Assessment Schedule – 2021

Scholarship Physics (93103)

Evidence Statement

Q	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
ONE (a)	The average binding energy per nucleon rises sharply to a peak at about ^{56}Fe, and then slowly decreases. ^{235}U is near the end of the curve and so has a lower binding energy than elements with mass numbers in the range ~92–141. A higher binding energy means that more energy is needed to separate the nucleons, and so elements with higher binding energy are more stable. Therefore, it is energetically favourable for elements of high mass to undergo fission, as energy is released in the process.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	**SHOW** $E_k = 0.0400 \times 1.60 \times 10^{-19} = 6.40 \times 10^{-21}$ J $v = \sqrt{\dfrac{2E_k}{m}} = \sqrt{\dfrac{2 \times 6.40 \times 10^{-21}}{1.67 \times 10^{-27}}} = 2769 \text{ m s}^{-1}$ $p = mv = 1.67 \times 10^{-27} \times 2769 = 4.62 \times 10^{-24} \text{ kg m s}^{-1}$ $\lambda = \dfrac{h}{p} = \dfrac{6.63 \times 10^{-34}}{4.62 \times 10^{-24}} = 1.43 \times 10^{-10}$ m			
(c)	**SHOW** For neutron (waves) reflected from adjacent planes of crystals, the difference in path length is $2d \sin\theta$ (from the diagram). Therefore, the condition for diffraction is $2d \sin\theta = n\lambda$. So, $\sin\theta = \dfrac{n\lambda}{2d}$ (when $n = 1$) $\sin\theta = \dfrac{\lambda}{2d} = \dfrac{1.43 \times 10^{-10}}{2 \times 2.20 \times 10^{-10}} = 0.326$ $\theta = \sin^{-1}(0.326) = 19.0°$			
(d)(i)	As in (b), $v = 2769 \text{ m s}^{-1}$ $t = \dfrac{d}{v} = \dfrac{100}{2769} = 0.0361 \text{ s}$ $h = \tfrac{1}{2}gt^2 = \tfrac{1}{2} \times 9.81 \times 0.0361^2 = 6.40 \times 10^{-3} \text{ m} = 6.40 \text{ mm}$			
(ii)	No. Electric fields produce a force $F = qE$, but if $q = 0$, the force is zero, and so the electric field will have no effect at all.			

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TWO (a)(i)	If the 3rd harmonic of the D string is played at the same time as the 4th harmonic of the A string a beat will be heard if they are not at the same frequency. If they are at the same frequency, as they should be, no beat will be heard.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(ii)	$3f_\text{D} = 4f_\text{A}$ $\therefore f_\text{D} = \frac{4f_\text{A}}{3} = \frac{4 \times 110.0}{3} = 146.7 \text{ Hz}$			
(b)	**SHOW** Centre spring: $F = kx = k(L - L_0)$ Each side spring: $F_\theta = kx = k\left(\frac{L}{\cos\theta} - L_0\right)$ $\therefore F_\text{perp} = F_\theta \cos\theta = k\left(\frac{L}{\cos\theta} - L_0\right)\cos\theta = k(L - L_0\cos\theta)$ Net force from all 3 springs: $F = k(L - L_0) + 2k(L - L_0\cos\theta)$ $= kL - kL_0 + 2kL - 2kL_0\cos\theta$ $= k(3L - L_0(1 + 2\cos\theta))$			
(c)	**SHOW** Balanced torques on bridge: $Fd_2 = 6Td_1$ $kd_2(3L - L_0(1 + 2\cos\theta)) = 6Td_1$ $T = \frac{kd_2(3L - L_0(1 + 2\cos\theta))}{6d_1}$ Wave speed: $v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{kd_2(3L - L_0(1 + 2\cos\theta))}{6\mu d_1}}$ For the fundamental frequency: $\lambda = 2z, \therefore f = \frac{v}{\lambda} = \frac{v}{2z}$ $f = \sqrt{\frac{\frac{kd_2(3L - L_0(1 + 2\cos\theta))}{6\mu d_1}}{4z^2}}$ $= \sqrt{\frac{kd_2(3L - L_0(1 + 2\cos\theta))}{24\mu d_1 z^2}}$			
(d)	As the torque applied by the springs remains constant, the remaining strings must all still apply the same net torque, so the tension in each string must increase. As the tension has increased, the wave speed also increases. As v has increased, and the wavelength of the fundamental standing wave is constant, the fundamental frequency of each string increases.			

