Topic 1: Working as a Physicist

Throughout their study of physics at this level, students should develop their knowledge and understanding of what it means to work scientifically. They should also develop their competence in manipulating quantities and their units, including making estimates.

Students should gain experience of a wide variety of practical work that gives them opportunities to develop their practical and investigative skills by planning, carrying out and evaluating experiments. Through studying a range of examples, contexts and applications of physics, students should become increasingly knowledgeable of the ways in which the scientific community and society as a whole use scientific ideas and methods, and how the professional scientific community functions.

Students should develop their ability to communicate their knowledge and understanding of physics in ways that are appropriate to the content and to the audience.

It is not intended that this part of the specification be taught as a discrete topic. Rather, the knowledge and skills specified here should pervade the entire course and should be taught using examples and applications from the rest of the specification.

Students should:
1.   know and understand the distinction between base and derived quantities and their SI units
2.   be able to demonstrate their knowledge of practical skills and techniques for both familiar and unfamiliar experiments
3.   be able to estimate values for physical quantities and use their estimate to solve problems
4.   understand the limitations of physical measurement and apply these limitations to practical situations
5.   be able to communicate information and ideas in appropriate ways using appropriate terminology
6.   understand applications and implications of science and evaluate their associated benefits and risks
7.   understand the role of the scientific community in validating new knowledge and ensuring integrity
8.   understand the ways in which society uses science to inform decision making

Topic 2: Mechanics

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include strobe photography or the use of a video camera to analyse projectile motion, determine the centre of gravity of an irregular rod, investigate the conservation of momentum using light gates and air track.

Mathematical skills that could be developed in this topic include plotting two variables from experimental data, calculating rate of change from a graph showing a linear relationship, drawing and using the slope of a tangent to a curve as a measure of rate of change, distinguishing between instantaneous rate of change and average rate of change and identifying uncertainties in measurements, using simple techniques to determine uncertainty when data are combined, using angles in regular 2D and 3D structures with force diagrams and using sin, cos and tan in physical problems.

This topic may be studied using applications that relate to mechanics, for example, sports.

Students should:
9. be able to use the equations for uniformly accelerated motion in one dimension: $$s = \frac{(u+v)t}{2}$$ $$v = u + at$$ $$s = ut + \tfrac{1}{2}at^2$$ $$v^2 = u^2 + 2as$$
10. be able to draw and interpret displacement-time, velocity-time and acceleration-time graphs
11. 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
12. understand scalar and vector quantities and know examples of each type of quantity and recognise vector notation
13. be able to resolve a vector into two components at right angles to each other by drawing and by calculation
14. 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
15. understand how to make use of the independence of vertical and horizontal motion of a projectile moving freely under gravity
16. be able to draw and interpret free-body force diagrams to represent forces on a particle or on an extended but rigid body

	Students should:
17.	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*
18.	be able to use the equations for gravitational field strength $g = \dfrac{F}{m}$ and weight $W = mg$
19.	**CORE PRACTICAL 1: Determine the acceleration of a freely-falling object.**
20.	know and understand Newton's third law of motion and know the properties of pairs of forces in an interaction between two bodies
21.	understand that momentum is defined as $p = mv$
22.	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
23.	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
24.	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
25.	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
26.	be able to use the equation $E_k = \frac{1}{2}mv^2$ for the kinetic energy of a body
27.	be able to use the equation $\Delta E_{grav} = mg\Delta h$ for the difference in gravitational potential energy near the Earth's surface
28.	know, and understand how to apply, the principle of conservation of energy including use of work done, gravitational potential energy and kinetic energy
29.	be able to use the equations relating power, time and energy transferred or work done $P = \dfrac{E}{t}$ and $P = \dfrac{W}{t}$
30.	be able to use the equations $$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$ and $$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Topic 3: Electric Circuits

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include estimating power output of an electric motor, using a digital voltmeter to investigate the output of a potential divider and investigating current/voltage graphs for a filament bulb, thermistor and diode.

