characteristics, properties, and applications of travelling waves and stationary waves and concludes with a study of refraction, diffraction, superposition and interference. They will also study evidence for wave-particle duality of electromagnetic radiation and moving particles.

3.5.1 Oscillating Systems

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Mass-spring system: $T = 2\pi\sqrt{\frac{m}{k}}$ Simple pendulum: $T = 2\pi\sqrt{\frac{l}{g}}$ Variation of $\mathbf{E}_k$, $\mathbf{E}_p$, and total energy with both displacement and time. Effects of damping on oscillations.	1.0 weeks	• Use the mass-spring and pendulum equations to solve SHM problems. • Describe the energy changes that take place in SHM and sketch graphs of E_k, E_p and total energy. • Describe the effects of damping on oscillations including sketching appropriate graphs of damped systems.	• Rehearse mass-spring, pendulum and other harmonic oscillator problem solving using Exampro questions. • Students compare the form of the mass-spring and pendulum systems. • Discuss the energy changes that occur during SHM using the Nothing Nerdy simulation. • Students observe damped systems such as water in a U-tube or a damped spring. Different degrees of damping illustrated practically or with a simulator.		Rich Questions: How should a suspension system work to give the smoothest possible ride? Mass-spring resources from IOP Pendulum resources from IOP Nothing Nerdy Energy simulation Practical investigation of damped motion from school physics.co.uk Damped motion simulator Water in a U-tube ISA June 2012

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Skill developed by learning activities: Apply knowledge and understanding of scientific ideas to derive the equations for the mass spring and pendulum systems. Analyse and interpret data to reach conclusions on the relationship between variables in oscillating systems.		

3.5.2 Forced vibrations and resonance

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Qualitative treatment of free and forced vibrations. Resonance and the effects of damping on the sharpness of resonance. Examples of these effects in mechanical systems and situations involving stationary waves.	0.5 weeks	• Qualitative treatment of free and forced vibrations. • Resonance and the effects of damping on the sharpness of resonance. • Examples of these effects in mechanical systems and situations involving stationary waves.	• Demonstration and discussion of Barton's pendulum. • Student experiments on resonance from Institute of Physics (IOP) (hacksaw blade, book on string etc.). Students report back to group on one of the experiments. • Students investigate the effect of damping on resonance curves using a simulation from PhET • Student experiment: Determination of the Speed of Sound using resonance of an air column. • Resonance case studies: car suspension system questions and resources from IOP; Tacoma bridge disaster; shattering a glass with your voice.	Exam pro QSP.4A.10 Antonine education questions on vibrations.	Rich Question: Is it possible to shatter a glass with your voice alone? Scientific American Article– Fact or Fiction Opera Singer breaking a glass Mythbuster Shattering a glass with your voice from youtube Students experiments on resonance from IOP PHET resonance simulation Determining the speed of sound using an air column Car suspension systems and Tacoma bridge from IOP Tacoma Bridge Disaster video from youtube

3.5.3 Progressive waves

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Define the terms amplitude, frequency, period, wavelength. Phase and phase difference measured as angles (radians or degrees) or as fractions of a cycle. Use the equation $c = f\lambda$, $f = 1/T$	0.5 weeks	• Define the terms frequency, period, amplitude and wavelength of a wave. • Explain what is meant by phase and phase difference. • Use the equation $c = f\lambda$ in calculations	**Learning Activity:** • Video transverse waves in a long heavy spring and use video analysis to measure the frequency and wavelength. • Investigate the variation of the speed of a water wave with depth of water in a plastic tray. • Measure the speed of sound in air. • Use a spreadsheet to model the behaviour of a travelling wave using the full wave equation. • Practise calculations to calculate frequencies, periods and wavelengths of waves.	PHYA1 May 2013 Q6(d) PHYA1 Jan 2012 Q7	http://www.acs.psu.edu/drussell/demos/waves/wavemotion.html http://www.animations.physics.unsw.edu.au/waves-sound/

			Skills developed by learning activities: Demonstration of knowledge and understanding of the terms amplitude, frequency, period, wavelength, phase and phase difference Apply knowledge and understanding of the equation $c = f\lambda$ to calculate wavelengths and frequencies. Mathematical skills: Substitute numerical values into the wave equation. Mathematical skills: Use sin in the modelling of a transverse wave. Practical skills: generate and measure waves Practical skills: process and analyse data using a spread sheet.		

