VCE Physics

EP Curriculum Map

Unit 1: What ideas explain the physical world?

Area of Study 1: How can thermal effects be explained?

Thermodynamics principles

Content Descriptor	Lesson Names
Convert temperature between degrees Celsius and kelvin.	• Temperature
Describe the Zeroth Law of Thermodynamics as two bodies in contact with each other coming to a thermal equilibrium.	• Kinetic Theory and Gas Laws • Particle Model
Describe temperature with reference to the average kinetic energy of the atoms and molecules within a system.	• Kinetic Theory and Gas Laws • Particle Model
Investigate and apply theoretically and practically the First Law of Thermodynamics to simple situations: $Q = U + W$.	• First Law of Thermodynamics
Explain internal energy as the energy associated with random disordered motion of molecules.	• Conduction • Convection • Radiation
Distinguish between conduction, convection and radiation with reference to heat transfers within and between systems.	• Conduction • Convection • Radiation
Investigate and analyse theoretically and practically the energy required to: – raise the temperature of a substance: $Q = mc\Delta T$ – change the state of a substance: $Q = mL$	• Specific Heat Capacity
Explain why cooling results from evaporation using a simple kinetic energy model.	• Thermal Equilibrium • Heat Exchange Systems

Thermodynamics and climate science

Content Descriptor	Lesson Names

Identify regions of the electromagnetic spectrum as radio, microwave, infrared, visible, ultraviolet, x-ray and gamma waves.	• Electromagnetic Wave Model • The Electromagnetic Spectrum
Describe electromagnetic radiation emitted from the Sun as mainly ultraviolet, visible and infrared.	• Electromagnetic Wave Model • The Electromagnetic Spectrum
Calculate the peak wavelength of the re-radiated electromagnetic radiation from Earth using Wien's Law: $\lambda_{max} T$ = constant Compare the total energy across the electromagnetic spectrum emitted by objects at different temperatures such as the Sun. Describe power radiated by a body as being dependent on the temperature of the body according to the Stefan-Boltzmann Law, P∝T4	*Further development planned*
Explain the roles of conduction, convection and radiation in moving heat around in Earth's mantle (tectonic movement) and atmosphere (weather).	• The Enhanced Greenhouse Effect • The Greenhouse Effect
Model the greenhouse effect as the flow and retention of thermal energy from the Sun, Earth's surface and Earth's atmosphere.	• The Enhanced Greenhouse Effect • The Greenhouse Effect
Explain how greenhouse gases in the atmosphere (including methane, water and carbon dioxide) absorb and re-emit infrared radiation.	• The Enhanced Greenhouse Effect • The Greenhouse Effect
Analyse changes in the thermal energy of the surface of Earth and of Earth's atmosphere.	*Further development planned*
Analyse the evidence for the influence of human activity in creating an enhanced greenhouse effect, including affecting surface materials and the balance of gases in the atmosphere.	• Human Influences on Climate • Carbon Capture • Carbon Footprints • CFCs and the Ozone Layer

Issues related to thermodynamics

Content Descriptor	Lesson Names
Apply thermodynamic principles to investigate at least one issue related to the environmental impacts of human activity with reference to the enhanced greenhouse effect: – proportion of national energy use due to heating and cooling of homes – comparison of the operation and efficiencies of	• Housing Insulation • Energy Efficiency • Energy Efficient Houses • Heat Pumps • Refrigerators and Refrigerants • The Power Grid and You

domestic heating and cooling systems: heat pumps; resistive heaters; reverse-cycle air conditioners; evaporative coolers; solar hot water systems; and/or electrical resistive hot water systems – possibility of homes being built that do not require any active heating or cooling at all – use of thermal imaging and infrared thermography in locating heating losses in buildings and/or system malfunctions; cost savings implications – determination of the energy ratings of home appliances and fittings: insulation; double glazing; window size; light bulbs; and/or electrical gadgets, appliances or machines – cooking alternatives: appliance options (microwave, convection, induction); fuel options (gas, electricity, solar, fossil fuel) – automobile efficiencies: fuel options (diesel petrol, LPG and electric); air delivery options (naturally aspirated, supercharged and turbocharged); and fuel delivery options (common rail, direct injection and fuel injection).	
Explain how concepts of reliability, validity and uncertainty relate to the collection, interpretation and communication of data related to thermodynamics and climate science.	*Further development planned*

Area of Study 2: How do electric circuits work?

