**2021 A Levels H2 Physics Paper 3 suggested solutions**

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| **1** | **(a)** | **(i)** | $a = g\sin\theta$<br>$= 9.81\sin 40° = 6.31 \text{ m s}^{-2}$ |
| **1** | **(a)** | **(ii)** | $v^2 = u^2 + 2as$<br>$v^2 = 2(6.3057)(0.56)$<br>$v = 2.66 \text{ m s}^{-1}$ |
| **1** | **(b)** | **(i)** | $F = ma_c = m\frac{v^2}{r} = 0.072 \times \frac{(1.5)^2}{0.12} = 1.35 \text{ N}$ |
| **1** | **(b)** | **(ii)** | $N + mg = F_{\text{centripetal}}$<br>$N = 1.35 - (0.072)(9.81) = 0.644 \text{ N}$<br>The force is directed vertically downwards. |
| **2** | **(a)** | | Since gravitational force is attractive in nature, in order to separate two masses, positive work must be done by an external force since the exernal force and displacement are in the same direction.<br>Hence, gravitational potential energy and hence potential increases with separation of the masses.<br>Since the maximum gravitational potential at infinite separation is defined to be zero, thus at any separation less than infinite, the gravitational potential is less than zero, hence it will be negative in value. |
| **2** | **(b)** | **(i)** | $\phi = -\frac{GM}{r} = -\frac{(6.67\times10^{-11})(6.2\times10^{23})}{3.4\times10^{6}} = -1.22\times10^{7} \text{ J kg}^{-1}$ |
| **2** | **(b)** | **(ii)** | Kinetic energy: $E_K = \frac{1}{2}mv^2 = \frac{1}{2}(2.8)(3.8\times10^3)^2 = 2.02\times10^7 \text{ J}$<br>Gain in Gravitational potential energy to travel out into space:<br>$\Delta U = m(\Delta\phi) = 2.8\left[0 - (-1.22\times10^7)\right] = 3.42\times10^7 \text{ J}$<br>Since the kinetic energy is not sufficient to overcome the gravitational potential required to travel out into space, the rock will return to the surface of the planet. |
| **3** | **(a)** | | Internal energy of an ideal gas is a function of its state and is the <u>sum</u> of the microscopic kinetic energy due to the random motion of the gas particles. There is no potential energy related to the relative position of the gas particles due to negligible forces of attraction between particles in an ideal gas.<br>Internal energy is equivalent to $\frac{3}{2}nRT$ |
| **3** | **(b)** | **(i)** | Using ideal gas equation *PV* = *nRT* (where *T* is in kelvin K):<br>Given that *n* remains the same and that *R* is a constant, |

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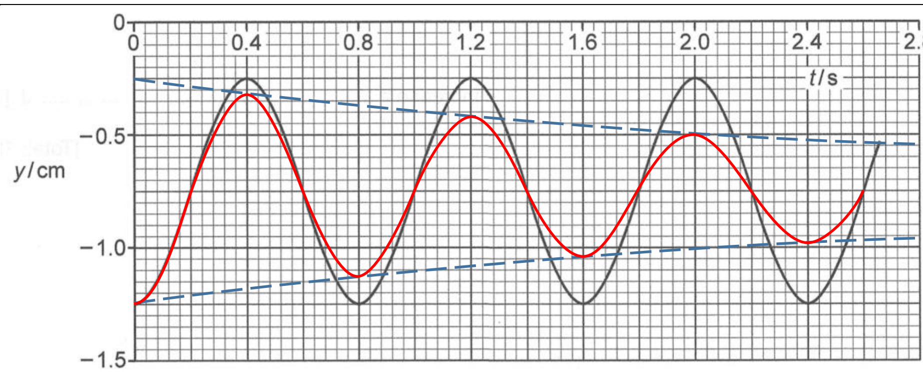
| | | | $\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$<br>$\frac{(1\times10^5)(3.2\times10^{-3})}{12+273}=\frac{(1\times10^5)(3.6\times10^{-3})}{\theta+273}$<br>$\theta=\frac{3.6}{3.2}(12+273)-273=47.625=47.6°\text{C}$ |
| 3 | (b) | (ii) | $W=p\Delta V=1.0\times10^5\times(3.6\times10^{-3}-3.2\times10^{-3})$<br>$=40\text{ J}$ |
| 3 | (c) | (i) | Using 1st Law of Thermodynamics:<br>$\Delta U=Q+W$<br>$\Delta U=101+(-40)=61\text{ J}$<br>($W_{\text{on gas}}=-W_{\text{by gas against atmosphere}}$) |
| 3 | (c) | (ii) | $PV=NkT$<br>Increase in KE per molecule $=\frac{\Delta U}{N}=\frac{\Delta U(kT)}{PV}=\frac{61(1.38\times10^{-23}\times(12+273))}{(1\times10^5)(3.2\times10^{-3})}$<br>$=7.50\times10^{-22}\text{ J}$ |
| 4 | (a) | (i) | 0.50 cm |
| 4 | (a) | (ii) | $\omega=\frac{2\pi}{T}=\frac{2\pi}{0.8}=7.85\text{ rad s}^{-1}$ |
| 4 | (a) | (iii) | $v_0=x_0\omega=(0.50\times10^{-2})(7.8540)=0.0393\text{ m s}^{-1}$ |
| 4 | (b) | | <br><br>Same starting amplitude, with decreasing amplitude a time passes due to larger damping effect due to air resistance from the increased surface area of the card. To draw the decrease in amplitude clearly, students can consider using exponential decay dashed lines to guide succeeding amplitudes.<br>Due to damping, the period may increase slightly (not shown here, but if increases slightly, must make sure that the new period is consistent over the 3 cycles).<br>Note that -0.75 cm is the equilibrium point and should match the original graph (if period is unchanged). |

