1.3 Mechanics

This topic covers rectilinear motion, forces, energy and power. It may be studied using applications that relate to mechanics such as sports.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiments.

Candidates will be assessed on their ability to:

1	be able to use the equations for uniformly accelerated motion in one dimension: $s = \frac{(u+v)t}{2}$ $v = u + at$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
2	be able to draw and interpret displacement-time, velocity-time and acceleration-time graphs
3	know the physical quantities derived from the slopes and areas of displacement-time, velocity-time and acceleration-time graphs, including cases of non-uniform acceleration and understand how to use the quantities
4	understand scalar and vector quantities and know examples of each type of quantity and recognise vector notation
5	be able to resolve a vector into two components at right angles to each other by drawing and by calculation
6	be able to find the resultant of two coplanar vectors at any angle to each other by drawing, and at right angles to each other by calculation
7	understand how to make use of the independence of vertical and horizontal motion of a projectile moving freely under gravity
8	be able to draw and interpret free-body force diagrams to represent forces on a particle or on an extended but rigid body using the concept of *centre of gravity* of an extended body
9	be able to use the equation $\sum F = ma$, and understand how to use this equation in situations where *m* is constant (Newton's second law of motion), including Newton's first law of motion where $a = 0$, objects at rest or travelling at constant velocity *Use of the term 'terminal velocity' is expected.*
10	be able to use the equations for gravitational field strength $g = \frac{F}{m}$ and weight $W = mg$
11	**CORE PRACTICAL 1: Determine the acceleration of a freely-falling object**
12	know and understand Newton's third law of motion and know the properties of pairs of forces in an interaction between two bodies
13	understand that momentum is defined as $p = mv$

14	know the principle of conservation of linear momentum, understand how to relate this to Newton's laws of motion and understand how to apply this to problems in one dimension
15	be able to use the equation for the moment of a force, moment of force = Fx where x is the perpendicular distance between the line of action of the force and the axis of rotation
16	be able to use the concept of centre of gravity of an extended body and apply the principle of moments to an extended body in equilibrium
17	be able to use the equation for work $\Delta W = F\Delta s$, including calculations when the force is not along the line of motion
18	be able to use the equation $E_k = \frac{1}{2}mv^2$ for the kinetic energy of a body
19	be able to use the equation $\Delta E_{grav} = mg\Delta h$ for the difference in gravitational potential energy near the Earth's surface
20	know, and understand how to apply, the principle of conservation of energy including use of work done, gravitational potential energy and kinetic energy
21	be able to use the equations relating power, time and energy transferred or work done $P = \frac{E}{t}$ and $P = \frac{W}{t}$
22	be able to use the equations $\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$ and $\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$

1.4 Materials

This topic covers density, flow of liquids, Hooke's law, the Young modulus and elastic strain energy.

This topic should be studied using a variety of applications, for example making and testing food, engineering materials, spare-part surgery for joint replacement.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiments.

Candidates will be assessed on their ability to:

23	be able to use the equation density $\rho = \frac{m}{V}$
24	understand how to use the relationship upthrust = weight of fluid displaced
25	a be able to use the equation for viscous drag (Stokes' Law), $F = 6\pi\eta rv$. b understand that this equation applies only to small spherical objects moving at low speeds with *laminar flow* (or in the absence of *turbulent flow*) and that viscosity is temperature dependent
26	**CORE PRACTICAL 2: Use a falling-ball method to determine the viscosity of a liquid**
27	be able to use the Hooke's law equation, $\Delta F = k\Delta x$, where k is the stiffness of the object
28	understand how to use the relationships • *(tensile or compressive) stress = force/cross-sectional area* • *(tensile or compressive) strain= change in length/original length* *Young modulus = stress/strain.*
29	a be able to draw and interpret force-extension and force-compression graphs b understand the terms limit of proportionality, elastic limit, yield point, elastic deformation and plastic deformation and be able to apply them to these graphs
30	be able to draw and interpret tensile or compressive stress-strain graphs, and understand the term *breaking stress*
31	**CORE PRACTICAL 3: Determine the Young modulus of a material**
32	be able to calculate the elastic strain energy E_{el} in a deformed material sample, using the equation $\Delta E_{el} = \frac{1}{2}F\Delta x$, and from the area under the force-extension graph *The estimation of area and hence energy change for both linear and non-linear force-extension graphs is expected.*

