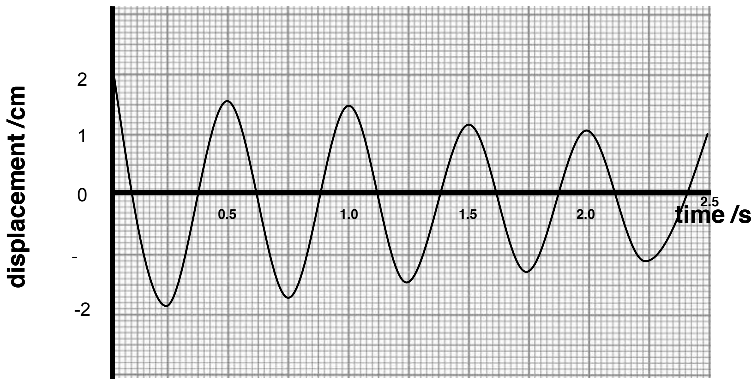
Question			Marking details	Marks Available
1	*(a)*	(i)	Increase (change) in the internal energy [of the system]	1
		(ii)	Heat supplied to (flowing into) [the system]	1
		(iii)	Work done by the system	1
	(b)		$PV = nRT$	
			$T = \frac{PV}{nR}$ (1) $= \frac{(1.01 \times 10^5)(1.3 \times 1.00 \times 10^{-2})}{(0.4)(8.31)}$ = 395 K (1)unit mark	2
	(c)	(i)	$(1.01 \times 10^5)(0.3 \times 1.00 \times 10^{-2})$ = 303 [J] on gas (1)	
		(ii)	0 / No work (1)	
		(iii)	$\frac{1}{2}(0.3 \times 1.00 \times 10^{-2})(0.2 \times 1.01 \times 10^5) + (0.3 \times 1.00 \times 10^{-2})(1.01 \times 10^5)$	
			= 30 + 303	
			= 333 [J] (1) by gas ecf from (c)(i) (1)	4
	(d)		Convincing evidence of multiplication by 3 for the 3 cycles (1)	
			$\Delta U = 0$ (1)	
			$Q = \Delta U + W$ = 0 + 90 = 90[J] into gas (1) ecf from (c)(iii)	3
			Question 1 total	[12]

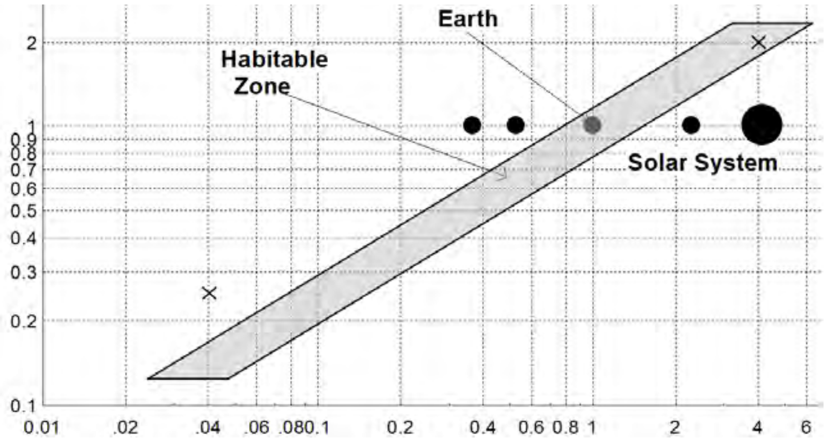
Question			Marking details	Marks Available
3	*(a)*		Acceleration α displacement from central (fixed) point (1) is directed towards the central (fixed) point (1)	2
	(b)	(i)	$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.40} = 15.7$ [rad s^{-1}] (1) $v_{max} = \omega A = (15.7)(0.05) = 0.79$ [m s^{-1}] (1)	2
		(ii)	$a_{max} = \omega^2 A$ (1) $= (15.7)^2(0.05) = 12.3$ [m s^{-2}] (1)	2
	(c)		$x = 0.05 \sin\left(15.7t - \frac{\pi}{2}\right)$ [m] 0.05 (1) 15.7 (1) $-\frac{\pi}{2}$ (1) or accept $-90°$	3
	(d)		Loses contact when $a = -g$ (1) $-\omega^2 x = -g$ $x = \frac{9.81}{(15.7)^2} = 0.04$ [m] (1)	2
			Question 3 total	[11]