Concepts to model electricity

Content Descriptor	**Lesson Names**
Apply concepts of charge (Q), electric current (I), potential difference (V), energy (E) and power (P), in electric circuits.	• Circuit Properties • Electricity and Charge
Explore different analogies used to describe electric current and potential difference.	• Potential • Current
Investigate and analyse theoretically and practically electric circuits using the relationships: $I = \frac{Q}{t}, V = \frac{E}{Q}, P = \frac{E}{t} = VI$	• Electricity and Charge • Measuring Electricity • Potential • Current • Power • Electrical Potential Energy and Work • Potential Difference

Justify the use of selected meters (ammeter, voltmeter, multimeter) in circuits.	• Measuring Electricity • Electrical Potential Energy and Work • Potential Difference
Apply the kilowatt-hour ($kW\ h$) as a unit of energy.	• Power

Circuit electricity

Content Descriptor	Lesson Names
Model resistance in series and parallel circuits using – current versus potential difference ($I - V$) graphs – resistance as the potential difference to current ratio, including R = constant for ohmic devices – equivalent effective resistance in arrangements in • series: $R_T = R_1 + R_2 +... + R_n$ and • parallel: $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} +... + \frac{1}{R_n}$	• Potential • Electrical Potential Energy and Work • Potential Difference
Calculate and analyse the effective resistance of circuits comprising parallel and series resistance and voltage dividers.	• Circuits
Model household (AC) electrical systems as simple direct current (DC) circuits.	• Circuit properties
Compare power transfers in series and parallel circuits.	• Circuits • Circuit properties
Explain why the circuits in homes are mostly parallel circuits..	• Circuits • Circuit Analysis • Designing Simple Circuits • Complex Circuits

Using electricity

Content Descriptor	Lesson Names
Investigate and apply theoretically and practically concepts of current, resistance, potential difference (voltage drop) and power to the operation of electronic circuits comprising resistors, light bulbs, diodes, thermistors, light dependent resistors (LDRs), light-emitting diodes (LEDs) and potentiometers (quantitative analysis restricted to use of $I = \frac{V}{R}$ and $P = VI$).	• Circuit Analysis • Designing Simple Circuits • Complex Circuits • Combination Circuits and Voltage Dividers • Diodes, Variable Resistors and Transducers
Investigate practically the operation of simple circuits	• Introduction to Ohm's Law

containing resistors, variable resistors, diodes and other non-ohmic devices.	• Calculating Using Ohm's Law
Describe energy transfers and transformations with reference to transducers.	• Diodes, Variable Resistors and Transducers

Electrical safety

Content Descriptor	**Lesson Names**
Model household electricity connections as a simple circuit comprising fuses, switches, circuit breakers, loads and earth. Compare the operation of safety devices including fuses, circuit breakers and residual current devices (RCDs). Describe the causes, effects and treatment of electric shock in homes and identify the approximate danger thresholds for current and duration.	*Further development planned*

Area of Study 3: What is matter and how is it formed?

Origins of atoms

Content Descriptor	**Lesson Names**
Describe the Big Bang as a currently held theory that explains the origins of the Universe.	• The Big Bang Theory
Describe the origins of both time and space with reference to the Big Bang Theory.	*Further development planned*
Explain the changing Universe over time due to expansion and cooling.	• The Big Bang Theory • Cosmic Background Radiation
Apply scientific notation to quantify and compare the large ranges of magnitudes of time, distance, temperature and mass considered when investigating the Universe. Explain the change of matter in the stages of the development of the Universe including inflation, elementary particle formation, annihilation of anti-matter and matter, commencement of nuclear fusion, cessation of fusion and the formation of atoms.	*Further development planned*

