

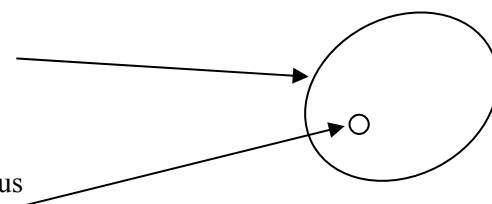
PH4

Question		Marking details	Marks Available
1.	(a)	[In any interaction] the [vector] sum of bodies' <i>momenta</i> [accept 'total momentum'] stays constant (1), provided no [resultant] external force acts [accept: in a closed system] (1) NB. Separate marks but statement of conservation of energy loses both marks.	2
	(b)	(i) $1.67 \times [10^{-27}] \times 3150 \pm 9.98 \times [10^{-27}] \times 225 = 11.6 \times [10^{-27}]v$ (1) [10^{-27} consistently dropped or masses given as 1, 6, 7 ✓] With minus sign (i.e. signs correct) (1) $v = 260 \text{ m s}^{-1}$ (1) [no ecf] Arrow to right (1)	4
		(ii) $\Sigma \text{ KE initially} = 8.54 \times 10^{-21} \text{ J}$ (1) $\Sigma \text{ KE finally} = 3.92 \times 10^{-21} \text{ J}$ (1) [Correct answer other than powers of 10 → 1 mark]	2
	(c)	$\Delta mv = \frac{h}{\lambda}$ or $v = \frac{h}{\lambda m}$ (1) [or $\frac{h}{\lambda} = 3.88 \times 10^{-21} \text{ [Ns]}$] $v = 3.3 \times 10^5 \text{ m s}^{-1}$ (1) [No penalty for attempts to include initial momentum (which is $3.0 \times 10^{-24} \text{ Ns}$)]	2
			10

Question		Marking details	Marks Available
2.	(a)	(i) Relevant comment, e.g. stem suggests not at equilibrium when released / graph shows equilibrium at $t = 0$ / graph contradicts stem	1
		(ii) I. 0.08 m (1) II. 1.2 s (1)	1 1
	(b)	$k = \frac{4\pi^2 m}{T^2}$ (1) [correct transposition at any stage] $= 11 \text{ N m}^{-1}$ (1) ((unit including any SI equivalent))	2
	(c)	(i) $\{\omega = 5.24 \text{ rad s}^{-1}\}$ or $\{\text{use of } v_{\text{max}} = \frac{2\pi A}{T} \text{ [or equiv]}\}$ (1) $v_{\text{max}} = 0.42 \text{ m s}^{-1}$ [accept $v_{\text{max}} = 0.080 \times 5.24$] + comment (1) [Full marks available for use of tangent $\rightarrow T = 0.42 \pm 0.7 \text{ m s}^{-1}$]	2
		(ii) Correct sequence of v values (i.e. correct phase) (1) t values correct, and reasonable curve plotted (1)	2
	(d)	(i) I. – [or “decrease”] (1) 0.035 J [± 0.003 J] (1) II. – 0.31 J [± 0.01 J] NB Correct sign required.	2 1
		(ii) [0.35J of] elastic [potential] energy gained (1) [Accept: [more] energy stored in spring [at 0.9s]]	1
	(e)	(i) ordinate labelled “amplitude” and abscissa labelled “frequency”	1
		(ii) ϕ is [close to] the natural frequency [or by implication] (1) [NB not resonant frequency] 0.83 Hz (1) [e.c.f. from (a)(ii)(II)]	2

Question		Marking details	Marks Available		
3.	(a)	(i)	I. $\overline{c^2} = \frac{3p}{\rho}$ (1) [transposition at any stage] $= \frac{3 \times 100 \times 10^3 \times 1.5 \times 10^{-3}}{2.4 \times 10^{-3}}$ (1) [correct substitution or by implication] $\sqrt{\overline{c^2}} = 433 \text{ m s}^{-1}$ (1) [Wrong attempts based on $pV = \frac{1}{3} Nm\overline{c^2}$ can score the last mark if $\sqrt{\overline{c^2}}$ correctly taken]	3	
			II. collisions [“random process” not enough]	1	
			III. $935^2 + 743^2 + 312^2$ [= 1.52×10^6] (1)		
			Division of sum by 3 even if $\frac{935 + 743 + 312}{3}$ [= 663 m s^{-1}] (1)		
			$C_{\text{rms}} = 712 \text{ m s}^{-1}$ (1) [no ecf]	3	
	(b)	(ii)	I. $T = \frac{pV}{nR}$ (1) [transposition at any stage] $T = 301 \text{ K or } \left\{ \frac{100 \times 10^3 \times 1.5 \times 10^{-3}}{0.050 \times 8.31} = 300 \text{ K or } 301 \text{ K} \right\}$ (1)	2	
			II. $N = 3.6 \times 10^{22}$	1	
			III. $\text{rmm} = \frac{2.4}{0.0600}$ (1) [award mark even if $2.4 \times$ used] $= 40$ (1) [NB no unit penalty]	2	
			(i) Attempt to find area under AB / use of $p\Delta V$ [or by implication] (1) 100 J (1)	2	
			(ii) Either $T_B = 500 \text{ K}$ (1) [or by impl.] $U_B = 374 \text{ J or } U_A = 224 \text{ J}$ (1) [or by impl.] $\Delta U = 150 \text{ J}$ (1) <table style="display: inline-table; vertical-align: middle; border-left: 1px solid black; padding-left: 10px;"> <tr> <td>Or</td> </tr> <tr> <td>$U = \frac{3}{2} pV$ (1) [or by impl.]</td> </tr> <tr> <td>$\Delta U = \frac{3}{2} p\Delta U$ (1) [or by impl.]</td> </tr> <tr> <td>$= 150 \text{ J}$ (1)</td> </tr> </table>	Or	$U = \frac{3}{2} pV$ (1) [or by impl.]
Or					
$U = \frac{3}{2} pV$ (1) [or by impl.]					
$\Delta U = \frac{3}{2} p\Delta U$ (1) [or by impl.]					
$= 150 \text{ J}$ (1)					
(iii) 250 J [e.c.f.]	1				
(iv) [U falls by 150 J and because the volume doesn't change] no work involved / $Q = \Delta U$ (1) 150 J (1) [ecf on answer to (ii)]	2				
			20		

