# Physics 2015



## AS & A2

## Note: AS represents only 40% of the content of the full A level

## Topic 1 Working as a physicist AS A2

| 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 AS A2

| 9.  | be able to use the equations for uniformly accelerated motion in one       |  |
|-----|--|--|
|     |  |  |
|     |  |  |
|     | S = 2  |  |
|     | v = u + at   |  |
|     | $s = ut + \frac{1}{2} a t^2$   |  |
|     | $v^2 = u^2 + 2as$  |  |
| 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 now to use the            |  |
| 10  | 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                      |  |
|     |  |  |
|     |  |  |
|     |  |  |

| 17  | be able to use the equation $\Sigma E = ma_{12}$ and understand how to use this  |  |
|-----|--|--|
| 17. | De able to use the equation $\sum r = ma$ , and understand now to use this equation is situations where m is constant (Newton's second law of          |  |
|     | equalion in Situations where $\pi$ 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  | Use of the term terminal velocity is expected $f_{a} = F/m$ and $f_{a} = F/m$ and  |  |
| 10. | Deable to use the equations for gravitational here strength $y = 1 / m$ and weight $M = ma$  |  |
| 10  | CORF PRACTICAL 1: Determine the acceleration of a freely-falling   |  |
| 13. | 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  |  |
| 20  | Kinetic energy   |  |
| 29. | De able to use the equations relating power, time and energy transiented $D = M/t$   |  |
| 20  | OF WORK done $P = E/L$ and $P = vv/L$  |  |
| 30. |  |  |
|     | useful energy output   |  |
|     | efficiency – total energy input  |  |
|     | chloichey – total chergy input   |  |
|     | and  |  |
|     | useful power output  |  |
|     | efficiency = total power input   |  |
|     |  |  |

## Topic 3 Electric circuits AS A2

| 31. | understand that electric current is the rate of flow of charged particles and be able to use the equation $I = \Delta Q / \Delta t$   |  |
|-----|---|--|
| 32. | understand how to use the equation $V = W / Q$  |  |
| 33. | understand that resistance is defined by $R = V / I$ 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<br>parallel using the principles of charge and energy conservation, and be<br>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 $P = V^2 / R$   |  |
| 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 $R = \rho I / A$  |  |
| 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  |  |
| 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<br>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 AS A2

| 49. | be able to use the equation density $\rho = m / V$                                  |  |
|-----|---|--|
| 50. | understand how to use the relationship upthrust = weight of fluid displaced         |  |
| 51. | a. be able to use the equation for viscous drag (Stokes's 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   |  |
|     | <ul> <li>(tensile/compressive) stress = force/cross-sectional area</li> </ul>       |  |
|     | <ul> <li>(tensile/compressive) strain= change in length/original length</li> </ul>  |  |
|     | <ul> <li>Young modulus = stress/strain</li> </ul>                                   |  |
| 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/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<br>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 AS A2

| 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:   |  |
|                   |   |  |
|                   | $v = \sqrt{T} / \mu$  |  |
| 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 $I = P / A$  |  |
| 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 $n = c / v$   |  |
| 72.               | be able to calculate critical angle using $\sin C = 1/n$  |  |
| 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  |  |
| 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 $P = 1/f$   |  |
| 78.               | understand that for this lesses in combination $\mathbf{P} = \mathbf{P}_{t+1} + \mathbf{P}_{t+1}$   |  |
| 70                |   |  |
| 79.               | know and understand the terms real image and virtual image  |  |
| 79.<br>80.        | know and understand the terms real image and virtual image<br>be able to use the equation $1 / u + 1 / v = 1 / f$ for a thin converging or  |  |
| 79.<br>80.        | know and understand the terms real image and virtual image<br>be able to use the equation $1 / u + 1 / v = 1 / f$ for a thin converging or<br>diverging lens with the real is positive convention   |  |
| 79.<br>80.<br>81. | know and understand the terms real image and virtual image<br>be able to use the equation $1 / u + 1 / v = 1 / f$ for a thin converging or<br>diverging lens with the real is positive convention<br>know and understand that magnification = image height/object height and              |  |
| 79.<br>80.<br>81. | know and understand the terms real image and virtual image<br>be able to use the equation $1 / u + 1 / v = 1 / f$ for a thin converging or<br>diverging lens with the real is positive convention<br>know and understand that magnification = image height/object height and<br>m = v / u |  |