Particles in the nucleus

Content Descriptor	Lesson Names
Explain nuclear stability with reference to the forces that operate over very small distances.	• Nuclear Model • Nuclear Forces
Describe the radioactive decay of unstable nuclei with reference to half-life.	• Introduction to Radiation • Types of Radiation • Radioactive Decay • Half-Life
Model radioactive decay as random decay with a particular half-life, including mathematical modelling with reference to whole half-lives.	• Types of Radiation • Radioactive Decay • Half-Life
Apply a simple particle model of the atomic nucleus to explain the origin of α, β^-, β^+ and γ radiation, including changes to the number of nucleons.	• Types of Radiation • Radioactive Decay • Half-Life
Explain nuclear transformations using decay equations involving α, β^-, β^+ and γ radiation.	• Types of Radiation • Balancing Nuclear Equations
Analyse decay series diagrams with reference to type of decay and stability of isotopes.	• Introduction to Radiation • Types of Radiation • Radioactive Decay • Half-Life
Relate predictions to the subsequent discoveries of the neutron, neutrino, positron and Higgs boson.	*Further development planned*
Describe quarks as components of subatomic particles.	• Elementary Particles • The Standard Model
Distinguish between the two types of forces holding the nucleus together: the strong nuclear force and the weak nuclear force.	• The Fundamental Forces
Compare the nature of leptons, hadrons, mesons and baryons.	• Conservation Laws
Explain that for every elementary matter particle there exists an antimatter particle of equal mass and opposite charge, and that if a particle and its antiparticle come into contact they will annihilate each other to create radiation.	*Further development planned*

Energy from the atom

Content Descriptor	Lesson Names
Explain nuclear energy as energy resulting from the	• Energy

conversion of mass: $E = mc^2$.	
Compare the processes of nuclear fusion and nuclear fission.	• Nuclear Fission • Nuclear Fusion
Explain, using a binding energy curve, why both fusion and fission are reactions that produce energy. Explain light as an electromagnetic wave that is produced by the acceleration of charges. Describe the production of synchrotron radiation by an electron radiating energy at a tangent to its circular path. Model the production of light as a result of electron transitions between energy levels within an atom.	• Transmutation and Decay

Unit 2: What do experiments reveal about the physical world?

Area of Study 1: How can motion be described and explained?

Concepts used to model motion

Content Descriptor	**Lesson Names**
Identify parameters of motion as vectors or scalars.	• Scalars and Vectors
Analyse graphically, numerically and algebraically, straight-line motion under constant acceleration: $v = u + at$, $v^2 = u^2 + 2as$, $s = \frac{1}{2}(u + v)t$, $s = ut + \frac{1}{2}at^2$, $s = vt - \frac{1}{2}at^2$	• Acceleration-Time Graphs • Distance and Time • Displacement • Displacement and Compass Directions • Speed • Velocity
Graphically analyse non-uniform motion in a straight line.	• Distance-Time Graphs • Displacement-Time Graphs • Velocity-Time Graphs • Acceleration-Time Graphs • Summary of Motion Graphs
Apply concepts of momentum to linear motion: $p = mv$.	• Momentum

Forces and motion

Content Descriptor	**Lesson Names**
Explain changes in momentum as being caused by a net force.	• Momentum • Conservation of Momentum
Model the force due to gravity, F_g, as the force of gravity acting at the centre of mass of a body, $F_g = mg$, where g is the gravitational field strength ($9.8\ N\ kg^{-1}$ near the surface of Earth).	• Types of Forces: Gravity
Model forces as vectors acting at the point of application (with magnitude and direction), labelling these forces using the convention 'force on A by B' or $F_{on\ A\ by\ B} = -F_{on\ B\ by\ A}$.	• Scalars and Vectors • Forces in One Dimension • Forces in Two Dimensions
Apply Newton's three laws of motion to a body on which forces act: $a = \frac{F_{net}}{m}$, $F_{on\ A\ by\ B} = -F_{on\ B\ by\ A}$.	• Scalars and Vectors • Forces in One Dimension • Forces in Two Dimensions

Apply the vector model of forces, including vector addition and components of forces, to readily observable forces including the force due to gravity, friction and reaction forces.	• Scalars and Vectors • Forces in One Dimension • Forces in Two Dimensions
Calculate torque: $\tau = r_{\perp}F$	• Torque • Torque from Force at an Angle
Investigate and analyse theoretically and practically translational forces and torques in simple structures that are in rotational equilibrium.	• Torque • Torque from Force at an Angle • Net Torque • Equilibrium

