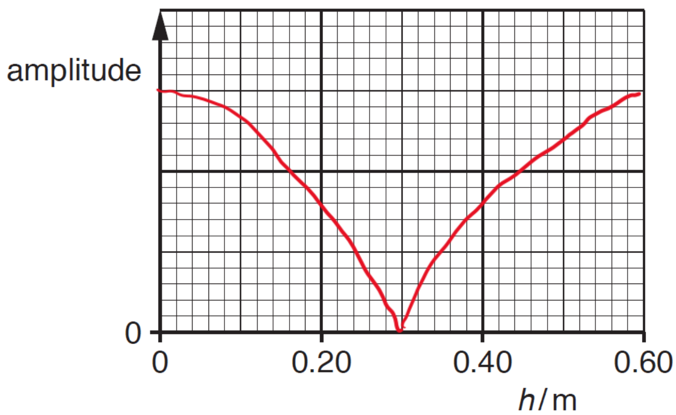
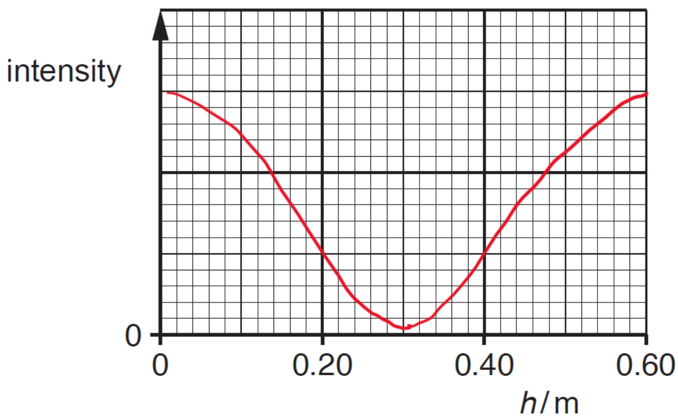
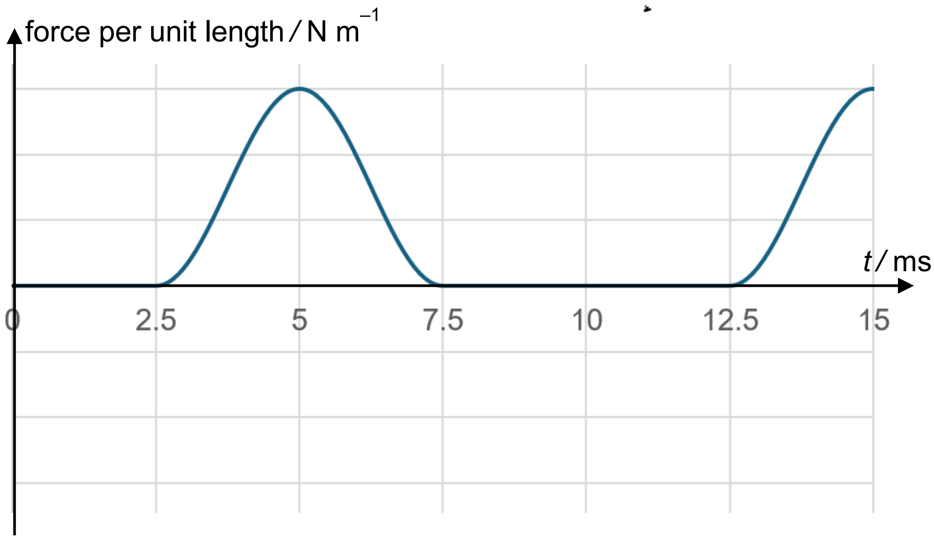
Qns	Answer	Marks
1(a)	(incident) wave reflects at end/top of tube (incident) wave and reflected wave superpose waves have same frequency, wavelength and speed	**B1** **B1** **B1**
1(b)(i)	line has maximum value of amplitude at h = 0 and h = 0.60 m only AND line has minimum/zero value of amplitude at h = 0.30 m only modulus cosine graph (Sharp at h = 0.30 m)  	**M1** **A1**
1(b)(ii)	line has maximum value of amplitude at h = 0 and h = 0.60 m only AND line has minimum/zero value of amplitude at h = 0.30 m only AND modulus cosine-squared graph  	**B1**
1(c)(i)	vertical/along length of tube/along axis of tube	**B1**
1(c)(ii)	phase difference = 0	**A1**
1(c)(iii)	phase difference = 180°	**A1**
1(d)	$v = f\lambda$ $f = 340 / (2 \times 0.60)$	**C1**

