

Physics Study Design 2023 – 2027
Units 1 – 4: Key Knowledge
Selections and Deletions

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Unit 1: How is energy useful to society?

Area of Study 1: How are light and heat explained? (U1AoS1)

Electromagnetic radiation (U1AoS1)

- identify all electromagnetic waves as transverse waves travelling at the same speed, c , in a vacuum as distinct from mechanical waves that require a medium to propagate (U1AoS1)
- identify the amplitude, wavelength, period and frequency of waves (U1AoS1)
- calculate the wavelength, frequency, period and speed of travel of waves using: $\lambda = \frac{v}{f} = vT$ (U1AoS1)
- explain the wavelength of a wave as a result of the velocity (determined by the medium through which it travels) and the frequency (determined by the source) (U1AoS1)
- describe electromagnetic radiation emitted from the Sun as mainly ultraviolet, visible and infrared (U1AoS1)
- compare the wavelength and frequencies of different regions of the electromagnetic spectrum, including radio, microwave, infrared, visible, ultraviolet, x-ray and gamma, and compare the different uses each has in society (U1AoS1)
- ~~investigate and analyse theoretically and practically the behaviour of waves including:~~ (U1AoS1)
 - ~~refraction using Snell's Law: $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$ and $n_1 v_1 = n_2 v_2$~~ (U1AoS1)
 - ~~total internal reflection and critical angle including applications: $n_1 \sin(\theta_c) = n_2 \sin(90^\circ)$~~ (U1AoS1)
- ~~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~~ (U1AoS1)
- ~~explain the formation of optical phenomena: rainbows; mirages~~ (U1AoS1)
- ~~investigate light transmission through optical fibres for communication~~ (U1AoS1)

Thermal energy (U1AoS1)

- ~~convert between Celsius and kelvin scales~~ (U1AoS1)
- ~~describe how an increase in temperature corresponds to an increase in thermal energy (kinetic and potential energy of the atoms) of a system:~~ (U1AoS1)
- ~~distinguish between conduction, convection and radiation with reference to heat transfers within and between systems~~ (U2AoS1)
- ~~explain why cooling results from evaporation using a simple kinetic energy model~~ (U2AoS1)
- ~~investigate and analyse theoretically and practically the energy required to:~~ (U1AoS1)
 - ~~raise the temperature of a substance: $Q = mc\Delta T$~~ (U1AoS1)
 - ~~change the state of a substance: $Q = mL$~~ (U1AoS1)

Interaction of thermal energy and electromagnetic radiation (U1AoS1)

- ~~calculate the peak wavelength of the radiated electromagnetic radiation using Wien's Law: $\lambda_{\text{max}} T = \text{constant}$~~ (U1AoS1)
- ~~compare the total energy across the electromagnetic spectrum emitted by objects at different temperatures~~ (U1AoS1)
- ~~apply concepts of energy transfer, energy transformation, temperature change and change of state to climate change and global warming.~~ (U1AoS1)

Area of study 2: How is energy from the nucleus utilised? (U1AoS2)

Radiation from the nucleus.(U1AoS2)

- ~~explain nuclear stability with reference to the forces in the nucleus including electrostatic forces, the strong nuclear force and the weak nuclear force.(U1AoS2)~~
- ~~model radioactive decay as random decay with a particular half-life, including mathematical modelling with reference to whole half-lives.(U1AoS2)~~
- ~~describe the properties of α , β^- , β^+ and γ radiation.(U1AoS2)~~
- ~~explain nuclear transformations using decay equations involving α , β^- , β^+ and γ radiation.(U1AoS2)~~
- ~~analyse decay series diagrams with reference to type of decay and stability of isotopes.(U1AoS2)~~
- ~~explain the effects of α , β and γ radiation on humans, including:.(U1AoS2)~~
 - ~~different capacities to cause cell damage .(U1AoS2)~~
 - ~~short- and long-term effects of low and high doses .(U1AoS2)~~
 - ~~ionising impacts of radioactive sources outside and inside the body.(U1AoS2)~~
 - ~~calculations of absorbed dose (gray), equivalent dose (sievert) and effective dose (sievert).(U1AoS2)~~
- ~~evaluate the use of medical radioisotopes in therapy including the effects on healthy and damaged tissues and cells.(U1AoS2)~~