2.3 Waves and Particle Nature of Light

This topic covers the properties of different types of wave, including standing waves. Refraction, polarisation and diffraction are also included and the wave/particle nature of light. This topic should be studied by exploring the applications of waves, for example applications in medical physics or music.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiments.

Candidates will be assessed on their ability to:

33	understand the terms amplitude, frequency, period, speed and wavelength
34	be able to use the wave equation $v = f\lambda$
35	be able to describe longitudinal waves in terms of pressure variation and the displacement of molecules
36	be able to describe transverse waves
37	be able to draw and interpret graphs representing transverse and longitudinal waves including standing/stationary waves
38	**CORE PRACTICAL 4: Determine the speed of sound in air using a 2-beam oscilloscope, signal generator, speaker and microphone**
39	know and understand what is meant by *wavefront, coherence, path difference, superposition, interference* and *phase*
40	be able to use the relationship between *phase difference* and *path difference*
41	know what is meant by a *standing/stationary* wave and understand how such a wave is formed, know how to identify nodes and antinodes
42	be able to use the equation for the speed of a transverse wave on a string $v = \sqrt{\frac{T}{\mu}}$
43	**CORE PRACTICAL 5: Investigate the effects of length, tension and mass per unit length on the frequency of a vibrating string or wire**
44	be able to use the equation for the intensity of radiation $I = \frac{P}{A}$
45	know and understand that at the interface between medium 1 and medium 2 $n_1 \sin\theta_1 = n_2 \sin\theta_2$ where refractive index is $n = \frac{c}{v}$
46	be able to calculate critical angle using $\sin C = \frac{1}{n}$

47	be able to predict whether total internal reflection will occur at an interface
48	understand how to measure the refractive index of a solid material
49	understand what is meant by plane polarisation
50	understand what is meant by diffraction and use Huygens' construction to explain what happens to a wave when it meets a slit or an obstacle
51	be able to use $n\lambda = d\sin\theta$ for a diffraction grating
52	**CORE PRACTICAL 6: Determine the wavelength of light from a laser or other light source using a diffraction grating**
53	understand how diffraction experiments provide evidence for the wave nature of electrons
54	be able to use the de Broglie equation $\lambda = \frac{h}{p}$
55	understand that waves can be transmitted and reflected at an interface between media
56	understand how a pulse-echo technique can provide information about the position of an object and how the amount of information obtained may be limited by the wavelength of the radiation or by the duration of pulses
57	understand how the behaviour of electromagnetic radiation can be described in terms of a wave model and a photon model, and how these models developed over time
58	be able to use the equation $E = hf$, that relates the photon energy to the wave frequency
59	understand that the absorption of a photon can result in the emission of a photoelectron
60	understand the terms 'threshold frequency' and 'work function' and be able to use the equation $hf = \phi + \frac{1}{2}mv_{max}^2$
61	be able to use the electronvolt (eV) to express small energies
62	understand how the photoelectric effect provides evidence for the particle nature of electromagnetic radiation
63	understand atomic line spectra in terms of transitions between discrete energy levels and understand how to calculate the frequency of radiation that could be emitted or absorbed in a transition between energy levels.

2.4 Electric Circuits

This topic covers the definitions of various electrical quantities, for example current, potential difference and resistance, Ohm's law and non-ohmic conductors, potential dividers, e.m.f. and internal resistance of cells and negative temperature coefficient thermistors.

This topic should be studied using applications such as space technology.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiments.