3.5.4 Longitudinal and transverse waves

Prior knowledge: The difference between transverse and longitudinal waves.

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Nature of longitudinal and transverse waves. Examples to include: sound, electromagnetic waves, and waves on a string. Students will be expected to know the direction of displacement of particles/fields relative to the direction of energy propagation and that all electromagnetic waves travel at the same speed in a vacuum. Use of ultrasound in medicine.	1.0 weeks	• Distinguish between longitudinal and transverse waves. • Recognise that electromagnetic waves are transverse and all examples of electromagnetic waves travel at the same speed in a vacuum. • Describe the polarisation of transverse waves. • Describe applications of polarisers.	**Learning Activity:** • Use a slinky to demonstrate transverse and longitudinal waves. • Give details of electromagnetic waves and identify their key properties. • Demonstrate the polarisation of a transverse wave using a heavy spring and a vertical narrow gap. • Demonstrate the polarisation of light using polarisation. • Investigate how the transmitted intensity of light varies with the angle between the planes of polarisation of two polarisers. • Research the uses of polarisers.	PHYA1 May 2013 Q6 PHYA1 May 2014 Q7 PHYA1 May 2012 Q7	http://science.hq.nasa.gov/kids/imagers/ems/waves2.html http://missionscience.nasa.gov/ems/02_anatomy.html http://hyperphysics.phy-astr.gsu.edu/hbase/waves/emwv.html http://www.cyberphysics.co.uk/topics/light/polarisation.htm

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
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.			**Skills developed by learning activities:** Demonstration of knowledge and understanding of longitudinal and transverse waves. Demonstration of knowledge and understanding electromagnetic waves and their properties. Demonstration of knowledge and understanding of the polarisation of transverse waves. Practical skills: Use a light source and polarisers to investigate polarisation. Apply knowledge and understanding of the polarisation to explain applications. Analyse, interpret and evaluate scientific information, and ideas to identify applications of polarisation.		Rich Questions: How do we measure the speed of light? What affect does the motion of a light source have on the speed of light emitted from the source? What are the consequences of this?

3.5.5 Principle of superposition of waves and formation of stationary waves

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Stationary waves. Nodes and antinodes on strings. $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ for the first harmonic. 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 formed on a string and those produced with microwaves and sound waves should be considered. Stationary waves on strings will be described in terms of harmonics.	1.5 weeks	• Explain what is meant by a stationary wave. • Define the terms node and antinode. • Calculate the frequency of the first harmonic produced by a stationary wave on a string. • Describe the formation of a stationary wave by two waves of the same frequency travelling in opposite directions. • Use graphs to demonstrate the formation of standing waves. • Describe the formation of standing waves produced by microwaves and sound waves.	**Learning Activity:** • Investigate the variation of the frequency of stationary waves on a string with length, tension and mass per unit length. • Practise calculations to determine the frequency of the first harmonic. • Model the formation of stationary waves using a spreadsheet. • Demonstrate examples of stationary waves using strings, sound waves and microwaves. **Skills developed by learning activities:** Demonstration of knowledge and understanding of standing waves including the meaning of nodes and antinodes.	PHYA1 May 2014 Q7 (d) PHYA1 Jan 2013 Q6 PHYA1 May 2012 Q6 PHYA1 Jan 2011 Q4	http://phet.colorado.edu/en/simulation/wave-on-a-string https://www.youtube.com/watch?v=HpovwbPGEoo Rich Question: How are standing waves used in musical instruments?

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Knowledge of experiments that investigate the variation of the frequency of stationary waves on a string with length, tension and mass per unit length of the string.			Practical skills: Generate and measure waves. Mathematical skills: Substitute numerical values into equation for frequency of first harmonic. Apply knowledge and understanding in calculations of the frequencies of the first harmonic. Apply knowledge and understanding of waves to explain the formation of standing waves. Demonstration of knowledge and understanding of different examples of stationary waves.		

