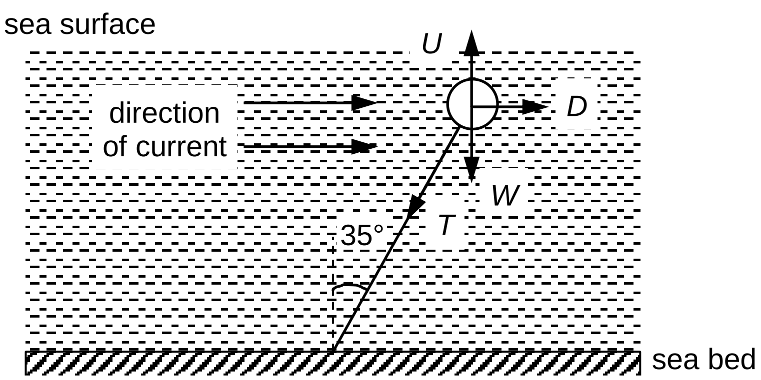
Answers to 2021 JC2 Preliminary Examination Paper 3 (H2 Physics)

No.	Solution	Remarks
1(a)(i)	Upthrust is the <u>net upward force</u> acting on a body submerged in a fluid due to the <u>difference in pressure at the top and bottom</u> of the immersed portion of the body.	[1] for correct answer
1(a)(ii)	Upthrust $U = \frac{4}{5} V \rho_{sea} g$ $= \frac{4}{5}(7.5\times10^{-2})(1.03\times10^{3})(9.81)$ $= 606.3$ ≈ 606 N	[1] for correct equation and numerical substitution [1] for correct answer
1(a)(iii)	$U = T + mg$ $T = U - mg$ $= 606.3 - (8.0)(9.81)$ $= 527.8$ $= 530$ N (shown)	[1] for correct method and numerical substitution
1(b)(i)	 [1] for correct *T*, *U* and *D*	
1(b)(ii)	Resolving forces horizontally, $T \sin 35^\circ = D$ --- (1) Resolving forces vertically, $T \cos 35^\circ + W = U$ $T = \frac{U - W}{\cos 35^\circ}$ --- (2) Substitute (2) into (1),	[1] for correct equations by resolution of forces