Qns	Answer	Marks
	= 280 Hz	**A1**
1(e)(i)	*f* = 340 / 0.60 = 570 Hz (or 2 x 280 = 560 Hz)	 **A1**
1(e)(ii)	0.60 / 4 = 0.15 m	**A1**

Qns	Answer	Marks
2(a)(i)	$R = \frac{\rho L}{A} = \frac{\rho L}{\pi r^2}$ $= \frac{(1.1\times 10^{-6})(120\times 10^{-2})}{\pi(\frac{1.1}{2}\times 10^{-3})^2}$ $= 1.38898... = 1.4\ \Omega$ (2 s.f.)	M1
2(a)(ii)	Let potential at Y be 5.0 V R_{PQ}//1.8 Ω = $\frac{1.4\times 1.8}{1.4+1.8}$ = 0.7875 Ω PD across $R_{PQ} = \frac{0.7875}{0.7875+2.5}\times 5.0$ = 1.198 V	C1
	PD across XY = $5.0 - \frac{1.198}{2}$ = 4.4 V	C1 A1
2(b)(i)	**<u>Current in wire A is in magnetic field produced by current in wire B</u>**. Wire A experiences a magnetic force towards wire B according to **<u>Fleming's Left Hand Rule</u>**.	B1
	From **<u>Newton's third law</u>**, an equal and opposite force acts on wire B. (or apply FLH rule again on wire B)	B1
2(b)(ii)1.	$I_A = -3.0\cos(200\pi t) = -3.0\cos(200\pi(6.5\times 10^{-3}))$ = 1.76 A From graph, I_B = 1.2 A	C1 For both I_A and I_B
	$B_B = \frac{\mu_0 I}{2\pi d}$ $= \frac{(4\pi\times 10^{-7})(1.2)}{2\pi(0.05)} = 4.8\times 10^{-6}$ F per unit length on wire A = $B_B I_A L / L = B_B I_A$ $= (4.8\times 10^{-6})(1.76)$	C1
	$= 8.4\times 10^{-6}$ N m^{-1}	A1

2(b)(ii)2.	 • positions and shape of graph during intervals of non-zero force • positions of intervals of zero force	**B1** **B1**
2(b)(ii)3.	$\langle P \rangle = I_{rms}{}^2 R = \left(\frac{3.0}{2}\right)^2 (15)$ $= 34\ \text{W}$	**A1**

<table>
<tr><th>Qns</th><th>Answer</th><th>Marks</th></tr>
<tr><td>3 (a)(i)</td><td>(W =) 2.60 $\times 10^5 \times$ (3.80 – 2.30) $\times$ 10^{-3} = 390 J</td><td>A1</td></tr>
<tr><td>3(a)(ii)</td><td>no (total) change (in internal energy)

gas returns to its original temperature/ state/ no change to pressure and volume</td><td>B1

B1</td></tr>
<tr><td>3(b)</td><td>A to B row all correct (1370, – 390, 980)

B to C row all correct (0, 550, 550)

C to A row: ΔU adds to the other two ΔU values to give zero

C to A row: w = 0 and q adds to w to give ΔU value
complete correct answer:

<table>
<tr><th>change</th><th>q / J</th><th>w / J</th><th>ΔU / J</th></tr>
<tr><td>A to B</td><td>(+)1370</td><td>–390</td><td>(+)980</td></tr>
<tr><td>B to C</td><td>0</td><td>(+)550</td><td>(+)550</td></tr>
<tr><td>C to A</td><td>–1530</td><td>0</td><td>–1530</td></tr>
</table>
</td><td>B1