Nuclear energy.(U1AoS2)

- ~~explain, qualitatively, nuclear energy as energy resulting from the conversion of mass.(U1AoS2)~~
- ~~explain fission chain reactions including:.(U1AoS2)~~
 - ~~the effect of mass and shape on criticality.(U1AoS2)~~
 - ~~neutron absorption and moderation.(U1AoS2)~~
- ~~compare the processes of nuclear fusion and nuclear fission .(U1AoS2)~~
- ~~explain, using a binding energy curve, why both fusion and fission are reactions that release energy.(U1AoS2)~~
- ~~investigate the viability of nuclear energy as an energy source for Australia..(U1AoS2)~~

Area of Study 3: How can electricity be used to transfer energy? (U1AoS3)

Concepts used to model electricity.(U1AoS3)

- apply concepts of charge (Q), electric current (I), potential difference (V), energy (E) and power (P), in electric circuits.(U1AoS3)
- analyse and evaluate different analogies used to describe electric current and potential difference .(U1AoS3)
- investigate and analyse theoretically and practically electric circuits using the relationships:
 $I = \frac{Q}{t}$, $V = \frac{E}{Q}$, $P = \frac{E}{t} = VI$.(U1AoS3)
- justify the use of selected meters (ammeter, voltmeter, multimeter) in circuits .(U1AoS3)
- ~~apply the kilowatt-hour (kW h) as a unit of energy.(U1AoS3)~~

Circuit electricity.(U1AoS3)

- ~~model resistance in series and parallel circuits using:.(U1AoS3)~~
 - ~~current versus potential difference ($I-V$) graphs.(U1AoS3)~~

- resistance as the potential difference to current ratio, including $R = \text{constant}$ for ohmic devices.(U1AoS3)
- equivalent resistance in arrangements in.(U1AoS3)
- series: $R_{\text{equivalent}} = R_1 + R_2 + \dots + R_n$ and.(U1AoS3)
- parallel: $\frac{1}{R_{\text{equivalent}}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$.(U1AoS3)
- calculate and analyse the equivalent resistance of circuits comprising parallel and series resistance.(U1AoS3)
- analyse circuits comprising voltage dividers.(U1AoS3)
- model household (AC) electrical systems as simple direct current (DC) circuits.(U1AoS3)
- compare power transfers in series and parallel circuits.(U1AoS3)
- explain why the circuits in homes are mostly parallel circuits.(U1AoS3)

Using electricity.(U1AoS3)

- 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 $P = VI$). (U1AoS3)
- investigate practically the operation of simple circuits containing resistors, variable resistors, diodes and other non-ohmic devices .(U1AoS3)
- describe energy transfers and transformations with reference to resistors, light bulbs, diodes, thermistors, light dependent resistors (LDRs), light-emitting diodes (LEDs) and potentiometers in common devices.(U1AoS3)

Electrical safety in the home.(U1AoS3)

- model household electricity connections as a simple DC circuit comprising fuses, switches, circuit breakers, loads and earth.(U1AoS3)
- compare the operation of safety devices including fuses, circuit breakers and residual current devices (RCDs).(U1AoS3)
- describe the causes, effects and first aid treatment of electric shock and identify the approximate danger thresholds for current and duration. (U1AoS3)

Unit 2: How does physics help us to understand the world? (U2AoS1)

Area of Study 1: How is motion understood? (U2AoS1)

Concepts used to model motion (U2AoS1)

- identify parameters of motion as vectors or scalars (U2AoS1)
- analyse graphically, numerically and algebraically, straight-line motion under constant acceleration: (U2AoS1)

$$v = u + at, v^2 = u^2 + 2as, s = \frac{1}{2}(u + v)t, s = ut + \frac{1}{2}at^2, s = vt - \frac{1}{2}at^2 \text{ (U2AoS1)}$$

- analyse, graphically, non-uniform motion in a straight line (U2AoS1)
- apply concepts of momentum to linear motion: $p = mv$ (U2AoS1)

Forces and motion (U2AoS1)

