2025 SH2 H2 Physics Preliminary Examination

Paper 3 9749/03

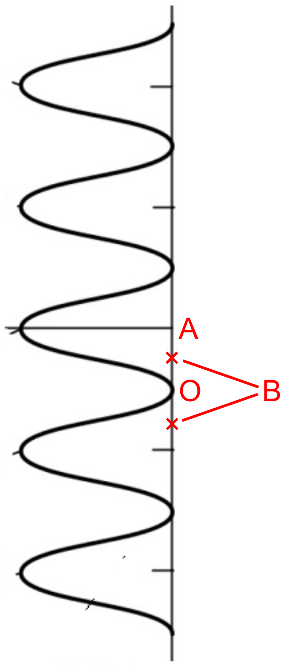
Section A

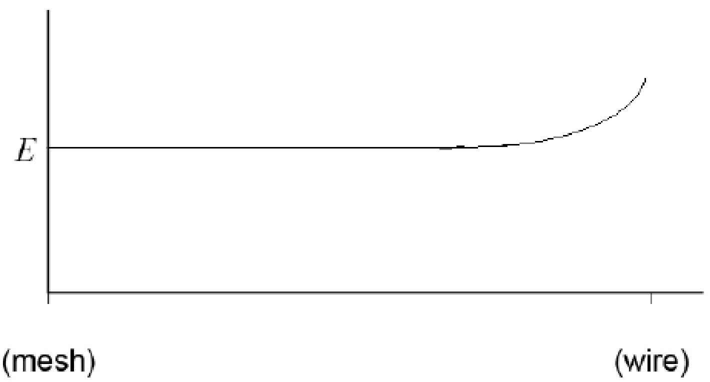
1(a)	<u>work done per unit mass</u> in bringing a (small test) mass from <u>infinity to that point</u>	B1
1(b)(i)	correct read off of ϕ and x, e.g. $-\frac{GM}{R} = -6.3 \times 10^7$ correct equation and substitution of G, M and R, e.g. $M = \frac{6.3 \times 10^7 \times 6.4 \times 10^6}{6.67 \times 10^{-11}}$ = 6.0 × 10^{24} kg (shown)	B1 B1
1(b)(ii)1.	attempt to apply Conservation of Energy in any understandable form, e.g. Gain in KE = Loss in GP $\frac{1}{2}\cancel{m}v^2 = \cancel{m}(\phi_i - \phi_f)$ $v = \sqrt{2(0-(-2.1)) \times 10^7}$ value of $\phi_f = -2.1 \times 10^7$ J kg^{-1} (read off when x = 3R) = <u>6500 m s^{-1}</u> Comment: the most common mistake was substituting x = 2R. Some candidates thought the mass was in a circular orbit which is the wrong context.	C1 C1 A1
1(b)(ii)2.	$a = \frac{F}{m} = \frac{\frac{GM\cancel{m}}{x^2}}{\cancel{m}} = \frac{GM}{(3R)^2} = \frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24}}{(3 \times 6.4 \times 10^6)^2}$ allow also a = g (ecf awarded if sub x = 2R) = <u>1.1 m s^{-2}</u> Comment: similar mistake to the previous part. It is inappropriate to find the gradient on the graph as this is an approximate method. The question asks you to calculate not estimate the acceleration. The more precise method should be chosen. Also, using equations of motion is wrong as the acceleration is not constant here.	 C1 A1
1(b)(iii)	lower (or more negative) gravitational potential energy due to presence of the Moon hence higher speed	M1 A1

2(a)(i)	change in momentum of molecule per collision = $-mu - mu = -2mu$ OR $= mu - (-mu) = \underline{2mu}$	**A1**
2(a)(ii)	average force $\left(= \dfrac{\text{impulse per collision}}{\text{time between collisions}}\right) = \dfrac{2mu}{2x/u}$ $= \dfrac{mu^2}{x}$ (shown)	**M1**
2(b)(i)	$W = p\Delta V$ $= (7.0\times10^5)\ [\ (20 - 5) \times10^{-6}\ ]$ $= \underline{10.5\text{ J}}$ Comment: some responses perhaps thought the work done is the area within the cycle. Negative sign should not be applied as this is work done by.	**C1** **A1**
2(b)(ii)	(table below) third row (C → A) second row (B → C) first row (A → B) – value in red (allow ecf) first row (A → B) – values in blue (allow ecf) Comment: the sign for work done for A → B is sometimes given wrongly	 **B1** **B1** **B1** **B1**
2(b)(iii)	useful work done = 10.5 − 3.7 = 6.8 J $\text{efficiency} = \dfrac{\text{useful work done}}{\text{total energy input}} \times 100\% = \dfrac{6.8}{36.8} \times 100\%$ $= \underline{18\%}$ Comment: few got this correct, in particular, the energy input must be the heat supplied to the system. No process can be 100% efficient or more.	**C1** **A1**