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	T increases by a factor of $\frac{6}{5}$, so v increases by a factor of $\sqrt{\frac{6}{5}}$, and f also increases by a factor of $\sqrt{\frac{6}{5}}$, so the new fundamental frequency of the "A" string will be $\sqrt{\frac{6}{5}} \times 110.0 = 120.5\ \text{Hz}$			

Q	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
THREE (a)	**SHOW** Vertical motion: $v_{\mathrm{i}} = v\sin\theta,\ v_{\mathrm{f}} = -v\sin\theta,\ a = -g,\ t = ?$ $v_{\mathrm{f}} = v_{\mathrm{i}} + at, \therefore t = \dfrac{v_{\mathrm{f}} - v_{\mathrm{i}}}{a} = \dfrac{-v\sin\theta - v\sin\theta}{-g}$ $= \dfrac{2v\sin\theta}{g}$ Horizontal motion: $d = v\cdot t = v\cos\theta\cdot\dfrac{2v\sin\theta}{g} = \dfrac{2v^2\sin\theta\cos\theta}{g} = \dfrac{v^2}{g}2\sin\theta\cos\theta$ $d = \dfrac{v^2}{g}\sin 2\theta = \dfrac{v^2}{g}\sin\left(2\times 45°\right) = \dfrac{v^2}{g}\sin 90° = \dfrac{v^2}{g}$	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	**SHOW** Horizontal motion: $t = \dfrac{2v\sin\theta}{g},\ v_{\mathrm{i}} = v\cos\theta$ (from part (a)), $a = -\dfrac{F}{m},\ d = v_{\mathrm{i}}t + \dfrac{1}{2}at^2$ $d = v\cos\theta\cdot\dfrac{2v\sin\theta}{g} - \dfrac{1}{2}\dfrac{F}{m}\left(\dfrac{2v\sin\theta}{g}\right)^2$ $= \dfrac{2v^2}{g}\sin\theta\cos\theta - \dfrac{2Fv^2\sin^2\theta}{mg^2}$ $= \dfrac{v^2}{g}\left(2\sin\theta\cos\theta - \dfrac{2F\sin^2\theta}{mg}\right)$ $= \dfrac{v^2}{g}\left(\sin 2\theta - \dfrac{2F\sin^2\theta}{mg}\right)$			
(c)	More realistic assumptions are that the direction of the drag force is always directly opposite to the direction of motion, and that the size of the drag force increases with velocity. This means that the ball will have a larger downwards acceleration on the way up, as the drag has a downwards component, so the ball will reach a lower max height and the flight time will be less, reducing the horizontal distance. The drag also has a horizontal component, which will act to reduce the horizontal velocity. This drag force component will reduce compared to a constant force. This may result in a change in range.			

