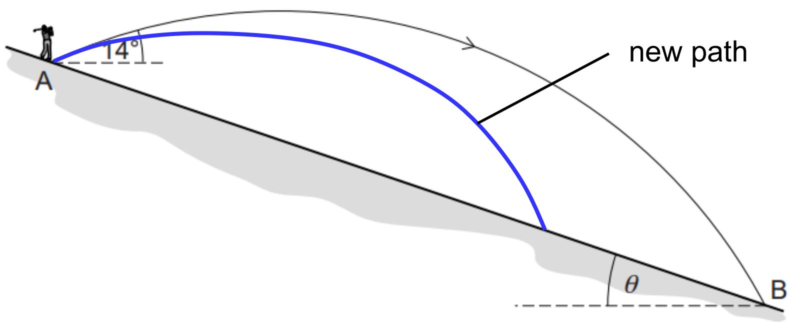
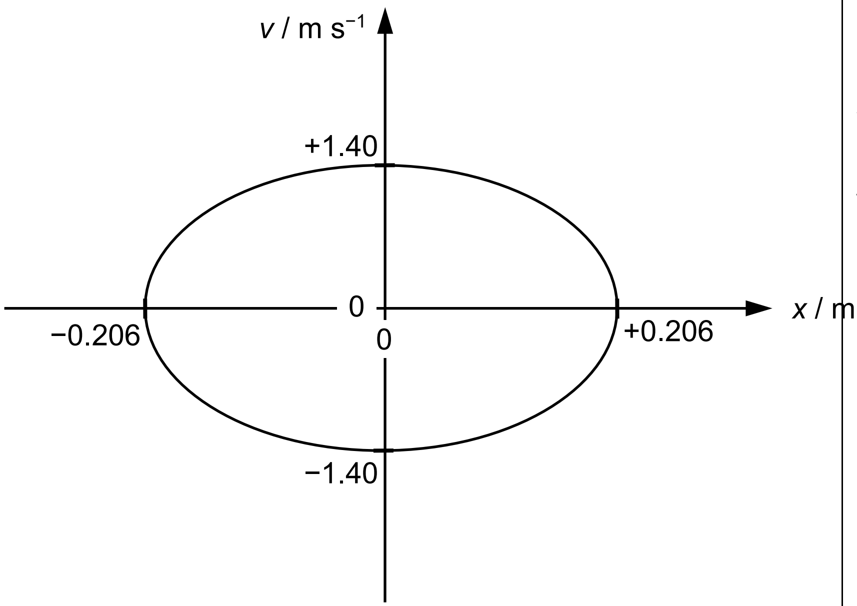
Answers to 2023 JC2 Preliminary Examination Paper 3 (H2 Physics)

Suggested Solutions:

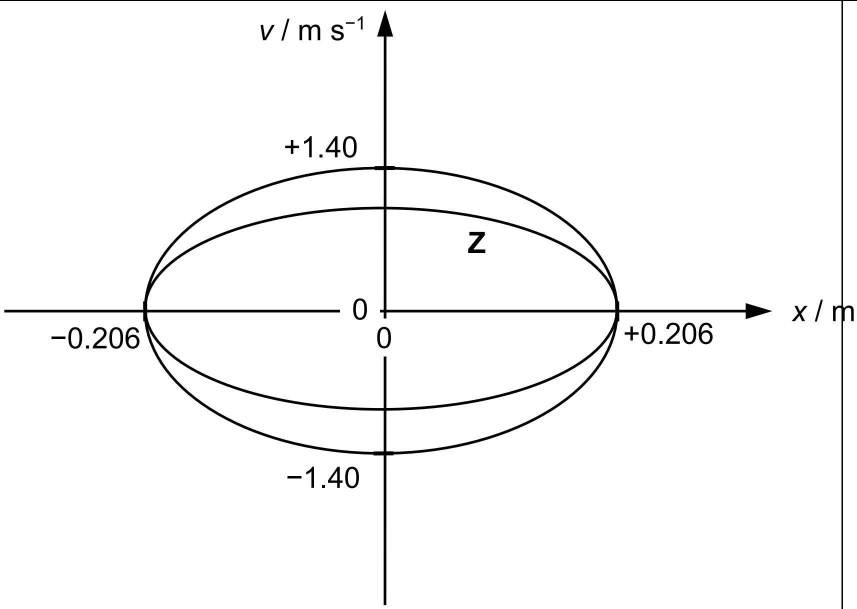
No.	**Solution**	**Remarks**
1(a)(i)	horizontal component $= 67\cos 14^\circ$ $= 65.01$ $\approx 65.0 \text{ m s}^{-1}$ vertical component $= 67\sin 14^\circ$ $= 16.21$ $\approx 16.2 \text{ m s}^{-1}$	[1] for correct answer [1] for correct answer
1(a)(ii)	horizontal displacement $= 65.01 \times 4.9$ $= 318.5$ $\approx 319 \text{ m}$	[1] for correct substitution and answer
1(a)(iii)	Using $s_y = u_y t + \frac{1}{2} a_y t^2$, Taking downward as positive, $s_y = (-16.21)(4.9) + \frac{1}{2}(9.81)(4.9)^2$ $= 38.34$ $\approx 38.3 \text{ m}$	[1] for correct substitution [1] for correct answer
1(a)(iv)	angle of the slope to the horizontal $\theta = \tan^{-1}\left(\frac{38.34}{318.5}\right)$ $= 6.864$ $\approx 6.86^\circ$	[1] for correct substitution [1] for correct answer
1(b)(i)	 [1] for correct new path Note: new path under present path	