3.5.6 Interference

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Path difference. Coherence. Interference and diffraction using a laser as a source of monochromatic light. 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. Fringe spacing $w = \frac{\lambda D}{s}$ Production of interference pattern using white light. Students are expected to show awareness of safety issues associated with using lasers.	2.0 weeks	• Explain the meaning of path difference and coherence. • Describe the Young's double slit experiment and calculate fringe spacing using data from the experiment. • Distinguish between the fringe patterns produced by monochromatic and white light. • Analyse different examples of the double slit experiment using both electromagnetic and sound waves. • Explain how knowledge and understanding of the nature of electromagnetic radiation has changed over time.	**Learning Activity:** • Demonstrate how path difference determines whether interference is constructive or destructive. • Demonstrate with a laser the interference pattern produced by a double slit. Use measurements from the pattern to determine the wavelength of the laser light. • Carry out the Young's double slit experiment using an incandescent lamp and filters. • Examine the interference produced by a white light source and identify the differences between this pattern and the pattern produced by monochromatic light. • Demonstrate the interference of sound waves by using two loudspeakers connected to the same source.	PHYA1 Jan 2013 Q7 PHYA1 May 2011 Q7	http://www.physicsclassroom.com/class/light/Lesson-1/Two-Point-Source-Interference https://www.youtube.com/watch?v=G-R8LGy-OVs

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Students will be expected to describe and explain interference produced with sound and electromagnetic waves.			• Investigate the historical development of how the understanding of the nature of electromagnetic radiation has changed over time. **Required Practical 4:** Investigation of interference effects to include the Young's slit experiment and interference by a diffraction grating. **Skills developed by learning activities:** Demonstration of knowledge and understanding of path difference and coherence Apply knowledge and understanding of path difference to determine whether interference is constructive or destructive. Practical skills: Use light source or laser to investigate interference.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Mathematical skills: Change the subject of the fringe separation equation to determine the wavelength of light. Demonstration of knowledge and understanding of the difference in the fringe pattern produced by monochromatic and white light sources. Demonstration of knowledge and understanding of examples of interference of sound waves. Analyse scientific information, ideas and evidence about the nature of light.		

3.5.7 Diffraction

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
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. Plane transmission diffraction grating at normal incidence. Derivation of $d \sin\theta = n\lambda$ Applications of diffraction gratings.	1.0 weeks	• Describe the diffraction patterns produced using a single slit with monochromatic light and contrast this with the pattern produced by white light. • Discuss the effect on the width of the central maximum when the slit width is varied. • Describe the use of the plane diffraction grating. • Use the grating equation in calculations. • Describe uses of the diffraction grating such as the analysis of spectra.	**Learning Activity:** • Demonstrate the single slit diffraction pattern for white light and monochromatic light. • Demonstrate the effect of changing slit width on the central maxima of the diffraction pattern. • Investigate interference by a plane diffraction grating. • Derive the equation for normal incidence on a plane diffraction grating. • Use the diffraction grating equation to determine the wavelength of a light source. • Practise calculations using the diffraction grating. • Investigate applications of the diffraction grating.	PHYA1 May 2014 Q6 PHYA1 May 2013 Q7 PHYA1 Jan 2012 Q5 PHYA1 Jan 2011 Q3	http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/grating.html Rich Question: How does the spectrum from a diffraction grating differ from that produced by a prism?

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Skills developed by learning activities: Demonstration of knowledge and understanding of the main features of a single slit diffraction pattern. Apply knowledge and understanding of interference patterns to explain the diffraction pattern produced by a plane diffraction grating. Apply knowledge and understanding of path difference to derive the diffraction grating equation. Apply knowledge and understanding of the diffraction grating equation in calculations. Mathematical skills: Use of sine in diffraction grating equation. Analyse scientific information to determine applications of the diffraction grating.		