| 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 $n\lambda = dsin\theta$ 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 $\lambda = h / p$                     |  |
| 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 $hf = \phi + \frac{1}{2} mv^{2}_{max}$                   |  |
| 94. | be able to use the electronvolt (eV) to express small energies               |  |
| 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 A2

| 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 $E_k = p^2 / 2m$ for the kinetic energy                   |   |
|      | of a nonrelativistic 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 = $2\pi / \omega$   |   |
| 105. | be able to use vector diagrams to derive the equations for centripetal                           |   |
|      | acceleration $a = v^2 / r = r\omega^2$ and understand how to use these equations                 |   |
| 106. | understand that a resultant force (centripetal force) is required to produce                     |   |
|      | and maintain circular motion   | l |
| 107. | be able to use the equations for centripetal force F = ma = m v <sup>2</sup> / = mr $\omega^{2}$ |   |
| 1    |  | 4 |

## Topic 7 Electric and Magnetic Fields A2

| 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 $E = F / Q$ and be able  |  |
|  | to use this equation   |  |
| 110.   | be able to use the equation $F = Q_1 Q_2 / 4\pi\epsilon_0 r^2$ , for the force between two   |  |
|  | charges  |  |
| 111.   | be able to use the equation $E = Q / 4\pi\epsilon_0 r^2$ for the electric field due to a   |  |
|  | point charge   |  |
| 112.   | know and understand the relation between electric field and electric   |  |
| 440  | potential $\mathbf{r} = \frac{1}{2} \left[ \frac{1}{2} + \frac{1}{2} \right]$  |  |
| 113.   | be able to use the equation $E = V / d$ for an electric field between parallel   |  |
| 114  | plates $V = \Omega / 4\pi \alpha r - for a radial field$   |  |
| 114.   | be able to use $V = Q/4\pi\epsilon_{01} = 101$ a facial field  |  |
| 115.   | to describe radial and uniform electric fields   |  |
| 116.   | understand that capacitance is defined as $C = Q / V$ and be able to use   |  |
|  | this equation  |  |
| 117.   | be able to use the equation $W = \frac{1}{2} Q V$ 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   |  |
|  | $W = \frac{1}{2} C \sqrt{2}$ and $W = \frac{1}{2} C \sqrt{2}$  |  |
| 110  | $W = \frac{1}{2} C VZ$ and $W = \frac{1}{2} Q / C$   |  |
| 110.   | capacitor circuits and understand the significance of the time constant RC   |  |
| 119  | CORE PRACTICAL 11: Use an oscilloscope or data logger to display   |  |
|  |  |  |
| _  | and analyse the potential difference (p.d.) across a capacitor as it   |  |
|  | and analyse the potential difference (p.d.) across a capacitor as it charges and discharges through a resistor.  |  |
| 120.   | and analyse the potential difference (p.d.) across a capacitor as it charges and discharges through a resistor.<br>be able to use the equation $Q = Q_0 e^{-t/RC}$ and derive and use related  |  |
| 120.   | and analyse the potential difference (p.d.) across a capacitor as it charges and discharges through a resistor.<br>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,   |  |
| 120.   | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_0 e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations  |  |
| 120.   | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_0 e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = l_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations  |  |
| 120.   | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_0 e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$\ln Q = Q_0 - t/RC$ , $\ln I = \ln I_0 - t/RC$ and $\ln V_0 - t/RC$  |  |
| 120.   | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_0 e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = l_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$ln Q = Q_0 - t/RC$ , $ln I = ln l_0 - t/RC$ and $ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux  |  |
| 120.   | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$In Q = Q_0 - t/RC$ , $In I = In I_0 - t/RC$ and $In V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$   |  |
| 120.<br>121.<br>122.   | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_0 e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$In Q = Q_0 - t/RC$ , $In I = In I_0 - t/RC$ and $In V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation F = Bqv sin $\theta$ and apply Fleming's left-hand  |  |
| 120.<br>121.<br>122.   | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = l_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$ln Q = Q_0 - t/RC$ , $ln I = ln l_0 - t/RC$ and $ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation F = Bqv sin $\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field   |  |
| 120.<br>121.<br>122.<br>123.   | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$In Q = Q_0 - t/RC$ , $In I = In I_0 - t/RC$ and $In V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation F = Bqv sin $\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation F = BII sin $\theta$ and apply Fleming's left-hand rule  |  |
| 120.<br>121.<br>122.<br>123.   | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$\ln Q = Q_0 - t/RC$ , $\ln I = \ln I_0 - t/RC$ and $\ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation $F = Bqv \sin\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation $F = BII \sin\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field  |  |
| 120.<br>121.<br>122.<br>123.<br>124.                                 | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = b e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$\ln Q = Q_0 - t/RC$ , $\ln I = \ln b_0 - t/RC$ and $\ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation $F = Bqv \sin\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation $F = BII \sin\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field<br>understand the factors affecting the e.m.f. induced in a coil when there is   |  |
| 120.<br>121.<br>122.<br>123.<br>124.                                 | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$\ln Q = Q_0 - t/RC$ , $\ln I = \ln I_0 - t/RC$ and $\ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation F = Bqv sin $\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation F = BII sin $\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>relative motion between the coil and a permanent magnet  |  |
| 120.<br>121.<br>122.<br>123.<br>124.<br>125.                         | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$In Q = Q_0 - t/RC$ , $In I = In I_0 - t/RC$ and $In V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation F = Bqv sin $\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation F = BII sin $\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>relative motion between the coil and a permanent magnet<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>a change of current in another coil linked with this coil  |  |