Energy and motion

Content Descriptor	**Lesson Names**
Apply the concept of work done by a constant force using: – work done = constant force × distance moved in direction of force: $W = Fs$ – work done = area under force-distance graph	• Momentum • Conservation of Momentum
Investigate and analyse theoretically and practically Hooke's Law for an ideal spring: $F = -k\Delta x$.	• Types of Forces: Gravity • Hooke's Law
Analyse and model mechanical energy transfers and transformations using energy conservation: – changes in gravitational potential energy near Earth's surface: $E_g = mg\Delta h$ – potential energy in ideal springs: $E_k = \frac{1}{2}k\Delta x^2$ – kinetic energy: $E_k = \frac{1}{2}mv^2$	• Potential Energy • Identifying KE or PE • Calculating KE and GPE • Mechanical Energy and Springs
Analyse rate of energy transfer using power: $P = \frac{E}{t}$	• Power • Energy Transfer
Calculate the efficiency of an energy transfer system: $\eta = \frac{useful\ energy\ in}{useful\ energy\ out}$.	• Energy Efficiency
Analyse impulse (momentum transfer) in an isolated system (for collisions between objects moving in a straight line): $I = \Delta p$	• Impulse
Investigate and analyse theoretically and practically momentum conservation in one dimension.	• Momentum

Area of Study 2

Content Descriptor	Lesson Names
Area of Study 2.1: What are stars? Area of Study 2.2: Is there life beyond Earth's Solar System? Area of Study 2.3: How do forces act on the human body? Area of Study 2.4: How can AC electricity charge a DC device? Area of Study 2.5: How do heavy things fly? Area of Study 2.6: How do fusion and fission compare as viable nuclear energy power sources? Area of Study 2.7: How is radiation used to maintain human health? Area of Study 2.8: How do particle accelerators work? Area of Study 2.9: How can human vision be enhanced? Area of Study 2.10: How do instruments make music? Area of Study 2.11: How can improvements in ball sports be improved? Area of Study 2.12: How does the human body use electricity?	*Further development planned*

Unit 3: How do fields explain motion and electricity?

Area of Study 1: How do things move without contact?

Fields and interactions

Content Descriptor	Lesson Names
Describe gravitation, magnetism and electricity using a field model.	• Introduction to Fields
Investigate and compare theoretically and practically gravitational, magnetic and electric fields, including directions and shapes of fields, attractive and repulsive fields, and the existence of dipoles and monopoles.	• Magnetic Fields • Examples of Magnetic Fields (Solenoids) • Permanent Magnetic Fields • Magnetic Field of a Current-Carrying Wire
Investigate and compare theoretically and practically gravitational fields and electrical fields about a point mass or charge (positive or negative) with reference to: – the direction of the field – the shape of the field – the use of the inverse square law to determine the magnitude of the field – potential energy changes (qualitative) associated with a point mass or charge moving in the field.	*Further development planned*
Investigate and apply theoretically and practically a vector field model to magnetic phenomena, including shapes and directions of fields produced by bar magnets, and by current-carrying wires, loops and solenoids.	• Magnetic Fields • Examples of Magnetic Fields (Solenoids) • Permanent Magnetic Fields • Magnetic Field of a Currenty-Carrying Wire
Identify fields as static or changing, and as uniform or non-uniform.	• Examples of Magnetic Fields • Permanent Magnetic Fields

Effects of fields

Content Descriptor	Lesson Names
Enalyse the use of an electric field to accelerate a charge, including: – electric field and electric force concepts: $E = k\frac{Q}{r^2}$ and $F = k\frac{q_1 q_2}{r^2}$ – potential energy changes in a uniform electric field: $W = qV,\ E = \frac{V}{d}$	• Coulomb's Law for Two Charges • Electrical Potential Energy and Work • Force on a Charge in a Magnetic Field • Motion of Charges in a Magnetic Field

– the magnitude of the force on a charged particle due to a uniform electric field: $F = qE$.	
Analyse the use of a magnetic field to change the path of a charged particle, including: – the magnitude and direction of the force applied to an electron beam by a magnetic field: $F = qvB$, in cases where the directions of v and B are perpendicular or parallel – the radius of the path followed by a low-velocity electron in a magnetic field: $qvB = \frac{mv^2}{r}$	• Coulomb's Law for Two Charges • Electrical Potential Energy and Work • Force on a Charge in a Magnetic Field • Motion of Charges in a Magnetic Field
Analyse the use of gravitational fields to accelerate mass, including: – gravitational field and gravitational force concepts: $g = G\frac{M}{r^2}$ and $F_g = G\frac{m_1 m_2}{r^2}$ – potential energy changes in a uniform gravitational field: $E_g = mg\Delta h$ – the change in gravitational potential energy from area under a force-distance graph and area under a field-distance graph multiplied by mass.	• The Earth's Gravitational Field • Gravitational Potential Energy and Work • Newton's Law of Universal Gravitation