Candidates will be assessed on their ability to:

64	understand that electric current is the rate of flow of charged particles and be able to use the equation $I = \frac{\Delta Q}{\Delta t}$
65	understand how to use the equation $V = \frac{W}{Q}$
66	understand that resistance is defined by $R = \frac{V}{I}$ and that Ohm's law is a special case when $I \propto V$ for constant temperature
67	(a) understand how the distribution of current in a circuit is a consequence of charge conservation (b) understand how the distribution of potential differences in a circuit is a consequence of energy conservation
68	be able to derive the equations for combining resistances in series and parallel using the principles of charge and energy conservation, and be able to use these equations
69	be able to use the equations $P = VI$, $W = VIt$ and be able to derive and use related equations, e.g. $P = I^2R$ and $P = \frac{V^2}{R}$
70	understand how to sketch, recognise and interpret current-potential difference graphs for components, including ohmic conductors, filament bulbs, thermistors and diodes
71	be able to use the equation $R = \frac{\rho l}{A}$
72	**CORE PRACTICAL 7: Determine the electrical resistivity of a material**
73	be able to use $I = nqvA$ to explain the large range of resistivities of different materials
74	understand how the potential along a uniform current-carrying wire varies with the distance along it
75	understand the principles of a potential divider circuit and understand how to calculate potential differences and resistances in such a circuit
76	be able to analyse potential divider circuits where one resistance is variable including thermistors and light dependent resistors (LDRs)

77	know the definition of *electromotive force (e.m.f.)* and understand what is meant by *internal resistance* and know how to distinguish between e.m.f. and *terminal potential difference*
78	**CORE PRACTICAL 8: Determine the e.m.f. and internal resistance of an electrical cell**
79	understand how changes of resistance with temperature may be modelled in terms of lattice vibrations and number of conduction electrons and understand how to apply this model to metallic conductors and negative temperature coefficient thermistors
80	understand how changes of resistance with illumination may be modelled in terms of the number of conduction electrons and understand how to apply this model to LDRs.

3.3 Planning

Students will be expected to plan an experiment set by Pearson, although they will not be expected to carry it out.

Candidates will be assessed on their ability to:

Plan an experiment

- identify the apparatus required
- the range and resolution of measuring instruments including Vernier calipers (0.1mm) and micrometer screw gauge (0.01mm)
- discuss calibration of instruments, e.g. whether a meter reads zero before measurements are made
- describe how to measure relevant variables using the most appropriate instrument and correct measuring techniques
- identify and state how to control all other relevant variables to make it a fair test
- discuss whether repeat readings are appropriate
- identify health and safety issues and discuss how these may be dealt with
- discuss how the data collected will be used
- identify possible sources of uncertainty and/or systematic error and explain how these may be reduced or eliminated
- comment on the implications of physics (e.g. benefits/risks) and on its context (e.g. social/environmental/historical).

3.4 Implementation and measurements

Students will be given details of an experiment carried out by an inexperienced student. Results may be included.

Candidates will be assessed on their ability to:

Implementation and measurements

- comment on the number of readings taken
- comment on the range of measurements taken
- comment on significant figures
- check a reading that is inconsistent with other readings, e.g. a point that is not on the line of a graph – students may be shown a diagram of a micrometer that is being used to measure the diameter of a wire and be expected to write down the reading to the correct number of significant figures
- comment on how the experiment may be improved, possibly by using additional apparatus (e.g. to reduce errors) – examples may include using a set square to determine whether a ruler is vertical to aid the measurement of the extension of a spring.

3.5 Processing Results

Students will be provided with a set of experimental results that were obtained by a more-experienced student conducting an experiment.

Candidates will be assessed on their ability to:

Process results	• perform calculations, using the correct number of significant figures • plot results on a graph using an appropriate scale • use the correct units throughout • comment on the relationship obtained from the graph • determine the relationship between two variables or determine a constant with the aid of a graph, e.g. by determining the gradient using a large triangle • suggest realistic modifications to reduce errors • suggest realistic modifications to improve the experiment • discuss uncertainties, qualitatively and quantitatively • determine the percentage uncertainty in measurements for a single reading using **half** the resolution of the instrument **and** from multiple readings using the **half** range (students are **not** expected to compound percentage uncertainties).

