PH4

Question				Marking details	Marks Available
1	(a)			The total momentum (of a system) is constant (must have total, sum, vector sum etc.) (1) Provided no <u>external</u> [resultant] force (1) e.g. - The momentum before and after a collision is the same - 0 When two particles collide the sum of momentum stays the same as long as no forces are involved - 1	2
	(b)			$\lambda = \frac{c}{f}$ i.e. rearranged or $E = hf$ = 2.13x10^{-13} [J] (1) $p = \frac{h}{\lambda}$ **used** or $p = \frac{E}{c}$ **quoted** (1) Final evidence $p = \frac{6.63\times10^{-34}}{9.35\times10^{-13}}$ or $p = \frac{2.128\times10^{-13}}{3\times10^{8}}$ (= 7.09 x 10^{-22}) (1)	3
	(c)			Reasonable attempt at cons of mom e.g. initial p of Ni = final p of Ni ± p of photon (1) 2 440 x 9.95 x 10^{-26} = 7 x 10^{-22} - 9.95 x 10^{-26} v (1) Answer = 4 700 [m s^{-1}] or slightly different dependent on (b) (1) **ecf** on p	3
				Question 1 Total	**[8]**

Question				Marking details	Marks Available
2	(a)			$\frac{1}{3}\rho\overline{c^2}V = nRT$ i.e. some sort of combining both equations (1) Realising $\rho = \frac{Nm}{V}$ (any mistakes in *N* and *m* means max of 1/3) (1) (or equivalent steps) **Clear** algebra with no mistakes leading to $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$ or $\frac{1}{2}m\overline{c^2} = \frac{3}{2}\frac{R}{N_A}T$ (if it's difficult to follow don't award the mark - needs to be clear) (1)	3
	(b)	(i)		Mass of argon molecule = 6.3(08)x10^{-26} (1) Algebra or equivalent method $T = \frac{m\overline{c^2}}{3k}$ or $T = \frac{N_A m\overline{c^2}}{3R}$ (1) Answer = 605 [K] (1) **ecf**	3
		(ii)		$\sqrt{\overline{c^2}} \propto \sqrt{T}$ or correct substitution of 1 210 K (**ecf**) and algebra (1) Answer = $630 \times \sqrt{2}$ or 891 [m s^{-1}] (1)	2
				Question 2 Total	**[8]**

Question				Marking details	Marks Available
3	(a)	(i)		Graph is straight line through origin [hence proportional] (1) (accept acceleration is proportional to displacement) Negative gradient [hence direction ok] (1)	2
		(ii)		Gradient calculated correctly i.e. $\frac{1}{0.028}$ or 36 (or k calculated from $ma = kx$ i.e. 7.14 N m^{-1}) (1) Gradient = angular velocity squared i.e. method **explained** Or $f = \left(2\pi\sqrt{\frac{m}{k}}\right)^{-1}$ i.e. equation for T **and** $f = 1/T$(1) Answer = $\frac{5.98}{2\pi}$ = 0.95 [Hz] (1)	3
		(iii)		1 m s^{-2} read off graph Or 6^2 x 0.028 = 1 [m s^{-2}]etc.	1
		(iv)		Max speed = ωA or implied (= 0.167) (1) KE = $\frac{1}{2}mv^2$ or implied (1) Answer = 2.8 [mJ] (1) **ecf**	3
		(v)		$v = A\omega\cos\omega t$ used or $\varepsilon = 0$ stated (1) Rearrangement e.g. $\omega t = \cos^{-1}\frac{v}{A\omega}$ or implied (1) Correct answer = 0.156 [s] (1) **ecf**	3
	(b)			KE to PE **or** PE to KE (1) PE is both GPE and EPE (1) Energy gradually lost due to friction or air resistance or internal energy of spring/air etc. Not sound, not heat by itself - needs more e.g. lost as heat to the air ok (1) Detail of energy loss e.g. internal energy of air, KE of air particles	4
				Question 3 total	**[16]**