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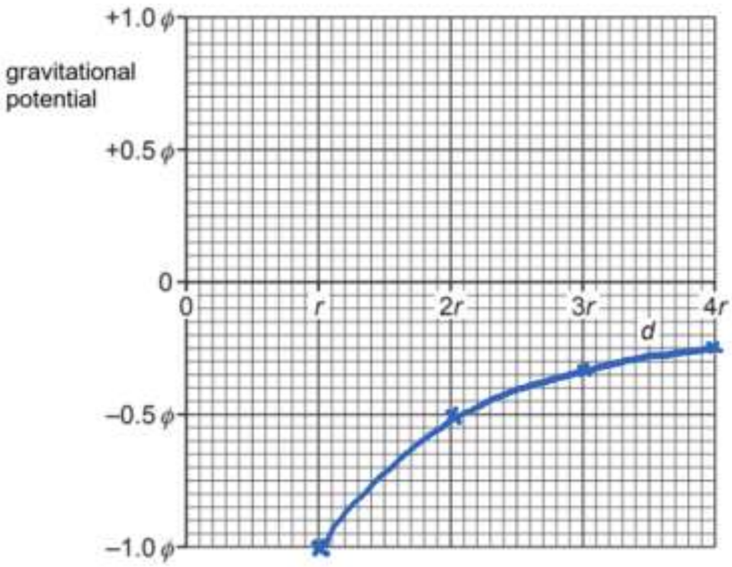
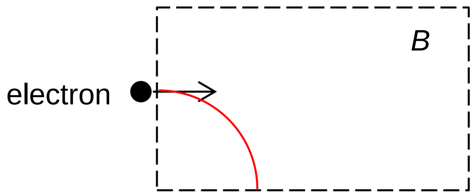
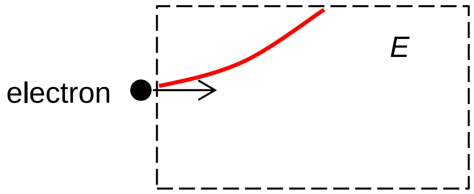
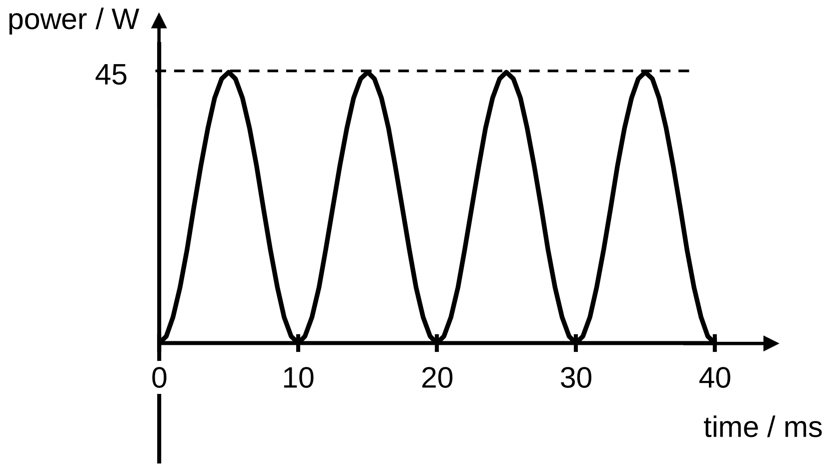
	$D=(U-W)\tan 35^\circ$ $=\left[\rho_{sea}Vg-mg\right]\tan 35^\circ$ $=\left[(1.03\times10^{3})(7.5\times10^{-2})(9.81)-(8.0)(9.81)\right]\tan 35^\circ$ $=475.7$ $=476$ N	[1] for correct numerical substitution [1] for correct answer
2(a)(i)	Work done per unit mass in bringing a small test mass from infinity to that point.	[1] for correct answer
2(a)(ii)	Potential at infinity is taken to be zero. Due to the attractive nature of the gravitational force, work done by an external agent to bring any mass from infinity to that point is always negative. Hence the potential at any point must always be negative.	[1] [1]
2(b)		[1] for correct shape [1] for at least 3 correct plots (i.e. r, $2r$ and $4r$)
2(c)(i)	Gravitational force provide the centripetal force for the spacecraft to move in circular orbit. $\frac{GMm}{R^2}=\frac{mv^2}{R}$ $\therefore v=\sqrt{\frac{GM}{R}}$ $=\sqrt{\frac{(6.67\times10^{-11})(6.0\times10^{24})}{4(6400000)}}$ $=3953$ $\approx 4.0\times10^{3}$ m s^{-1} (shown)	[1] for statement [1] for correct equation and numerical substitution

No.	Solution	Remarks
2(c)(ii) 1.	$\Delta U = U_f - U_i$ $= \left(-\frac{GMm}{R_f}\right) - \left(-\frac{GMm}{R_i}\right)$ $= \left(-\frac{(6.67\times10^{-11})(6.0\times10^{24})(8600)}{3(6.4\times10^{6})}\right) - \left(-\frac{(6.67\times10^{-11})(6.0\times10^{24})(8600)}{4(6.4\times10^{6})}\right)$ $= -4.48\times10^{10}$ J	[1] for correct equation and numerical substitution [1] for correct answer
2(c)(ii) 2.	$v_f = \sqrt{\frac{GM}{R}}$ $= \sqrt{\frac{(6.67\times10^{-11})(6.0\times10^{24})}{3(6.4\times10^{6})}}$ $= 4565 \approx 4.57\times10^{3}$ m s^{-1} $\Delta \text{KE} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ $= \frac{1}{2}(8600)(4565^2 - 3953^2)$ $= 2.24\times10^{10}$ J Since total energy = kinetic energy + gravitational potential energy and there is more loss in GPE than gain in KE, the total energy decrease.	[1] for correct quantitative method [1] for correct explanation and conclusion
3(a)	The first law of thermodynamics states that the increase in internal energy of a system is the sum of the heat supplied to the system and the work done on the system.	[1] correct definition
3(b)(i)	$\Delta U = Q + W$ For adiabatic process, $Q = 0$ $\Delta U = W = -500$ J	[1] correct answer
3(b)(ii)	Since internal energy decreases, <u>temperature of gas decreases</u>.	[1] correct answer
3(c)(i)	$\Delta U = Q + W$ For constant volume process, $W = 0$ $Q = \Delta U = \frac{3}{2}nR\Delta T$ $= \frac{3}{2}(2.5)(8.31)(500-300)$ $= 6232.5$ $= 6230$ J molar heat capacity $= \frac{6232.5}{(2.5)(200)}$ $= 12.465$ $= 12.5$ J mol^{-1} K^{-1}	[1] for correct equation and substitution [1] for correct Q [1] for correct molar heat capacity

