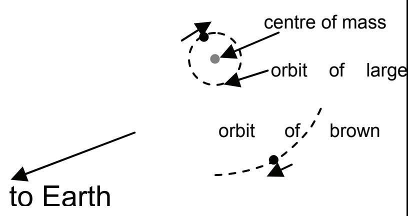
PH4 Mark Scheme – January 2010

Question			Marking details	Marks Available
1	*(a)*		Acceleration $\propto$ displacement [from a fixed point] (1) and directed towards a fixed point (1) **Or** $a = [-]\omega^2 x$ (1); – sign **and** defined a and x, ω^2 a constant(1)	2
	(b)	(i)	$T = 2\pi\sqrt{\frac{m}{k}}$ [or by impl.](1) $T^2 = 4\pi^2 \frac{m}{k}$, i.e. correct squaring [or by impl.](1) $m = 0.127$ kg (1)	3
		(ii)	$\omega\left[=\frac{2\pi}{T}\right] = \frac{2\pi}{0.42\text{ s}}$ ✓[=14.96 [rad] s^{-1}]	1
	(c)	(i)	$v_{max} = \omega A$ (**subs**)(1) = 0.194 m s^{-1} [accept 0.19 or 0.20] (1)	2
		(ii)	$a_{max} = [-]\omega^2 A$ (**subs**)(1) = 2.91 m s^{-2} (1) [no penalty for minus sign in answer; no **2nd** penalty for 10^2 error]	2
	(d)	(i)	$^T/_4$ or 0.105 s	1
		(ii)	**Either** $a = [-]\ 2.91 \sin \omega t$ (1) [or impl.] $\omega t = \sin^{-1}\left(\frac{2.9}{2.91}\right)$ (1) [or impl.] $t = 0.054$ s (1) **or** $a = -\omega^2 x \rightarrow x = 0.0094$ m (1) $0.0094 = 0.13 \sin \omega t$ (**subs**) (1) $t = 0.054$ s (1) [–0.054 s loses 2nd mark, or equivalent wrong sector slip, e.g. 4.2 – 0.054 or even 2.1 – 0.054 etc.]	3
				[14]
2	*(a)*		$p\left[=\frac{h}{\lambda}\right] = \frac{6.63\times10^{-34}\text{ J s}}{620\times10^{-9}\text{ m}}$ (✓) [= 1.07×10^{-27} kg m s^{-1}]	1
	(b)		$1.1 \times 10^{-27} = [\pm]\ 1.1 \times 10^{-27} + mv$ [i.e. accept incorrect sign] (1) $2.2 \times 10^{-27} = 1.67 \times 10^{-27}\ v$ (1) $v = 1.28$ m s^{-1} (1) [$mv = 1.1 \times 10^{-27} \rightarrow v = 0.64$ m s^{-1} – 1 mark only]	3
	(c)	(i)	more energy after collision (1) since photon energies are the same / energy increased by hydrogen KE or $\frac{1}{2}mv^2$ (1)	2
		(ii)	reflected photon has longer wavelength or red shift occurs [or converse argument or frequency argument]	1
				[7]

Question			Marking details	Marks Available
3	*(a)*		$pV = nRT$ (**subs**)(1) $n = \dfrac{60\times10^3\times0.05}{8.31\times278}$ (1) [=1.2986]	2
	(b)	(i)	**Either** $p = \frac{1}{3}\rho\overline{c^2}$ (1)* $\rho = \dfrac{m}{V}$ or $\dfrac{0.171}{0.05}$ (1) c_{rms} = 229 m s^{-1} (1) **or** $pV = \frac{1}{3}Nm\overline{c^2}$ (1) v = 0.05 m^3 **and** Nm = 0.171 (1) c_{rms} = 229 m s^{-1} (1) * Mark lost for incorrect substitution (e.g. of ρ) unless final root taken.	3
		(ii)	Division of m by 1.3 (1) Molar mass =0.132 kg / 132 g ((**unit**)) (1)	2 **[7]**
4.	*(a)*		ΔU – <u>change</u> / <u>increase</u> in *internal energy* Q – *Heat* supplied <u>to the gas /system</u> W – *Work* <u>done by the gas / system</u> Marking – all *italic* terms (1); all <u>underlined</u> terms (1)	2
	(b)	(i)	$W = p\Delta V$ **or** area under graph (1) $= 60\ 000 \times 50 \times 10^{-3}$ $= 3\ 000$ J (1)	2
		(ii)	Use of ΔT or $U_2 - U_1$ (1) ΔU = 4 500 J (1)	2
	(c)	(i)	0	1
		(ii)	Temperature decreases / gas cools / ΔU –ve (1) Heat flows out / Q –ve (1) [**not** 'decrease in heat']	2
	(d)	(i)	Returns to same temperature / point / p, V, T (1) [**or** internal energy depends only on T [accept p, V, T]]	1
		(ii)	attempt at closed area or AB – CD (1) [or by impl.] W [= 20 000 × 0.05] = 1000 J (1) Q = 1000 J (1)	3 **[13]**