- explain changes in momentum as being caused by a net force: $\Delta p = F_{net} \Delta t$ (U2AoS1)
- model the force due to gravity, F_g , as the force of gravity acting at the centre of mass of a body, $F_{\text{on body by Earth}} = mg$, where g is the gravitational field strength (9.8 N kg^{-1} near the surface of Earth) (U2AoS1)
- 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 $F_{\text{on A by B}} = -F_{\text{on B by A}}$ (U2AoS1)
- apply Newton's three laws of motion to a body on which forces act: $a = \frac{F_{net}}{m}$, $F_{\text{on A by B}} = -F_{\text{on B by A}}$ (U2AoS1)
- 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 normal forces (U2AoS1)

Energy and motion (U2AoS1)

- apply the concept of work done by a force using: (U2AoS1)
- work done = force $\times$ displacement: $W = F \cos \theta$, where force is constant (U2AoS1)
- work done = area under force vs distance graph (U2AoS1)
- investigate and analyse theoretically and practically Hooke's Law for an ideal spring: $F = -kx$, where x is extension (U2AoS1)
- analyse and model mechanical energy transfers and transformations using energy conservation: (U2AoS1)
- changes in gravitational potential energy near Earth's surface: $E_g = mg\Delta h$ (U2AoS1)
- elastic potential energy in ideal springs: $E_s = \frac{1}{2}kx^2$ (U2AoS1)
- kinetic energy: $E_k = \frac{1}{2}mv^2$ (U2AoS1)
- analyse rate of energy transfer using power: $P = \frac{E}{t}$ (U2AoS1)
- calculate the efficiency of an energy transfer system: $\eta = \frac{\text{useful energy out}}{\text{total energy in}}$ (U2AoS1)
- analyse impulse in an isolated system (for collisions between objects moving in a straight line): $F\Delta t = m\Delta v$ (U2AoS1)
- investigate and analyse theoretically and practically momentum conservation in one dimension (U2AoS1)

Equilibrium (U2AoS1)

- calculate torque, $\tau = r_{\perp} F$ (U2AoS1)
- analyse translational and rotational forces (torques) in simple structures in translational and rotational equilibrium (U2AoS1)

Application of motion (U2AoS1)

- investigate the application of motion concepts through a case study, for example, through motion in sport, vehicle safety, a device or a structure. (U2AoS1)

Area of Study 2: Options: How does physics inform contemporary issues and applications in society? (U2AoS2)

- How does physics explain climate change?
- How do fusion and fission compare as viable nuclear energy power sources?
- How do heavy things fly?
- How do forces act on structures and materials?
- How do forces act on the human body?
- How is radiation used to maintain human health?
- How does the human body use electricity?
- How can human vision be enhanced?
- How is physics used in photography?
- How do instruments make music?
- How can performance in ball sports be improved?
- How can AC electricity charge a DC device?
- How do astrophysicists investigate stars and black holes?
- How can we detect possible life beyond Earth's Solar System?
- How can physics explain traditional artefacts, knowledge and techniques?
- How do particle accelerators work?
- How does physics explain the origins of matter?
- How is contemporary physics research being conducted in our region?

Area of Study 3 : How do physicists investigate questions? (U2AoS3)

Investigation design (U2AoS3)

- apply the physics concepts specific to the selected investigation and explain their significance, including definitions of key terms, and physics representations
- evaluate the characteristics of the scientific methodology relevant to the investigation, selected from: experiment; fieldwork; classification and identification; modelling; simulation, and the development of a product, process or system
- apply techniques of primary qualitative and quantitative data generation relevant to the investigation
- identify and apply concepts of accuracy, precision, repeatability, reproducibility, resolution, and validity of data in relation to the investigation

- identify and apply health, safety and ethical guidelines relevant to the selected scientific investigation

Scientific evidence

- distinguish between an aim, a hypothesis, a model, a theory and a law
- identify and explain observations and experiments that are consistent with, or challenge, current models or theories
- describe the characteristics of primary data
- evaluate methods of organising, analysing and evaluating primary data to identify patterns and relationships including scientific error, causes of uncertainty, and limitations of data, methodologies and methods
- model the scientific practice of using a logbook to authenticate generated primary data

Science communication

- apply the conventions of scientific report writing including scientific terminology and representations, standard abbreviations, units of measurement, significant figures and acknowledgement of references
- apply the key findings of the selected investigation and their relationship to key physics concepts.