No.	Solution	Remarks
3(c)(ii)	For the constant pressure process, in addition to the increase in internal energy, work is done by the gas hence more heat is supplied for the same change in temperature. This will result in a larger molar heat capacity.	[1] for work done [1] for more heat supplied
4(a)	$E = \dfrac{V_{\text{bottom}} - V_{\text{top}}}{d}$ $1.40 \times 10^4 = \dfrac{V_{\text{bottom}} - 140}{0.028}$ $V_{\text{bottom}} = 532 \text{ V}$	[1] for correct substitution [1] answer
4(b)(i)	$F_{\text{electron}} = qE$ $m_{\text{electron}} a = qE$ $a = \dfrac{qE}{m_{\text{electron}}}$ $= \dfrac{(1.60 \times 10^{-19})(1.4 \times 10^4)}{9.11 \times 10^{-31}}$ $= 2.45884 \times 10^{15}$ $= 2.5 \times 10^{15} \text{ m s}^{-2}$ (2 s.f.)	[1] correct substitution
4(b)(ii)	Consider horizontal motion, $s_x = u_x t + \frac{1}{2} a_x t^2$ $0.120 = 5.0 \times 10^7 t$ $t = 2.4 \times 10^{-9} \text{ s}$	[1] correct substitution [1] answer
4(c)	Consider vertical motion, $s_y = u_y t + \frac{1}{2} a_y t^2$ $= \frac{1}{2}(2.5 \times 10^{15})(2.4 \times 10^{-9})^2$ $= 7.2 \times 10^{-3} \text{ m}$ Since <u>0.72 cm is less than 1.4 cm</u> (distance away from the bottom plate), the electron does not hit the plates, thus emerging from between the plates at the opposite end. Or To hit the plate, the minimum vertical displacement from straight-through direction = 1.4 cm $s_y = u_y t + \frac{1}{2} a_y t^2$ $1.4 \times 10^{-2} = \frac{1}{2}(2.5 \times 10^{15}) t^2$ $t = 3.3 \times 10^{-9} \text{ s}$	[1] correct substitution [1] answer [1] correct conclusion [1] correct substitution [1] answer

