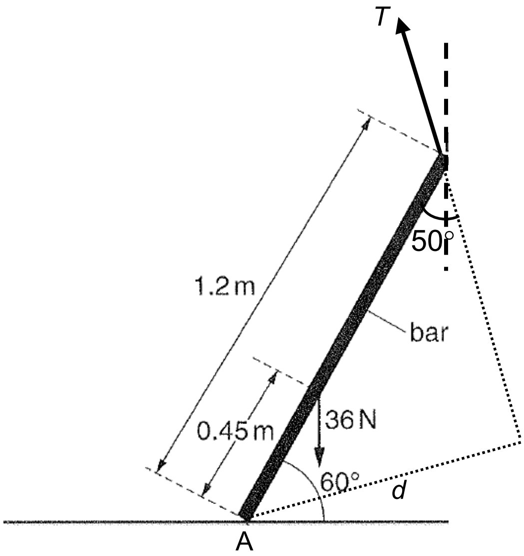
Answers to 2023 JC2 Preliminary Examination Paper 2 (H2 Physics)

Suggested Solutions:

No.	Solution	Remarks
1(a)(i)	$B = \frac{\phi}{A} = \frac{50 \times 10^{-6}}{4.00 \times 10^{-4}} = 0.125$ T $\frac{\Delta B}{B} = \frac{\Delta \phi}{\phi} + \frac{\Delta A}{A} = \frac{5}{50} + \frac{0.01}{4.00} = 0.1025$ ΔB = (0.125 T)(0.1025) = 0.01 T (1 s.f.) → B = (0.13 ± 0.01) T	[1] value of $\frac{\Delta B}{B}$ [1] value of ΔB to 1 s.f. [1] answer
1(a)(ii)	The percentage (or fractional) uncertainty of ϕ is more significant than that of A.	[1]
1(b)(i)	 The perpendicular distance from A to line of action of T is given by d = 1.2 sin 50° Taking moments about A, (36)(0.45 cos 60°) = T (1.2 sin 50°) $T = \frac{(36)(0.45 \cos 60^\circ)}{1.2 \sin 50^\circ}$ $= 8.8115$ $= 8.8$ N (shown) OR Anti-clockwise moment = T_y (1.2 cos 60°) + T_x (1.2 sin 60°) = (T cos 20°)(1.2 cos 60°) + (T sin 20°)(1.2 sin 60°)	[1] moment equation [1] numerical answer before 8.8 N

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1(b)(ii)	Let F_x and F_y be the horizontal and vertical components of F respectively. Consider vertical forces: 36 N = $T\cos 20° + F_y$ → $F_y = 36 - 8.81\cos 20° = 27.72$ N Consider horizontal forces: $F_x = T_x = T\sin 20°$ $= 8.81\sin 20°$ $= 3.01$ N $F = \sqrt{F_x^2 + F_y^2} = \sqrt{3.01^2 + 27.72^2} = 27.9$ N	[1] value of F_y [1] value of F_x [1] answer
2(a)	The phase difference is due to the extra distance x travelled by the wave from the student to the wall and back to him (x = 0.60 m) and also the phase change of π rad due to reflection at the wall. Phase difference $\phi = \dfrac{2\pi x}{\lambda} + \pi$ $= \dfrac{2\pi(0.60)}{0.40} + \pi$ $= 4\pi$ rad (or 0 or 2π rad)	[1] value of x [1] substitution [1] answer
2(b)(i)	When x_1 = 1.10 m, $A_1 = 1.2 \times 10^{-8}$ m When x_2 = 1.70 m, A_2 = ? $\dfrac{A_2}{A_1} = \dfrac{x_1}{x_2} \rightarrow A_2 = A_1\left(\dfrac{x_1}{x_2}\right) = 1.2\times10^{-8}\left(\dfrac{1.10}{1.70}\right)$ $= 0.78\times10^{-8}$ m Assumption: no energy is absorbed by the wall upon reflection	[1] substitution [1] answer [1] assumption
2(b)(ii)	Since $\phi = 4\pi$ rad, they are in phase, so Amplitude of resultant wave = $(1.2 + 0.78) \times 10^{-8}$ m $= 2.0 \times 10^{-8}$ m	[1] answer
2(c)	$\dfrac{I_r}{I_1} = \left(\dfrac{A_r}{A_1}\right)^2 \rightarrow I_r = I_1\left(\dfrac{A_r}{A_1}\right)^2 = 1.0\times10^{-6}\left(\dfrac{2.0\times10^{-8}}{1.2\times10^{-8}}\right)^2$ $= 2.8\times10^{-6}$ W m^{-2}	[1] substitution [1] answer
3(a)(i)	The electric field strength E at a point is the negative of the potential gradient $-\dfrac{dV}{dx}$ at that point.	[1]
3(a)(ii)	The equipotential lines are equally spaced with the same potential difference between consecutive lines.	[1]

