2022 H2 Physics Preliminary Examination Solution
Paper 1

Qn	Ans	Solution
1	D	$\Delta v = \frac{4.5}{100} \times 335.61 = 15.1 = 20$ (1 s.f.) $v \pm \Delta v = (340 \pm 20)$ m s^{-1} v is rounded off to the nearest tens place.
2	A	unit of $\sigma =$ unit of $\left(\frac{P}{AeT^4}\right)$ $=$ unit of $\left(\frac{W/t}{AeT^4}\right)$ $=$ unit of $\left(\frac{F \times d}{tAeT^4}\right)$ $=$ unit of $\left(\frac{m \times a \times d}{tAeT^4}\right)$ $= \left(\frac{\text{kg m s}^{-2}\text{ m}}{\text{s m}^2\text{ K}^4}\right) =$ kg s^{-3} K^{-4}
3	C	Take direction to the right and upwards as positive. $s_x = u_x t$ $t = \frac{s_x}{u_x} = \frac{3.4\cos 30°}{5.0\cos 60°}$ $v_y = u_y + a_y t = 5.0\sin 60° + (-9.81)\left(\frac{3.4\cos 30°}{5.0\cos 60°}\right) = -7.2240$ m s^{-1} $\tan\beta = \frac{v_y}{v_x}$, where β is the angle that the final velocity makes with the horizontal $\beta = \tan^{-1}\left(\frac{7.2240}{5.0\cos 60°}\right) = 70.911°$ $\theta = 70.911° - 30° = 40.911° = 41°$ OR $v_y^{\ 2} = u_y^{\ 2} + 2a_y s_y$ $v_y = \pm\left[(5.0\sin 60°)^2 + 2(-9.81)(-3.4\sin 30)\right]^{1/2} = -7.2183$ m s^{-1} or 7.2183 m s^{-1} (reject) $\tan\beta = \frac{v_y}{v_x}$, where β is the angle that the final velocity makes with the horizontal $\beta = \tan^{-1}\left(\frac{7.2183}{5.0\cos 60°}\right) = 70.897°$ $\theta = 70.897° - 30° = 40.897° = 41°$

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<td>4</td>
<td>A</td>
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Based on the given graph, the direction upwards is positive.

At time t, the ball is at its maximum height, and its displacement is +S1 (or +S2).

At time $2t$, the ball is back at its initial point and is accelerating as it moves downwards (negative velocity). Hence its displacement is zero (S1 = S2) and the gradient of the displacement-time graph is negative.

At time $3t$, the ball hits the ground since its velocity is $-2u$ and acceleration is constant at $-g$. Its displacement is –S3 from the initial point.

From $2t$ to $3t$, since the ball is accelerating as it moves downwards, its speed increases. Hence the gradient of the displacement-time graph should be negative with increasing magnitude.
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<td>5</td>
<td>C</td>
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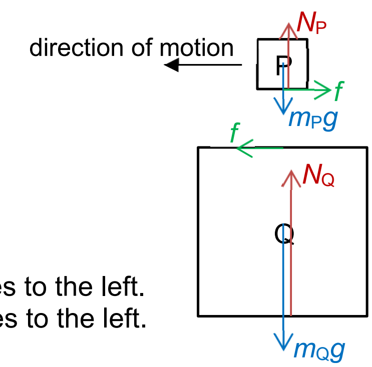
When P starts to slide:
Consider block P:
$-f = m_P a_P$
Consider block Q:
$f = m_Q a_Q$

$-m_P a_P = m_Q a_Q$
Since $m_P < m_Q$, $|a_P| > |a_Q|$
Friction on Block P causes it to decelerate as it moves to the left.
Friction on Block Q causes it to accelerate as it moves to the left.


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<td>6</td>
<td>A</td>
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from the time the column is dropped to when it just reaches the surface of the soil,
increase in K.E. = decrease in G.P.E

$$\frac{1}{2}Mv^2 - 0 = MgH$$

$$v = \sqrt{2gH}$$

from the time the column enters the soil to the time when it comes to a stop,
by Newton's second law and taking direction downwards as positive,

$$F_R = \frac{dp}{dt}$$

$$Mg - f = \frac{\Delta p}{\Delta t} \quad \text{where } f \text{ is the average resistive force}$$