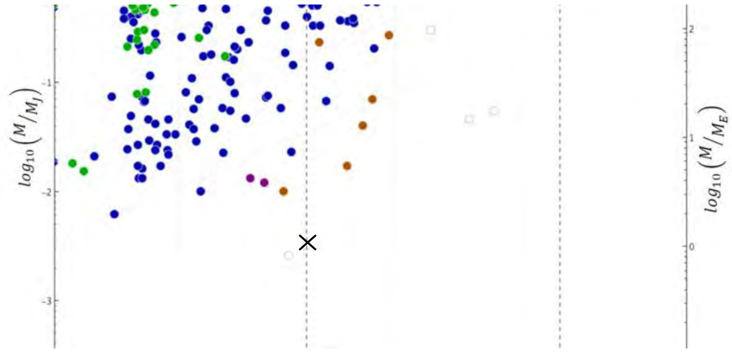
Question			Marking details	Marks Available
4	*(a)*	(i)		
			Scales on both axes (1) Period and shape (1) Amplitude (1)	3
		(ii)	e.g. air resistance magnetic damping friction by itself is not enough - needs either reference or implication to air resistance	1
	(b)	(i)	General shape with label (accept if peak on or just to left of f_o)	1
		(ii)	Smaller values than A with peak not to the right and correct shape	1
		(iii)	At a <u>certain</u> driving <u>frequency</u> there is a <u>maximum</u> (peak) in the <u>amplitude</u> of the oscillating load. At this frequency the system is at resonance.	1
		(iv)	e.g. microwave cooking (1) driving force : by microwave radiation (1) responding oscillator : water molecules (1)	3
			Question 4 Total	[10]

Question			Marking details	Marks Available
5	*(a)*	(i)	$PV = n RT$ $n = \frac{PV}{RT} = \frac{(3.04 \times 10^5)(0.025)}{(8.31)(280)} = 3.27$[mol]	1
		(ii)	$N = n N_A = (3.27)(6.02\text{x}10^{23}) = 1.97\text{x}10^{24}$ allow ecf from (i)	1
		(iii)	$\rho = \frac{(m_r \text{ x } 10^{-3})n}{V} = \frac{(4\text{x}10^{-3})(3.27)}{0.025} = 0.52$[kg m^{-3}] (1) formula with m_r (1)	2
		(iv)	$P = \frac{1}{3}\rho\overline{c^2}$ $\sqrt{\overline{c^2}} = \sqrt{\frac{3P}{\rho}} = \sqrt{\frac{3(3.04\text{x}10^5)}{0.52}} = 1324$[$ms^{-1}$] (1) allow ecf from (iii) Rearrange equation (1)	2
	(b)	(i)	(Combining of the two given equations to give) $\frac{1}{3}N m\overline{c^2} = nRT$ (1) KE of gas (i.e. of the N molecules) = $\frac{1}{2}N m\overline{c^2}$ [= number of atoms x $\frac{1}{2}m\overline{c^2}$] (1) (can award for K.E. of one molecule i.e. K.E. = $\frac{1}{2}m\overline{c^2}$ only if it is clearly noted that it is for one molecule) $\therefore$ KE of gas [$\frac{1}{2}N m\overline{c^2}$] = $\frac{3}{2}nRT$ manipulation mark (1) Internal energy of gas (U) = KE + PE and PE = 0 (for ideal gas) (1) [or internal energy is only the KE] (so $U = \frac{3}{2}n RT$)	4
		(ii)	$U = \frac{3}{2}n RT = \frac{3}{2}(3.27)(8.31)(280) = 11\ 413$ [J]	1
			Question 5 Total	[11]