Mathematical skills that could be developed in this topic include substituting numerical values into algebraic equations using appropriate units for physical quantities and applying the equation $y = mx + c$ to experimental data.

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

Students should:
31.   understand that electric current is the rate of flow of charged particles and be able to use the equation $I = \dfrac{\Delta Q}{\Delta t}$
32.   understand how to use the equation $V = \dfrac{W}{Q}$
33.   understand that resistance is defined by $R = \dfrac{V}{I}$ and that Ohm's law is a special case when $I \propto V$ for constant temperature
34.   understand how the distribution of current in a circuit is a consequence of charge conservation
35.   understand how the distribution of potential differences in a circuit is a consequence of energy conservation
36.   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
37.   be able to use the equations $P = VI$, $W = VIt$ and be able to derive and use related equations, e.g. $P = I^2 R$ and $P = \dfrac{V^2}{R}$
38.   understand how to sketch, recognise and interpret current-potential difference graphs for components, including ohmic conductors, filament bulbs, thermistors and diodes
39.   be able to use the equation $R = \dfrac{\rho l}{A}$
40.   **CORE PRACTICAL 2: Determine the electrical resistivity of a material.**
41.   be able to use $I = nqvA$ to explain the large range of resistivities of different materials

Students should:	
42.	understand how the potential along a uniform current-carrying wire varies with the distance along it
43.	understand the principles of a potential divider circuit and understand how to calculate potential differences and resistances in such a circuit
44.	be able to analyse potential divider circuits where one resistance is variable including thermistors and light dependent resistors (LDRs)
45.	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*
46.	**CORE PRACTICAL 3: Determine the e.m.f. and internal resistance of an electrical cell.**
47.	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
48.	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.

Topic 4: Materials

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic.

Mathematical skills that could be developed in this topic include determining the slope of a linear graph and calculating or estimating, by graphical methods as appropriate, the area between a curve and the x-axis and realising the physical significance of the area that has been determined.

This topic may be studied using applications that relate to materials, for example spare-part surgery.

	Students should:
49.	be able to use the equation density $\rho = \dfrac{m}{V}$
50.	understand how to use the relationship upthrust = weight of fluid displaced
51.	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
52.	**CORE PRACTICAL 4: Use a falling-ball method to determine the viscosity of a liquid.**
53.	be able to use the Hooke's law equation, $\Delta F = k\Delta x$, where k is the stiffness of the object
54.	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*
55.	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
56.	be able to draw and interpret tensile or compressive stress-strain graphs, and understand the term *breaking stress*
57.	**CORE PRACTICAL 5: Determine the Young modulus of a material**
58.	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*.

Topic 5: Waves and Particle Nature of Light

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include determining the refractive index of solids and liquids, measuring the focal length of a lens, and using models of structures to investigate stress concentrations.

Mathematical skills that could be developed in this topic include using calculators to handle sin x, identifying uncertainties in measurements and using simple techniques to determine uncertainty when data are combined.

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

	Students should:
59.	understand the terms *amplitude*, *frequency*, *period*, *speed* and *wavelength*
60.	be able to use the wave equation $v = f\lambda$
61.	be able to describe longitudinal waves in terms of pressure variation and the displacement of molecules
62.	be able to describe transverse waves
63.	be able to draw and interpret graphs representing transverse and longitudinal waves including standing/stationary waves
64.	**CORE PRACTICAL 6: Determine the speed of sound in air using a 2-beam oscilloscope, signal generator, speaker and microphone.**
65.	know and understand what is meant by *wavefront*, *coherence*, *path difference*, *superposition*, *interference* and *phase*
66.	be able to use the relationship between *phase difference* and *path difference*
67.	know what is meant by a *standing*/*stationary* wave and understand how such a wave is formed, know how to identify nodes and antinodes
68.	be able to use the equation for the speed of a transverse wave on a string $$v = \sqrt{\frac{T}{\mu}}$$
69.	**CORE PRACTICAL 7: Investigate the effects of length, tension and mass per unit length on the frequency of a vibrating string or wire.**
70.	be able to use the equation intensity of radiation $I = \dfrac{P}{A}$
71.	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 $n = \dfrac{c}{v}$
72.	be able to calculate *critical angle* using $\sin C = \dfrac{1}{n}$
73.	be able to predict whether total internal reflection will occur at an interface
74.	understand how to measure the refractive index of a solid material