Question				Marking details	Marks Available
4	(a)			$T = \frac{pV}{nR}$ seen or implied (1) Evidence of 1 correct substitution (1) Evidence of all 3 substituted correctly (1) A - (0.500 ± 0.002, 80 000 ± 2 000) B - (0.260 ± 0.002, 235 000 ± 2 000) C - (0.260 ± 0.002, 80 000 ± 2 000)	3
	(b)			$U = \frac{3}{2}nRT$ used (1) Evidence of ΔT being used or differences in U being calculated (once) (1) AB = 31 500 [J], BC = - 60 500 [J], CA = 29 000 [J] (1)	3
	(c)	(i)		AB approximated as a trapezium (accept triangle gives 19 000 J) (1) AB = - 38 000 [J] (1) AB ≈ (- 32 000 ± 3 000) J due to better method ✓✓✓ e.g. two trapezia or 2 triangles or square counting, or any attempt at integrating pV (unlikely) etc. (i.e. 2 marks for good method 1 mark for correct answer) (1)	3
		(ii)		BC = 0 (independent)	1
		(iii)		CA = 19 200 [J]	1
	(d)	(i)		$Q = \Delta U + W$ i.e. equation used (1) Correct answer with **their** figures e.g. 31 500 – 38 000 = -6 500 (also **ecf** possible for 31 500 + 38 000 = 69 500) (1)	2
		(ii)		No time for heat transfer	1
				Question 4 Total	**[14]**

Question				Marking details	Marks Available
5	(a)	(i)		$g = \frac{GM}{r^2}$ used (1)	
				Answer = 3.7 m s^{-2} or N kg^{-1} or equivalent (1) **UNIT MARK**	2
		(ii)		$V_g = -\frac{GM}{r}$ used (1)	
				Answer = ± 9.02 [MJ kg^{-1}] (1) **ecf** on km conversion	2
		(iii)		Negative amount of work bringing mass from ∞ (accept no work done bringing from ∞ or system will do work or work is done in the other direction etc.)	1
	(b)	(i)		$PE = V_g \times m$ or implied (1)	
				$KE = \frac{1}{2}mv^2$ used (1)	
				Answer = 656 kJ - 4.1 MJ = - 3.44 [MJ] (1)	3
		(ii)		$-\frac{GMm}{r} = -3.44$ MJ (1)	
				r = 2 905 km (1)	
				Height = 465 [km] (1) **ecf**	3
				Question 5 Total	**[11]**

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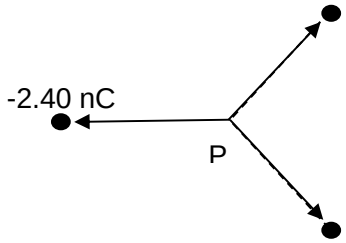
Question				Marking details	Marks Available
6	(a)			Arrows pointing towards charges similar to shown ✓✓  Arrows pointing away from charges similar to shown ✓	2
	(b)			$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ used (1) The 2 vertical components cancel or no field into or out of page (1) Pythagoras or trig e.g. $\sqrt{5^2 - 4^2} = 3$ or recognising 3,4,5 triangle (equivalent is to realise cos θ = 3/5 or $\theta = 53^o$ etc.) (1) 2 nC charge field x2 **and** x3/5 **ecf** (for horizontal components) (1) Calculations all ok e.g. 8 640 = 7 200 x 2 x 3/5 or equivalent shown (1)	5
	(c)			$V = \frac{Q}{4\pi\varepsilon_0 r}$ used (1) Attempt at adding all 3 potentials (1) - 360 -360 - 432 = - 1 152 V or J C^{-1} or equivalent (1) **UNIT MARK**	3
	(d)			Use of PE = $q\Delta V$ must be a change (1) Rearrangement i.e. $v^2 = \frac{2\times PE}{m}$ allow **ecf** on V (1) Answer = 18.3 x 10^6 [m s^{-1}] (**ecf** only if a ΔV used) (1)	3
				Question 6 Total	**[13]**

Question				Marking details	Marks Available
7	(a)			$T = 2\pi\sqrt{\frac{(1.4\times10^{10})^3}{6.67\times10^{-11}\times(1.6\times10^{29}+3.7\times10^{27})}}$ (1) Answer = 3.15 x 10^6 [s] or implied (3.19 x 10^6 s if M_2 omitted) (1) 36.5 [days] (1) (36.9 if M_2 omitted gets 2/3)	3
	(b)	(i)&(ii)		$r_1 = \frac{M_2}{M_1+M_2}d$ used or $M_1r_1 = M_2r_2$ used (1) Star orbit radius = 0.032 x 10^{10} [m] (1) Planet orbit radius = 1.37 x 10^{10} [m] (1)	3
	(c)	(i)		$v = \frac{2\pi r}{T}$ or $v = \omega r$ and $\omega = 2\pi f$ (1) $v = \frac{2\pi\times0.032\times10^{10}}{3.15\times10^6}$ (= 631) (1) **ecf**	2
		(ii)		$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ values substituted or not possible (1) Answer = 3.9 [pm] because mean radial speed unknown (1) Don't penalise using 2 x v if explained	2
				Question 7 Total	**[10]**

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