No.	Solution	Remarks
1(b)(ii)1.	The path of the ball at the start is determined by the direction of the force of the club acting on the ball **or** air resistance has acted only for a short period of time.	[1] for correct answer
1(b)(ii)2.	The horizontal velocity is much reduced by air resistance.	[1] for correct answer
2(a)(i)	Gravitational force on satellite provides for centripetal force to keep satellite in orbit. $\frac{GM_E M_S}{r^2} = M_S r\omega^2$ $\frac{GM_E}{r^2} = r\left(\frac{2\pi}{T}\right)^2$ $T = \sqrt{\frac{4\pi^2 r^3}{GM_E}} = \sqrt{\frac{4\pi^2(9.0\times10^6)^3}{(6.67\times10^{-11})(5.97\times10^{24})}}$ $= 8500s$	[1] correct substitution [1] correct answer
2(a)(ii)	Work done = increase in total energy of satellite $= E_{T,f} - E_{T,i}$ $= \left(-\frac{GM_E M_s}{2r_f}\right) - \left(-\frac{GM_E M_s}{2r_i}\right)$ $= \frac{(6.67\times10^{-11})(5.97\times10^{24})(500)}{2}\left(-\frac{1}{1.0\times10^7} + \frac{1}{9.0\times10^6}\right)$ $= 1.1\times10^9$ J	[1] correct substitution [1] correct answer
2(b)(i)	The gravitational force acts towards centre of Earth provides the centripetal force and thus, gravitational force must lie on the plane of orbit which passes through centre of Earth. Additionally, in order for the satellite to orbit such that it remains at a fixed relative position above the Earth, its axis of rotation must coincide with Earth's axis of rotation and thus it has to orbit in the equatorial plane.	[1] [1] [1]
2(b)(ii)	Geostationary satellites move in orbits where they are at a fixed relative position above the Earth. This allows the satellites to constantly receive and transmit telecommunication signals to and from the same position on the Earth's surface.	[1]
3(a)(i)	The internal energy of a system is the sum of a random distribution of kinetic and potential energies associated with the molecules of a system.	[1]