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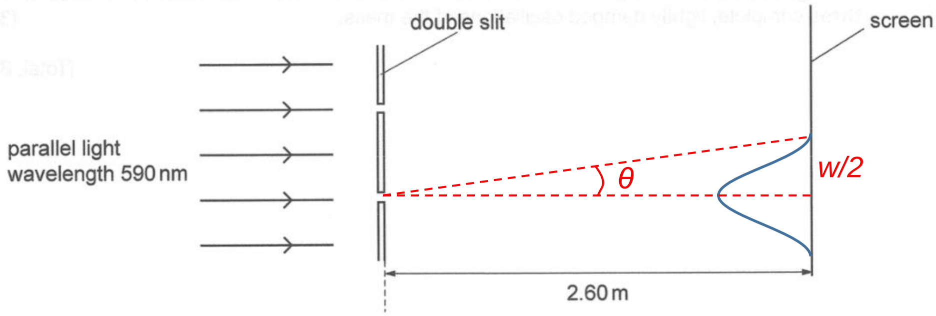
| 5 | (a) | | Diffraction of a wave is the spreading of the wave after it passes through a small opening or around an obstacle. |
| 5 | (b) | (i) | Single slit diffraction:<br><br><br>$\sin\theta = \frac{\lambda}{b}$, $\tan\theta = \frac{w/2}{2.60}$<br>at small angle, $\sin\theta \approx \tan\theta$<br>$\frac{\lambda}{b} \approx \frac{w}{2 \times 2.6}$<br>$w = \frac{590 \times 10^{-9}}{0.10 \times 10^{-3}} \times 2 \times 2.6 = 0.0307 \text{ m}$ |
| 5 | (b) | (ii) | Let fringe separation be X.<br>$X = \frac{\lambda D}{a} = \frac{(590 \times 10^{-9})(2.6)}{1.4 \times 10^{-3}} = 0.0010957 \text{ m}$<br>$\text{number of fringes} = \frac{0.0307}{0.0010957} = 28$<br><br>(more accurate way: if we take w/2 (half the width, first minima) and divide by X, we get 14.009, which means the 14th fringe falls at the minima, so can only the 13th fringe, so one side there are 13 fringes, the other side there are also 13 fringe, then plus the zero-order fringe we get 13 + 13 + 1 = 27) |

