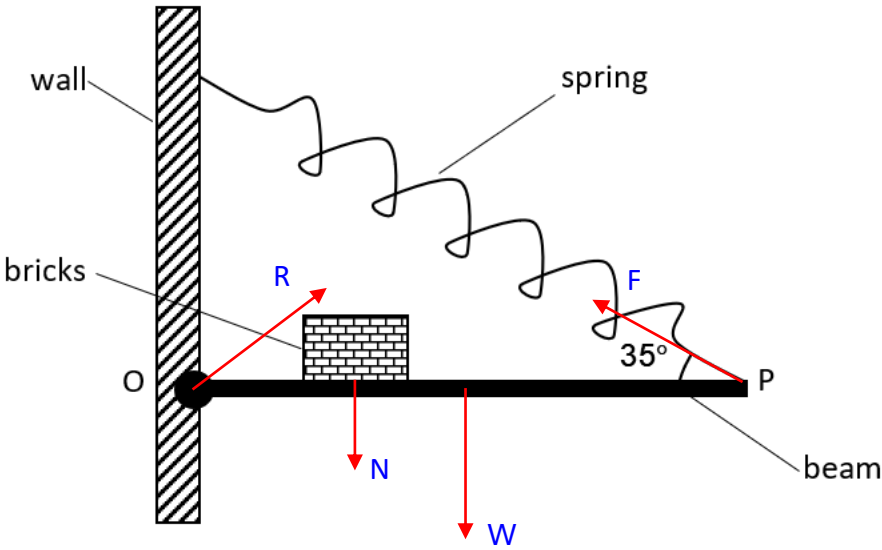
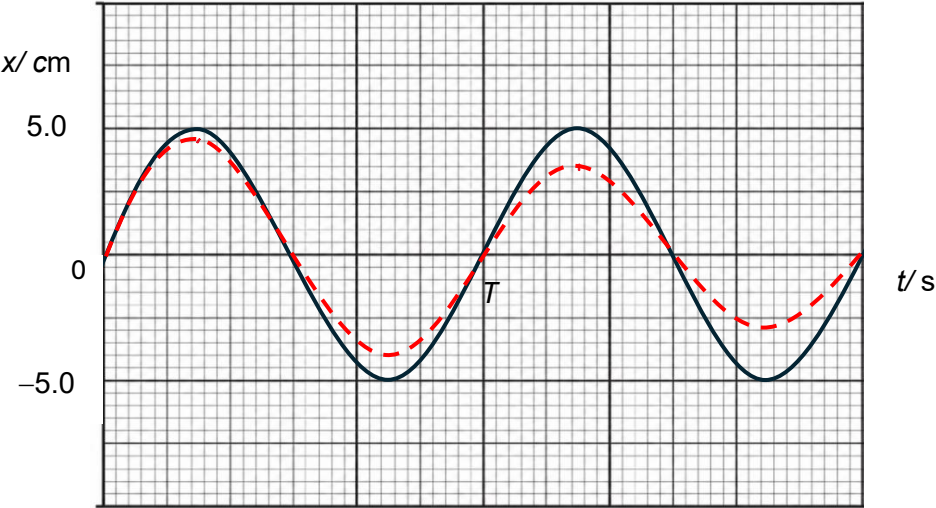


Qns	Answer	Marks
1(a)	Moment of a force is the product of the force and its perpendicular distance to the pivot. <u>Examiner's Comments</u> Generally well done by candidates.	B1
1(b)(i)	$\cos 35^\circ = \frac{6.8}{y}$ $y = \frac{6.8}{\cos 35^\circ} = 8.3 \text{ m}$ extension $x = 8.3 - 7.0$ $= 1.3 \text{ m}$ <u>Examiner's Comments</u> Generally well done by candidates.	M1 A0
1(b)(ii)	 W: weight of beam (or gravitational force by earth on beam) N: normal contact/reaction force by bricks on beam F: force by spring on beam (or spring force / tension / elastic force) (EITHER) R: contact/reaction force by wall/hinge on beam (OR) R_{vertical}: vertical component of contact/reaction force by wall/hinge on beam $R_{\text{horizontal}}$: horizontal component of contact/reaction force by wall/hinge on beam	B1