4.3 Further Mechanics

This topic covers impulse, conservation of momentum in two dimensions and circular motion.

It can be studied using applications that relate to, for example, a modern rail transportation system.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiments.

Candidates will be assessed on their ability to:

81	understand how to use the equation impulse $= F\Delta t = \Delta p$ (Newton's second law of motion)
82	**CORE PRACTICAL 9: Investigate the relationship between the force exerted on an object and its change of momentum**
83	understand how to apply conservation of linear momentum to problems in two dimensions
84	**CORE PRACTICAL 10: Use ICT to analyse collisions between small spheres, e.g. ball bearings on a table top**
85	understand how to determine whether a collision is elastic or inelastic
86	be able to derive and use the equation $E_k = \frac{p^2}{2m}$ for the kinetic energy of a non-relativistic particle
87	be able to express angular displacement in radians and in degrees, and convert between these units
88	understand what is meant by *angular velocity* and be able to use the equations $v = \omega r$ and $T = \frac{2\pi}{\omega}$
89	be able to use vector diagrams to derive the equations for centripetal acceleration $a = \frac{v^2}{r} = r\omega^2$ and understand how to use these equations
90	understand that a resultant force (centripetal force) is required to produce and maintain circular motion
91	be able to use the equations for centripetal force $F = ma = \frac{mv^2}{r} = mr\omega^2$.

4.4 Electric and Magnetic Fields

This topic covers Coulomb's law, capacitors, magnetic flux density and the laws of electromagnetic induction.

This topic may be studied using applications that relate to, for example, communications and display techniques.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiment.

Candidates will be assessed on their ability to:

92	understand that an electric field (force field) is defined as a region where a charged particle experiences a force
93	understand that electric field strength is defined as $E = \frac{F}{Q}$ and be able to use this equation
94	be able to use the equation $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$ for the force between two charges
95	be able to use the equation $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ for the electric field due to a point charge
96	know and understand the relation between electric field and electric potential
97	be able to use the equation $E = \frac{V}{d}$ for an electric field between parallel plates
98	be able to use $V = \frac{Q}{4\pi\varepsilon_0 r}$ for a radial field
99	be able to draw and interpret diagrams using field lines and equipotentials to describe radial and uniform electric fields
100	understand that capacitance is defined as $C = \frac{Q}{V}$ and be able to use this equation
101	be able to use the equation $W = \frac{1}{2}QV$ for the energy stored by a capacitor, be able to derive the equation from the area under a graph of potential difference against charge stored and be able to derive and use the equations $W = \frac{1}{2}CV^2$ and $W = \frac{\frac{1}{2}Q^2}{C}$

102	be able to draw and interpret charge and discharge curves for resistor capacitor circuits and understand the significance of the time constant *RC*
103	**CORE PRACTICAL 11: Use an oscilloscope or data logger to display and analyse the potential difference (p.d.) across a capacitor as it charges and discharges through a resistor**
104	be able to use the equation $Q = Q_0 e^{-t/RC}$ and derive and use related equations for exponential discharge in a resistor-capacitor circuit, $I = I_0\ e^{-t/RC}$, and $V = V_0\ e^{-t/RC}$ and the corresponding log equations $\ln Q = \ln Q_0 - \frac{t}{RC}$, $\ln I = \ln I_0 - \frac{t}{RC}$ and $\ln V = \ln V_0 - \frac{t}{RC}$
105	understand and use the terms *magnetic flux density B, flux* ϕ and *flux linkage N*ϕ
106	be able to use the equation $F = Bqv\sin\theta$ and apply Fleming's left-hand rule to charged particles moving in a magnetic field
107	be able to use the equation $F = BIl\sin\theta$ and apply Fleming's left-hand rule to current carrying conductors in a magnetic field
108	understand the factors affecting the e.m.f. induced in a coil when there is relative motion between the coil and a permanent magnet
109	understand the factors affecting the e.m.f. induced in a coil when there is a change of current in another coil linked with this coil
110	understand how to use Faraday's law to determine the magnitude of an induced e.m.f. and be able to use the equation that combines Faraday's and Lenz's laws $\mathscr{E} = \frac{-\mathrm{d}(N\phi)}{\mathrm{d}t}$.