Table for 2(b)(ii):

heating supplied to gas / J	work done on gas / J	increase in internal energy of gas / J
36.8	− 10.5	26.3
− 30.0	zero	− 30.0
zero	3.7	3.7

3(a)	When two or more waves <u>meet at a point</u>, the <u>resultant displacement at that point is equal to the vector sum of the displacements</u> due to the individual waves at that point. Examiner's comment: The student did not score for this question.	**B1** **B1**
3(b)(i)	wavelength = $\frac{3.0 \times 10^{8}}{2.5 \times 10^{10}}$ = 0.012 m	**B1**
3(b)(ii)1.	waves are in anti-phase at the sources and have no path difference to reach O waves meet in anti-phase at O and destructive interference occurs Examiner's comment: Many student failed to state "No path difference when the two waves reach O."	**M1** **A1**
3(b)(ii)2.	path difference = $\frac{1}{2}\lambda$ = <u>0.0060 m</u>	**A1**
3(b)(iii)	$x\left(=\frac{\lambda D}{a}\right)=\frac{(0.012)(2.3)}{0.18}$ = <u>0.15 m</u>	**M1** **A1**
3(b)(iv)	point B is above or below point O such that distance OB ≈ ½ distance OA  	**B1**

4(a)	electric force exerted per unit positive charge placed at that point **B1** Examiner's comment: The student did not score for this question.
4(b)(i)	For the electric potential at point P to be zero, the contribution by one sphere must be positive and the other negative, hence opposite signs of charges on spheres **M1** electric fields (due to X and Y are not zero and) must be in the same direction **A1** hence not zero Examiner's comment: The student did not score for this question.
4(b)(ii)1.	$V_X = \frac{-Q}{4\pi\varepsilon_0 x}$ $V_Y = \frac{+2Q}{4\pi\varepsilon_0 y}$ $V_X + V_Y = 0$ $\frac{Q}{4\pi\varepsilon_0 x} = \frac{2Q}{4\pi\varepsilon_0 y}$ **B1** $y = 2x$ (shown)
4(b)(ii)2.	$E = \frac{Q}{4\pi\varepsilon_0 x^2} + \frac{2Q}{4\pi\varepsilon_0 (2x)^2}$ **C1** $= \frac{3Q}{8\pi\varepsilon_0 x^2}$ **A1** Examiner's comment: The student did not score for this question. Many students did not realise that the resultant field is in the same direction.
4(c)(i)	horizontal line above zero up to at least 2/3 of the x-axis **B1** curves upwards thereafter **B1**  Examiner's comment: The student did not score for this question. Many students did not realise that the electric field is constant, i.e a horizontal line between 0 < potential < 1600 V.
4(c)(ii)	Both the electron and argon ion travels through the same potential difference and hence loses the same amount of EPE and gains the same amount of KE **M1** gain in KE of the electron = gain in KE of the argon ion

	$\frac{1}{2}m_e v_e{}^2 = \frac{1}{2}m_A v_A{}^2$ $\frac{v_e}{v_A} = \sqrt{\frac{6.64\times10^{-26}}{9.11\times10^{-31}}}$ = 270 **A1** **OR** gain in KE of the electron = e ΔV **M1** ½ (9.11×10^{-31}) $v^2{}_e$ = 1.6×10^{-19} (4000 – 2000) -------- (1) gain in KE of the Argon ion = e ΔV ½ (6.64×10^{-26}) $v^2{}_{Ar}$ = 1.6×10^{-19} (2000 – 0) ------------ (2) (1)/(2), $\frac{v_e}{v_A} = \sqrt{\frac{6.64\times10^{-26}}{9.11\times10^{-31}}}$ = 270 **A1** Examiner's comment: Most student obtained zero for this question. Many students gave unclear working/no substitution of values in the working/no explanation of why kinetic energy of electron is equal to kinetic of Argon ion. **Zero marks were awarded** to student as long as student did not give explanation/substitute values inside equation even if their numerical answer is correct.
4(c)(iii)	argon encounters more collisions than electron/ electron encounters fewer collisions than Argon OR electron is less ionising (than Argon) / argon is more ionising (than electron) and electron loses less energy (than Argon) / argon loses more energy (than electron), hence ratio is larger **B1** Examiner's comment: Most students were able to explain to answer this question. Students must appreciate besides the speed of object, other factors, i.e mass of object, distance travelled by object affects the amount of air resistance.