| 120.<br>121.<br>122.<br>123.<br>124.<br>125.                         | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$In Q = Q_0 - t/RC$ , $In I = In I_0 - t/RC$ and $In V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation F = Bqv sin $\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation F = BII sin $\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>relative motion between the coil and a permanent magnet<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>a change of current in another coil linked with this coil<br>understand how to use Lenz's law to predict the direction of an induced   |  |
| 120.<br>121.<br>122.<br>123.<br>124.<br>125.<br>126.                 | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = l_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$ln Q = Q_0 - t/RC$ , $ln I = ln l_0 - t/RC$ and $ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation F = Bqv sin $\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation F = Bll sin $\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>relative motion between the coil and a permanent magnet<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>a change of current in another coil linked with this coil<br>understand how to use Lenz's law to predict the direction of an induced<br>e m f. and how the prediction relates to energy conservation   |  |
| 120.<br>121.<br>122.<br>123.<br>124.<br>125.<br>126.                 | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = b e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$\ln Q = Q_0 - t/RC$ , $\ln I = \ln b - t/RC$ and $\ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation F = Bqv sin $\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation F = Bll sin $\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>relative motion between the coil and a permanent magnet<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>a change of current in another coil linked with this coil<br>understand how to use Lenz's law to predict the direction of an induced<br>e.m.f., and how the prediction relates to energy conservation<br>understand how to use Faraday's law to determine the magnitude of an  |  |
| 120.<br>121.<br>122.<br>123.<br>124.<br>125.<br>126.<br>127.         | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$\ln Q = Q_0 - t/RC$ , $\ln I = \ln I_0 - t/RC$ and $\ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation F = Bqv sin $\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation F = BII sin $\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>relative motion between the coil and a permanent magnet<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>a change of current in another coil linked with this coil<br>understand how to use Lenz's law to predict the direction of an induced<br>e.m.f., and how the prediction relates to energy conservation<br>understand how to use Faraday's law to determine the magnitude of an<br>induced e.m.f. and be able to use the equation that combines Faraday's  |  |
| 120.<br>121.<br>122.<br>123.<br>124.<br>125.<br>126.<br>127.         | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = b e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$\ln Q = Q_0 - t/RC$ , $\ln I = \ln b - t/RC$ and $\ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation $F = Bqv \sin\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation $F = Bll \sin\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>relative motion between the coil and a permanent magnet<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>a change of current in another coil linked with this coil<br>understand how to use Lenz's law to predict the direction of an induced<br>e.m.f., and how the prediction relates to energy conservation<br>understand how to use Faraday's law to determine the magnitude of an<br>induced e.m.f. and be able to use the equation that combines Faraday's<br>and Lenz's laws E = -d(N $\phi$ ) / dt  |  |
| 120.<br>121.<br>122.<br>123.<br>124.<br>125.<br>126.<br>127.<br>128. | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = I_0 e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$\ln Q = Q_0 - t/RC$ , $\ln I = \ln I_0 - t/RC$ and $\ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation $F = Bqv \sin\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation $F = BII \sin\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>relative motion between the coil and a permanent magnet<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>a change of current in another coil linked with this coil<br>understand how to use Lenz's law to predict the direction of an induced<br>e.m.f., and how the prediction relates to energy conservation<br>understand how to use Faraday's law to determine the magnitude of an<br>induced e.m.f. and be able to use the equation that combines Faraday's<br>and Lenz's laws $E = -d(N\phi) / dt$<br>understand what is meant by the terms frequency. period, peak value and   |  |
| 120.<br>121.<br>122.<br>123.<br>124.<br>125.<br>126.<br>127.<br>128. | and analyse the potential difference (p.d.) across a capacitor as it<br>charges and discharges through a resistor.<br>be able to use the equation $Q = Q_{0}e^{-t/RC}$ and derive and use related<br>equations for exponential discharge in a resistor-capacitor circuit,<br>$I = b e^{-t/RC}$ , and $V = V_0 e^{-t/RC}$ and the corresponding log equations<br>$\ln Q = Q_0 - t/RC$ , $\ln I = \ln b - t/RC$ and $\ln V_0 - t/RC$<br>understand and use the terms magnetic flux density B, flux $\phi$ and flux<br>linkage N $\phi$<br>be able to use the equation F = Bqv sin $\theta$ and apply Fleming's left-hand<br>rule to charged particles moving in a magnetic field<br>be able to use the equation F = Bll sin $\theta$ and apply Fleming's left-hand rule<br>to current carrying conductors in a magnetic field<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>relative motion between the coil and a permanent magnet<br>understand the factors affecting the e.m.f. induced in a coil when there is<br>a change of current in another coil linked with this coil<br>understand how to use Lenz's law to predict the direction of an induced<br>e.m.f., and how the prediction relates to energy conservation<br>understand how to use Faraday's law to determine the magnitude of an<br>induced e.m.f. and be able to use the equation that combines Faraday's<br>and Lenz's laws E = -d(N $\phi$ ) / dt<br>understand what is meant by the terms frequency, period, peak value and<br>rootmean-square value when applied to alternating currents and potential |  |