4.5 Nuclear and Particle Physics

This topic covers atomic structure, particle accelerators and the standard quark-lepton model.

This topic is the subject of current research, involving the acceleration and detection of high-energy particles. It may be taught by exploring a range of experiments such as

- alpha scattering and the nuclear model of the atom
- accelerating particles to high energy
- detecting and interpreting interactions between particles.

Candidates will be assessed on their ability to:

111	understand what is meant by *nucleon number (mass number)* and *proton number (atomic number)*
112	understand how large-angle alpha particle scattering gives evidence for a nuclear model of the atom and how our understanding of atomic structure has changed over time
113	understand that electrons are released in the process of thermionic emission and how they can be accelerated by electric and magnetic fields
114	understand the role of electric and magnetic fields in particle accelerators (linac and cyclotron) and detectors (general principles of ionisation and deflection only)
115	be able to derive and use the equation $r = \frac{p}{BQ}$ for a charged particle in a magnetic field
116	be able to apply conservation of charge, energy and momentum to interactions between particles and interpret particle tracks
117	understand why high energies are required to investigate the structure of nucleons
118	be able to use the equation $\Delta E = c^2 \Delta m$ in situations involving the creation and annihilation of matter and antimatter particles
119	be able to use MeV and GeV (energy) and MeV/c^2, GeV/c^2 (mass) and convert between these and SI units
120	understand situations in which the relativistic increase in particle lifetime is significant (use of relativistic equations not required)
121	know that in the standard quark-lepton model particles can be classified as: • baryons (e.g. neutrons and protons), which are made from three quarks • mesons (e.g. pions), which are made from a quark and an antiquark • leptons (e.g. electrons and neutrinos), which are fundamental particles • photons and that the symmetry of the model predicted the top quark
122	know that every particle has a corresponding antiparticle and be able to use the properties of a particle to deduce the properties of its antiparticle and vice versa
123	understand how to use laws of conservation of charge, baryon number and lepton number to determine whether a particle interaction is possible
124	be able to write and interpret particle equations given the relevant particle symbols.

5.2 Assessment information

- First assessment: June 2020.
- The assessment is 1 hour and 45 minutes.
- The assessment is out of 90 marks.
- Candidates must answer all questions.
- The paper may include multiple-choice, short open, open-response, calculations and extended-writing questions.
- The paper will include questions that target mathematics at Level 2. A minimum of 36 marks will be awarded for mathematics at Level 2 or above in this paper.
- Candidates will be expected to apply their knowledge and understanding to familiar and unfamiliar contexts.
- This paper may contain some synoptic questions which require knowledge and understanding from Units 1, 2 and 4.
- Calculators may be used in the examination. Please see *Appendix 11: Use of calculators*.

5.3 Thermodynamics

This topic covers specific heat capacity, specific latent heat, internal energy and the gas equation.

This topic may be studied using applications that relate, for example, to space technology.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiments.

Candidates will be assessed on their ability to:

125	be able to use the equations $\Delta E = mc\Delta\theta$ and $\Delta E = L\Delta m$
126	**CORE PRACTICAL 12: Calibrate a thermistor in a potential divider circuit as a thermostat**
127	**CORE PRACTICAL 13: Determine the specific latent heat of a phase change**
128	understand the concept of *internal energy* as the random distribution of potential and kinetic energy amongst molecules
129	understand the concept of *absolute zero* and how the average kinetic energy of molecules is related to the absolute temperature
130	be able to use the equation $pV = N\mathrm{k}T$ for an ideal gas
131	**CORE PRACTICAL 14: Investigate the relationship between pressure and volume of a gas at fixed temperature**
132	be able to derive and use the equation $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}\mathrm{k}T$

5.4 Nuclear Decay

This topic covers radioactive decay.