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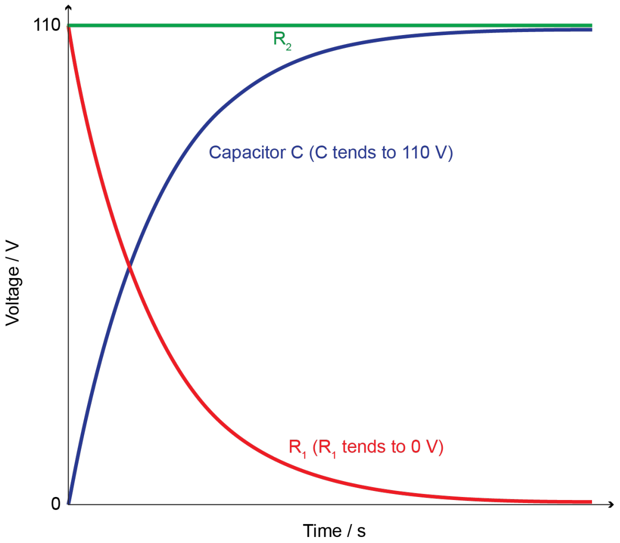
(d)(i)	**SHOW** $E_{\mathrm{i}} = \frac{1}{2}mv_{\mathrm{i}}^2 + \frac{1}{2}I\omega_{\mathrm{i}}^2;\ \omega_{\mathrm{i}} = \frac{v_{\mathrm{i}}}{R}$ $E_{\mathrm{i}} = \frac{1}{2}mv_{\mathrm{i}}^2 + \frac{\frac{1}{2}\times\frac{2}{5}mR^2 \times v_{\mathrm{i}}^2}{R^2} = \frac{7}{10}mv_{\mathrm{i}}^2$ $E_{\mathrm{h}} = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 + mgh = \frac{7}{10}mv^2 + mgh$ $E_{\mathrm{h}} = E_{\mathrm{i}}$ $\frac{7}{10}mv^2 + mgh = \frac{7}{10}mv_{\mathrm{i}}^2$ $\frac{7}{10}v^2 = \frac{7}{10}v_{\mathrm{i}}^2 - gh$ $v^2 = v_{\mathrm{i}}^2 - \frac{10gh}{7}$ $v = \sqrt{v_{\mathrm{i}}^2 - \frac{10gh}{7}}$			
(ii)	Max height when $v = 0$. $0 = \sqrt{v_{\mathrm{i}}^2 - \frac{10gh}{7}}$ $0 = v_{\mathrm{i}}^2 - \frac{10gh}{7}$ $\frac{10gh}{7} = v_{\mathrm{i}}^2$ $h = \frac{7v_{\mathrm{i}}^2}{10g}$			

Q	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
FOUR (a)	 R_2 is in parallel with the supply, so receives constant 110 V. The capacitor is initially uncharged, so starts at 0 V, but as it stores charge, the voltage increases until it reaches 110 V when fully charged. As R_1 is in series with the capacitor, it initially has voltage of 110 V when the current flow in this branch is limited by only the resistance and $V_C = 0$ V. As the capacitor voltage increases and the current drops, the voltage across R_1 decreases until it reaches 0 V, when the current has stopped flowing through this branch.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	R_2 is connected directly in parallel with the power supply, so will always have the same voltage as the power supply, constant 110 V. L will induce a back EMF to oppose the changing / increasing current. Initially there is a large rate of change of current, so there is a large induced back EMF. This will initially be equal to the voltage of the supply (110 V), but as the current increases, the rate of change of current decreases, so the induced back EMF decreases. The inductor voltage tends to the voltage across the resistive component of the inductor (10 V) as the current becomes constant, and no more back EMF is induced. As R_1 is in series with L, the voltages across R_1 and L must always add to 110 V. As the voltage across L starts at 110 V and drops tending towards 10 V, the voltage across R_1 must start at 0 V and increase, tending towards 100 V. OR As the inductor opposes the increasing current, the initial current through R_1 is 0 A, so the initial voltage across R_1 is 0 V (Ohm's Law).			
(c)	Current through R_2 is constant, $I_2 = \frac{V_2}{R_2} = \frac{100}{25.0} = 4.0$ A. When $I_1 = I_2 = 4.0$ A, $V_1 = I_1R_1 = 4.0 \times 22.4 = 89.6$ V Reading from the graph, $V_{R1} = 89.6$ V at approximately 1.1 s – 1.2 s.			

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(d)	Final steady current through inductor and R_1: $I = \frac{V}{R} = \frac{100}{22.4} = 4.46\text{ A}$ Inductor resistance: $R_L = \frac{V_L}{I} = \frac{10}{4.46} = 2.24\ \Omega$ OR… as final V_L is 10% of final V_{R1}, the inductor resistance is 10% of R_1: $R_L = \frac{22.4}{10} = 2.24\ \Omega$ Reading off the graph, the time constant for the R_1 and L branch of the circuit is 0.5 s (time taken for R_1 voltage to increase to 63% of final / 63 V) Inductor inductance: $L = \tau \times R = 0.5 \times (22.4 + 2.24) = 12.32\text{ H}$			

Cut Scores

Scholarship	Outstanding Scholarship
18 – 27	29 – 32