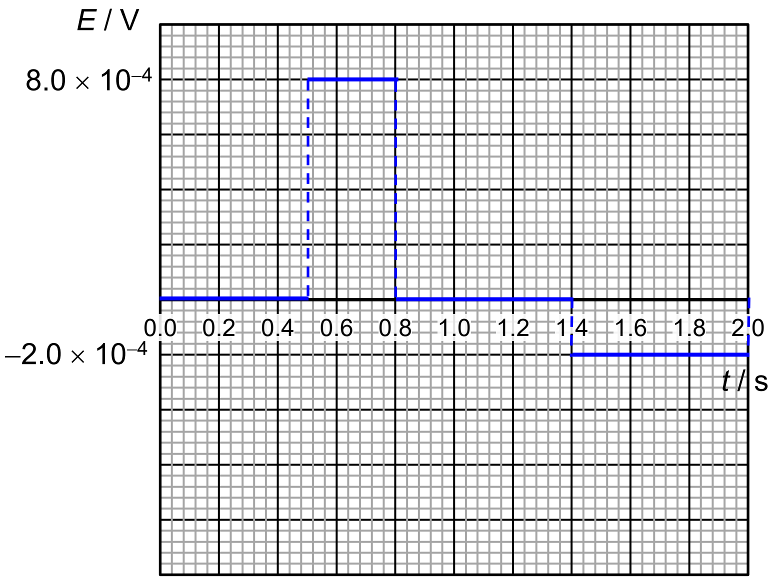
No.	Solution	Remarks
3(a)(ii)	$\Delta U = Q + W$ ΔU – increase in internal energy Q – heat supplied to the system W – work done on the system	[1] equation [1] correct definition of symbols
3(a)(iii)	There is work done by gas against the atmosphere during expansion for gas at constant pressure. Using $\Delta U = Q + W \rightarrow Q = \Delta U + W_{BY}$, amount of heat supplied has to be larger for the same amount of increase in internal energy. Since ΔT depends on ΔU, therefore a larger amount of heat must be supplied to have the same amount of ΔT.	[1] [1] [1]
3(b)	Let θ be the equilibrium temperature. $m_w\, c_w\, (90 - \theta) = m_{ice}\, L_f + m_{water\ at\ 0\ °C}\, c_w\, (\theta - 0)$ $(0.5)(4200)(90 - \theta) = (0.1)(3.34 \times 10^5) + (0.1)(4200)(\theta)$ $\theta = 61.7$ °C	[1] substitution [1] answer
4(a)	Simple harmonic motion is defined as 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]
4(b)(i)	Angular frequency $\omega = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$ $= \sqrt{\frac{18.5}{0.400}} = 6.80$ rad s^{-1} Amplitude $x_0 = \frac{v_{max}}{\omega} = \frac{1.40}{6.80} = 0.206$ m	[1] value for ω [1] answer
4(b)(ii)	Maximum tension of the spring occurs at the lowest position. At the lowest position, acceleration is maximum $= (6.80)^2(0.206)$ $= 9.53$ m s^{-2} At lowest point, $T - mg = ma$ $T = mg + ma$ $= (0.400)(9.81) + (0.400)(9.53)$ $T = 7.74$ N	[1] value for max acceleration [1] sub [1] ans

<table>
<tr><th>No.</th><th>Solution</th><th>Remarks</th></tr>
<tr><td>4(c)(i)</td><td>
</td><td>[1] shape

[1] 4 numerical values

Allow e.c.f.</td></tr>
<tr><td>4(c)(ii)</td><td>
</td><td>[1] for same amplitude and smaller maximum speed</td></tr>
<tr><td>5(a)(i)</td><td>Since copper has one conduction electron per atom, the number density of charge carriers is equal to the number of atoms per unit volume.
$\text{number of mole} = \dfrac{\text{mass}}{\text{molar mass}}$
number of mole per unit volume
$= \dfrac{\text{density}}{\text{molar mass}}$
$= \dfrac{8.9 \times 10^{3}}{63.5 \times 10^{-3}}$
$= 1.40157 \times 10^{5}\ \text{m}^{-3}$</td><td>[1]</td></tr>
</table>