Application of field concepts

Content Descriptor	Lesson Names
Apply the concepts of force due to gravity, F_g, and normal reaction force, F_N, including satellites in orbit where the orbits are assumed to be uniform and circular.	• Earth's Gravitational Field • Gravitational Potential Energy and Work
Model satellite motion (artificial, Moon, planet) as uniform circular orbital motion: $a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$	• Satellite Motion • Kepler's Laws of Planetary Motion
Describe the interaction of two fields, allowing that electric charges, magnetic poles and current carrying conductors can either attract or repel, whereas masses only attract each other. Investigate and analyse theoretically and practically the force on a current carrying conductor due to an external magnetic field, $F = nIlB$, where the directions of I and B are either perpendicular or parallel to each other.	• Magnetic Force on a Wire • Electromagnetic Induction in a Conductor
Investigate and analyse theoretically and practically the operation of simple DC motors consisting of one coil,	• Magnetic Force on a Wire • Electromagnetic Induction in a Conductor

containing a number of loops of wire, which is free to rotate about an axis in a uniform magnetic field and including the use of a split ring commutator.	
Model the acceleration of particles in a particle accelerator (limited to linear acceleration by a uniform electric field and direction change by a uniform magnetic field).	• Particle Accelerators

Area of Study 2: How are fields used to move electrical energy?

Generation of electricity

Content Descriptor	**Lesson Names**
Calculate magnetic flux when the magnetic field is perpendicular to the area, and describe the qualitative effect of differing angles between the area and the field: $\Phi_B = B_\perp A$.	• Magnetic Flux
Investigate and analyse theoretically and practically the generation of electromotive force (emf) including AC voltage and calculations using induced emf, $\varepsilon = -N\frac{\Delta\Phi_B}{\Delta t}$, with reference to: – rate of change of magnetic flux – number of loops through which the flux passes – direction of induced emf in a coil.	• Magnetic Flux • Properties of Inductors • Behaviour of Inductors • Torque on Coils in a Magnetic Field
Explain the production of DC voltage in DC generators and AC voltage in alternators, including the use of split ring commutators and slip rings respectively.	• Generators

Transmission of electricity

Content Descriptor	**Lesson Names**
Compare sinusoidal AC voltages produced as a result of the uniform rotation of a loop in a constant magnetic field with reference to frequency, period, amplitude, peak-to-peak voltage (V_{p-p}) and peak-to-peak current (I_{p-p}).	• Alternating Current
Compare alternating voltage expressed as the root-mean-square (rms) to a constant DC voltage	• Alternating Current

developing the same power in a resistive component.	
Convert between rms, peak and peak-to-peak values of voltage and current.	*Further development planned*
Analyse transformer action with reference to electromagnetic induction for an ideal transformer: $\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_1}{I_2}$	• Transformers
Analyse the supply of power by considering transmission losses across transmission lines.	• Transformers
Identify the advantage of the use of AC power as a domestic power supply.	• Alternating Current

Area of Study 3: How fast can things go?

Newton's laws of motion

Content Descriptor	**Lesson Names**
Investigate and apply theoretically and practically Newton's three laws of motion in situations where two or more coplanar forces act along a straight line and in two dimensions.	• Newton's First Law • Newton's Second Law • Newton's Third Law
Investigate and analyse theoretically and practically the uniform circular motion of an object moving in a horizontal plane, $\left(F_{net} = \frac{mv^2}{r}\right)$, including: – a vehicle moving around a circular road – a vehicle moving around a banked track – an object on the end of a string.	• Uniform Circular Motion • Vertical Circular Motion • Circular Motion on Banked Curves
Model natural and artificial satellite motion as uniform circular motion.	• Satellite Motion
Investigate and apply theoretically Newton's second law to circular motion in a vertical plane (forces at the highest and lowest positions only).	• Newton's Second Law • Vertical Circular Motion
Investigate and analyse theoretically and practically the motion of projectiles near Earth's surface, including a qualitative description of the effects of air resistance.	• Projectile Motion
Investigate and apply theoretically and practically the laws of energy and momentum conservation in isolated systems in one dimension.	• Conservation of Energy • Conservation of Momentum