Unit 3: How do fields explain motion and electricity? (U3AoS1)

Area of Study 1: How do physicists explain motion in two dimensions? (U3AoS1)

Newton's laws of motion (U3AoS1)

- 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 (U3AoS1)
- investigate and analyse theoretically and practically the uniform circular motion of an object moving in a horizontal plane: $(F_{net} = \frac{mv^2}{r})$, including: (U3AoS2)
 - a vehicle moving around a circular road (U3AoS1)
 - a vehicle moving around a banked track (U3AoS1)
 - an object on the end of a string (U3AoS1)
- model natural and artificial satellite motion as uniform circular motion (U3AoS1)
- investigate and apply theoretically Newton's second law to circular motion in a vertical plane (forces at the highest and lowest positions only) (U3AoS1)
- investigate and analyse theoretically and practically the motion of projectiles near Earth's surface, including a qualitative description of the effects of air resistance (U3AoS1)
- investigate and apply theoretically and practically the laws of energy and momentum conservation in isolated systems in one dimension (U3AoS1)

Relationships between force, energy and mass (U3AoS1)

- investigate and analyse theoretically and practically impulse in an isolated system for collisions between objects moving in a straight line: $F\Delta t = m\Delta v$ (U3AoS1)
- investigate and apply theoretically and practically the concept of work done by a force using: (U3AoS1)
 - work done = force $\times$ displacement (U3AoS1)
 - work done = area under force vs distance graph (one dimensional only) (U3AoS1)
- analyse transformations of energy between kinetic energy, elastic potential energy, gravitational potential energy and energy dissipated to the environment (considered as a combination of heat, sound and deformation of material): (U3AoS1)
 - kinetic energy at low speeds: $E_k = \frac{1}{2}mv^2$; elastic and inelastic collisions with reference to conservation of kinetic energy (U3AoS1)
 - elastic potential energy: area under force-distance graph including ideal springs obeying Hooke's Law: $E_s = \frac{1}{2}kx^2$ (U3AoS1)
 - 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. (U3AoS1)

Area of Study 2: How do things move without contact? (U3AoS2)

Fields and interactions (U3AoS2)

- describe gravitation, magnetism and electricity using a field model (U3AoS2)
- investigate and compare theoretically and practically gravitational, magnetic and electric fields, including directions and shapes of fields, attractive and repulsive effects, and the existence of dipoles and monopoles (U3AoS2)

- investigate and compare theoretically and practically gravitational fields and electrical fields about a point mass or charge (positive or negative) with reference to: (U3AoS2)
 - the direction of the field (U3AoS2)
 - the shape of the field (U3AoS2)
 - the use of the inverse square law to determine the magnitude of the field (U3AoS2)
 - potential energy changes (qualitative) associated with a point mass or charge moving in the field (U3AoS2)
- investigate and apply theoretically and practically a field model to magnetic phenomena, including shapes and directions of fields produced by bar magnets, and by current-carrying wires, loops and solenoids (U3AoS2)
- identify fields as static or changing, and as uniform or non-uniform (U3AoS2)

Effects of fields (U3AoS2)

- analyse the use of an electric field to accelerate a charge, including: (U3AoS2)
 - electric field and electric force concepts: $E = k \frac{Q}{r^2}$ and $F = k \frac{q_1 q_2}{r^2}$ (U3AoS2)
 - potential energy changes in a uniform electric field: $W = qV$, $E = \frac{V}{d}$ (U3AoS2)
 - the magnitude of the force on a charged particle due to a uniform electric field: $F = qE$ (U3AoS2)
- analyse the use of a magnetic field to change the path of a charged particle, including: (U3AoS2)
 - 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 (U3AoS2)
 - the radius of the path followed by an electron in a magnetic field: $qvB = \frac{mv^2}{r}$, where $v \ll c$ (U3AoS2)
- analyse the use of gravitational fields to accelerate mass, including: (U3AoS2)
 - gravitational field and gravitational force concepts: $g = G \frac{M}{r^2}$ and $F_g = G \frac{m_1 m_2}{r^2}$ (U3AoS2)
 - potential energy changes in a uniform gravitational field: $E_g = mg\Delta h$ (U3AoS2)
- analyse the change in gravitational potential energy from area under a force vs distance graph and area under a field vs distance graph multiplied by mass (U3AoS2)

Application of field concepts (U3AoS2)