No.	Solution	Remarks
	number of atoms per unit volume $= \text{number of mole per unit volume} \times N_A$ $= 1.40157 \times 10^5 \times 6.02 \times 10^{23}$ $= 8.44 \times 10^{28}$ $\approx 8.4 \times 10^{28}\ \text{m}^{-3}$ Hence number density of charge carriers $= 8.4 \times 10^{28}\ \text{m}^{-3}$	[1] answer before rounding off
5(a)(ii)	Using $I = Anvq$ $17 \times 10^{-3} = \pi \times \left(\frac{1.8 \times 10^{-3}}{2}\right)^2 \times 8.4 \times 10^{28} \times v \times 1.60 \times 10^{-19}$ $v = 4.97 \times 10^{-7}$ $\approx 5.0 \times 10^{-7}\ \text{m s}^{-1}$	[1] for correct substitution [1] for correct answer
5(b)	Current is the same in all segments of the wire, including the thinner segment. For the thinner segment, the cross-sectional area is smaller. The charge carriers hence move with a higher drift velocity (number density of charge carriers does not change).	[1] same current and smaller cross-sectional area [1] higher drift velocity
6(a)	Faraday's law of electromagnetic induction states that the induced e.m.f. in a coil is directly proportional to the rate of change of magnetic flux linkage through the coil.	[1]
6(b)(i)	$B = \mu_0 n I$ $= 4\pi \times 10^{-7} \times \left(\frac{400}{1.6}\right) \times 3.8$ $= 1.19 \times 10^{-3}\ \text{T}$ $\Phi = NBA$ $= 80 \times \left(1.19 \times 10^{-3}\right) \times \pi \times \left(\frac{0.040}{2}\right)^2$ $= 1.2 \times 10^{-4}\ \text{Wb}$	[1] value of B [1] sub [1] ans
6(b)(ii)	$E_{mean} = \frac{\Delta\Phi}{\Delta t}$ $= \frac{2 \times 1.2 \times 10^{-4}}{0.30}$ $= 8.0 \times 10^{-4}\ \text{V}$	[1] sub [1] ans

No.	Solution	Remarks
6(b)(iii)		[1] E = 0 V from t = 0 to 0.5 s & 0.8 s to 1.4 s [1] $E = 8.0 \times 10^{-4}$ V from t = 0.5 s to 0.8 s [1] $E = -2.0 \times 10^{-4}$ V from t =1.4 s to 2.0 s
6(b)(iv)	The magnitude of the <u>maximum e.m.f. induced in the coil increases</u>, The iron core in the solenoid <u>increases the magnetic flux density in the coil</u>, resulting in <u>increase in the magnetic flux linkage in the coil</u>. Hence by Faraday's law, the magnitude of the maximum e.m.f. induced in the coil increases,	[1] state [1] explain
7(a)(i)	r.m.s. current $I_{rms} = \frac{I_o}{\sqrt{2}} = \frac{2}{\sqrt{2}}$ $= 1.4$ A	[1] substitution [1] answer
7(a)(ii)	r.m.s. voltage $V_{rms} = \frac{V_o}{\sqrt{2}}$ $= \frac{240}{\sqrt{2}}$ V Mean power supplied $\langle P \rangle = I_{rms} V_{rms}$ $\langle P \rangle = \left(\frac{2}{\sqrt{2}}\right)\left(\frac{240}{\sqrt{2}}\right)$ $= 240$ W **OR** Peak power $P_o = V_o I_o$ = (240)(2) 480 W $\langle P \rangle = \frac{P_o}{2} = \frac{480}{2} = 240$ W	[1] substitution [1] answer

<table>
<tr><th>No.</th><th>Solution</th><th>Remarks</th></tr>
<tr><td>7(b)(i)</td><td>

$\frac{V_2}{V_1}=\frac{N_2}{N_1}\rightarrow\frac{V_2}{240}=\frac{10}{500}\rightarrow V_2=4.8\text{ V}$

$\frac{V_1}{V_2}=\frac{I_2}{I_1}=\frac{N_1}{N_2}\rightarrow\frac{I_2}{2}=\frac{500}{10}\rightarrow I_2=100\text{ A}$

Assumption:
Transformer is 100% efficient / ideal with zero ohmic, magnetic leakage, copper and core losses. The output power is equal to the input power of the transformer.</td><td>[1] answer

[1] answer

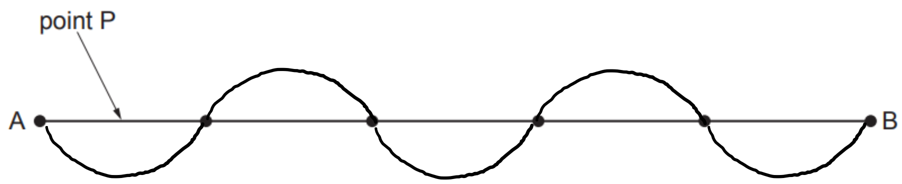
[1] reasonable answer</td></tr>
<tr><td>7(b)(ii)</td><td>Welding
Induction furnace
Smelting scrap metal</td><td>[1] reasonable answer</td></tr>
<tr><td>8(a)(i)</td><td>When the vibrator oscillates the string, the waves travel along string and <u>get reflected at fixed points A and B</u>.