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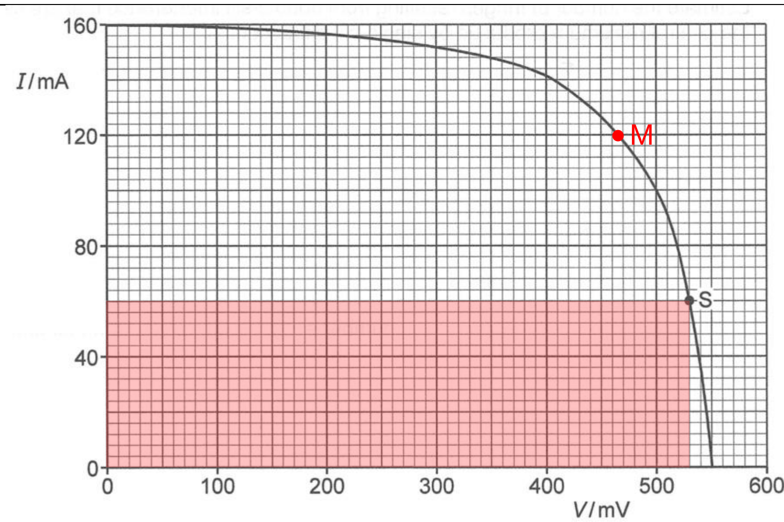
| 6 | (a) | (i)<br>(ii) | <br>Comment: Maximum power is obtained when the area under the graph is the largest (most squarish). |
| 6 | (b) | (i) | $I$ = 100 mA, $V$ = 500 mV<br>$R = \frac{V}{I} = \frac{0.500}{0.100} = 5.0\ \Omega$ |
| 6 | (b) | (ii) | $P = VI = 0.500 \times 0.100 = 0.0500$ W |
| 6 | (b) | (iii) | e.m.f. of solar cell (when $I = 0$) $= 0.550$ V<br>$\therefore$ at $V = 0.500$ V and $I = 0.100$ A,<br>Using $\varepsilon = IR + Ir$<br>$0.550 = 0.500 + 0.100r$<br>$r = 0.500\ \Omega$<br>Comment: Mistakes include working out the internal resistance at points other than the one required. Maximum power theorem does not work for such a circuit. |
| 7 | (a) | | Similarity: Both potentials are inversely proportional to the distance from point mass/point charge.<br>Difference: Electrical potential can be positive or negative for positive and negative point charges respectively. However, gravitational potential is always negative. |
| 7 | (b) | (i) | Opposite charges.<br>The charge at A is positive since the potential at smaller values of $x$ is positive, and the charge at B is negative since the potential at larger values of $x$ (closer to 12 cm) is negative. |

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| **7** | **(b)** | **(ii)** | Since the sum of the potentials due to charge A and charge B gives the effective potential shown on the graph, we should take the potential of zero at $x$ = 9 cm.<br>$V_A + V_B = 0$<br>$\frac{Q_A}{4\pi\varepsilon_0 x} + \frac{-Q_B}{4\pi\varepsilon_0 (0.12 - x)} = 0$<br>$\frac{Q_A}{Q_B} = \frac{0.09}{0.12 - 0.09}$<br>$= 3.0$ |
| **7** | **(b)** | **(iii)** | <br>$E = -\frac{dV}{dx} = -\frac{(-70 - 180)}{(12 - 1) \times 10^{-2}} = -2.27 \times 10^3 \text{ N C}^{-1}$<br>Magnitude of electric field strength is $2.27 \times 10^3 \text{ N C}^{-1}$. |
| **8** | **(a)** | | Magnetic flux density $B$ is defined as the force $F$ per unit length per unit current acting on an long straight current-carrying wire that is placed at right angle to the magnetic field in the region.<br>$B = \frac{F}{IL}$ , where $I$ is the current in the wire and $L$ is the length of the wire.<br>The units for $B$ is T or N $A^{-1}$ $m^{-1}$ or kg $A^{-1}$ $s^{-2}$ |
| **8** | **(b)** | **(i)** | The magnetic force acting on the moving charge is always perpendicular to the velocity of the charge and hence the force provides a centripetal acceleration, causing the particle to move in circular motion without a change in its speed. |