Einstein’s theory of special relativity

Content Descriptor	**Lesson Names**
Describe Einstein’s two postulates for his theory of special relativity that: – the laws of physics are the same in all inertial (non-accelerated) frames of reference – the speed of light has a constant value for all observers regardless of their motion or the motion of the source.	• Origins of Special Relativity • Einstein's Theory of Special Relativity
Compare Einstein’s theory of special relativity with the principles of classical physics.	• Classical Relativity • Einstein's Theory of Special Relativity
Describe proper time (t_0) as the time interval between two events in a reference frame where the two events occur at the same point in space.	• Relativity of Simultaneity
Describe proper length (L_0) as the length that is measured in the frame of reference in which objects are at rest.	• Relativity of Simultaneity
Model mathematically time dilation and length contraction at speeds approaching c using equations: $t = t_0\gamma$ and $L = \frac{L_0}{\gamma}$ where $\gamma = \left(1 - \frac{v^2}{c^2}\right)^{-\frac{1}{2}}$	• Time Dilation • Length Contraction
Explain why muons can reach Earth even though their half-lives would suggest that they should decay in the outer atmosphere.	• Evidence for Special Relativity: Muons

Relationships between force, energy and mass

Content Descriptor	**Lesson Names**
Investigate and analyse theoretically and practically impulse in an isolated system for collisions between objects moving in a straight line: $F\Delta t = m\Delta v$	• Momentum • Impulse • Conservation of Momentum
Investigate and apply theoretically and practically the concept of work done by a constant force using: – work done = constant force × distance moved in direction of net force – work done = area under force-distance graph	• Work and Power
Analyse transformations of energy between kinetic energy, strain potential energy, gravitational potential energy and energy dissipated to the environment (considered as a combination of heat, sound and deformation of material):	• Energy Efficiency • Energy Calculations

– kinetic energy at low speeds: $E_k = \frac{1}{2}mv^2$ elastic and inelastic collisions with reference to conservation of kinetic energy – strain potential energy: area under force-distance graph including ideal springs obeying Hooke's Law: $E_s = \frac{1}{2}k\Delta x^2$ – gravitational potential energy: $E_g = mg\Delta h$ or from area under a force-distance graph and area under a field-distance graph multiplied by mass.	
Interpret Einstein's prediction by showing that the total 'mass-energy' of an object is given by: $E_{tot} = E_k + E_0 = \gamma mc^2$ where $E_0 = mc^2$, and where kinetic energy can be calculated by: $E_k = (\gamma - 1)mc^2$.	• Mass-Energy Equivalence • Mass Defect in Nuclear Physics
Describe how matter is converted to energy by nuclear fusion in the Sun, which leads to its mass decreasing and the emission of electromagnetic radiation.	• Nuclear Fusion

Unit 4: How can two contradictory models explain both light and matter?

Area of Study 1: How can waves explain the behaviour of light?

Properties of mechanical waves

Content Descriptor	Lesson Names
Explain a wave as the transmission of energy through a medium without the net transfer of matter.	• Transfer of Energy Through Waves
Distinguish between transverse and longitudinal waves.	• Transverse and Longitudinal Waves
Identify the amplitude, wavelength, period and frequency of waves.	• Transverse and Longitudinal Waves
Calculate the wavelength, frequency, period and speed of travel of waves using: $v = f\lambda = \frac{\lambda}{t}$	• Transverse and Longitudinal Waves • Wave Speed
Investigate and analyse theoretically and practically constructive and destructive interference from two sources with reference to coherent waves and path difference: $n\lambda$ and $\left(n - \frac{1}{2}\right)\lambda$ respectively.	• Superposition Principle • Two Source Interference of Waves
Explain qualitatively the Doppler effect.	• The Doppler Effect
Explain resonance as the superposition of a travelling wave and its reflection, and with reference to a forced oscillation matching the natural frequency of vibration.	• Superposition Principle
Analyse the formation of standing waves in strings fixed at one or both ends.	• Standing Waves in Strings
Investigate and explain theoretically and practically diffraction as the directional spread of various frequencies with reference to different gap width or obstacle size, including the qualitative effect of changing the $\frac{\lambda}{w}$ ratio.	• Huygens' Principle • Multi-slit diffraction