Qns	Answer	Marks
	Examiner's Comments This question was poorly attempted by candidates. Some candidates used the masses of bricks and beam for calculation instead of their respective weights. Some candidates did not include the perpendicular distance from the line of action of the force to the pivot O. Some candidates used $(F \cos 35^\circ)(6.8)$ for the anticlockwise moment contributed by the spring force which is incorrect.	
1(b)(iv)	$E_p = \frac{1}{2} kx^2$ $= \frac{1}{2} (1700)(1.3)^2$ $= 1437$ $= 1400 \text{ J (2 s.f.)}$ Note: Can also use $E_p = \frac{1}{2} Fx$ or $E_p = \frac{1}{2} \left(\frac{F^2}{k} \right)$ Accept both 2 s.f. and 3 s.f. Allow ECF. Note: accept 1400 J, 1410 J, 1430 J and 1440 J Examiner's Comments Generally well done by candidates.	C1 A1
1(b)(v)	As the pile of bricks is moved towards the pivot O, <u>the clockwise moment about the pivot</u> (due to the bricks) <u>decreases</u> (as the perpendicular distance from pivot to line of action of the force decreases). (The total clockwise moment decreases). <u>A lower anti-clockwise moment is needed to maintain equilibrium. Therefore, the force exerted by the string (on the beam) decreases.</u> Examiner's Comments Generally well done by candidates. A few candidates mentioned that clockwise moment increases which is incorrect. A few candidates mentioned that the anticlockwise moment is contributed by the bricks and clockwise moment is contributed by the tension in the string which is incorrect.	B1 B1

Qns	Answer	Marks
2(a)	g and r are constants so a is proportional to x the negative sign shows that a and x are in opposite directions/ a is always directed towards the equilibrium <u>Marker's Comments</u> This question was generally well done. Some students simply quoted defining features of SHM without relating the specific evidence from the equation to the relevant part of SHM. Others quoted both pieces of evidence without specific which evidence maps to which part of SHM.	B1 B1
2(b)	since $a = -\frac{gx}{r}$ and $a = -\omega^2 x$ so $\omega^2 = \frac{g}{r}$ $\omega^2 = \frac{9.81}{0.28}$ $\omega = 5.9 \text{ rad s}^{-1} (5.92)$ <u>Marker's Comments</u> This question was generally well done. Some students thought that angular frequency was f	M1 A1
2(c)(i)	Negative sine graph $\max a = \omega^2 x_0 = 5.92 (0.05) = 1.7 \text{ m s}^{-2}$ <u>Marker's Comments</u> This question was generally well done.	B1 B1

Qns	Answer	Marks
(c)(ii)	since this is a light damping oscillation, period remain the same as before and remains constant over time Amplitude consistently decreases and first peak must be less than 5.0cm Marker's Comments Some students wrongly assumed that the first amplitude would remain at 5.0 cm. Others thought that the decrease in amplitude would only happen after each period, e.g. drawing the same decreased amplitude for the first and second humps, then the same further decreased amplitude for the third and fourth humps. Some students considered the period to be slightly larger than the undamped oscillation. While this is correct, most of these candidates failed to ensure that this increased period still needs to remain constant over time. Since this can be difficult to draw, students are therefore advised to consider the same period as that of undamped oscillation. 	B1 B1
(c)(iii)	Loss in energy $= \frac{1}{2} m \omega^2 x_{oi}^2 - \frac{1}{2} m \omega^2 x_{of}^2$ $= \frac{1}{2} \times 0.090 \times 5.9^2 \times 0.050^2 - \frac{1}{2} \times 0.090 \times 5.9^2 \times 0.025^2$ $= 0.294 = 0.29 \text{ J}$ Marker's Comments The classic mathematical mistake committed for this question includes that of thinking that $(x_2^2 - x_1^2)$ is the same as $(x_2 - x_1)^2$. Other issues included the omission of square for angular frequency ω and failure to convert units to that of SI units.	M1 A1

Qns	Answer	Marks
	Since the value of angular frequency ω is taken from part 2(b), full ecf credit was awarded. However, some students had left part 2(b) blank and so were unable to gain any credit for this part. In such cases, students should provide a reasonable value for the earlier part (e.g. not "0" or "1") to continue with this part.	