5(a)(i)	Induced emf E = BLv or E is proportional to v where v is the instantaneous velocity of the rod. **M1** Graph showed a straight line (passing through the origin) indicating that e.m.f. varies linearly with (directly proportional to) time. Hence the rod's velocity must be increasing linearly with (directly proportional to) time. Therefore acceleration of the rod is uniform. **A1** Comments: 1. Question did not asked students to explain why an emf is induced, hence students should not be wasting time writing about changes in flux linkage / flux cutting, quoting Faraday's law and explaining why an emf is induced. 2. Those who could recall the expression E = Blv were able to successfully answer the question. 3. Those who tried to explain in terms of rate of flux cutting or rate of change of flux linkage merely paraphrased the question ie "emf varies linearly with time, hence rate of change of flux linkage is constant / increase linearly with time and therefore acceleration is constant".
5(a)(ii)	kinetic energy is converted to electrical energy (to drive the current around the circuit) / thermal energy in the resistor **M1** resulting in the decrease in the kinetic energy of the rod / rod slowing down. **A1** hence external work needed to maintain constant kinetic energy / speed Comments: 1. Very few students accounted for the conversion of kinetic energy to electrical energy / thermal energy in the resistor. 2. Majority of students explained in terms of the retarding force exerted by the magnetic field on the induced current / rod causing the rod to slow down. 3. A significant number of students thought that the rod is accelerating and hence external work is needed to prevent the rod from accelerating.
5(b)(i)	period = $2\pi / 40\pi$ = 0.050 s = <u>50 ms</u> **A1** Comment: Most students were able to perform this calculation.
5(b)(ii)	mean power = $I_{rms}^2 R$ $= \left(\frac{3.5}{\sqrt{2}}\right)^2 (400)$ **C1** = <u>2450 W</u> **A1** Comment: Most students could perform this calculation. A small but significant number of students do not know how to find the power.
5(b)(iii)	*Sine squared graph with* peaks at $\frac{1}{4}T, \frac{3}{4}T, \frac{5}{4}T, \frac{7}{4}T$ 3 marks

	Modulus of sine graph *with* peaks at $\frac{1}{4}T, \frac{3}{4}T, \frac{5}{4}T, \frac{7}{4}T$	2 marks
	Modulus of sine graph with two peaks	1 mark
	Graphs showing negative power (example sine graph)	0 mark

6(a)(i)	$E = -\frac{13.6}{2^2}$ = <u>−3.4 eV</u>	**A1**
6(a)(ii)	The negative (total) energy is a convention used to show that the particle is <u>confined</u> / <u>bounded</u> / <u>trapped</u> <u>within the atom</u>. Comments: Only a few students could score the mark. The answers that were not accepted include: 1. Electrons are negatively charged. Total energy can still be positive evenly for a negatively charged particle. 2. Electron is attracted to the nucleus. Same reason as 1. (ie total energy can still be positive). 3. Any other variety of answers that do not include the words underlined above.	**B1**
6(b)(i)	$\frac{hc}{\lambda_1} = -\frac{13.6}{3^2} - (-3.4)$ $\lambda_1 = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{\left[-\frac{13.6}{3^2} - (-3.4)\right] \times 1.60 \times 10^{-19}}$ = <u>6.58×10^{-7} m</u> <u>**Red**</u> Comment: Most students could perform this calculation correctly. Common mistakes include failure to convert eV to joules or did not find ΔE. Not many students could associate 658 nm with the red end of the visible spectrum.	**A1** **B1**
6(b)(ii)	$\frac{hc}{\lambda_2} = -3.4 - \left(-\frac{13.6}{1^2}\right)$	**C1**