$$Mg - f = \frac{p_f - p_i}{\Delta t}$$

$$Mg - f = \frac{0 - Mv}{t}$$

$$f = Mg + \frac{Mv}{t} = Mg + \frac{M\sqrt{2gH}}{t} = Mg\left(1 + \sqrt{\frac{2H}{gt^2}}\right)$$
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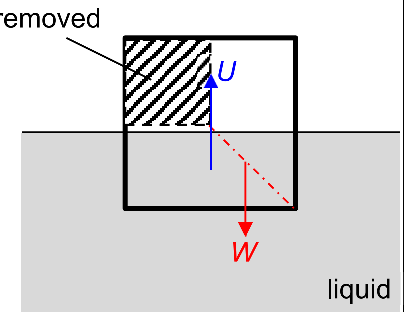
7	**B**	When a quarter of the cube is removed, the C.G. changes to the new geometrical centre and the weight decreases. Upthrust remains unchanged initially. Hence $U > W$ and there is a resultant force upwards. Since the upthrust and the weight are now not acting along the same line of action, there will be a resultant clockwise moment. 
8	**B**	$E_k = \frac{1}{2}m\left(v_x^2 + v_y^2\right)$ where $v_x = u_x$ and $v_y = u_y - gt$ $E_k = \frac{1}{2}m\left(u_x^2 + \left(u_y - gt\right)^2\right)$ $E_p = mgh = mg(u_y t - \frac{1}{2}gt^2)$ From the above equations, the variation with time of the energies is a quadratic relationship. By the conservation of energy, the increase in G.P.E. is equal to the decrease in K.E. as the ball moves upwards to its highest point and the decrease in G.P.E. is equal to the increase in K.E. as the ball moves downwards back to the ground. At $t = 0$ and when ball is back to the ground, $E_k = \frac{1}{2}m\left(u_x^2 + u_y^2\right)$ and $E_p = 0$ At maximum height, $v_y = 0$, $t = \frac{u_y}{g}$ $E_k = \frac{1}{2}mu_x^2$, $E_p = mgh = mg\left(\frac{u_y^2}{2g}\right) = \frac{1}{2}mu_y^2$
9	**D**	$F = ma = m\left(\frac{v-u}{t}\right) = \frac{mv}{t}$ since $u = 0$ $\text{K.E.} = \frac{1}{2}mv^2 = \frac{(mv)^2}{2m} = \frac{F^2t^2}{2m} \Rightarrow \text{K.E.} \propto \frac{t^2}{m}$ $\frac{\text{gain in kinetic energy of body A}}{\text{gain in kinetic energy of body B}} = \frac{\text{K.E.}_A - 0}{\text{K.E.}_B - 0}$ $= \frac{t_A^2}{m_A} \div \frac{t_B^2}{m_B}$ $= \frac{t_A^2 m_B}{t_B^2 m_A}$ $= \left(\frac{2t}{t}\right)^2\left(\frac{2m}{m}\right)$ $= 8$

10	**D**	As the sphere moves from highest to lowest point, increase in K.E. = decrease in G.P.E. $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mg(2L)$ $v^2 = 2\left(2gL + \frac{1}{2}u^2\right)$ When the sphere is at the lowest point, $T - mg = \frac{mv^2}{L}$ $T = \frac{mv^2}{L} + mg$ $= \frac{2m\left(2gL + \frac{1}{2}u^2\right)}{L} + mg$ $= \frac{2(0.40)\left(2(9.81)(0.50) + 0.5(2.5)^2\right)}{0.50} + (0.40)(9.81)$ $= 24.62 = 25\text{ N}$
11	**B**	Since the total energy $E_T = -\frac{GMm}{2R}$ of the satellite decreases due to work done against drag forces, its orbital radius R decreases. As R decreases, kinetic energy $E_k = \frac{GMm}{2R}$ increases, hence orbital speed increases. Since $\frac{GMm}{R^2} = m\omega^2 R = m\left(\frac{2\pi}{T}\right)^2 R \quad \Rightarrow \quad T^2 \propto R^3$ The orbital period T decreases as R decreases.
12	**A**	Gravitational force provides the centripetal force. $\frac{GMm}{R^2} = m\frac{v^2}{R}$ $v = \sqrt{\frac{GM}{R}} = \sqrt{\frac{G\rho\left(\frac{4}{3}\pi R^3\right)}{R}} = \sqrt{\frac{4}{3}\pi\rho G R^2} \Rightarrow v \propto \sqrt{\rho R^2}$ $\frac{v_M}{v_E} = \sqrt{\frac{\rho_M {R_M}^2}{\rho_E {R_E}^2}} = \sqrt{\frac{\rho_M {R_M}^2}{(1.25\rho_M)(4R_M)^2}}$ $v_M = \left(\sqrt{\frac{1}{1.25 \times 16}}\right)(7.90)$ $= 1.7665 = 1.77\text{ km s}^{-1}$