| 129. | be able to use the equations Vrms = V0 / $\sqrt{2}$ and Irms = I0 / $\sqrt{2}$ |  |
|------|--|--|
|------|--|--|

## Topic 8 Nuclear and Particle Physics A2

| 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 $r = p/BQ$ 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<br>and annihilation of matter and antimatter particles   |  |
| 138. | be able to use MeV and GeV (energy) and MeV/c <sup>2</sup> , GeV/c <sup>2</sup> (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. | <ul> <li>know that in the standard quark-lepton model particles can be classified as:</li> <li>baryons (e.g. neutrons and protons) which are made from three quarks</li> <li>mesons (e.g. pions) which are made from a quark and an antiquark</li> <li>leptons (e.g. electrons and neutrinos) which are fundamental particles</li> <li>photons</li> <li>and that the symmetry of the model predicted the top quark</li> </ul> |  |
| 141. | know that every particle has a corresponding antiparticle and be able to<br>use the properties of a particle to deduce the properties of its antiparticle<br>and vice versa   |  |
| 142. | understand how to use laws of conservation of charge, baryon number<br>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 A2

| 144. | Be able to use the equations $\Delta E = m c \Delta \theta$ 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 $pV = 1/3$ N m <c<sup>2&gt;using the kinetic theory model</c<sup>        |  |
|------|---|--|
| 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 <c<sup>2&gt; = <math>\frac{3}{2}</math> k T</c<sup>      |  |
| 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 $\lambda_{max}T = 2.90 \times 10^{-3} \text{ m K}$ for black body radiators. |  |