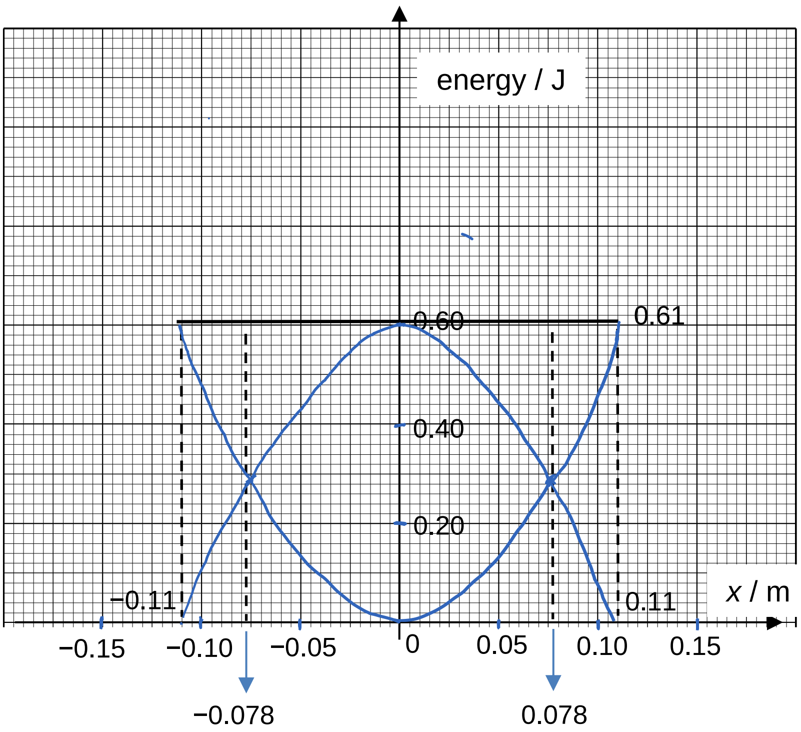
No.	Solution	Remarks
	Since <u>3.3 ns is longer than the 2.4 ns</u>, the electron does not hit the plates, thus emerging from between the plates at the opposite end.	[1] correct conclusion
5(a)(i)	 <u>Circular</u> path downwards	[1] for both sketch and description
5(a)(ii)	 <u>Parabolic</u> path upwards	[1] for sketch [1] for description
5(b)	Magnetic force on the electron provides for its centripetal force $Bqv = \frac{mv^2}{r}$ $B = \frac{mv}{qr}$ $= \frac{(9.11\times10^{-31})(1.8\times10^{8})}{(1.60\times10^{-19})(0.012)}$ $= 8.5\times10^{-2}$ T When electron emerges undeviated, the magnetic and electric forces acting on the electron are equal in magnitude but opposite in direction. magnetic force = electric force $Bqv = qE$ $v = \frac{E}{B}$ $E = vB$ $= (1.8\times10^{8})(8.5\times10^{-2})$ $= 1.5\times10^{7}$ V m^{-1}	[1] correct *B* [1] substitution [1] answer

No.	Solution	Remarks
5(c)	The upwards magnetic force is smaller than the downwards electric force. Hence the path curves downwards. (do not accept circular path)	[1] for explanation [1] for description
6(a)	The root-mean-square value of an alternating current is the value of steady direct current which would produce the same mean power as the alternating current in a given resistance.	[1] answer
6(b)(i)	Period, T = 20 ms Frequency, $f = \frac{1}{T} = \frac{1}{20 \times 10^{-3}} = 50$ Hz	[1] answer
6(b)(ii)	Peak value = 3.0 A	[1] answer
6(b)(iii)	Root-mean-square value $= \frac{\text{peak value}}{\sqrt{2}}$ $= \frac{3.0}{\sqrt{2}}$ $= 2.1$ A	[1] answer
6(c)	 Peak power, $P_0 = I_0^2 R$ $= 3.0^2 \times 5.0$ $= 45$ W	[1] correct graph [1] correct value of peak power