Light as a wave

Content Descriptor	Lesson Names
Describe light as an electromagnetic wave which is produced by the acceleration of charges, which in turn produces changing electric fields and associated	• Introduction to the Ray Model • The Electromagnetic Nature of Light

changing magnetic fields.	
Identify that all electromagnetic waves travel at the same speed, c, in a vacuum.	• Introduction to the Ray Model • The Electromagnetic Nature of Light
Compare the wavelength and frequencies of different regions of the electromagnetic spectrum, including radio, microwave, infrared, visible, ultraviolet, x-ray and gamma, and identify the distinct uses each has in society.	• Introduction to the Ray Model • The Electromagnetic Nature of Light
Explain polarisation of visible light and its relation to a transverse wave model.	• Polarisation of Light
Investigate and analyse theoretically and practically the behaviour of waves including: – refraction using Snell's Law: $n_1 sin(\theta_1) = n_2 sin(\theta_2)$ and $n_1 v_1 = n_2 v_2$ – total internal reflection and critical angle including applications: $n_1 sin(\theta_c) = n_2 sin(90^{\circ})$	• Reflection • Refraction • Introduction to Snell's Law • Total Internal Reflection
Investigate and explain theoretically and practically colour dispersion in prisms and lenses with reference to refraction of the components of white light as they pass from one medium to another.	• Refraction
Explain the results of Young's double slit experiment with reference to: – evidence for the wave-like nature of light – constructive and destructive interference of coherent waves in terms of path differences: $n\lambda$ and $\left(n - \frac{1}{2}\right)\lambda$ respectively – effect of wavelength, distance of screen and slit separation on interference patterns: $\Delta x = \frac{\lambda L}{d}$	• Young's Double Slit Experiment • Multi-slit Diffraction

Area of Study 2: How are light and matter similar?

Behaviour of light

Content Descriptor	Lesson Names
Investigate and describe theoretically and practically the effects of varying the width of a gap or diameter of an obstacle on the diffraction pattern produced by light and apply this to limitations of imaging using light.	• Young's Double Slit Experiment • Multi-slit Diffraction • Polarisation of Light
Analyse the photoelectric effect with reference to:	• The Photoelectric Effect

– evidence for the particle-like nature of light – experimental data in the form of graphs of photocurrent versus electrode potential, and of kinetic energy of electrons versus frequency – kinetic energy of emitted photoelectrons: $E_{k\,max} = hf - \Phi$, using energy units of joule and electron-volt – effects of intensity of incident irradiation on the emission of photoelectrons	• Intensity of Waves
Describe the limitation of the wave model of light in explaining experimental results related to the photoelectric effect.	*Further development planned*

Matter as particles or waves

Content Descriptor	Lesson Names
Interpret electron diffraction patterns as evidence for the wave-like nature of matter. Distinguish between the diffraction patterns produced by photons and electrons . Calculate the de Broglie wavelength of matter: lambda =hp.	*Further development planned*

Similarities between light and matter

Content Descriptor	Lesson Names
Compare the momentum of photons and of matter of the same wavelength including calculations using: $p = \frac{h}{\lambda}$. Explain the production of atomic absorption and emission line spectra, including those from metal vapour lamps. Interpret spectra and calculate the energy of absorbed or emitted photons: E=hf. Analyse the absorption of photons by atoms, with reference to: – the change in energy levels of the atom due to	*Further development planned*

electrons changing state – the frequency and wavelength of emitted photons: E=hf=hc Describe the quantised states of the atom with reference to electrons forming standing waves, and explain this as evidence for the dual nature of matter.	
Interpret the single photon/electron double slit experiment as evidence for the dual nature of light/matter.	• Young's Double Slit Experiment
Explain how diffraction from a single slit experiment can be used to illustrate Heisenberg's uncertainty principle. Explain why classical laws of physics are not appropriate to model motion at very small scales.	*Further development planned*

Production of light from matter

Content Descriptor	**Lesson Names**
Compare the production of light in lasers, synchrotrons, LEDs and incandescent lights.	*Further development planned*