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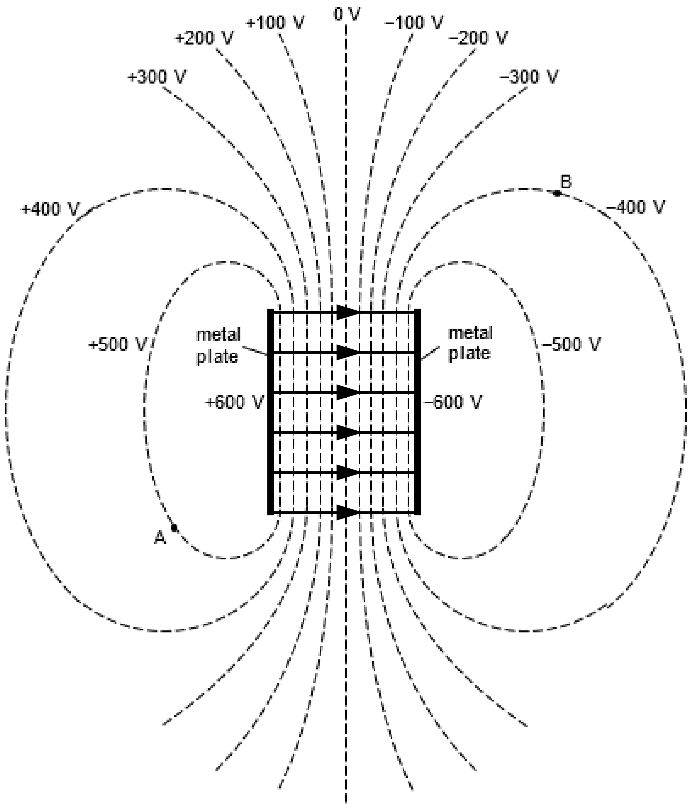
3(a)(iii)	Since $E=\dfrac{V}{d}$, we have $E=\dfrac{600-(-600)}{2.5\times10^{-2}}$ $E=4.8\times10^{4}\ \text{N C}^{-1}$	[1] for correct substitution [1] for correct answer
3(b)		[1] for six uniform field lines between the plates [1] for correct direction of field lines
3(c)(i)	Since the gain in electric potential energy of the particle is $q\Delta V$, we have $q\times(-400-500)=1.44\times10^{-16}$ $q=-1.60\times10^{-19}\ \text{C}$	[1] for correct substitution [1] for correct answer
3(c)(ii)	The particle is an electron.	[1] No e.c.f. from **(c)(i)**
3(c)(iii)	By conservation of energy, loss in k.e. = gain in e.p.e. $\dfrac{1}{2}\times9.11\times10^{-31}\times\left[\left(3.50\times10^{7}\right)^{2}-v_f^{\,2}\right]=1.44\times10^{-16}$ $v_f\approx3.01\times10^{7}\ \text{m s}^{-1}$	[1] for applying conservation of energy [1] for correct answer