This topic may be studied using applications that relate to, for example, medical physics and carbon dating.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiments.

Candidates will be assessed on their ability to:

133	understand the concept of *nuclear binding* energy and be able to use the equation $\Delta E = c^2 \Delta m$ in calculations of nuclear mass (including mass deficit) and energy
134	use the *atomic mass unit (u)* to express small masses and convert between this and SI units
135	understand the processes of nuclear fusion and fission with reference to the binding energy per nucleon curve
136	understand the mechanism of nuclear fusion and the need for very high densities of matter and very high temperatures to bring about and maintain nuclear fusion
137	understand that there is background radiation and how to take appropriate account of it in calculations
138	understand the relationships between the nature, penetration, ionising ability and range in different materials of nuclear radiations (alpha, beta and gamma)
139	be able to write and interpret nuclear equations given the relevant particle symbols
140	**CORE PRACTICAL 15: Investigate the absorption of gamma radiation by lead**
141	understand the spontaneous and random nature of nuclear decay
142	be able to determine the half-lives of radioactive isotopes graphically and be able to use the equations for radioactive decay activity $A = \lambda N$, $\frac{dN}{dt} = -\lambda N$, $\lambda = \frac{\ln 2}{t_{1/2}}$, $N = N_0 e^{-\lambda t}$ and $A = A_0 e^{-\lambda t}$ and derive and use the corresponding log equations.

5.5 Oscillations

This topic covers simple harmonic motion and damping.

This topic may be studied using applications that relate to, for example, the construction of buildings in earthquake zones.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiments.

Candidates will be assessed on their ability to:

143	understand that the condition for simple harmonic motion is $F = -kx$, and hence understand how to identify situations in which simple harmonic motion will occur
144	be able to use the equations $a = -\omega^2 x$, $x = A\cos \omega t$, $v = -A\omega \sin \omega t$, $a = -A\omega^2 \cos \omega t$, and $T = \frac{1}{f} = \frac{2\pi}{\omega}$ and $\omega = 2\pi f$ as applied to a simple harmonic oscillator
145	be able to use equations for a simple harmonic oscillator $T = 2\pi\sqrt{\frac{m}{k}}$, and a simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$
146	be able to draw and interpret a displacement-time graph for an object oscillating and know that the gradient at a point gives the velocity at that point
147	be able to draw and interpret a velocity-time graph for an oscillating object and know that the gradient at a point gives the acceleration at that point
148	understand what is meant by *resonance*
149	**CORE PRACTICAL 16: Determine the value of an unknown mass using the resonant frequencies of the oscillation of known masses**
150	understand how to apply conservation of energy to damped and undamped oscillating systems
151	understand the distinction between *free* and *forced oscillations*
152	understand how the amplitude of a forced oscillation changes at and around the natural frequency of a system and know, qualitatively, how damping affects resonance
153	understand how damping and the plastic deformation of ductile materials reduce the amplitude of oscillation.

5.6 Astrophysics and Cosmology

This topic covers gravitational fields and the physical interpretation of astronomical observations, the formation and evolution of stars and the history and future of the universe.

Candidates will be assessed on their ability to:

154	understand that a gravitational field (force field) is defined as a region where a mass experiences a force
155	understand that gravitational field strength is defined as $g = \frac{F}{m}$ and be able to use this equation
156	be able to use the equation $F = \frac{Gm_1 m_2}{r^2}$ (Newton's law of universal gravitation)
157	be able to derive and use the equation $g = \frac{Gm}{r^2}$ for the gravitational field due to a point mass
158	be able to use the equation $V_{grav} = \frac{-Gm}{r}$ for a radial gravitational field
159	be able to compare electric fields with gravitational fields
160	be able to apply Newton's laws of motion and universal gravitation to orbital motion
161	understand what is meant by a *black body radiator* and be able to interpret radiation curves for such a radiator
162	be able to use the Stefan-Boltzmann law equation $L = \sigma A T^4$ for black body radiators
163	be able to use Wien's law equation $\lambda_{max} T$ = 2.898 x 10^{-3} m K for black body radiators
164	be able to use the equation, intensity $I = \frac{L}{4\pi d^2}$ where L is luminosity and d is distance from the source
165	understand how astronomical distances can be determined using trigonometric parallax
166	understand how astronomical distances can be determined using measurements of intensity received from standard candles (objects of known luminosity)
167	be able to sketch and interpret a simple Hertzsprung-Russell diagram that relates stellar luminosity to surface temperature
168	understand how to relate the Hertzsprung-Russell diagram to the life cycle of stars
169	understand how the movement of a source of waves relative to an observer/detector gives rise to a shift in frequency (Doppler effect)