The incident and reflected waves along the string, superpose and interfere to form stationary waves on the string.

OR

The two waves along the string travel with same speed in opposite directions, superpose and interfere to form stationary waves on the string.</td><td>[1] reflection at fixed ends

[1] incident and reflected waves superpose and interfere</td></tr>
<tr><td>8(a)(ii)</td><td colspan="2">



Line has an approximate sinusoidal shape with maximum downward displacement at P and zero displacement at each node.

[1] for correct shape</td></tr>
<tr><td>8(a)(iii)</td><td>

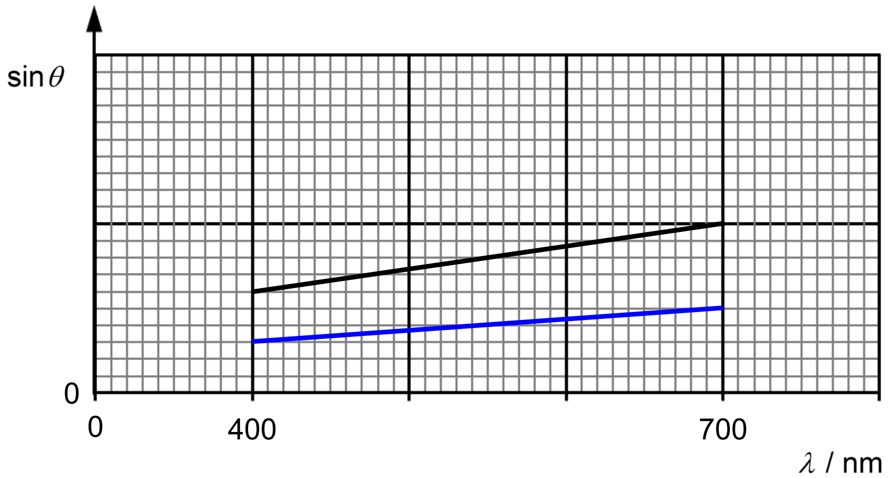
Using $v=f\lambda=\frac{\lambda}{T}$,

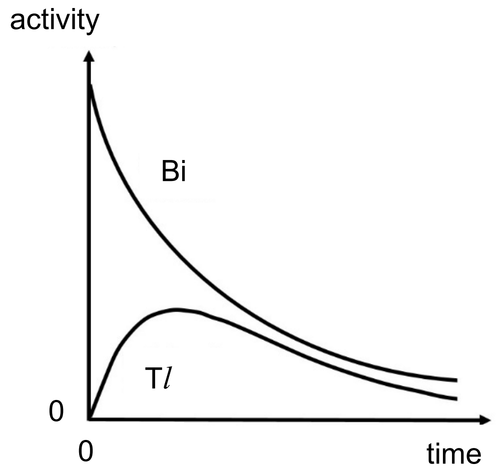
$\lambda=vT$
$=35\times0.040$
$=1.4\text{ m}$

Distance AB
$=2.5\lambda$
$=2.5\times1.4$
$=3.5\text{ m}$</td><td>[1] for correct wavelength

[1] for correct answer</td></tr>
</table>

No.	Solution	Remarks
8(a)(iv)	No. of periods $= \frac{t}{T}$ $= \frac{0.060}{0.040}$ $= 1.5$ Amplitude $= \frac{72}{6}$ $= 12$ mm	[1] for correct substitution [1] for correct answer
8(b)(i)	Constant phase difference between the waves.	[1] for correct answer
8(b)(ii)1.	Path difference $= 1.5\lambda$ $= 1.5 \times 640$ $= 960$ nm	[1] for correct answer
8(b)(ii)2.	Phase difference $= 360^\circ \times 1.5$ $= 540^\circ$	[1] for correct answer. Accept 180°
8(b)(iii)	Distance OR $= 1.5x$ $= 1.5\frac{\lambda D}{a}$ $= 1.5 \times \frac{(640 \times 10^{-9})(1.8)}{0.44 \times 10^{-3}}$ $= 3.928 \times 10^{-3}$ $\approx 3.9 \times 10^{-3}$ m	[1] for correct substitution [1] for correct answer
8(b)(iv)	The bright fringes are brighter due to the increased intensity. No change to the intensity of the dark fringes. The fringe separation remains unchanged.	[1] [1] [1]
8(b)(v)	Since the fringe separation is <u>directly proportional to the wavelength</u> of the incident light and <u>inversely proportional to the slit separation</u>. Blue light has a <u>shorter wavelength</u>. So <u>decrease the slit separation</u> in order to maintain the same fringe separation.	[1] for correct explanation [1] for correct answer