13	**D**	$pV = nRT$ $p = \frac{nRT}{V}$ $= \frac{mRT}{M_R V}$ $= \frac{(1.5)(8.31)(273.15+25)}{\left(\frac{20}{1000}\right)(3.7)}$ $= 50222 \text{ Pa} = 50 \text{ kPa}$
14	**D**	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$ $\sqrt{\langle c^2 \rangle} = \sqrt{\frac{3pV}{Nm}} = \sqrt{\frac{3kT}{m}}$ $c_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.38\times10^{-23})(273.15+100)}{18(1.66\times10^{-27})}} = 719.04 = 720 \text{ m s}^{-1}$
15	**D**	Using $Q = mc\Delta\theta$ heat gained by metal = heat lost by liquid $mc(\theta_f - 20) = (3m)(2.5c)(100 - \theta_f)$ $\theta_f - 20 = 750 - 7.5\theta_f$ $8.5\theta_f = 750 + 20$ $\theta_f = 90.59 = 91 \text{ °C}$
16	**A**	$E = \frac{1}{2}m\omega^2 x_0^2$ $E_p = \frac{1}{2}m\omega^2 x^2 = \frac{1}{2}m\omega^2\left(\frac{x_0}{3}\right)^2 = \frac{1}{9}E$
17	**B**	At $T/4$, the mass is at the equilibrium position where $d = 25$ cm. At $T/2$, the mass is at the highest point of its oscillation. Hence the amplitude of the oscillations is 15 cm.
18	**C**	After passing through the first polariser, intensity is halved, i.e. 20 W m^{-2}. Subsequently, the intensity after passing through the 2nd and 3rd polarisers is $I_f = \frac{1}{2}I_0\cos^2\theta\cos^2(90° - \theta) = \frac{1}{2}I_0\cos^2\theta\sin^2\theta$ $\cos\theta\sin\theta = \sqrt{\frac{2I_f}{I_0}}$ $\sin 2\theta = 2\sqrt{\frac{2I_f}{I_0}} = 2\sqrt{\frac{2\times2.5}{40}} = \frac{1}{\sqrt{2}}$ $\theta = 22.5°$

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<tr><td>19</td><td>B</td><td>

Table shows $\sin\theta = \dfrac{n\lambda}{d}$

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<tr><th>order</th><th>violet (400 nm)</th><th>red (700 nm)</th></tr>
<tr><td>1</td><td>$\dfrac{400\text{ nm}}{d}$</td><td>$\dfrac{700\text{ nm}}{d}$</td></tr>
<tr><td>2</td><td>$\dfrac{800\text{ nm}}{d}$</td><td>$\dfrac{1400\text{ nm}}{d}$</td></tr>
<tr><td>3</td><td>$\dfrac{1200\text{ nm}}{d}$</td><td>$\dfrac{2100\text{ nm}}{d}$</td></tr>
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Since $\dfrac{1200\text{ nm}}{d} < \dfrac{1400\text{ nm}}{d}$, 3rd order spectrum overlaps with the 2nd order spectrum.

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The constant electric force on the electron is pointing vertically downwards, in the direction of increasing potential.

$|E| = \left|-\dfrac{\Delta V}{\Delta x}\right| = \dfrac{2V}{d} \quad \Rightarrow \quad |\Delta V| = |E|(\Delta x) = \dfrac{2V}{d}(\Delta x)$ where Δx is the vertical distance

work done by external force, $W = q(\Delta V) = -e(V_f - V_i)$

From X to Y: This is along an equipotential line. Since there is no change in potential, the work done is zero.

From Y to Z: decrease in potential energy

$W_{YZ} = (-e)(V_Z - V_Y) = (-e)\left(\dfrac{2V}{d}(\Delta x)\right) = -\dfrac{2V}{d}er\cos 30° = -\dfrac{2V}{d}er\sin 60°$

From Z to X: increase in potential energy

$W_{ZX} = (-e)(V_X - V_Z) = (-e)\left(-\dfrac{2V}{d}(\Delta x)\right) = \dfrac{2V}{d}er\cos 30° = \dfrac{2V}{d}er\sin 60°$

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<tr><td>21</td><td>B</td><td>

increase in K.E. = decrease in E.P.E.