170	be able to use the equations for redshift $z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$ for a source of electromagnetic radiation moving relative to an observer and $v = H_0 d$ for objects at cosmological distances
171	understand the controversy over the age and ultimate fate of the universe associated with the value of the Hubble constant and the possible existence of dark matter.

6.3 Planning

Students will be expected to plan an experiment set by Pearson, although they will not be expected to carry it out.

Candidates will be assessed on their ability to:

Plan an experiment	• identify the most appropriate apparatus, giving details. These may include the range and resolution of instruments and/or relevant dimensions of apparatus (e.g. the length of string used for a pendulum) • discuss calibration of instruments, e.g. whether a meter reads zero before measurements are made • describe how to measure relevant variables using the most appropriate instrument(s) and techniques • identify and state how to control all other relevant variables to make it a fair test • discuss whether repeat readings are appropriate • identify health and safety issues and discuss how these may be dealt with • discuss how the data collected will be used.

6.4 Implementation and Measurements

Students will be given partial details of how an experiment was carried out.
Results may be included.

Candidates will be assessed on their ability to:

Implementation and measurements	• comment on how the experiment could have been improved, possibly by using additional apparatus (e.g. to reduce errors) – examples may include using set squares to measure the diameter of a cylinder and using a marker for timing oscillations • comment on the number of readings taken • comment on the range of measurements taken • comment on significant figures – students may be required to identify and/or round up any incorrect figures in a table of results • identify and/or amend units that are incorrect • identify and check a reading that is inconsistent with other readings, e.g. a point that is not on the line of a graph.

6.5 Analysis

Students may be given a set of experimental results to analyse.

Candidates will be assessed on their ability to:

Analyse data	• perform calculations, using the correct number of significant figures • plot results on a graph using an appropriate scale and units – the graph could be logarithmic in nature • use the correct units throughout • comment on the trend/pattern obtained • determine the relationship between two variables or determine a constant with the aid of the graph, e.g. by determining the gradient using a large triangle • use the terms precision, accuracy and sensitivity appropriately • suggest realistic modifications to reduce errors • suggest realistic modifications to improve the experiment • discuss uncertainties qualitatively and quantitatively • compound percentage uncertainties correctly • determine the percentage uncertainty in measurements for a single reading using **half** the resolution of the instrument **and** from multiple readings using the **half** range.

Appendix 7: Equations

Students need not memorise formulae for these qualifications.

The formulae below will be supplied in each examination. Any other formulae that are required will be provided in the question. Symbols used comply with the Association for Science Education (ASE) guidelines (which are based on International Union of Pure and Applied Physics (IUPAP) recommendations).

Unit 1: Mechanics and Materials

Mechanics

Kinematic equations of motion

$$s = \frac{(u+v)t}{2}$$

$$v = u + at$$

$$s = ut + \tfrac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

Momentum

$$p = mv$$

Moment of force

$$= Fx$$

Materials

Density

$$\rho = \frac{m}{V}$$

Stokes' law

$$F = 6\pi \eta r v$$

Hooke's law

$$\Delta F = k\Delta x$$

Young modulus

$$\text{Stress } \sigma = \frac{F}{A}$$

$$\text{Strain } \varepsilon = \frac{\Delta x}{x}$$