	Students should:
75.	understand the term *focal length* of converging and diverging lenses
76.	be able to use ray diagrams to trace the path of light through a lens and locate the position of an image
77.	be able to use the equation power of a lens $P = \dfrac{1}{f}$
78.	understand that for thin lenses in combination $P = P_1 + P_2 + P_3 + \ldots$
79.	know and understand the terms *real image* and *virtual image*
80.	be able to use the equation $\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$ for a thin converging or diverging lens with the real is positive convention
81.	know and understand that magnification = image height/object height and $m = \dfrac{v}{u}$
82.	understand what is meant by *plane polarisation*
83.	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
84.	be able to use $n\lambda = d\sin\theta$ for a diffraction grating
85.	**CORE PRACTICAL 8: Determine the wavelength of light from a laser or other light source using a diffraction grating.**
86.	understand how diffraction experiments provide evidence for the wave nature of electrons
87.	be able to use the de Broglie equation $\lambda = \dfrac{h}{p}$
88.	understand that waves can be transmitted and reflected at an interface between media
89.	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
90.	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
91.	be able to use the equation $E = hf$, that relates the photon energy to the wave frequency
92.	understand that the absorption of a photon can result in the emission of a photoelectron
93.	understand the terms *threshold frequency* and *work function* and be able to use the equation $hf = \phi + \tfrac{1}{2}mv_{\max}^2$
94.	be able to use the *electronvolt* (eV) to express small energies

Students should:
95.   understand how the photoelectric effect provides evidence for the particle nature of electromagnetic radiation
96.   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.

Topic 6: Further Mechanics

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include investigating the effect of mass, velocity and radius of orbit on centripetal force.

Mathematical skills that could be developed in this topic include translating between degrees and radians and using trigonometric functions.

This topic may be studied using applications that relate to mechanics, for example, transportation.

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

Topic 7: Electric and Magnetic Fields

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include using a coulomb meter to measure charge stored and using an electronic balance to measure the force between two charges.

Mathematical skills that could be developed in this topic include sketching relationships which are modelled by $y = k/x$, and $y = k/x^2$, using logarithmic plots to test exponential and power law variations, interpreting logarithmic plots and sketching relationships that are modelled by $y = e^{-x}$.

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

Students should:
108. understand that an electric field (force field) is defined as a region where a charged particle experiences a force
109. understand that electric field strength is defined as $E = \dfrac{F}{Q}$ and be able to use this equation
110. be able to use the equation $F = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$, for the force between two charges
111. be able to use the equation $E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ for the electric field due to a point charge
112. know and understand the relation between electric field and electric potential
113. be able to use the equation $E = \dfrac{V}{d}$ for an electric field between parallel plates
114. be able to use $V = \dfrac{Q}{4\pi\varepsilon_0 r}$ for a radial field
115. be able to draw and interpret diagrams using field lines and equipotentials to describe radial and uniform electric fields
116. understand that capacitance is defined as $C = \dfrac{Q}{V}$ and be able to use this equation
117. 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 $W = \dfrac{\frac{1}{2}Q^2}{C}$
118. be able to draw and interpret charge and discharge curves for resistor capacitor circuits and understand the significance of the time constant RC