## Topic 10 Space A2

| 156. | be able to use the equation, intensity $I = L / 4\pi d^2$ 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 $\Delta\lambda / \lambda \approx \Delta f / f \approx v/c$ 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.   |  |

## Topic 11 Nuclear Radiation A2

| 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<br>densities of matter and very high temperatures to bring about and<br>maintain nuclear fusion          |  |
| 168. | understand that there is background radiation and how to take<br>appropriate account of it in calculations   |  |
| 169. | understand the relationships between the nature, penetration, ionising<br>ability and range in different materials of nuclear radiations (alpha, beta<br>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:<br>activity $A = dN / dt = \lambda N$ , $\lambda = ln2 / t_{1/2}$ , $N = N_0 e^{-\lambda t}$ and $A = A_0 e^{-\lambda t}$ and derive and use the corresponding log equations. |  |

#### Topic 12 Gravitational Fields A2

| 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 = F / m and be      |  |
|      | able to use this equation  |  |
| 176. | be able to use the equation $F = G m_1 m_2 / r^2$ (Newton's law of universal     |  |
|      | gravitation)   |  |
| 177. | be able to derive and use the equation $g = G m / r^2$ for the gravitational     |  |
|      | field due to a point mass  |  |
| 178. | be able to use the equation $v_{grav} = -GWr^2$ 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 A2

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

| 191. | understand how damping and the plastic deformation of ductile materials |  |
|------|---|--|
|      | reduce the amplitude of oscillation.                                    |  |

**Core Practicals** 

| 1  | Determine the acceleration of a freely-falling object.                     |  |
|----|--|--|
| 2  | Determine the electrical resistivity of a material.                        |  |
| 3  | Determine the e.m.f. and internal resistance of an electrical cell.        |  |
| 4  | Use a falling-ball method to determine the viscosity of a liquid.          |  |
| 5  | Determine the Young modulus of a material                                  |  |
| 6  | Determine the speed of sound in air using a 2-beam oscilloscope, signal    |  |
|    | generator, speaker and microphone.   |  |
| 7  | Investigate the effects of length, tension and mass per unit length on the |  |
|    | frequency of a vibrating string or wire.                                   |  |
| 8  | Determine the wavelength of light from a laser or other light source using |  |
|    | a diffraction grating.   |  |
| 9  | Investigate the relationship between the force exerted on an object and    |  |
|    | its change of momentum.  |  |
| 10 | Use ICT to analyse collisions between small spheres, e.g. ball bearings    |  |
|    | on a table top.  |  |
| 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.  |  |
| 12 | Calibrate a thermistor in a potential divider circuit as a thermostat.     |  |
| 13 | Determine the specific latent heat of a phase change.                      |  |
| 14 | Investigate the relationship between pressure and volume of a gas at       |  |
|    | fixed temperature.   |  |
| 15 | Investigate the absorption of gamma radiation by lead.                     |  |
| 16 | Determine the value of an unknown mass using the resonant                  |  |
|    | frequencies of the oscillation of known masses.                            |  |

#### Mechanics:

Kinematic equations of motions = (u + v)t / 2s = displacement (vector)v = u + atv = final velocity $s = ut + \frac{1}{2}at^2$ u = initial velocity $v^2 = u^2 + 2as$ a = accelerationt = timeForces

| ΣF = m a              | m = mass                         |
|-----------------------|----------------------------------|
| g = F / m             | g = gravitational field strength |
| w = m g               | w = weight                       |
| Moment of force = F x | F = force                        |
|                       | x = distance (scalar)            |

Momentum

p = m v

p = momentum

Work, energy and power $\Delta W = F \Delta s$  $\Delta W = work done$  $E_k = \frac{1}{2} m v^2$  $E_k = kinetic energy$  $\Delta E_{grav} = m g \Delta h$  $\Delta E_{grav} = gravitational potential energy$ h = heightP = powerP = W / tE = energyW = work done