Question			Marking details	Marks Available
5	*(a)*	(i)	$g = \frac{GM}{r^2}$ (1) (**subs**) = 1.63 m s^{-2} / N kg^{-1} ((**unit**)) (1)	2
		(ii)	$F = mg$ **or** $F = \frac{GMm}{r^2}$ [or by impl.] (1) F = 3.25 N (1)	2
	(b)	(i)	KE = [½ mv^2] = 1.96 MJ	1
		(ii)	Gravitational PE = [–] $\frac{GMm}{r}$ (**subs**)[**or** $V = -\frac{GM}{r}$ **and** PE = mV] (1) $= -\frac{6.67\times10^{-11}\times7.35\times10^{22}\times2}{1.74\times10^{6}}$ (1) [= –5.635 MJ] [no sign penalty here]	2
		(iii)	Total incident energy = –3.7 MJ [–3.675 MJ] [e.c.f.](1) $[-]3.7\text{ MJ} = [-]\frac{GMm}{r}$ (1) $r\left[=\frac{GMm}{3.7\times10^{6}}\right]$ = 2.67 × 10^6 m [or by impl.](1) height = 0.93 ×10^6 m (1) [Errors from mistake over signs → –1; 0.60 × 10^6 m arising from use of *mgh* scores 1 only]	4 **[11]**
6	*(a)*		$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ (**subs**)(1) [or by impl.] = 2.33 × 10^{-7} N (1)	2
	(b)	(i)	Arrows drawn from **P** directed away from the 2 +3.6 nC charges	1
		(ii)	[Vertically] up[wards] **or** correct double arrow shown [e.c.f.]	1
		(iii)	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$ (**subs**)(1) [or by impl.] = 129.5 V m^{-1} (1) $E_{\text{Total}} = \sqrt{129.5^2 + 129.5^2}$ **or** 2 × 130 sin 45° / cos 45° (1) [freestanding, i.e. $E_{\text{Tot}} = E_{\text{indiv}} \times \sqrt{2}$ gets 3$^{\text{rd}}$ mark] = 183.1 V m^{-1} / N C^{-1} ((**unit**)) (1) [91.6 V loses only 1 mark]	4
	(c)		Potential energy = $\frac{Qq}{4\pi\varepsilon_0 r}$ **or** $V = \frac{Q}{4\pi\varepsilon_0 r}$ (**subs**)(1) attempt at adding both PEs or potentials <u>as scalars</u> (1) Work done = 1.295 × 10^{-7} J (1) [0.65 × 10^{-7} J loses only 1 mark]	3 **[11]**

Question			Marking details	Marks Available
7			Objects [seem to] travel too fast at large distances from centre (1) **Either**: As orbital speed $\propto \sqrt{m}$ (m = enclosed mass) [accept v increases as m increases] (1) this suggests that the galaxy has extra [or hidden] mass (1). Extra mass related to dark matter. **Or**: Far from centre, the mass within the orbit should be ~ constant (1) so orbital speed v should be $\propto \frac{1}{\sqrt{r}}$ (theoretical) (1) So enclosed mass $\propto \sqrt{r}$ for constant v (1) **Alt**: Observed speeds too large [for objects to remain in galaxy] (1) …so equation shows M is 'too large' (1) Speed doesn't fall off [at large distance] as theory suggests so mass extends beyond visible galaxy (1) Extra mass attributed to dark matter (1)	4 **[4]**

Question			Marking details	Marks Available
8	*(a)*		Reasonable orbit of star and companion in mutual orbit shown with Earth shown or direction towards Earth (1). Star orbits the centre of mass[accept 'common point'] [of the binary system] (1)  Sensible comment relating radial velocity and position in diagram (1)[e.g. – in position shown – red shift – longer wavelength; ½ orbit later – towards Earth so blue shift]	3
	(b)	(i)	1700 [± 50] m s^{-1}	1
		(ii)	$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ (1) (**subs** v and c)[or by impl.] $\Delta\lambda \left[= \frac{1700[\text{ecf}] \times 600 \times 10^{-9}}{3 \times 10^{8}} \right] = 3.4 \times 10^{-12}$ m (1) [No penalty for subsequent addition of $\Delta\lambda$ to λ]	2
	(c)	(i)	170 [± 2] days	1
		(ii)	$v = \frac{2\pi r}{T}$ [**or** $v = \omega r$ **and** $\omega = \frac{2\pi}{T}$] (1) $r = \frac{1700 \times 170 \times 24 \times 60 \times 60}{2\pi}$ [e.c.f.][= 3.97 × 10^{9}]m (1)	2
	(d)		$T = 2\pi\sqrt{\frac{d^3}{G(m_1 + m_2)}}$ (**subs**)(1) $d = \sqrt[3]{\frac{T^2 GM}{4\pi^2}} = 6.63 \times 10^{10}$ m (1)	2
			Either $r_1 = \frac{m_1}{m_1 + m_2} d$ (**subs**)(1) $m_2 = \frac{m_1 r_1}{d - r_1} = 5.1 \times 10^{28}$ kg (1) **Or** $m_1 r_1 = m_2 r_2$ (1) $m_2 \approx \frac{m_1 r_1}{d}$ since $d \gg r_2$ $m_2 = 4.8 \times 10^{28}$ kg (1) [or 4.4 × 10^{28} kg if 7 × 10^{10} m used]	2
				[13]

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