No.	Solution	Remarks
6(d)	$\frac{I_s}{I_p}=\frac{N_p}{N_s}$ $\frac{I_s}{3}=\frac{300}{6000}$ $I_s=0.15$ A	[1] substitution [1] answer
7(a)(i)	A photon is a quantum of electromagnetic radiation with energy given by *hf*, where *h* is the Planck's constant and *f* is the frequency of the wave.	[1] for correct answer
7(a)(ii)	The energy required by the hydrogen atom for it to transit from the ground state to its first excited state is 10.2 eV.	[1] for correct answer
7(b)(i)	$E_3 \rightarrow E_1$: $\Delta E=E_3-E_1$ $=-9.0\times10^{-19}-\left(-24.6\times10^{-19}\right)$ $=15.6\times10^{-19}$ J $\Delta E=hf$ $f=\frac{\Delta E}{h}=\frac{15.6\times10^{-19}}{6.63\times10^{-34}}$ $=2.353\times10^{15}$ $\approx 2.35\times10^{15}$ Hz	[1] for correct expression and numerical substitution [1] for correct answer
7(b)(ii)	$\Delta E_{31}=\Delta E_{32}+\Delta E_{21}$ $\Delta E_{21}=\Delta E_{31}-\Delta E_{32}$ $\frac{hc}{\lambda}=h\left(f_{31}-f_{32}\right)$ $\lambda=\frac{hc}{h\left(f_{31}-f_{32}\right)}$ $=\frac{3.00\times10^{8}}{2.35\times10^{15}-1.09\times10^{15}}$ $=2.381\times10^{-7}$ ≈ 238 nm	[1] for correct method and numerical substitution [1] for correct answer
7(c)	The accelerated electrons strike the anode metal and knock out electrons from the inner shells of the target atoms, causing the electrons in the innermost shell to be vacant. An electron in an outer shell transits from a higher energy level to fill up the vacancy in the inner shell, and an X-ray photon can be produced. Since the energy transitions between discrete energy levels are fixed, the energy gaps produce photons of fixed energies.	[1] [1] [1]

No.	Solution	Remarks
8(a)	Simple harmonic motion is an oscillatory motion in which the acceleration of an object is directly proportional to the displacement of the object from its equilibrium position, and the acceleration is always directed towards that position.	[1] for *a* proportional to *x* [1] for direction of *a*
8(b)(i)	$F_{\text{result}} = -k(e+x) + k(e-x)$ $= -ke - kx + ke - kx$ $= -2kx$ $F_{\text{result}} = ma$ $-2kx = ma$ $a = -\frac{2k}{m}x$ (shown)	[1] for correct equation [1] for correct expression for resultant force [1] for correct equation and substitution
8(b)(ii)	$\omega^2 = \frac{2k}{m}$ $\omega = \sqrt{\frac{2k}{m}}$ $= \sqrt{\frac{2(50)}{0.600}}$ $= 12.91$ $f = \frac{\omega}{2\pi}$ $= 2.05$ Hz	[1] for correct calculation of ω [1] for correct value of *f*
8(b)(iii)	$v_{\text{max}} = \omega x_0$ $1.4 = (12.91)x_0$ $x_0 = 0.11$ m	[1] for correct equation and substitution [1] for correct answer
8(b)(iv) 1.	Total energy, $E_T = \frac{1}{2}m\omega^2 x_0^2$ $= \frac{1}{2}(0.600)\left[\frac{2(50)}{0.600}\right](0.11)^2$ $= 0.61$ J	[1] for correct equation and substitution [1] for correct answer

<table>
<tr><th>No.</th><th>Solution</th><th>Remarks</th></tr>
<tr><td>8(b)(iv) 2.</td><td>When potential energy E_P = kinetic energy E_K,
$\frac{1}{2}m\omega^2\left(x_0^{\ 2}-x^2\right)=\frac{1}{2}m\omega^2x^2$
$x_0^{\ 2}-x^2=x^2$
$x^2=\frac{x_0^{\ 2}}{2}$
$x=\frac{x_0}{\sqrt{2}}$
$=0.078$ m</td><td>[1] for correct equation and substitution

[1] for correct answer</td></tr>
<tr><td>8(b)(v)</td><td></td><td>[1] for TE line with value

[1] for KE line with correct amplitude values

[1] for PE line with correct intersection with KE line</td></tr>
<tr><td>8(b)(vi) 1.</td><td>If the mass of the block is larger, the angular frequency of the oscillation is lower according to the equation $\omega=\sqrt{\frac{2k}{m}}$ hence the frequency of oscillation is lower.</td><td>[1] angular frequency lower
[1] frequency lower</td></tr>
<tr><td>8(b)(vi) 2.</td><td>If the surface is rough, there will be friction between the block and surface which opposes the motion of the block. This is a damping force which will cause the amplitude of the oscillation to decrease over time.</td><td>[1] friction as damping force
[1] amplitude decreases over time</td></tr>
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