- apply the concepts of force due to gravity and normal force including in relation to satellites in orbit where the orbits are assumed to be uniform and circular (U3AoS2)
- model satellite motion (artificial, Moon, planet) as uniform circular orbital motion: $a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$ (U3AoS2)
- 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 (U3AoS2)
- investigate and analyse theoretically and practically the force on a current carrying conductor due to an external magnetic field, $F = nIB$, where the directions of I and B are either perpendicular or parallel to each other (U3AoS2)
- investigate and analyse theoretically and practically the operation of simple DC motors consisting of one coil, 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 (U3AoS2)
- investigate, qualitatively, the effect of current, external magnetic field and the number of loops of wire on the torque of a simple motor (U3AoS2)
- model the acceleration of particles in a particle accelerator (including synchrotrons) as uniform circular motion (limited to linear acceleration by a uniform electric field and direction change by a uniform magnetic field). (U3AoS2)

Area of Study 3: How are fields used in electricity generation? (U3AoS3)

Generation of electricity (U3AoS3)

- 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: $\Phi_B = B_{\perp} A$ (U3AoS3)
- 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: (U3AoS3)
 - rate of change of magnetic flux (U3AoS3)
 - number of loops through which the flux passes (U3AoS3)
 - direction of induced emf in a coil (U3AoS3)
- 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 (U3AoS3)
- describe the production of electricity using photovoltaic cells and the need for an inverter to convert power from DC to AC for use in the home (not including details of semiconductors action or inverter circuitry) (U3AoS3)

Transmission of electricity (U3AoS3)

- 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}) (U3AoS3)
- compare alternating voltage expressed as the root-mean-square (rms) to a constant DC voltage developing the same power in a resistive component (U3AoS3)
- analyse transformer action with reference to electromagnetic induction for an ideal transformer: (U3AoS3)
$$\frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$$
- analyse the supply of power by considering transmission losses across transmission lines. (U3AoS3)

Unit 4: How have creative ideas and investigation revolutionised thinking in physics? (U4AoS1)

Area of Study 1: How has understanding about the physical world changed? (U4AoS1)

Light as a wave (U4AoS1)

- describe light as a transverse electromagnetic wave which is produced by the acceleration of charges, which in turn produces changing electric fields and associated changing magnetic fields (U4AoS1)
- identify that all electromagnetic waves travel at the same speed, c , in a vacuum (U4AoS1)
- explain the formation of a standing wave resulting from the superposition of a travelling wave and its reflection (U4AoS1)
- analyse the formation of standing waves (only those with nodes at both ends is required) (U4AoS1)
- 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, and apply this to limitations of imaging using electromagnetic waves (U4AoS1)
- explain the results of Young's double slit experiment with reference to: (U4AoS1)
 - evidence for the wave-like nature of light (U4AoS1)
 - constructive and destructive interference of coherent waves in terms of path differences: $n\lambda$ and $(n + \frac{1}{2})\lambda$ respectively, where $n = 0, 1, 2, \dots$ (U4AoS1)
 - effect of wavelength, distance of screen and slit separation on interference patterns: $\Delta x = \frac{\lambda L}{d}$ when $L \gg d$ (U4AoS1)

Light as a particle (U4AoS1)

- apply the quantised energy of photons: $E = hf = \frac{hc}{\lambda}$ (U4AoS1)
- analyse the photoelectric effect with reference to: (U4AoS1)
 - evidence for the particle-like nature of light (U4AoS1)
 - experimental data in the form of graphs of photocurrent versus electrode potential, and of kinetic energy of electrons versus frequency (U4AoS1)
 - kinetic energy of emitted photoelectrons: $E_{k \max} = hf - \phi$, using energy units of joule and electron-volt (U4AoS1)
 - effects of intensity of incident irradiation on the emission of photoelectrons (U4AoS1)
- describe the limitation of the wave model of light in explaining experimental results related to the photoelectric effect (U4AoS1)

Matter as particles or waves (U4AoS1)

- interpret electron diffraction patterns as evidence for the wave-like nature of matter (U4AoS1)
- distinguish between the diffraction patterns produced by photons and electrons (U4AoS1)
- calculate the de Broglie wavelength of matter: $\lambda = \frac{h}{p}$ (U4AoS1)

Similarities between light and matter (U4AoS1)