Students should:
119. **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.**
120. 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 $$\ln Q = \ln Q_0 - \frac{t}{RC} , \ \ln I = \ln I_0 - \frac{t}{RC} \text{ and } \ln V = \ln V_0 - \frac{t}{RC}$$
121. understand and use the terms *magnetic flux density B*, *flux ϕ* and *flux linkage Nϕ*
122. 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
123. 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
124. understand the factors affecting the e.m.f. induced in a coil when there is relative motion between the coil and a permanent magnet
125. 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
126. understand how to use Lenz's law to predict the direction of an induced e.m.f., and how the prediction relates to energy conservation
127. 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 $$\mathscr{E} = \frac{- \, \mathrm{d}(N\phi)}{\mathrm{d}t}$$
128. understand what is meant by the terms *frequency*, *period, peak value* and *root-mean-square value* when applied to alternating currents and potential differences
129. be able to use the equations $V_{rms} = \dfrac{V_0}{\sqrt{2}}$ and $I_{rms} = \dfrac{I_0}{\sqrt{2}}$

Topic 8: Nuclear and Particle Physics

Mathematical skills that could be developed in this topic include using appropriate units in calculations.

Students should:
130. understand what is meant by *nucleon number (mass number)* and *proton number (atomic number)*
131. 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
132. understand that electrons are released in the process of thermionic emission and how they can be accelerated by electric and magnetic fields
133. understand the role of electric and magnetic fields in particle accelerators (linac and cyclotron) and detectors (general principles of ionisation and deflection only)
134. be able to derive and use the equation $r = \dfrac{p}{BQ}$ for a charged particle in a magnetic field
135. be able to apply conservation of charge, energy and momentum to interactions between particles and interpret particle tracks
136. understand why high energies are required to investigate the structure of nucleons
137. be able to use the equation $\Delta E = c^2 \Delta m$ in situations involving the creation and annihilation of matter and antimatter particles
138. be able to use MeV and GeV (energy) and MeV/c^2, GeV/c^2 (mass) and convert between these and SI units
139. understand situations in which the relativistic increase in particle lifetime is significant (use of relativistic equations not required)
140. 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
141. 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
142. understand how to use laws of conservation of charge, baryon number and lepton number to determine whether a particle interaction is possible
143. be able to write and interpret particle equations given the relevant particle symbols.

Topic 9: Thermodynamics

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include investigating the relationship between the volume and temperature of a fixed mass of gas.

Mathematical skills that could be developed in this topic include substituting numerical values into algebraic equations using appropriate units for physical quantities.

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

Students should:
144. be able to use the equations $\Delta E = mc\Delta\theta$ and $\Delta E = L\Delta m$
145. **CORE PRACTICAL 12: Calibrate a thermistor in a potential divider circuit as a thermostat.**
146. **CORE PRACTICAL 13: Determine the specific latent heat of a phase change.**
147. understand the concept of *internal energy* as the random distribution of potential and kinetic energy amongst molecules
148. understand the concept of *absolute zero* and how the average kinetic energy of molecules is related to the absolute temperature
149. be able to derive and use the equation $pV = \frac{1}{3}Nm\langle c^2\rangle$ using the kinetic theory model
150. be able to use the equation $pV = NkT$ for an ideal gas
151. **CORE PRACTICAL 14: Investigate the relationship between pressure and volume of a gas at fixed temperature.**
152. be able to derive and use the equation $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$
153. understand what is meant by a *black body radiator* and be able to interpret radiation curves for such a radiator
154. be able to use the Stefan-Boltzmann law equation $L = \sigma AT^4$ for black body radiators
155. be able to use Wien's law equation $\lambda_{max}T = 2.898 \times 10^{-3}$ m K for black body radiators.

Topic 10: Space

Mathematical skills that could be developed in this topic include using approximations and sketching relationships which are modelled by $y = k/x^2$.

This topic may be studied using contexts such as the formation and evolution of stars and the history and future of the universe.

Students should:
156. be able to use the equation, intensity $I = \dfrac{L}{4\pi d^2}$ where L is luminosity and d is distance from the source
157. understand how astronomical distances can be determined using trigonometric parallax
158. understand how astronomical distances can be determined using measurements of intensity received from standard candles (objects of known luminosity)
159. be able to sketch and interpret a simple Hertzsprung-Russell diagram that relates stellar luminosity to surface temperature
160. understand how to relate the Hertzsprung-Russell diagram to the life cycle of stars
161. understand how the movement of a source of waves relative to an observer/detector gives rise to a shift in frequency (Doppler effect)
162. be able to use the equations for redshift $z = \dfrac{\Delta\lambda}{\lambda} \approx \dfrac{\Delta f}{f} \approx \dfrac{v}{c}$ for a source of electromagnetic radiation moving relative to an observer and $v = H_0 d$ for objects at cosmological distances
163. 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.