Qns	Answer	Marks
3(a)(i)	$Q_{\text{water at } 5.0^{\circ}\text{C to water at } 0^{\circ}\text{C}} = m_{\text{water}} c_{\text{water}} \Delta T$ $= 220 \times 4.18 \times (5.0 - 0)$ $= 4598 \text{ J}$ $= 4600 \text{ J (2 s.f.)}$ <u>Examiner's Comments</u> Generally well done by candidates. Some candidates did not take note of the units such as kg and $\text{J g}^{-1} ^{\circ}\text{C}^{-1}$ which results in incorrect calculation.	B1
3(a)(ii)	$Q_{\text{water at } 0^{\circ}\text{C to ice at } 0^{\circ}\text{C}} = m_{\text{water}} L_f$ $= 220 \times 334$ $= 73480 \text{ J}$ $= 73500 \text{ J (3 s.f.)}$ Note: accept 73000 J and 73500 J. <u>Examiner's Comments</u> Generally well done by candidates. Some candidates did not take note of the units such as kg and J g^{-1} which results in incorrect calculation. Some candidates calculate the heat released for the water from 5°C water to 0°C ice which is incorrect.	B1
3(b)	$Q_{\text{ice at } -8.0^{\circ}\text{C to ice at } 0^{\circ}\text{C}} = m_{\text{ice}} c_{\text{ice}} \Delta T$ $= 500 \times 2.09 \times [0 - (-8.0)]$ $= 8360 \text{ J (3 s.f.)}$ Note: accept 8360 J and 8400 J. <u>Examiner's Comments</u> Generally well done by candidates.	B1

Qns	Answer	Marks
	Some candidates did not take note of the units such as kg and $\text{J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$ which results in incorrect calculation.	
3(c)	0 °C Since <u>the heat needed to raise the temperature of the original ice to 0 °C (= 8360 J) is greater than the heat released by water as its temperature decreases to 0 °C (= 4598 J), but is less than the total heat released by water as it freezes to 0 °C ice (= 4598 + 73480 = 78078 J), the original water will not fully freeze into 0 °C ice.</u> The final state will be <u>water-ice mixture at 0 °C.</u> Note: When the temperature of the water decreases to 0 °C (releasing 4598 J of heat), the temperature of the original ice is still below 0 °C (to raise it to 0 °C, 8360 J of heat is needed). Hence, the original water will continue to partially freeze, until the original ice is at 0 °C. The final product is a water-ice mixture at 0 °C. Examiner's Comments This question was poorly attempted by candidates. Many candidates give vague responses that did not answer the question or provide incomplete explanation. Many candidates mentioned that the ice in the bucket melts which is incorrect. Many candidates also mentioned that the original water will freeze to 0 °C ice and did not realise that the water will not fully freeze into 0 °C ice. The final state will be water-ice mixture at 0 °C.	A1 M1

Qns	Answer	Marks
4(a)(i)	Power received = $\frac{\text{Area of source}}{4\pi r^2} \times \text{Power of source}$ $= \frac{450 \times 10^{-4}}{4\pi (3500)^2} \times 15.0$ [M1] $= 4.4 \times 10^{-9} \text{ W}$ [A1] Marker's Comments Common mistake included the wrong denominator considered, eg. Many omitted the factor "4" while others considered "4/3 πr^3".	
4(a)(ii)	Energy from the source radiates uniformly in all directions Marker's Comments This question was not well done	B1

Qns	Answer	Marks
4(a)(iii)	Intensity $\propto$ Amplitude² $\text{Intensity} = \frac{\text{Power}}{4\pi r^2} \propto \frac{1}{r^2}$ Hence $A \propto \frac{1}{r}$ $\frac{A_{3.5}}{A_{2.5}} = \frac{r_{2.5}}{r_{3.5}}$ $\frac{A_{3.5}}{A_o} = \frac{2.5}{3.5} \quad [\text{M1}]$ $A_{3.5} = 0.71 A_o \quad [\text{A1}]$ Marker's Comments Common mistakes included arriving at the relationship of $A \propto 1/r^2$ or $A^2 \propto 1/r$. Students should also be reminded not to leave their answers in fractions, but to compute them accordingly.	
4(b)(i)	Oscillations/ vibrations occur in a <u>single direction</u> (in a plane) that is <u>perpendicular to the direction of transfer of energy/propagation</u>. Marker's Comments This question was poorly done. The most common near-miss (hence not accepted) attempt is as follows: Oscillations occur in a single plane that is perpendicular to the direction of transfer of energy. The above statement looks very similar to the suggested answer. But the key concept is that there must only be one DIRECTION of oscillation. Saying that the oscillation has to be in one PLANE is wrong since there exists an infinite number of possible directions of oscillations in that plane. Further, even without polarisation, all the oscillations of a given unpolarised transverse wave are inherently perpendicular to the direction of energy propagation.	B1
4(b)(ii)	Apply Malus' Law, $I_1 = I_o (\cos 40^\circ)^2$ $I_2 = I_o (\cos 40^\circ)^2 (\cos 80^\circ)^2$ $= 0.018 I_o \text{ (2 s.f.)}$ Marker's Comments The most common mistake was that of $I_o \cos^2 40^\circ \cos^2 40^\circ$	M1 A1

Qns	Answer	Marks
	Students should note that when applying Malu's law, the value of θ is taken from the previous axis of polarisation, not the vertical axis. Other mistakes included the omission of square. A small handful calculated this question in Radian mode.	