$\dfrac{1}{2}mv^2 - 0 = q|\Delta V|$

$v = \sqrt{\dfrac{2q|\Delta V|}{m}} = \sqrt{\dfrac{2qEd}{m}} \Rightarrow v \propto \sqrt{Ed}$ for the same charge to mass ratio

$\dfrac{v_2}{v_1} = \sqrt{\dfrac{E_2 d_2}{E_1 d_1}}$

$v_2 = \left(\sqrt{\dfrac{2E(2d)}{Ed}}\right)v$

$= 2v$

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22	**C**	$I_T = I_1 + I_2$ $\frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2}$ $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ Since the resistors are in parallel, the p.d. across each resistor is the same.
23	**C**	$V_X = R_X I$ The graph for X is a straight line with positive gradient and it passes through the origin. $V_Y = E - R_X I$ The graph for Y is a straight line with negative gradient and positive vertical intercept, *E*. The current through the 2 resistors is always the same at any time. The total p.d. across the 2 resistors is always *E*. Hence as the reading of Y decreases, the reading of X increases.
24	**D**	For a long straight wire, $B = \frac{\mu_0 I}{2\pi d}$ At Q, $B_Q = B_{\text{earth}} - \left(B_{\text{due to P}} + B_{\text{due to R}}\right)$ $= \left(2.0 \times 10^{-5}\right) - 2\left(\frac{\left(4\pi \times 10^{-7}\right)(1.0)}{2\pi(0.30)}\right)$ $= 1.8667 \times 10^{-5}\ \text{T}$ (northwards) $\frac{F}{L} = B_Q I_Q = \left(1.8667 \times 10^{-5}\right)(2.0)$ $= 3.7334 \times 10^{-5} = 3.7 \times 10^{-5}\ \text{N m}^{-1}$ Using Fleming's Left Hand Rule, the direction of the force is towards the West.
25	**A**	In field Y, the magnetic forces on the sides QR and PS of the coil are constant in magnitude, and they always act perpendicularly to the area of the coil, even as the coil rotates. This means the distance between the forces remains the same. Hence the torque on the coil is constant in magnitude throughout its rotation.
26	**B**	The p.d. induced between the centre and the edge of the disc is $V = BAf$, where *A* is the area of the disc, πr^2. Hence, $V = B\left(\pi r^2\right)\left(\frac{\omega}{2\pi}\right) = \frac{1}{2}Br^2\omega$, where $\omega = 2\pi f$. Since XY $= \frac{r}{2}$, $V_{XY} = \frac{1}{2}B\left(\frac{r}{2}\right)^2 \omega = \frac{1}{4}V$.
27	**C**	$\frac{N_s}{N_p} = \frac{V_s}{V_p}$ $N_p = \frac{V_p}{V_s}N_s = \frac{120\sqrt{2}}{8.0}(250) = 5303 = 5300$

28	**C**	The range of wavelengths for visible light is 400 nm to 700 nm. Since $E = \frac{hc}{\lambda}$, the energies of these photons range from $\frac{(6.63\times10^{-34})(3.00\times10^{8})}{(700\times10^{-9})(1.60\times10^{-19})} = 1.7759 \text{ eV}$ to $\frac{(6.63\times10^{-34})(3.00\times10^{8})}{(400\times10^{-9})(1.60\times10^{-19})} = 3.1078 \text{ eV}$. Only 3 transitions will result in emissions of such photons: $6.12 - 4.28 = 1.84 \text{ eV}$ $6.81 - 4.28 = 2.53 \text{ eV}$ $7.02 - 4.28 = 2.74 \text{ eV}$
29	**D**	When each electron is accelerated through the electric field, increase in K.E = decrease in E.P.E. $\text{final K.E. of electron} - 0 = \lvert -e\Delta V \rvert$ The X-ray photon with the shortest wavelength is produced when an electron loses all its K.E. (maximum loss in K.E. possible) to form the highest energy X-ray photon. $\text{final K.E. of electron} - 0 = \frac{hc}{\lambda_{\text{min}}}$ $\lambda_{\text{min}} = \frac{hc}{\lvert -e\Delta V \rvert} = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{(1.60\times10^{-19})(30\times10^{3})} = 4.1438\times10^{-11} = 4.1\times10^{-11} \text{ m}$
30	**C**	initial count rate of source alone, $C_0 = 100 - 20 = 80 \text{ s}^{-1}$ no. of half-lives, $n = \frac{t}{t_{1/2}} = \frac{60}{20} = 3$ $\frac{C}{C_0} = \left(\frac{1}{2}\right)^n$ $C = \left(\frac{1}{2}\right)^n C_0 = \left(\frac{1}{2}\right)^3 (80)$ recorded count rate $= \left(\frac{1}{2}\right)^3 (80) + 20 = 30 \text{ s}^{-1}$