PH4

Question			Marking details	Marks Available
1.	*(a)*		[In any interaction] the [vector] sum of bodies' *momenta* [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) $v = 260$ m s^{-1} (1) [no ecf] Arrow to right (1)	4
		(ii)	Σ KE initially $= 8.54 \times 10^{-21}$ J (1) Σ KE finally $= 3.92 \times 10^{-21}$ J (1) [Correct answer other than powers of 10 $\rightarrow$ 1 mark]	2
	(c)		$\Delta mv = \frac{h}{\lambda}$ or $v = \frac{h}{\lambda m}$ (1) [or $\frac{h}{\lambda} = 3.88 \times 10^{-21}$ [Ns]] $v = 3.3 \times 10^{5}$ m s^{-1} (1) [No penalty for attempts to include initial momentum (which is 3.0×10^{-24} Ns)]	2
				10

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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** {use of $v_{max} = \frac{2\pi A}{T}$ [or equiv]}(1) $v_{max} = 0.42\ \text{m s}^{-1}$ [accept $v_{max} = 0.080 \times 5.24$] + comment (1) [Full marks available for use of tangent → $T = 0.42 \pm 0.7\ \text{m s}^{-1}$]	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
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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 $\sqrt{\ }$ correctly taken]	3
			II. collisions ["random process" not enough]	1
			III. $935^2 + 743^2 + 312^2$ [$= 1.52 \times 10^6$] (1) Division of sum by 3 even if $\frac{935 + 743 + 312}{3}$ [$= 663 \text{ m s}^{-1}$] (1) $C_{\text{rms}} = 712 \text{ m s}^{-1}$ (1) [no ecf]	3
		(ii)	I. $T = \frac{pV}{nR}$ (1) [transposition at any stage] $T = 301$ K **or** $\{\frac{100 \times 10^3 \times 1.5 \times 10^{-3}}{0.050 \times 8.31} = 300$ K or 301 K$\}$ (1)	2
			II. $N = 3.6 \times 10^{22}$	1
			III. rmm $= \frac{2.4}{0.0600}$ (1) [award mark even if 2.4× used] $= 40$ (1) [NB no unit penalty]	2
	(b)	(i)	Attempt to find area under AB / use of $p\Delta V$ [or by implication] (1) 100 J (1)	2
		(ii)	Either $T_B = 500$ K (1) [or by impl.] $U_B = 374$ J **or** $U_A = 224$ J (1) [or by impl.] $\Delta U = 150$ J (1) Or $U = \frac{3}{2}pV$ (1) [or by impl] $\Delta U = \frac{3}{2}p\Delta U$ (1)[or by impl.] $= 150$ J (1)	3
		(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

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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 = $\dfrac{7.0\times10^{-12}}{4\pi\times8.85\times10^{-12}\times(0.38)^2}$ N C^{-1} (1) [= 0.44 N C^{-1}] [Accept 9.0× [F^{-1}m] for $\dfrac{1}{4\pi\varepsilon_0}$; 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 <u>force</u> on a charge placed at P ; 0.38 m must be used. E_{res} = 0.50 N C^{-1} **or** 0.50 V m^{-1} ((**unit**)) (1) [Award last mark for 0.25 N C^{-1} but not for other mistake] NB. Direction **not** required. Use of 45° rather than 55° [i.e. Es at right angles → 1st and 3rd marks available].	4
		(iii)	I. Fields from charges cancel (1) [or equivalent, e.g. fields from charges are equal and opposite] II. Coulomb's law or inverse square law (however stated) [holds for individual charges]	1 1
	(b)	(i)	Force on ion = 4.8 × 10^{-19} C × 0.50 N C^{-1} (1) (ecf) [or by impl.] [= 2.4 × 10^{-19} N] Acceleration $\left[=\dfrac{2.4\times10^{-19}\text{ N}}{4.5\times10^{-26}\text{ kg}}\right]$ = 5.3 × 10^{6} 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_{res} graph peaks (1) [or equivalent]	2
		(iii)	PE = $q\dfrac{Q}{4\pi\varepsilon_0 r}\times 2$ (1) [or by implication] = 1.95 × 10^{-19} J (1) [or by implication] KE = 9.0 × 10^{-20} J (1) [independent mark] Total = 2.85 × 10^{-19} J (1) [no general e.c.f. but use of r^2 → no ecf; use of 0.38 m only loses 2nd mark; use of incorrect charge loses 1st and 2nd marks] [Omission of factor of 2 penalised only once → 1.88 × 10^{-19} J]	4
		(iv)	At large distance, PE negligible / KE$_{max}$ = Total energy at 0 (1) [or by impl.] $\frac{1}{2}mv^2$ = 2.85 × 10^{-19} J (1) e.c.f. [or by impl.] v_{max} = 3600 m s^{-1} (1)	3
				18

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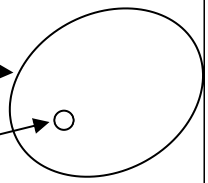
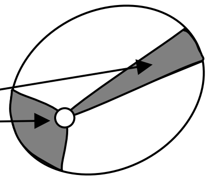
5.	*(a)*	(i)	I. …Ellipse stated **and** shown (1)  …with star at one focus stated **or** shown (1)	2
			II. Faster when closer to the star (1) Equal areas in equal intervals of time stated **and** shown (1) 	2
		(ii)	I. $\frac{GMm}{r^2} = \frac{mv^2}{r}$ [Accept $\frac{GM}{r^2} = \frac{v^2}{r}$] [$\frac{GMm}{r^2} = mr\omega^2$ acceptable only if $\omega = \frac{v}{r}$ explicitly involved, with clear algebra]	1
		(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 $d \neq r$] (1) [or equivalent]	2
	(b)	(i)	I. $v = c\frac{\Delta\lambda}{\lambda}$ with evidence of correct use (1) [e.g. substitutions with no more than numerical slips] $v_A = 9.5[1] \times 10^5$ m s^{-1}, **and** $v_B = 5.3[0] \times 10^5$ m s^{-1} (1)	2
		(ii)	II. $\bar{v} = 7.4 \times 10^5$ m s^{-1}	1
		(iii)	III. $v_{rot} = 2.1 \times 10^5$ m s^{-1}	1
	(c)		I. $M = \frac{v^2 r}{G}$ (1) [transposition at any stage] Substitution of v, r pair from dotted graph (1) $M = 1.1 \times 10^{41}$ kg (1) [e.c.f on slips in reading dotted graph] Slips in powers of 10 penalised by only 1 mark.	3
			II. Any 2 × (1) from Mass larger than 1.1×10^{41} kg / actual mass large than theoretical [**or** M] (✓) $v = \sqrt{\frac{GM}{r}}$ assumes the mass is central (✓) Mass distributed [however expressed] (✓)	2
				18