No.	Solution	Remarks
8(c)(i)	Using $d\sin\theta = n\lambda \quad (n=4)$, $d\sin\theta = 4\lambda$ $\sin\theta = \frac{4}{d}\lambda$ So, $G = \frac{4}{d}$ $\therefore \quad d = \frac{4}{G}$	[1] for correct answer
8(c)(ii)	 [1] straight line from 400 nm to 700 nm that is always below printed line and has a smaller gradient than printed line [1] straight line is 3 small squares high at wavelength of 400 nm and 5 small squares high at wavelength of 700 nm	
9(a)	The half-life of a radioactive nuclide is the <u>time taken for the radioactive nuclei to reduce to half its initial value</u>.	[1]
9(b)(i)	For α-decay: $^{214}_{83}\text{Bi} \rightarrow {}^{210}_{81}\text{T}l + {}^{4}_{2}\text{He}$ For β⁻-decay: $^{214}_{83}\text{Bi} \rightarrow {}^{214}_{84}\text{Po} + {}^{0}_{-1}\text{e}$	[1] [1]
9(b)(ii)	mass difference $= 213.9987u - (209.9901u + 4.0015u)$ $= 0.0071u$ energy released $= \Delta mc^2$ $= 0.0071(1.66\times10^{-27})(3.00\times10^{8})^2$ $= 1.06074\times10^{-12}$ $\approx 1.06\times10^{-12}$ J	[1] [1] for correct substitution [1] for correct answer

No.	Solution	Remarks
9(b)(iii)	The mass difference of reactant and products in both decay processes are different. So the total amount of energy released for each process will also be different. Hence the γ-ray photons emitted will have different energies.	[1] [1]
9(c)(i) and 9(c)(ii)		[1] for correct Bi graph [1] for correct Tl graph
9(d)(i)	214 g of Bi contains 1 mol of atoms, which is 6.02×10^{23} atoms. number of atoms in sample $= \frac{2.0 \times 10^{-6}}{214}\left(6.02 \times 10^{23}\right)$ $= 5.626 \times 10^{15}$ $\approx 5.6 \times 10^{15}$ (shown)	[1] correct substitution
9(d)(ii)	activity $A = \lambda N$ $\lambda = \frac{A}{N}$ $= \frac{3.3 \times 10^{12}}{5.626 \times 10^{15}}$ $= 5.866 \times 10^{-4}$ $\approx 5.9 \times 10^{-4}$ s^{-1}	[1] correct substitution [1] correct answer
9(d)(iii)	$t_{1/2} = \frac{\ln 2}{\lambda}$ $= \frac{\ln 2}{5.866 \times 10^{-4}}$ $= 1182$ $\approx 1.2 \times 10^{3}$ s	[1] for correct answer

No.	Solution	Remarks
9(d)(iv)	$A = A_o e^{-\lambda t}$ $3.3\times10^{6} = 3.3\times10^{12} e^{-5.866\times10^{-4}t}$ $\dfrac{3.3\times10^{6}}{3.3\times10^{12}} = e^{-5.866\times10^{-4}t}$ $t = 2.355\times10^{4}$ $\approx 2.4\times10^{4}$ s	[1] correct substitution [1] correct answer
9(e)	β - particles are fast moving electrons and the β - particles are emitted collide with the atoms of the lead container. These collisions result in the β - particles undergoing deceleration, either being slowed down by collision or by deflection. The electrons will then release energy in the form of the continuous spectrum of the X-ray produced, also called Bremsstrahlung radiation.	[1] [1] [1] [1]