Question		Marking details	Marks Available
4.	(a)	(i) Arrows shown at P away from both the two charges [Resultant shown → ignore; other arrows shown in other directions → s.i.f.]	1
		(ii) E at P due to one charge = $\frac{7.0 \times 10^{-12}}{4\pi \times 8.85 \times 10^{-12} \times (0.38)^2} \text{ N C}^{-1}$ (1) [= 0.44 N C ⁻¹] [Accept 9.0 × [F ⁻¹ m] for $\frac{1}{4\pi\epsilon_0}$; treat 0.31m as slip: give first mark] Multiplication by cos 55° (1) Multiplication by 2 (1) } NB These 2 marks available for clear working to calculate force on a charge placed at P ; 0.38 m must be used.	4
		(iii) I. Fields from charges cancel (1) [or equivalent, e.g. fields from charges are equal and opposite]	1
		II. Coulomb's law or inverse square law (however stated) [holds for individual charges]	1
		(b) (i) Force on ion = $4.8 \times 10^{-19} \text{ C} \times 0.50 \text{ N C}^{-1}$ (1) (ecf) [or by impl.] [= $2.4 \times 10^{-19} \text{ N}$] Acceleration $\left[= \frac{2.4 \times 10^{-19} \text{ N}}{4.5 \times 10^{-26} \text{ kg}} \right] = 5.3 \times 10^6 \text{ m s}^{-2}$ (1) ((unit)) (ecf) applies within this calculation on the incorrect force)	2
	(ii) Speed never decreases [accept: always accelerates](1) [or by implication] Speed increases at greatest rate where $E_{r,f}$ graph peaks (1) [or equivalent]	2	
	(iii) PE = $q \frac{Q}{4\pi\epsilon_0 r} \times 2$ (1) [or by implication] = $1.95 \times 10^{-19} \text{ J}$ (1) [or by implication] KE = $9.0 \times 10^{-20} \text{ J}$ (1) [independent mark] Total = $2.85 \times 10^{-19} \text{ J}$ (1) [no general e.c.f. but use of $r^2 \rightarrow$ no ecf; use of 0.38 m only loses 2 nd mark; use of incorrect charge loses 1 st and 2 nd marks] [Omission of factor of 2 penalised only once → $1.88 \times 10^{-19} \text{ J}$]	4	
	(iv) At large distance, PE negligible / $\text{KE}_{\text{max}} = \text{Total energy at 0}$ (1) [or by impl.] $\frac{1}{2}mv^2 = 2.85 \times 10^{-19} \text{ J}$ (1) e.c.f. [or by impl.] $v_{\text{max}} = 3600 \text{ m s}^{-1}$ (1)	3	
		18	

Question			Marking details	Marks Available	
5.	(a)	(i)	I. ...Ellipse stated and shown (1)		2
			II. Faster when closer to the star (1) Equal areas in equal intervals of time stated and shown (1)		
		(ii)	I. $\frac{GMm}{r^2} = \frac{mv^2}{r}$ [Accept $\frac{GM}{r^2} = \frac{v^2}{r}$] [$\frac{GMm}{r^2} = mr\omega^2$ acceptable only if $\omega = \frac{v}{r}$ explicitly involved, with clear algebra]	2	
		(iii)	II. Planet wouldn't orbit centre of star / planet [and star] orbit centre of mass [or equiv.] (1) We'd need $\frac{GMm}{d^2} = \frac{mv^2}{r}$ [in which d=r] (1) [or equivalent]	1	
		(b)	(i)	I. $v = c \frac{4.4}{3}$ with evidence of correct use (1) [e.g. substitutions with no more than numerical slips] $v_A = 9.5[1] \times 10^5 \text{ m s}^{-1}$, and $v_B = 5.3[0] \times 10^5 \text{ m s}^{-1}$ (1)	
	(ii)	II. $\bar{v} = 7.4 \times 10^5 \text{ m s}^{-1}$	1		
	(iii)	III. $v_{\text{rot}} = 2.1 \times 10^5 \text{ m s}^{-1}$	1		
	(c)	I. $M = \frac{v^2 r}{G}$ (1) [transposition at any stage] Substitution of v, r pair from <u>dotted</u> graph (1) $M = 1.1 \times 10^{41} \text{ kg}$ (1) [e.c.f on slips in reading <u>dotted</u> graph] Slips in powers of 10 penalised by only 1 mark.	3		
	II. Any $2 \times (1)$ from Mass larger than $1.1 \times 10^{41} \text{ kg}$ / actual mass large than theoretical [or M] (✓) $v = \sqrt{\frac{GM}{r}}$ assumes the mass is central (✓) Mass distributed [however expressed] (✓)	2			
					18