- discuss the importance of the idea of quantisation in the development of knowledge about light and in explaining the nature of atoms (U4AoS1)
- compare the momentum of photons and of matter of the same wavelength including calculations using: $p = \frac{h}{\lambda}$ (U4AoS1)
- explain the production of atomic absorption and emission line spectra, including those from metal vapour lamps (U4AoS1)
- interpret spectra and calculate the energy of absorbed or emitted photons: $E = hf$ (U4AoS1)
- analyse the emission or absorption of a photon by an atom in terms of a change in the electron energy state of the atom, with the difference in the states' energies being equal to the photon energy:
 $E = hf = \frac{hc}{\lambda}$ (U4AoS1)
- interpret the single photon and the electron double slit experiment as evidence for the dual nature of light and matter (U4AoS1)

Einstein's special theory of relativity (U4AoS1)

- describe the limitation of classical mechanics when considering motion approaching the speed of light (U4AoS1)
- describe Einstein's two postulates for his special theory of relativity that: (U4AoS1)
 - the laws of physics are the same in all inertial (non-accelerated) frames of reference (U4AoS1)
 - the speed of light has a constant value for all observers regardless of their motion or the motion of the source (U4AoS1)
- interpret the null result of the Michelson-Morley experiment as evidence in support of Einstein's special theory of relativity (U4AoS1)
- compare Einstein's special theory of relativity with the principles of classical physics (U4AoS1)
- 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 (U4AoS1)
- describe proper length (L_0) as the length that is measured in the frame of reference in which objects are at rest (U4AoS1)
- model mathematically time dilation and length contraction at speeds approaching c using the equations: $t = \gamma t_0$ and $L = \frac{L_0}{\gamma}$ where $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$ (U4AoS1)
- explain and analyse examples of special relativity including that: (U4AoS1)
 - muons can reach Earth even though their half-lives would suggest that they should decay in the upper atmosphere (U4AoS1)
 - particle accelerator lengths must be designed to take the effects of special relativity into account (U4AoS1)
 - time signals from GPS satellites must be corrected for the effects of special relativity due to their orbital velocity (U4AoS1)

Relationship between energy and mass (U4AoS1)

- interpret Einstein's prediction by showing that the total 'mass-energy' of an object is given by: (U4AoS1)
 $E_{\text{tot}} = E_k + E_0 = \gamma mc^2$ where $E_0 = mc^2$, and where kinetic energy can be calculated by: $E_k = (\gamma - 1)mc^2$ (U4AoS1)
- apply the energy-mass relationship to mass conversion in the Sun, to positron-electron annihilation and to nuclear transformations in particle accelerators (details of the particular nuclear processes are not required). (U4AoS1)

Area of Study 2: How is scientific inquiry used to investigate fields, motion or light? (U4AoS2)

Investigation design (U4AoS2)

- identify the physics concepts specific to the investigation and explain their significance, including definitions of key terms and physics representations (U4AoS2)
- explain the characteristics of the selected scientific methodology and method including: techniques of primary qualitative and quantitative data generation relevant to the selected investigation; and appropriateness of the use of independent, dependent and controlled variables in the selected scientific investigation (U4AoS2)
- identify and apply concepts of accuracy, precision, repeatability, reproducibility, resolution and validity of data; and the identification of, and distinction between, error and uncertainty (U4AoS2)
- identify and apply health, safety and ethical guidelines relevant to the selected investigation (U4AoS2)

Scientific evidence (U4AoS2)

- discuss the nature of evidence that supports or refutes a hypothesis, model or theory (U4AoS2)
- apply methods of organising, analysing and evaluating primary data to identify patterns and relationships including: the physical significance of the gradient of linearised data; causes of uncertainty; use of uncertainty bars; and assumptions and limitations of data, methodologies and methods (U4AoS2)
- model the scientific practice of using a logbook to authenticate generated primary data (U4AoS2)

Science communication (U4AoS2)

- apply the conventions of science communication: scientific terminology and representations; symbols, equations and formulas; standard abbreviations; significant figures; and units of measurement (U4AoS2)
- apply the conventions of scientific poster presentation, including succinct communication of the selected scientific investigation, and acknowledgement of references (U4AoS2)
- explain the key findings and implications of the selected investigation. (U4AoS2)