Qns	Answer	Marks
5(a)	When an object freefalls, the ONLY force acting on the object is its weight ($= mg$). Hence, the <u>freefall acceleration</u> $a = \frac{F}{m} = \frac{mg}{m} = g$ is equal to the gravitational field strength g. OR By definition of gravitational field strength, $g = F_{\text{gravitational}}/m$ and from Newton's 2nd Law, <u>for a freely falling body, the ONLY force acting is gravitational force</u> hence $F_{\text{net}} = mg = ma$. Therefore, $a = g$. <u>Examiner's Comments</u> A significant number of students appeared to answer a different, but related question: why g is approximately constant near the Earth's surface. Students should take care to identify precisely what the question is asking rather than relying on a memorised response to a familiar looking question. A key point required in this answer is that when an object is <u>in free fall</u>, the ONLY force acting on it is its weight. Some responses suggested that air resistance continues to act during free fall. By definition, free fall refers to motion under the influence of gravity alone. So air resistance is neglected. Another misconception seen in a small number of responses was that the resultant force is zero or that ma "balances" mg. Remember that ma is not an additional force. It represents net force or resultant force. And resultant force is due to weight only. Some students wrote equations only as their entire answer. While the equations are correct, this is not a complete explanation. For explanation questions, Cambridge expects the relevant physical reasoning to be stated in words.	M1 A1

Qns	Answer	Marks
5(b)	$g = \frac{GM}{r^2}$ $M = \frac{gr^2}{G} = \frac{9.81 \times (6.37 \times 10^6)^2}{6.67 \times 10^{-11}} = 5.9679 \times 10^{24} = 5.97 \times 10^{24}$ <u>Examiner's Comments</u> Mostly well done. Being a show question, formula and substitution, as well as a few more s.f. MUST be shown before rounding to the final value to get the full marks.	B1
5(c)	$\phi = -\frac{GM}{r} = -\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{6.37 \times 10^6} = -6.25 \times 10^7 \text{ J kg}^{-1}$ <u>Examiner's Comments</u> Mostly well done. A small number of students omitted the negative sign in their final answer. The following question actually provided a useful check, as it indicated that the gravitational potential should be negative. Students are encouraged to use information from later parts of a question to check the consistency of their earlier answers. A noticeable number of students also gave their final answer to 2 sf, even though the values provided in the question were given to 3 sf. The usual minimum significant figures rule applies: the final answer should normally be quoted to the same number of significant figures as the least precise data used in the calculation. In this case, 3 sf was appropriate.	B1
5(d)	The <u>gravitational potential is taken to be zero at infinity</u>. Since the gravitational force is attractive, <u>the work done by the external force</u> to bring the test mass from infinity to a point <u>is negative</u>. Hence, the gravitational potential is negative. <u>Examiner's Comments</u> A number of students gave an incomplete definition of gravitational potential, referring to simply energy or work done. Remember that gravitational potential is defined as work done by external force PER UNIT MASS in bringing a small test mass from infinity to the point. Omitting the phrase "per unit mass" makes the definition of potential incomplete. While definition is not required, if students refer to potential as work done rather than work done by external force per unit mass, they are making a conceptual error and will not obtain full marks.	B1 B1 A0

Qns	Answer	Marks
	It is also important to identify <u>which</u> force is doing the work. Poor responses referred only to “work done” without specifying whether this was work done by the gravitational force or by the external force. In this context, the relevant quantity is the work done by the external force. Since gravitational force is attractive, the external force required to move the test mass slowly from infinity towards the attracting mass acts opposite to the displacement. The work done by this external force is therefore negative, giving a negative gravitational potential. A further misconception involved statements such as “the work done is opposite in direction to the displacement”. Work done is a scalar quantity and has no direction. It is the force that may act in the same or opposite direction to the displacement. In this case, the external force acts opposite to the displacement, and hence the work done by the external force is negative. Students should therefore be precise with the language used: • force has a direction; • displacement has a direction; • work done is a scalar and may be positive or negative, but it does not have a direction.	