No.	Solution	Remarks
4(a)(i)	p.d. across LDR $= \dfrac{400}{400+8400}\left[4.0-\left(-2.0\right)\right] = 0.27273$ V p.d. across LDR $= V_p - \left(-2.0\right)$ $0.27273 = V_p + 2.0$ $V_p = 0.27273 - 2.0$ ≈ -1.7 V	[1] for p.d. across LDR [1] for correct answer
4(a)(ii)	When a burglar blocks the laser beam, the resistance of the LDR will be high (or increases). Hence the p.d across the LDR and alarm will be high (or increases). This will turn on the alarm.	[1] [1]
4(b)(i)	There will be no deflection in the galvanometer when the p.d across JY = 1.5 V. Let the balance length (between J and Y) be L_{JY}. Then $V_{\text{JY}} = \dfrac{L_{\text{JY}}}{1.00}\left(\dfrac{1.6}{1.6+0.50}\right)(4.0)$ $1.5 = \dfrac{L_{\text{JY}}}{1.00}\left(\dfrac{1.6}{1.6+0.50}\right)(4.0)$ $L_{\text{JY}} = 0.4922$ ≈ 0.49 m	[1] for correct substitution [1] for correct answer
4(b)(ii)	When 1.5 Ω resistor is connected across points A and B, the terminal p.d across cell E is $V_{\text{terminal}} = \dfrac{1.5}{1.5+0.50}(1.5)$ $= 1.125$ V There will be null deflection when $V'_{\text{JY}} = 1.125$ V $V'_{\text{JY}} = \dfrac{L'_{\text{JY}}}{1.00}\left(\dfrac{1.6}{1.6+0.50}\right)(4.0)$ $1.125 = \dfrac{L'_{\text{JY}}}{1.00}\left(\dfrac{1.6}{1.6+0.50}\right)(4.0)$ $L'_{\text{JY}} = 0.3691$ ≈ 0.37 m	[1] for correct V_{terminal} [1] for correct substitution [1] for correct answer
5(a)	Gain in kinetic energy = Loss in electric potential energy $\dfrac{1}{2}mv^2 - 0 = eV - 0$ $\dfrac{1}{2}\left(9.11\times10^{-31}\right)v^2 = \left(1.60\times10^{-19}\right)(200)$ $v = 8.382\times10^6$ $\approx 8.38\times10^6$ m s^{-1}	[1] statement [1] correct answer before rounding off

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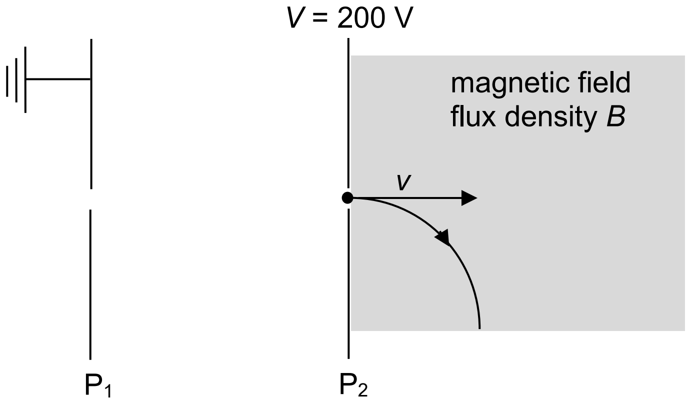
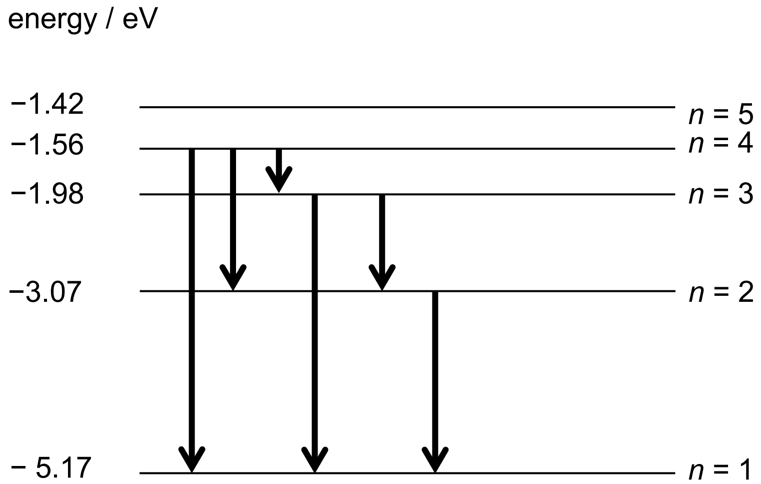
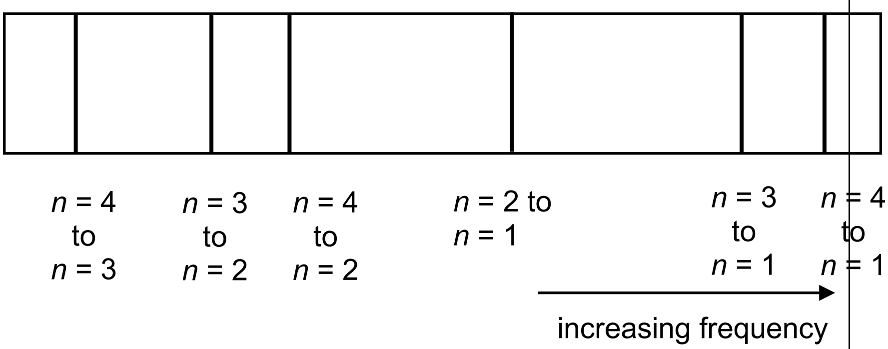
5(b)(i)		[1] path
5(b)(ii)	For circular motion, $Bqv = \frac{mv^2}{r}$ $B = \frac{mv}{qr}$ $B = \frac{9.11\times10^{-31}\left(8.38\times10^{6}\right)}{1.60\times10^{-19}\left(2.8\times10^{-2}\right)}$ $= 1.7\times10^{-3}$ T	[1] for correct substitution [1] for correct answer
5(c)(i)	The component of the velocity parallel to the magnetic field, is <u>unaffected by the magnetic field</u>. The component of the velocity perpendicular to the magnetic field results in a <u>magnetic force acting on the electron perpendicular to its motion</u>. Combining these 2 effects produces a <u>helical path</u> of the electron.	[1] for correct effect [1] for correct effect [1] correct path
5(c)(ii)	Radius of curvature, $r = \frac{mv_{\perp}}{Bq}$ $= \frac{9.11\times10^{-31}\left(8.38\times10^{6}\sin 30^{\circ}\right)}{1.60\times10^{-19}\left(1.7\times10^{-3}\right)}$ $= 1.4\times10^{-2}$ m	[1] for correct substitution [1] for correct answer