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Topic 11: Nuclear Radiation

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include measuring the half-life of a radioactive material.

Mathematical skills that could be developed in this topic include applying the concepts underlying calculus (but without requiring the explicit use of derivatives or integrals) by solving equations involving rates of change, for example. $\Delta x / \Delta t = -\lambda x$ using a graphical method or spreadsheet modelling and understanding probability in the context of radioactive decay.

This topic may be studied using applications that relate to nuclear radiation, for example nuclear power stations and medical physics.

Students should:
164. 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
165. use the *atomic mass unit (u)* to express small masses and convert between this and SI units
166. understand the processes of nuclear fusion and fission with reference to the binding energy per nucleon curve
167. 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
168. understand that there is background radiation and how to take appropriate account of it in calculations
169. understand the relationships between the nature, penetration, ionising ability and range in different materials of nuclear radiations (alpha, beta and gamma)
170. be able to write and interpret nuclear equations given the relevant particle symbols
171. **CORE PRACTICAL 15: Investigate the absorption of gamma radiation by lead.**
172. understand the spontaneous and random nature of nuclear decay
173. be able to determine the half-lives of radioactive isotopes graphically and be able to use the equations for radioactive decay: activity $A = \dfrac{\mathrm{d}N}{\mathrm{d}t} = -\lambda N$, $\lambda = \dfrac{\ln 2}{t_{\frac{1}{2}}}$, $N = N_0\, \mathrm{e}^{-\lambda t}$ and $A = A_0\, \mathrm{e}^{-\lambda t}$ and   derive and use the corresponding log equations.

Topic 12: Gravitational Fields

Mathematical skills that could be developed in this topic include sketching relationships that are modelled by $y = k/x$, $y = k/x^2$.

Students should:
174. understand that a gravitational field (force field) is defined as a region where a mass experiences a force
175. understand that gravitational field strength is defined as $g = \dfrac{F}{m}$ and be able to use this equation
176. be able to use the equation $F = \dfrac{Gm_1 m_2}{r^2}$ (Newton's law of universal gravitation)
177. be able to derive and use the equation $g = \dfrac{Gm}{r^2}$ for the gravitational field due to a point mass
178. be able to use the equation $V_{grav} = \dfrac{-Gm}{r}$ for a radial gravitational field
179. be able to compare electric fields with gravitational fields
180. be able to apply Newton's laws of motion and universal gravitation to orbital motion.

Topic 13: Oscillations

In order to develop their practical skills, students should be encouraged to carry out a range of practical experiments related to this topic. Possible experiments include measuring gravitational field strength using a simple pendulum and measuring a spring constant from simple harmonic motion.

Mathematical skills that could be developed in this topic include sketching relationships that are modelled by $y = \sin x$, $y = \cos x$.

Students should:
181. 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
182. 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 $T = \dfrac{1}{f} = \dfrac{2\pi}{\omega}$ and $\omega = 2\pi f$ as applied to a simple harmonic oscillator
183. be able to use equations for a simple harmonic oscillator $T = 2\pi\sqrt{\dfrac{m}{k}}$, and a simple pendulum $T = 2\pi\sqrt{\dfrac{l}{g}}$
184. 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
185. 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
186. understand what is meant by *resonance*
187. **CORE PRACTICAL 16: Determine the value of an unknown mass using the resonant frequencies of the oscillation of known masses.**
188. understand how to apply conservation of energy to damped and undamped oscillating systems
189. understand the distinction between *free* and *forced oscillations*
190. 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
191. understand how damping and the plastic deformation of ductile materials reduce the amplitude of oscillation.