B1

B1

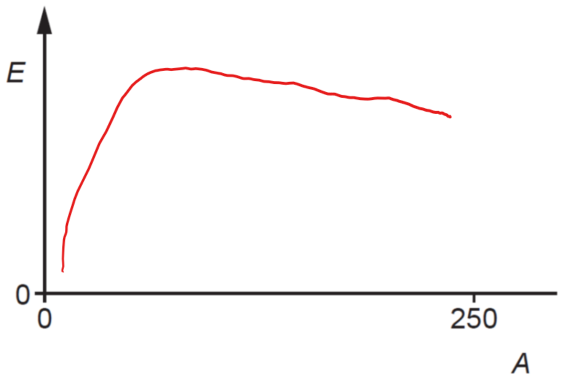
B1</td></tr>
<tr><td>3(c)</td><td>when vapourising, greater change in separation of atoms or molecules/ bonds are completely broken (compared to partially broken), hence a greater change in potential energy and internal energy

greater change in volume, hence a greater work done</td><td>B1

B1</td></tr>
</table>

Qns	Answer	Marks
4(a)(i)	product of number of turns of coil, (magnetic) flux density and area	**M1**
	area perpendicular to the (magnetic) field	**A1**
	OR	
	Magnetic flux linkage through a loop is product of magnetic flux through the loop and number of turns of wire in the loop.	**B1**
	Magnetic flux is the product of an area and component of magnetic flux density perpendicular to that area.	**B1**
4(a)(ii)	flux = $B \times \pi r^2$ $= 0.17 \times \pi\ 0.36^2$ $= 6.9 \times 10^{-2}$ Wb	**C1**
	time for one revolution = 1 / 25 s	
	e.m.f. = rate of cutting flux **or** $\frac{\Delta\Phi}{\Delta t}$	**C1**
	$= 0.069 \times 25$ $= 1.7$ V	**A1**
4(a)(iii)	current (in disc) is perpendicular to magnetic field causes force to act on disc **OR** current (in disc) is perpendicular to magnetic field **OR** current causes force to act on disc	**B1**
	force opposes rotation of disc	**B1**
	Fleming's left-hand rule indicates current is from rim to axle	**B1**

Qns	Answer	Marks
4(b)(i)	ring cuts (magnetic) flux and causes induced e.m.f. in ring	B1
	(induced) e.m.f. causes (eddy/induced) currents (in ring)	B1
	currents (in ring) cause magnetic field (around ring)	M1
	two fields interact to cause resistive/opposing force	A1
	OR	
	current (in ring) is in a magnetic field	(M1)
	which causes resistive force	(A1)
	OR	
	currents (in ring) dissipate thermal energy	(M1)
	(thermal) energy comes from energy of oscillations	(A1)
4(b)(ii)	current cannot pass all the way around the ring	B1
	(induced) currents smaller (OR no currents)	B1
	smaller resistive force (so more oscillations) (OR no resistive force) **or** smaller rate of dissipation of energy (so more oscillations)	B1

Qns	Answer	Marks
5(a)(i)	energy required to separate the nucleons (in the nucleus) to infinity	**M1** **M1**
5(a)(ii)	curve starting close to the origin and forming a single peak peak shown to left of centre, with steep line on LHS of peak and shallow line on RHS of peak  **Fig. 5.1**	**B1**
5(b)(i)	Fusion	**B1**
5(b)(ii)	both particles have low *A* values or both particles are at left-hand end of graph He-3 has higher binding energy (per nucleon) than the total binding energy of both H-2	**B1** **B1**
5(c)	Δm = [(2 × 2.014102) – (3.016029 + 1.008665)] u = 0.00351 u (Correct substitution and correct answer) $E = \Delta mc^2$ $= 0.00351 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$ $= 5.24 \times 10^{-13}$ J (Correct substitution and correct answer) 1.0 mol of deuterium forms 0.500 mol of helium-3 total energy = $0.500 \times 6.02 \times 10^{23} \times 5.24 \times 10^{-13}$ (Correct substitution) $= 1.58 \times 10^{11}$ J	 **C1** **C1** **C1** **C1** **A1**