Qns	Answer	Marks
6(a)	The principle of superposition states that when <u>two or more waves meet</u> at a point, the <u>resultant displacement</u> is the <u>sum of the individual displacements of each wave</u> at that point. Note: Do NOT accept if students mention the “amplitude add up”. The correct term is displacement. Examiner’s Comments This is a definition question, so precise terminology matters. The resultant displacement is the sum of the individual displacements of the waves at that point. Responses stating that the “amplitudes add up” should not be accepted, as amplitude and displacement are not the same quantity. Some students referred specifically to two waves meeting at a point. While this captures the basic idea, the principle of superposition applies to two	B1

Qns	Answer	Marks
	<u>or more waves</u>. This was not penalised here, but students should use the more general wording expected in the definition. A very small number of students wrote “one or more waves”. This is not acceptable because a single wave cannot be said to “meet” another wave at a point. The definition requires the idea of two or more waves overlapping at the same point. For definition questions, students should take particular care to use the exact physical quantities and conditions required, as imprecise wording can result in the mark being lost.	
6(b)	Incident and reflected waves are of the <u>same type, frequency and wavelength</u>, and have the same speed, approximately the <u>same amplitude</u> and travel in opposite direction along the same tube. Incident wave from the loudspeaker reflects at the end / right side of the glass tube such that they <u>superpose</u> to form a stationary wave. Note: Do not accept if students write meet / overlap without superpose. The word interfere is not accepted as well. Examiner’s Comments There were several recurring issues in this part. For the first marking point, the incident and reflected waves should be described using the relevant properties of the sound waves: they are of the same type, frequency and wavelength, travel at the same speed in opposite directions along the tube, and have approximately the same amplitude. Since the context is a sound wave, references to the waves being polarised or unpolarised are not appropriate and indicate a misunderstanding of the nature of sound waves. Some students described the waves as coherent. Although the incident and reflected waves are indeed coherent, this is not the specific condition being tested here. The expected description is that the waves have the same frequency, type and wavelength. In addition, because the question refers to an observable stationary wave, the waves should also have approximately the same amplitude.	B1 B1 B1

Qns	Answer	Marks
	Students should also state clearly that the incident wave is reflected at the open end of the tube. A significant number of weaker responses suggested that reflection occurred at the microphone or from the walls of the tube. These responses show a misunderstanding of how the reflected wave is produced in this arrangement. Finally, the incident and reflected waves must superpose to form a stationary wave. Words such as “meet”, “overlap” or “interfere” on their own are not sufficiently precise for this marking point. The required idea is that the two waves superpose. A number of students also misinterpreted the question as asking how the stationary wave could be observed or detected, and described methods such as adding dust and looking for regions where the dust accumulates. While this is related to stationary waves, it does not answer the question being asked here, which is about how the stationary wave is formed. Students should therefore pay close attention to the command and context of the question, and become familiar with common question types. Before answering, identify whether the question is asking about formation, observation, explanation or measurement, as these require different responses.	
6(c)(i)	Amplitude of stationary wave: $0.06 + 0.06 = 0.12$ mm Examiner's Comments Mostly well done.	B1

Qns	Answer	Marks
6(c)(ii)	General shape (include spacing) of a stationary wave (including dotted cosine curve – no solid line) with displacement antinodes at the ends of the glass tube. Stationary waves fulfilling the 3rd harmonic, $n = 3$, since there are three pressure antinodes (three displacement nodes) #Although labelling N and AN is not a marking point, it is good practice to write it down. Note: Students should know that a pressure antinode corresponds to a displacement node. Hence, there should be 3 displacement nodes which correspond to the 3rd harmonic for a pipe with two open ends. <u>Incorrect answer:</u> Drawing the graph corresponding to the 4th harmonic. Examiner's Comments This question required a representation of the stationary wave, <u>not a drawing of the instantaneous positions of individual particles about their equilibrium positions.</u> The expected representation consists of two curves: one solid and one dotted, showing the two extreme displacement profiles of the stationary wave. A number of students drew two solid curves, or only one solid curve, or particle-position diagrams. These do not constitute the expected stationary-wave representation. Students should be familiar with this convention: when representing a stationary wave in this syllabus, both the solid and dotted displacement profiles should be shown. Labelling the nodes (N) and antinodes (AN) is good practice but is not required for the mark. Conversely, simply marking	B1 B1