	$$\lambda_2 = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{\left[-3.4 - \left(-\frac{13.6}{1^2}\right)\right] \times 1.60 \times 10^{-19}}$$ $= \underline{1.21 \times 10^{-7}\ \text{m}}$ **A1** Comment: Those who failed to perform the calculation in part (b)(i) correctly could not do this part as well. A significant number of students calculated 103 nm.
6(b)(iii)	All atoms that de-excite from *n* = 3 to *n* =2 will further de-excite from *n* = 2 to *n* = 1 to reach the ground state **B1** Comment: Only a small number of student stated the correct reason.
6(b)(iv)	Vertical lines at 103 nm, 121 nm and 658 nm (values of λ labelled) **B1** Height of vertical line at 121 nm = the one at 658 nm **B1** Relative separation between the 3 vertical lines **B1** Comment: Many drew x-ray spectrum (including the continuous braking radiation).

Section B

7(a)(i)	force by liquid due to pressure at bottom surface of tube = pressure of liquid at depth $h \times A$ = $\rho g h A$ **B1** Since tube is in equilibrium / no resultant force on tube, $\rho g h A = Mg$ **B1** Hence $M = \rho h A$ Examiner's comments: Several students ignored the requirement of the question to use the pressure due to a fluid and used principle of flotation instead, scoring only 1 mark for applying equilibrium concepts.
7(a)(ii)	magnitude of $F_{\text{net}} = \rho(h + x)Ag - Mg = \rho(h + x)Ag - \rho hAg = \rho Agx$ For downward displacement, upthrust > weight, hence upward resultant force. For upward displacement, weight > upthrust, hence downward resultant force Hence F_{net} is opposite to x, and $F_{\text{net}} = -\rho Agx$ (OR Taking downwards as positive, $F_{\text{net}} = W - U = Mg - \rho Vg = \rho hAg - \rho(h + x)Ag = -\rho Agx$) correct magnitude of F_{net} (with correct working) **B1** correct direction of F_{net} (either through explanation or careful handling of sign convention) **B1** (By Newton's 2nd Law,) $a = \frac{F_{\text{net}}}{M}$ **B1** $a = -\left(\frac{\rho Ag}{M}\right)x$ **A0** Examiner's comments: Several students have trouble applying the concept of a resultant force to the question. For such students, drawing a free body diagram is an important intermediate thinking tool to help. Another odd observation is the weak explanation of how the negative sign came about. Many students simply state that acceleration (or resultant force) opposite to displacement, leading to circular reason in the next part when students infer from the negative sign that accleeration and displacement are opposite.
7(a)(iii)	Since ρ, A, g and M are constant, the magnitude of acceleration a is proportional to the magnitude of displacement x **B1** The negative sign indicates that the direction of acceleration a is opposite to the direction of displacement x. Hence tube is performing simple harmonic motion. **B1** Examiner's comments: Students need to explain according to the context and use the key features of the equation they have derived.
7(a)(iv)1.	Comparing $a = -\left(\frac{\rho Ag}{M}\right)x$ with $a = -\omega^2 x$ $\omega^2 = \frac{\rho Ag}{M}$ **C1** $(2\pi f)^2 = \frac{1.2\times10^3\times5.3\times10^{-4}\times9.81}{0.130}$ **C1** $f = 1.1\text{ Hz}$ **A1** Examiner's comments: Oddly, a handful of students attempted the use of Equations of Motion which is wrong given acceleration is not constant.