Qns	Answer	Marks
6(a)	upthrust is greater than weight (resultant force is) upwards	B1 B1
6(b)	At equilibrium, Upthrust = Weight $\rho A hg = Mg$ ---(1) Taking downwards positive, at displacement *x*, Net force = mass x acceleration $Mg - Upthrust = Ma$ $Mg - \rho Vg = Ma$ where *V* is the volume of water displaced $Mg - \rho A(h + x)g = Ma$ $Mg - \rho Ahg - \rho Axg = Ma$ ----(2) Sub (1) into (2): $\rho Ahg - \rho Ahg - \rho Axg = Ma$ $-\rho Axg = Ma$ $a = -\left(\frac{A\rho g}{M}\right)x$ OR Additional upthrust = net force $\rho Axg = Ma$ Since *a* and *x* are opposite in directions, $a = -\frac{A\rho g}{M}x$ Note: For "show that" question, the first method is preferred.	 M1 M1 M1 (M1) (M1) M1
6(c)	*A, ρ, g and M are constant, hence* acceleration proportional to displacement negative sign indicates acceleration and displacement in opposite directions	B1 B1
6(d)(i)	$\omega = 2\pi / T$ $\omega = 2\pi / 1.3$ = 4.8 rad s^{-1}	C1 A1
6(d)(ii)	$\omega^2 = A\rho g / M$ $4.8^2 = (4.5 \times 10^{-4} \times \rho \times 9.81) / 0.17$ $\rho = 900$ kg m^{-3}	C1 C1 A1

Qns	Answer	Marks
6(d)(iii)1.	Total energy = <u>maximum</u> Kinetic energy Max velocity $v_{\max} = \omega x_{\max}$ = $\frac{1}{2}mv_{\max}{}^{2} = \frac{1}{2}m(\omega x_o)^2 = \frac{1}{2}m\omega^2 x_o{}^2$ algebra leading to final expression	**B1** **M1** **M1**
6(d)(iii)2.	$\frac{1}{2}(0.17)\left[(4.8)(0.20)\right]^2$ $= 0.078$ J	 **A1**
6(d)(iv)	0.92^6 decrease in energy = 0.078 – (0.078 × 0.92^6) = 30.7 mJ	**C1** **A1**
6(d)(v)	wave with same period (or slightly greater) AND peak height decreasing successively	**B1** **B1**

Qns	Answer	Marks
7(a)(i)	work done per unit mass in bringing a small test mass from infinity to that point	**B1** **B1**
7(a)(ii)	potential is zero at infinity Gravitational force is attractive work is done **by** (two) masses in moving them **closer** together work is done **on** (two) masses in moving them **apart** test mass getting closer from infinity loses potential energy	**Any 2**
7(b)	Loss in kinetic energy = Gain in Gravitational Potential Energy Initial KE – final KE = final GPE – initial GPE $\frac{1}{2}mv^2 - 0 = 0 - m\phi$ $v = \sqrt{-2\phi}$	**B1** **B1** **B1** **A0**
7(c)	ϕ = –GM / r = – ($6.67 \times 10^{-11} \times 7.3 \times 10^{22}$) / ($1.7 \times 10^{6}$) = – 2.9×10^{6} J kg^{-1}	 **C1** **A1**
7(d)	speed = $\sqrt{(2 \times 2.9 \times 10^{6})}$ = 2400 m s^{-1}	 **A1**
7(e)	$\frac{1}{2}m\langle c^2\rangle = (3/2)kT$ $\frac{1}{2}\, 3.34 \times 10^{-27} \times \langle c^2\rangle = (3/2)(1.38 \times 10^{-23})(400)$ $c_{r.m.s.}$ = 2200 m s^{-1}	**C1** **C1** **A1**
7(f)	r.m.s. speed is an average so many molecules have speeds greater than the escape speed **or** there is a distribution of molecular speeds (around the r.m.s. value) so many molecules have speeds greater than the escape speed	**B1**
7(g)(i)	Loss in GPE = Gain in KE $\left(-\frac{GMm}{r_X}\right)-\left(-\frac{GMm}{r_Y}\right)=\frac{1}{2}mv_Y{}^2-\frac{1}{2}mv_X{}^2$ $(6.67\times10^{-11})(1.99\times10^{30})\left[\left(-\frac{1}{8.44\times10^{11}}\right)+\left(\frac{1}{6.38\times10^{10}}\right)\right]=\frac{1}{2}v_Y{}^2-\frac{1}{2}(34.1\times10^{3})^2$ $v_Y = 70.8$ km s^{-1}	**B1** **C1** **C1** **A1**
7(g)(ii)	both Gravitational Potential Energy and Kinetic Energy equations include *m*, so path is unchanged OR It is independent on *m*, so path is unchanged.	**B1** **(B1)**

Qns	Answer	Marks
7(g)(iii)	Path higher than the original one AND Closest distance of approach is larger And if goes back, the bottom path is lower than the original one.	**B1**