Qns	Answer	Marks
	the positions of N and AN without drawing the appropriate wave profiles is not sufficient. Care is also needed at the ends of the tube. The wave profile should extend all the way to the ends rather than stopping slightly short. For an open end, there is a displacement antinode. Some students incorrectly assumed that the end near the loudspeaker must be a displacement node; the boundary condition depends on the end of the air column, not simply on the presence of the loudspeaker. The shape at an antinode should also be drawn carefully. At an antinode, the displacement is at a maximum, so the curve should turn smoothly at the end. Some drawings were ambiguous because the curve became almost straight or curved in the wrong direction near the end. Finally, students should use the information about pressure antinodes and displacement nodes carefully when identifying the harmonic. In this case, three pressure antinodes correspond to three displacement nodes, giving the third harmonic for a pipe open at both ends.	
6(c)(iii)	$L = 1.5\lambda \Rightarrow \lambda = \frac{L}{1.5}$ $v = f\lambda \Rightarrow f = \frac{v}{\lambda} = \frac{v}{\left(\frac{L}{1.5}\right)} = \frac{320}{\left(\frac{15.0}{1.5}\right)} = 32 \text{ Hz}$ Examiner's Comments <u>Accept ECF from sketched graph in 6(c)(ii).</u> As long as the waveform drawn in (c)(ii) can be interpreted clearly, students could receive full credit for correct calculation of the frequency based on the harmonic they had drawn. This means that an incorrect harmonic in the previous part did not automatically prevent students from scoring here however the working in this part MUST be consistent with their own sketch. Students should also note that simply obtaining the numerical answer 32 Hz is not sufficient. If the waveform drawn in (c)(ii) is not the 3rd harmonic then their answer is inconsistent with their representation and no marks can be awarded. The key point is therefore to follow through consistently from your own diagram. A clearly interpretable but incorrect sketch can still earn ECF marks in the subsequent calculation; an answer that does not follow from the sketch cannot.	M0 A1

Qns	Answer	Marks
7(a)(i)	${}_{83}^{210}\text{Bi} \rightarrow {}_{-1}^0\text{e} + {}_{84}^{210}\text{Po} + (\text{anti}) \text{ neutrino}$ Accept beta particle Examiners Comments: This part is mostly well done. It is preferred that students write (anti) neutrino out in words rather than symbols especially since most students wrote neutrino as 'v' instead of u.  Beta particle can also be written as ${}_{-1}^0\beta$. Do note that it is Greek letter beta not capital "B".	B2
(a)(ii)	total momentum/ total mass-energy/ total nucleon no/ total charge. Any two. Examiners Comments: Students were required to state any two quantities that are conserved in a nuclear reaction. A common issue was stating that total mass or total energy is conserved. In nuclear reactions, mass may be converted to energy and vice versa, so these should not be treated as separately conserved quantities. The appropriate statement is that total mass-energy is conserved. Care is also needed when referring to proton number. Total proton number (charge) is conserved, but the number of protons themselves need not remain unchanged, since nuclear reactions can involve the conversion of protons and neutrons. Students should therefore use the precise conserved quantities: total momentum, total mass-energy, total nucleon number, and total charge/proton number.	A2
(b)(i)	Mass of protons + neutrons = $[(83 \times 1.00729) + (127 \times 1.00867)] \text{ u}$ = 211.706 u Mass defect = 211.706 u - 209.939 u Mass defect = 1.767 u Examiner's Comments A number of weaker responses handled "u" inconsistently during the calculation.	M1 M1 A0

Qns	Answer	Marks
	Students should remember that “u” represents the unified atomic mass unit, defined in terms of the unified mass constant. It should therefore remain attached to the mass values throughout the calculation. Some students used only the numerical values during the working and added “u” only at the end. They lose 1 mark for presentation.	
(b)(ii)	Binding energy = $1.767 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$ $= 2.64 \times 10^{-10} \text{ J}$ Binding energy per nucleon = $[2.64 \times 10^{-10} / 1.60 \times 10^{-19} \times 10^6] / 210$ $= 7.86 \text{ MeV}$ Examiners' comments: This part is generally well done. The most common reason for losing marks was not answering the question fully. A number of students correctly calculated the total binding energy but stopped there even though the question asked for binding energy per nucleon. A smaller number of students had difficulty converting the binding energy from J to MeV. The question asked that the answer is left to 3sf yet some students did not read the question and used the wrong s.f.	M1 A1