7(a)(iv)2.	energy of oscillation $= E_{k\,max} = \frac{1}{2}m(\omega x_0)^2 = \frac{1}{2}(0.130)\left(\frac{1.2\times10^3\times5.3\times10^{-4}\times9.81}{0.130}\right)\times(0.0130)^2$ = 0.000527 J	**C1** **A1**
7(b)(i)	constant power spread over a larger wavefront **B1** hence lower intensity and lower amplitude **B1** Examiner's comments: Several students mention energy loss. But wave motion is essentially a phenomenon of energy loss from an oscillating water molecule to its surrounding water molecules (albeit usually with an energy input to maintain constant amplitude, in this case, a dipper is used). Students are to note that it is usually a misconception to talk about energy loss in the context of wave motion and refer to the increasing area of the wavefront with distance.	
7(b)(ii)	$\Delta\theta = \frac{\Delta x}{\lambda}\times 2\pi = \frac{2.0}{1.0}\times 2\pi = 4\pi$ rad **M1** Since the phase difference is an integral multiple of 2π rad, the dipper and the water 2.0 cm away are in phase **A1** OR $\Delta x = 2\lambda$ **M1** Since the path difference is an integral multiple of wavelength, the dipper and the water 2.0 cm away are in phase. **A1**	
7(b)(iii)	periodic curve with wavelength 1.0 cm **B1** graph passes through (2,−4), (2.5,3.2), (3,−2.6), (3.5,2.2) and (4,−2) **B1** Note: At 2.0 cm, in-phase with dipper means also negative maximum displacement (negative amplitude).	
7(b)(iv)	constant amplitude and periodic with period of 0.50 s **B1** graph starts at (0,−2.6) **B1** Note: At 2.0 cm, in-phase with dipper means also negative maximum displacement at *t* = 0 s. Examiner's comments: Some students draw the graph of a lightly damped oscillation. For an oscillation in a continuous wave motion, the amplitude is constant as rate of energy propagated away is equal to rate of energy received.	

8(a)(i)	β decay: ${}^{209}_{83}\mathrm{Bi} \rightarrow {}^{209}_{84}\mathrm{Po} + {}^{0}_{-1}\mathrm{e}$ Calculate total mass of polonium and β-particle = 208.982979u **M1** total mass of products > mass of bismuth, no β radiation α decay: ${}^{209}_{83}\mathrm{Bi} \rightarrow {}^{205}_{81}\mathrm{Tl} + {}^{4}_{2}\mathrm{He}$ Calculate total mass of thallium and α-particle = 208.977031u **M1** total mass of products < mass of bismuth, α radiation emitted use of mass comparison between products and reactant **M1** to determine that only α decay is possible **A1** Examiner's comments: Oddly, several students did not make mass comparisons when the data is all about masses.	

8(a)(ii)	mass of constituent nucleons = 83 × 1.007276 + (209 − 83) × 1.008664 **C1** mass defect = 1.715173u **C1** binding energy per nucleon = $1.715173 \times 1.66 \times 10^{-27} \times (3.00 \times 10^{8})^{2} / 209$ **M1** with correct conversion to eV to give 7.66 MeV **A1** Examiner's comments: Electrons are not nucleons and are not in nucleus!
8(b)(i)	curve fluctuates/curve is jagged **B1**
8(b)(ii)	10 min^{-1} (accept 9-11 min^{-1}) **B1**
8(b)(iii)	half-life determined at least twice **B1** half-life determined by accounting for background **M1** half-life = 1.5 hours (accept 1.4–1.6 hours) **A1** *At t = 0.1 h, count rate = 160 − 10 = 150 min^{-1}.* *expected half-life count rate = 75 min^{-1} corresponds to 85 min^{-1} on graph at 1.7 h* *half-life = 1.7 − 0.1 = 1.6 h* *At t = 1.3 h, count rate = 100 − 10 = 90 min^{-1}.* *expected half-life count rate = 45 min^{-1} corresponds to 55 min^{-1} on graph at 2.8 h* *half-life = 2.8 − 1.3 = 1.5 h* *Average half-life = 1.55 h* Examiner's comments: Not well done given that it is a simple question. Many students forget about the background count and the need to determine half-life at least twice especially given the random fluctuations of the graph.
8(c)(i)	half-life = $\ln 2 / 1.44 \times 10^{-11} = 4.8 \times 10^{10}$ yr **A1**
8(c)(ii)	$A_{Rb} / A_{Rb,0} = \exp(-1.44 \times 10^{-11} \times 4.0 \times 10^{9}) = 0.944$ **M1** valid quantitative comment that little change has occurred **A1** Examiner's comments: The second mark proves very elusive as students left their comment using the exact same words as what they are asked to show, i.e. 'almost constant'.
8(c)(iii)	positive intercept on the *R* axis **B1** straight / curve sloping gently upwards (curve of lower gradient towards end) **B1**
8(c)(iv)	a larger ratio implies an older sample (or references to the graph in **(iii)**) **B1** any one of the following: **B1** - need to know the initial value of *R* (or initial amount of Sr isotopes) - need to know the initial amount / percentage of rubidium Examiner's comments: There are several scripts that gave very convoluted equations which are redundant if the graph is known.