No.	Solution	Remarks
6(a)(i)	If all the electron's energy is absorbed, the electron could reach −5.17 + 3.7 = −1.47 eV level. Since there are no such energy level, the electron can only excite to −1.56 eV or n = 4 level. 	[1] for transitions to n = 1 [1] for transitions to n = 2 and n = 3
6(a)(ii)	 [1] for 3 spectral lines to the left and 2 spectral lines to the right [1] for correct spacing for the extreme 2 spectral lines on the right	
6(a)(iii)	If the electron absorbed the incoming photon, there is <u>no energy levels for it to excite to</u>. As such, there will be <u>no emission lines observed</u>.	[1]
6(b)(i)	The X-ray tube is evacuated so that the electrons emitted from the filament can move towards the metal target without colliding with air molecules and getting scattered.	[1]
6(b)(ii)	A photon is a quantum of electromagnetic radiation having a discrete amount of energy $E = hf$ where h is the Planck constant and f the frequency of radiation.	[1]
6(b)(iii)	From Fig. 6.3, $\lambda_{\text{min}} = 0.40 \times 10^{-11}$ m ,	

No.	Solution	Remarks
	$E=\dfrac{hc}{\lambda_{\text{min}}}$ $=\dfrac{(6.63\times10^{-34})(3.00\times10^{8})}{(0.40\times10^{-11})}$ $=4.97\times10^{-14}$ J	[1] correct substitution [1] correct answer
6(b)(iv)	$qV=4.97\times10^{-14}$ $(1.60\times10^{-19})V=4.97\times10^{-14}$ $V=310.6$ ≈ 310 kV	[1] substitution
7(a)(i)	The engine takes in air at a rate of 1300 kg s^{-1} $\dfrac{\Delta m}{\Delta t}=\rho A\dfrac{\Delta s}{\Delta t}$ $=\rho\left(\dfrac{\pi}{4}D^2\right)v_{\text{in}}$ $v_{\text{in}}=\dfrac{1300}{1.2\times\dfrac{\pi}{4}\times3.0^2}$ $=153.3$ ≈ 150 m s^{-1} (shown)	[1] for correct substitution [1] for correct calculated value before 150 m s^{-1}
7(a)(ii)	Thrust, $F=(m_{\text{air}}+m_{\text{fuel}})v_{\text{exhaust}}-m_{\text{air}}v_{\text{in}}$ $=(1300+17)(410)-(1300)(150)$ $=344970$ ≈ 345 kN	[1] for correct substitution [1] for correct answer
7(a)(iii)	By Newton's second law, $F=ma$ $a=\dfrac{F}{m}$ $=\dfrac{344970\times2}{\dfrac{2.75\times10^{6}}{9.81}}$ (because of 2 engines) $=2.461$ ≈ 2.46 m s^{-2}	[1] for correct substitution [1] for correct answer
7(b)	As air is deflected upwards upon contact with the stabiliser, it experiences a rate of change of momentum. By Newton's second law, this is the resultant force on the air by the stabiliser.	[1] for application of Newton's 2nd law