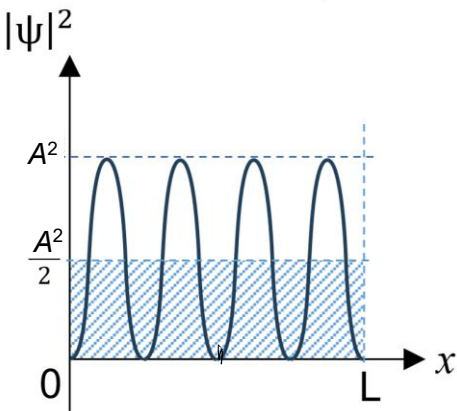
Qns	Answer	Marks
8(a)1	Since the circular path is in the clockwise direction it suggests that the magnetic <u>force must point rightwards</u> (from left to right) Using <u>Fleming's Left Hand Rule</u>, (when the magnetic field is out of the paper, and the magnetic force is towards the right), this is only possible if the particle is positively charged. Examiner's Comments Many students described the directions of force and velocity at a particular point on the trajectory, without specifying where they were considering. Many students quoted “Using Fleming's Left Hand Rule” at inappropriate/wrong parts in their answers.	B1 B1
8(a)2	For the positively charged particle to accelerate upwards it must experience an electric force that acts in the upward direction.	B1

Qns	Answer	Marks
	This occurs only if the electric field points upwards which corresponds to a higher electric potential at the bottom plate. Examiner's Comments By right, one must use 'accelerate' upwards. Words like 'move' or 'approach' were accepted as BoD.	B1
8(b)(i)	The electric field between parallel plates is uniform. $E = \frac{\Delta V}{\Delta d} = \frac{V_0}{d} = \frac{V}{0.5d}$ Hence, $V = \frac{V_0}{2}$ Examiner's Comments As a show question, students are expected to explain their reasoning clearly. The key argument for this question is "electric field is uniform", which must be mentioned to score the one mark. A more serious mistake by some students is the application of $E = q/4\pi\epsilon_0 r^2$, which applies only to point charges. Here, we have parallel plates with uniform E field.	M1 A0
8(b)(ii)	Gain in kinetic energy = Loss in electric potential energy $\frac{1}{2}mv^2 - 0 = q\Delta V = \frac{qV_0}{2}$ $\therefore v^2 = \frac{qV_0}{m}$ $v = \sqrt{\frac{qV_0}{m}}$	M1 A0
8(c)	The magnetic force <u>always</u> acts perpendicular to the direction of velocity (infinitesimal tangential displacement along the charged particle's path). No work is done, its kinetic energy remains constant and thus, the speed does not increase. Examiner's Comments Many students missed the key words 'always' or 'at any point in time/point on the trajectory'.	B1 B1

Qns	Answer	Marks
8(d)	The magnetic force (F_B) provides for the centripetal force (F_c) $F_B = F_c$ $Bqv = mr\omega^2 \Rightarrow Bq(r\omega) = mr\omega^2$ $\therefore \omega = \frac{Bq}{m}$ $\omega = \frac{2\pi}{T}$ $\frac{2\pi}{T} = \frac{Bq}{m}$ $\therefore T = \frac{2\pi m}{Bq}$ Since the particle travels half a circle, the time travelled in the upper dee is: $t = \frac{T}{2}$ $= \frac{\pi m}{Bq}$ <u>Alternative solution:</u> The magnetic force (F_B) provides for the centripetal force (F_c) $F_B = F_c$ $Bqv = \frac{mv^2}{r} \Rightarrow v = \frac{Bpr}{m}$ Since $v = \frac{\pi r}{t}$, where πr is the distance travelled and t is the time taken for the semicircular path $\frac{\pi r}{t} = \frac{Bqr}{m}$ $\therefore t = \frac{\pi m}{Bq}$ <u>Examiner's Comments</u> 'Magnetic force provides the centripetal force' must be stated in words, not in symbols.	B1 C1 M1 M1 A0 B1 C1 M1 M1 A0
8(e)	The time taken is <u>independent</u> of the velocity of the particle (only depends on m, B and q), Hence, it will always be the <u>same</u> as that found in (d).	M1 A1
8(f)	$t = 1.6 \text{ ns}$ $B = \frac{\pi m}{tq} = \frac{\pi}{(1.6 \times 10^{-9})(1.0 \times 10^8)} = 19.63495 = 20 \text{ T (2.s.f)}$	C1 A1