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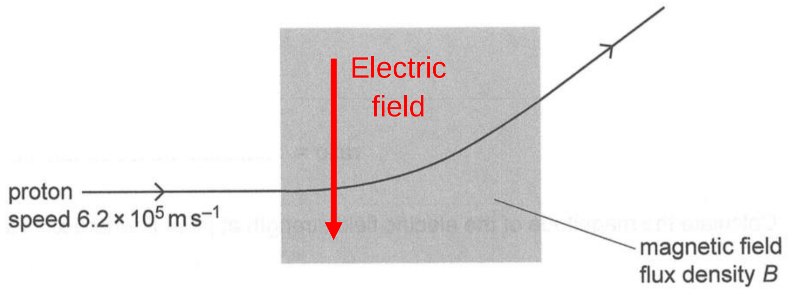
| **8** | **(b)** | **(ii)** | Magnetic force provides for centripetal force<br>$Bvq = \frac{mv^2}{r}$<br>$B = \frac{mv}{qr} = \frac{(1.67\times10^{-27})(6.2\times10^{5})}{(1.6\times10^{-19})(7.6\times10^{-2})} = 0.0851\text{ T}$ |
| **8** | **(c)** | **(i)** | <br><br>Since the magnetic force is upwards (proton curves upwards), the electric field needs to produce a downwards electric force to produce a net zero force on the proton. |
| **8** | **(c)** | **(ii)** | electric force + magnetic force $= 0$<br>$Eq - Bqv = 0$<br>$E = Bv = 0.085148(6.2\times10^{5}) = 5.28\times10^{4}\text{ V m}^{-1}$ |
| **8** | **(d)** | **(i)** | $B_{\text{r.m.s.}} = \frac{B_0}{\sqrt{2}} = \frac{6.4\times10^{-3}}{\sqrt{2}} = 4.53\text{ mT}$ |
| **8** | **(d)** | **(ii)** | Time: 1.0 ms and 4.0 ms (7.0 ms, 10 ms, 13 ms)<br>At the turning points, the rate of change of magnetic flux linkages is zero, hence no emf is induced. |

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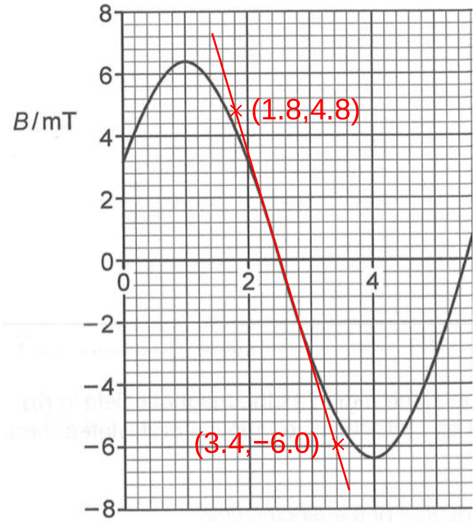
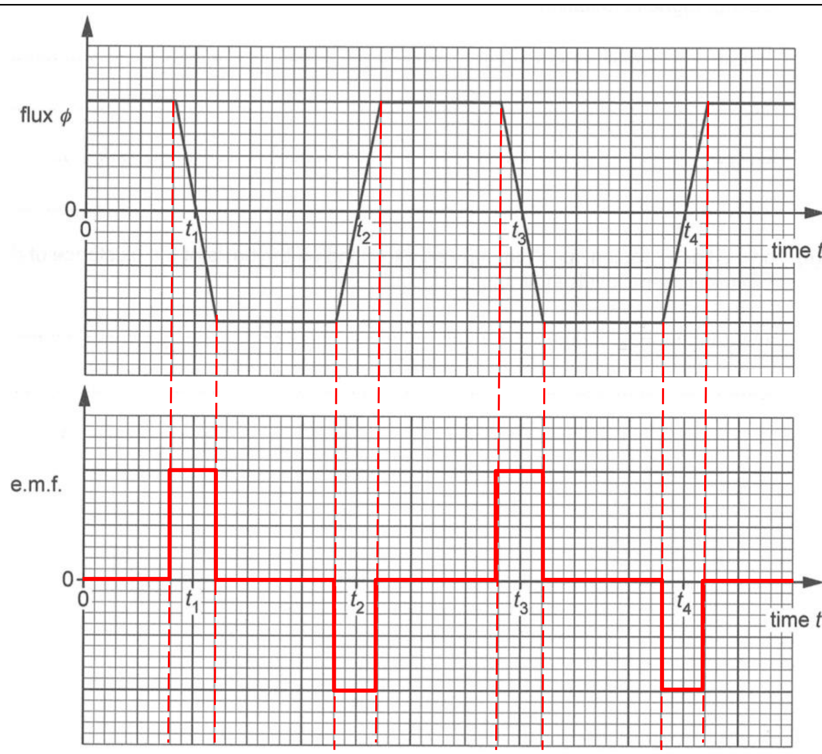
| 8 | **(e)** | | Use the graph to find the maximum rate of change of magnetic flux density in coil S.<br><br><br>emf induced $V = -\frac{d(N\phi)}{dt} = -NA\frac{dB}{dt}$<br>$= -270\times\pi\left(\frac{2.4\times10^{-2}}{2}\right)^{2}\times\frac{(-6.0-4.8)}{(3.4-1.8)}$<br>$= 0.824$ V |
| 8 | **(f)** | | <br> |