3.5.8 Refraction at a plane surface

Prior knowledge: The refraction of light

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Refractive index of a substance, $n = \frac{c}{c_s}$ Students should recall that the refractive index of air is approximately 1. Snell's law of refraction for a boundary $n_1 \sin\theta_1 = n_2 \sin\theta_2$ Total internal reflection $\sin\theta_c = \frac{n_2}{n_1}$ Simple treatment of fibre optics including the function of the cladding. Optical fibres will be limited to step index only. Material and modal dispersion. Students are expected to understand the principles and consequences of pulse broadening and absorption.	1.0 weeks	• Define refractive index in terms wave speed in different media. • Recall that the refractive index of air is approximately 1. • Use Snell's law to calculate angles when light crosses a boundary between two media. • Describe total internal reflection and distinguish this from partial reflection. • Calculate critical angles using refractive indices. • Describe the step index optic fibre. • Understand the principles and consequences of pulse broadening and absorption.	**Learning Activity:** • Define refractive index and practise calculations calculating refractive indices from wave speeds. • Define Snell's law. • Practise calculations using Snell's law. • Use Snell's law to determine the refractive index of a rectangular glass block. • Demonstrate total internal reflection and show the meaning of the critical angle. • Determine the critical angle of the material in a semi-circular block. • Practise calculations involving the critical angle and the refractive indices of the materials either side of the boundary.	PHYA1 May 2014 Q5 PHYA1 May 2013 Q5 PHYA1 Jan 2013 Q5 PHYA1 May 2012 Q4 PHYA1 Jan 2012 Q6 PHYA1 May 2011 Q5	http://www.learnerstv.com/animation/animation.php?ani=102&cat=physics http://hyperphysics.phy-astr.gsu.edu/hbase/geoopt/refr.html https://www.youtube.com/watch?v=0MwMkBET_5I

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			• Demonstrate optic fibres, pointing out the importance of cladding. • Define material and modal dispersion and point out the consequences of pulse broadening and absorption. **Skills developed by learning activities:** Demonstration of knowledge and understanding of refractive index and its relationship to wave speed. Demonstration of knowledge and understanding of Snell's law. Apply knowledge and understanding of Snell's law in calculations. Mathematical skills: Use of sine. Mathematical skills: Use of angles (incidence and refraction). Mathematical skills: Solve algebraic equations to determine angles of refraction.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Mathematical skills: Plot graph to determine refractive index. Demonstration of knowledge and understanding of total internal reflection and critical angle. Apply knowledge and understanding in calculations involving the critical angle. Mathematical skills: Solve algebraic equations to determine critical angles. Demonstration of knowledge and understanding of optic fibres and the importance of cladding. Demonstration of knowledge and understanding of material and modal dispersion. Practical skills: Apply scientific knowledge to explain the consequences of pulse broadening and absorption.		

3.5.9 Collisions of electrons with atoms

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Ionisation and excitation. Application in the fluorescent tube. Line spectra (eg of atomic hydrogen) as evidence for transitions between discrete energy levels in atoms. $hf = E1 - E2$ The electron volt. Characteristic and line spectrum for X-rays and use of X-rays in medical applications. Students should know the basic structure and operation of an X-ray tube. In questions energy levels may be given in eV or J. Students will be expected to be able to convert eV into J and vice versa.	0.5 weeks	• Describe the processes of excitation and ionisation. • Explain how excitation and ionisation apply in the fluorescent tube. • Define the electron volt. • Convert energies from eV to J and vice versa.	**Learning Activity:** • Show examples of line spectra with the use of discharge tubes and diffraction gratings or direct view spectroscopes. • Examine the structure of the fluorescent tube. • Practise calculations converting energy from joules to electron volts. **Skills developed by learning activities:** Demonstration of knowledge and understanding of nature of line spectra. Demonstration of knowledge and understanding of the structure of the fluorescent tube. Apply knowledge and understanding of the electron volt to perform calculations to convert energies in joules to electron volts. Mathematical skills: Recognise expressions in decimal and standard form when using energies in electron volts.	PHYA1 May 2014 Q4 PHYA1 Jan 2013 4	http://astronomy.swin.edu.au/cosmos/S/Spectral+Line http://www.colorado.edu/physics/2000/quantumzone/ https://www.youtube.com/watch?v=QI50GBUJ48s Rich Questions: How are line spectra used to measure the rotational speeds of stars? How do line spectra provide evidence of the Big Bang?