Qns	Answer	Marks
8(g)	At the upper dee, the charged particle has a kinetic energy of $\frac{qV_0}{2}$ Gain in kinetic energy = Loss in electric potential energy = qV_0 Thus, total kinetic energy = $\frac{qV_0}{2} + qV_0 = 1.5qV_0$ <u>Examiner's Comments</u> Too many students were careless when reading the question, not noticing the word 'lower dee' or did not consider the physical situation carefully.	C1 A1
8(h)	When the particle first travels into the upper dee, it has a kinetic energy of $0.5 qV_0$. The total kinetic energy of the particle can then be written as $E_k = (0.5 + n) qV_0$, where n is the number of times the particle is in either of the dees after exiting the upper dee for the first time. Since the kinetic energy is $6.5 qV_0$, $n = 6$. By doing a manual count, the particle will exit from the upper dee and then it passes the lower dee is a total of 3 times. <u>#Food for thought:</u> To generalize this: If $n = \text{odd}$, then we can tell that the particle exits from the lower dee and the number of times it will pass the lower dee is $\frac{(n+1)}{2}$ If $n = \text{even}$, then we can tell that the particle exits from the upper dee and the number of times it will pass the lower dee is $\frac{n}{2}$ <u>Examiner's Comments</u> Similar to the previous part, this question is rather simple if one is clear about the trajectory of the particle and the energy conversion along the way. Too many students attempted this problem without truly understanding these aspects (which aren't complicated at all, in fact).	C1 A1

Qns	Answer	Marks
9(a)(i)	The square of the wavefunction amplitude $ \psi(x) ^2$ is the <u>probability density function</u> of the particle at position x .	B1
9(a)(ii)	The probability of the particle residing between x_1 and x_2 is given by <u>the area under the $\psi(x) ^2$-x graph between x_1 and x_2.</u>	B1

Qns	Answer	Marks
	<u>Examiner's Comments</u> Many students talked about some graph without specifying what graph it is.	
9(b)(i)	$n = 4$. <u>Examiner's Comments</u> Many students did not know how to do this problem. To solve this problem, 1. Notice that the wave function plotted has two periods, so the argument ($n\pi x/L$) of the sine function is between 0 and 4π. 2. The maximum value of the argument is at $x = L$, so $n\pi L/L = n\pi = 4\pi$. Hence, $n = 4$.	B1
9(b)(ii)	 area under $= \frac{A^2}{2} L = 1$ $A = \sqrt{\frac{2}{L}}$ <u>Examiner's Comments</u> The construct (the diagram above) showing that the area under is equal to the rectangular area must be shown to score the first mark. Many students did it carelessly and lost the mark. Some students used integration, but did not show the detailed steps of performing the integration. They also lost one mark.	B1 M1 A1

Qns	Answer	Marks
9(b)(iii)	By symmetry of the graph, the <u>area under the $\psi(x) ^2$-x graph between $x = \frac{L}{8}$ and $x = \frac{L}{2}$ is $\frac{3}{8}$ of the total area</u>, which is equal to 1. Hence, the <u>probability is $\frac{3}{8} = 0.375$</u>. Examiner's Comments IMPORTANT NOTE: Many students referred to the construct in (b)(ii), and calculated the rectangular area between L/8 and L/2. It was accepted this time round, as it coincidentally gave the correct value. But in general, this method doesn't work. For example, the probability of the particle residing in a small region around $x=L/2$ is very small, according to the area under the original sine-squared curve. But using the construct, which replaces the area under by a rectangular area, the probability of the particle residing anywhere is the same. In other words, the construct changes the local probability distribution. It can only be used as a short cut to calculate the normalization factor A. The correct method is to look at the area under the original sine-squared curve, and use symmetry. See solution above.	B1 B1
9(b)(iv)	$E = \frac{h^2}{8mL^2} n^2 = \frac{(6.63 \times 10^{-34})^2}{8 \times 9.11 \times 10^{-31} \times (3.5 \times 10^{-10})^2} \times 4^2 = 7.87778 \times 10^{-18} \text{ J}$ $= \frac{7.87778 \times 10^{-18}}{1.60 \times 10^{-19}} = 49.2 \text{ eV}$ Examiner's Comments There were too many careless mistakes.	C1 A1
9(c)(i)1	<u>absorption spectrum</u> <u>dark lines on colourful/continuous background</u>	B1 B1
9(c)(i)2	When <u>white light containing all frequencies</u> passes through the cold gas, some <u>photons whose energies are exactly equal to the differences between the atomic energy levels will be absorbed</u>. Since the <u>energy levels are discrete</u>, only photons of certain frequencies are absorbed. Photons of these frequencies will be <u>re-radiated but in all directions</u> when the atoms deexcite. Consequently, the parts of the spectrum <u>corresponding to these frequencies appear darker</u> in comparison to the other frequencies.	B1 B1 B1 B1