efficiency = useful energy output / total energy input

efficiency = useful power output / total power input

| Potential difference                    |  |  |  |
|---|--|--|--|
| V = W / Q                               | W = work done  |  |  |
|   | Q = charge   |  |  |
| Resistance                              |  |  |  |
| R = V / I                               | R = resistance   |  |  |
| Electrical power, energy and efficiency |  |  |  |
| P = V I                                 | P = power  |  |  |
| $P = I^2 R$                             | I = current  |  |  |
| $P = V^2 / R$                           | V = voltage  |  |  |
| W = V I t                               | W = work done  |  |  |
| Resistivity                             |  |  |  |
| $R = \rho I / A$                        | $\rho$ = resistivity   |  |  |
|   | R = resistance   |  |  |
|   | I = length   |  |  |
|   | A = x-sectional area   |  |  |
| Current                                 |  |  |  |
| $I = \Delta Q / \Delta t$               | Q = charge   |  |  |
| I = n q <i>v</i> A                      | n = number of charge carriers m <sup>-3</sup><br>q = charge on carrier<br>v = drift velocity |  |  |
|   | A = cross-sectional area   |  |  |

| Ma | ter | ial | s: |
|----|-----|-----|----|

| ρ = density                             |
|---|
| m = mass                                |
| V = volume                              |
|   |
| n – viscocity                           |
| r = radius of the sphere                |
| v = velocity                            |
| v = velocity                            |
|   |
| k = spring constant                     |
| x = extension                           |
|   |
| p = pressure                            |
|   |
|   |
| F = force                               |
| A = x-sectional area                    |
| $\Delta x = extension$                  |
| x = original length                     |
|   |
|   |
| E <sub>at</sub> = elastic strain energy |
|   |

#### Waves

Wave speed  $v = f \lambda$ v = velocity of wave Speed of a transverse wave on a spring  $v = \sqrt{T} / \sqrt{\mu}$ T = tension  $\mu$  = mass per unit length Intensity of radiation I = P / AI = intensity Power of a lens P = 1 / fP = power *f* = focal length  $P = P_1 + P_2 + P_3 + \dots$ Thin lens equation 1/u + 1/v = 1/fu = object distance v = image distance Magnification for a lens magnification = Image height / Object height m = v / u**Diffraction grating**  $n \lambda = d \sin \theta$  $\lambda$  = wavelength **Refractive index**  $n_1 \sin\theta_1 = n_2 \sin\theta_2$ n = refractive index n = c / vc = speed of EM radiation in a vacuum Critical angle sinC = 1 / nPhoton model E = hfh = Planck's constant f = frequency Einstein's photoelectric Equation  $hf = \phi + \frac{1}{2} mv_{max}^2$  $\phi$  = work function  $\frac{1}{2} mv_{max}^2 = kinetic energy$ de Broglie wavelength  $\lambda = h / p$  $\lambda$  = wavelength p = momentum

The value of the following constants will be provided in each examination paper.

| Acceleration of free fall    | $g = 9.81 \text{ m s}^{-2}$                               | (close to Earth's surface) |  |
|------------------------------|---|----------------------------|--|
| Boltzmann constant           | $k$ = 1.38 $\times$ 10 $^{-23}$ J $K^{-1}$                |                            |  |
| Coulomb law constant         | k = 4 1 πεο = 8.99 x 109 N m <sup>2</sup> C <sup>-2</sup> |                            |  |
| Electron charge              | $e = -1.60 \times 10^{-19} C$                             |                            |  |
| Electron mass                | $m_e = 9.11 \times 10^{-31} \text{ kg}$                   |                            |  |
| Electronvolt                 | $1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$           |                            |  |
| Gravitational constant       | G = $6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$  |                            |  |
| Gravitational field strength | g = 9.81 N kg <sup>-1</sup>                               | (close to Earth's surface) |  |
| Planck constant              | h = $6.63 \times 10^{-34}  \text{J s}$                    |                            |  |
| Permittivity of free space   | $\epsilon_{o}$ = 8.85 $\times$ 10 $^{-12}$ F m–1          |                            |  |
| Proton mass                  | $m_p$ = 1.67 × 10 <sup>-27</sup> kg                       |                            |  |
| Speed of light in a vacuum   | c = $3.00 \times 108 \text{ m s}^{-1}$                    |                            |  |
| Stefan-Boltzmann constant    | $\sigma$ = 5.67 x 10-8 W m <sup>-2</sup>                  | K <sup>-4</sup>            |  |
| Unified atomic mass unit     | u = 1.66 x 10 <sup>-27</sup> kg                           |                            |  |