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	By Newton's third law, the air will exert a force of equal magnitude but in opposite direction, causing a downward force on the stabiliser and enabling the aircraft to take off.	[1] for application of Newton's 3rd law
7(c)(i)	Consider vertical forces in equilibrium, $N_R + N_F = W$ $N_F = W - N_R$ Take moments about the centre of gravity, $N_R X_R = N_F X_F + Fd$ $= (W - N_R) X_F + Fd$ $N_R (X_R + X_F) = WX_F + Fd$ $\therefore\ N_R = \frac{WX_F + Fd}{X_R + X_F}$ (shown)	[1] for vertical forces in equilibrium [1] for correct expression taking moments [1] for substitution
7(c)(ii)	$N_F = W - N_R$ $= W - \frac{WX_F + Fd}{X_R + X_F}$ $= \frac{W(X_R + X_F) - WX_F - Fd}{X_R + X_F}$ $= \frac{WX_R - Fd}{X_R + X_F}$	[1] for correct substitution
7(c)(iii)	When at rest without the thrust F, the contact force on the front landing gears is $\frac{WX_R}{X_R + X_F}$ and the contact force on the rear landing gears is $\frac{WX_F}{X_R + X_F}$. When accelerating, the thrust F results in the contact force on the front gears to decrease by $\frac{Fd}{X_R + X_F}$, while the contact force on the rear gears is increased by $\frac{Fd}{X_R + X_F}$, causing the weight transfer from the front gears to the rear gears.	[1] for explanation of contact forces without acceleration [1] for explanation of the transfer of force from front gears to the rear gears
7(d)(i)	Total energy used	[1] for correct substitution

No.	Solution	Remarks
	$=\left(5.5\times10^{3}\right)(12)\left(42\times10^{6}\right)$ $=2.772\times10^{12}$ $\approx 2.77\times10^{12}$ J	[1] for correct answer
7(d)(ii)	The amount of energy that the battery stores per kilogram of its mass is 0.260 kilowatt-hours.	[1]
7(d)(iii)	Mass of lithium battery $=\dfrac{2.772\times10^{12}}{0.260\times10^{3}\times60\times60}$ $=2.962\times10^{6}$ $\approx 2.96\times10^{6}$ kg	[1] for correct substitution [1] for correct answer
7(e)(i)	The total weight of the battery (2.9×10^{7} N) will be greater than the maximum take-off weight (MTOW) of 2.75×10^{6} N of the aircraft, which is not possible.	[1]
7(e)(ii)	Any two: 1. Jet fuel has a higher energy density (42 MJ kg^{-1}) compared to battery (0.260 kW h kg^{-1}, i.e. 9.36×10^{5} J kg^{-1}), hence more suitable for long-haul flights. 2. Electric aircrafts need batteries with high enough specific energy, so the mass penalty means they cannot fly long distances. 3. Lithium batteries can overheat and ignite, posing fire hazard on electric aircrafts. 4. Jet engine aircraft uses jet fuel which gets depleted over the course of the flight causing the aircraft to be lighter and hence burns less fuel whereas the mass of the battery-powered electric aircraft remains constant throughout the flight. 5. Jet engine aircraft takes a shorter time to refuel compared to the duration needed to recharge the lithium battery.	[2] Any other logical answer