3.5.10 Photoelectric effect

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Photon model of electromagnetic radiation, the Planck constant .$E = hf = \frac{hc}{\lambda}$ Description of the photoelectric effect. Explanation of threshold frequency in terms of the photon model. Explanation of work function and stopping potential. The photoelectric equation.	1.0 week	• Describe the photoelectric effect. • Recognise that the threshold frequency cannot be explained by the wave model of light and can deduce an explanation of threshold frequency in terms of the photon model. • Explain the terms work function and stopping potential. • Analyse the photoelectric effect using the photoelectric equation and calculate the maximum kinetic energy of emitted electrons. • Deduce that the emitted electrons have a range of kinetic energies up to the maximum value calculated using the photoelectric equation.	**Learning Activity:** • Demonstrate the photoelectric effect using a zinc plate on the cap of an electroscope and an ultraviolet light source. • Discuss the predictions made by the wave theory of light and explain how the threshold frequency cannot be explained with this model. Explain that applying scientific method means that the theory of light needs to be changed to explain the experimental observations of the photoelectric effect. • Outline the photon model of light and how this explains threshold frequency. • Practise using the photoelectric equation to calculate the maximum kinetic energy of emitted electrons. • Provide the opportunity to deduce the effect of changing the intensity of the incident light and the frequency of the incident light.	SAM 02 PHYA1 May 2013 Q4 PHYA1 May 2012 Q4	http://physics.info/photoelectric/ https://www.youtube.com/watch?v=0qKrOF-gJZ4 https://www.youtube.com/watch?v=kcSYV8bJox8

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			• Plot graphs of maximum kinetic energies of emitted electrons against frequency of incident light for different metal surfaces. Analyse the graph to find a value for the Planck constant, the threshold frequency and the work function. **Skills developed by learning activities:** Apply knowledge and understanding of the photoelectric effect both qualitatively and quantitatively. Analyse, interpret and evaluate scientific ideas and evidence to see why the wave model of light does not explain the photoelectric effect Mathematical skills: Recognise expressions in decimal and standard form when applying the photoelectric equation.		

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Mathematical skills: Substitute numerical values into the photoelectric equation. Practical skills: Process and analyse data from photoelectric experiments. Mathematical skills: Solve the photoelectric equation to determine maximum kinetic energies of electrons. Mathematical skills: Plot maximum kinetic energy against frequency of incident light. Practical skills: Plot and interpret graphs of maximum kinetic energy of emitted electrons against frequency of incident light. Mathematical skills: Determine the intercept and gradient of the maximum kinetic energy against frequency graph to find a value for Planck’s constant, threshold frequency and work function.		

3.5.11 Wave particle duality

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
Electron diffraction as a demonstration that particles possess wave properties. The photoelectric effect as a demonstration that electromagnetic waves have a particulate nature. The de Broglie wavelength. How and why the amount of diffraction changes when the momentum of the particle is changed.	0.5 weeks	• Identify that electron diffraction provides evidence of particles having wave properties. • Analyse the photoelectric effect and deduce that it demonstrates the particulate nature of electromagnetic waves. • Calculate the wavelength of a particle using the de Broglie equation. • Explain how and why the amount of diffraction changes when the momentum of a particle is changed.	**Learning Activity:** • Demonstrate electron diffraction and compare with diffraction of a laser through a single slit. • Discuss the photoelectric effect and how it provides evidence of the dual nature of light. • Practise calculations using the de Broglie equation. **Skills developed by learning activities:** Demonstration of knowledge and understanding of electron diffraction. Practical skills: Demonstration using electron diffraction tube. Practical skills: Demonstration of knowledge and understanding of the dual nature of light.	PHYA1 May 2014 Q3	http://hyperphysics.phy-astr.gsu.edu/hbase/mod1.html - c1 Rich Questions: Is there experimental evidence for the diffraction of protons or neutrons? Why do electron microscopes have a much better resolving power than optical microscopes?

Learning objective	Time taken	Learning Outcome	Learning activity with opportunity to develop skills	Assessment opportunities	Resources
			Apply of knowledge and understanding of the de Broglie equation to calculate the de Broglie wavelength. Mathematical skills: Use prefixes when expressing wavelength values.		