Question			Marking details	Marks Available
1	*(a)*		All α absorbed / stopped by paper (1) (nearly) all γ passes through (1)	2
	(b)		${}_{-1}^{0}[\beta]$ correct (1) Conservation of A and Z (but not for trivial ${}_{0}^{0}\beta$) (1)	2
	(c)		$\lambda = \frac{ln2}{T_{1/2}}$ used (1) $\frac{ln2}{28.8 \times 365 \times 24 \times 3600}$ [$= 7.63 \times 10^{-10}\ s^{-1}$] (1)	2
	(d)		Correct equation used i.e. some understanding of $A = A_0 e^{-\lambda t}$ or $A = \frac{A_0}{2^n}$ (1) Answer correct (110 GBq ecf on λ) (1)	2
	(e)		$A = \pm\lambda N$ used (e.g. 140 = 7.6 x 10^{-10} N is ok) (1) N = 1.83 x 10^{20} (1) Mass = 90 u x 1.83 x 10^{20} = 27.4 x 10^{-6} kg (27.4 mg) ecf on N (1) UNIT mark	3
			Question 1 total	[11]

Question			Marking details	Marks Available
2	*(a)*		LHS - RHS attempted (0.1859 u) (1)	
			x 931 or $E=mc^2$ used (must have u to kg conversion) (1)	
			173.1 [MeV] / 2.78 x 10^{-11} [J](1)	3
	(b)		[more or 3] neutrons are released (1)	
			These can produce fission (or, on average one of these....) (1)	2
	(c)		Control rods stop or absorb neutrons (1)	
			Moderator slows neutrons (1)	
			To increase [probability of] fission (or increase capture X-section) (1)	3
	(d)		[Highly] radioactive for many years / long half life (1)	
			Any sensible A level standard comment relating to - storage, leakage, transportation, cost, dirty bombs etc. (1)	2
			Question 2 Total	[10]

Question			Marking details	Marks Available
7	*(a)*		Because their star is the Sun or they all orbit the Sun or $\frac{M_{star}}{M_{Sun}} = 1$ Accept M_{star} is the same	1
	(b)	(i)		1
		(ii)		1
		(c)	(i) yes because it's in the habitable zone ecf (1) (ii)[no] because it is too hot or too close to star ecf (1)	2
		(d)	Eliminating r_S (1) $\frac{\cancel{M_S} v_S^2}{r_S} = \frac{G \cancel{M_S} M_p}{d^2} \rightarrow \frac{v_S^2}{M_p d / M_S} = \frac{GM_p}{d^2}$ or $M_s v_s^2 = \frac{G M_S r_S M_p}{d^2} = \frac{G M_p d M_p}{d^2}$ Remainder of algebra convincing (1)	2
		(e)	Because Doppler shift $\propto v_S$ (accept depends on) (1) and $v_S \propto M_P$ or v_S increases with M_P (1) and $v_S \propto M_S^{-0.5}$ or v_S decreases with M_S (1) and $v_S \propto d^{-0.5}$ or v_S decreases with d (1)	4

Question			Marking details	Marks Available
7	*(f)*		Some comment about most planets being large mass e.g. nearly all masses greater than M_E or average/median mass is close to mass of Jupiter etc. (1) Some comment about *d* being quite small on average e.g. mean/median *d* is only about 1 AU (not 0 AU!) or nearly all planets inside 10 AU etc. (1) The graph says nothing about the size of the star (1) Award a maximum of 2 marks only Most planets towards top left of graph (by itself) scores 1 mark	2
	(g)		 Accept a circle around the correct planet x correct – 1 mark, y correct – 1 mark	2
	(h)		$\frac{\pi r_1^2}{\pi r_2^2} = \mathbf{20}^2$ (1) Drops by 0.25% or drops to 99.75% or drops by $^1/_{400}$ (1) (correct answer implies first step)	2
	(i)		Radial velocity gives mass (1) Transit gives radius or area or diameter (1) Density = $\frac{mass}{volume}$ and volume from area or diameter or radius (1)	3
			Question 7 Total	[20]