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| **9** | **(a)** | **(i)** | 1.Tthere exist a minimum frequency of the radiation before photoelectrons are emitted and detected regardless of the intensity of light. This shows that the radiation comes in packets of energy and the energy packets depends on frequency of the radiation.<br>2. The maximum kinetic energy of the emitted photoelectrons is not dependent on the intensity of the incident radiation but is dependent on the frequency of the radiation.<br><br>OR Option: 3. there is no time delay in emission of electrons when light of frequency above the threshold frequency is shone on the metal. |
| **9** | **(a)** | **(ii)** | Since atoms have discrete energy levels which electrons reside in, an excited atom will have its electrons in higher energy levels and the electrons will de-excite and transit to a lower energy level.<br>This de-excitation transition of electron from a higher energy level to a lower energy level will result in an emission of photon that has an energy equivalent to the difference in the energy between these 2 levels.<br>Given the discrete energy levels, there are only discrete unique number of transitions that the electrons can take. Hence, the photons produced by the excited atoms will be of discrete energy. This leads to a discrete line emission spectrum (distinct lines representing distinct frequencies of photons.) |
| **9** | **(b)** | **(i)** | $E = hf = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3\times10^{8})}{(340\times10^{-9})}$<br>$= 5.85\times10^{-19}$ J<br>$= \frac{5.85\times10^{-19}}{1.6\times10^{-19}}$ eV<br>$= 3.6563$ eV<br>$= 3.66$ eV |
| **9** | **(b)** | **(ii)** | The least energetic photon produced will be a transition from −3.4 eV to −13.6 eV. This energy difference produces a photon of energy = 10.2 eV.<br><br>Given that the UV end of the visible light spectrum has a photon energy of about 3.66 eV, this transition produces a photon with energy much greater than the most energetic photon within the visible light spectrum and hence lies outside of the visible light spectrum range. |
| **9** | **(c)** | **(i)** | $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{53} = 0.013078 = 0.0131\ \text{day}^{-1}$<br>Decay constant $\lambda$ represents that probability of decay per unit time. |

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| **9** | **(c)** | **(ii)** | $N = N_0 e^{-\lambda t}$<br>$N = \frac{m}{m_1} e^{-0.0131(120)}$<br>$N = \frac{5.7 \times 10^{-12}}{7 \times \left(1.66 \times 10^{-27}\right)} e^{-0.0131(120)}$<br>$N = 1.02 \times 10^{14}$ nuclei |
| **9** | **(c)** | **(iii)** | Since beryllium-7 (in an excited state) decays by emitting only gamma rays, there is no change in the number of neutrons and protons. Gamma rays are energy packets without a change in proton number or neutron number or electron number.<br>Since the nucleon number and proton number of beryllium-7 stays the same after radioactive decay, a decayed beryllium-7 stay as beryllium-7 without a drop in the total number. |
| **9** | **(d)** | | By conservation of linear momentum:<br>$0 = p_{\gamma} + p_{\text{Be-7}}$<br>$0 = \frac{E_{\gamma}}{c} - m_{\text{Be-7}} v$<br>$\frac{0.48 \times 10^{6} \times 1.6 \times 10^{-19}}{3 \times 10^{8}} = \left(7 \times 1.66 \times 10^{-27}\right) v$<br>$v = 2.20 \times 10^{4}$ m s$^{-1}$<br><br>Note that: $E_{\text{photon}} = hf = \frac{hc}{\lambda} = \left(\frac{h}{\lambda}\right) c = pc$ |