PH4 Mark scheme – January 2011

Question			Marking details	Marks Available
1.	*(a)*	(i)	$pV = \frac{1}{3}Nm\overline{c^2}$ or $p = \frac{1}{3}\rho\overline{c^2}$ used. (1) Correct use of N and m **or** ρ = 11.0 kg m^{-3} (1) $c_{\text{r.m.s.}}$ = 286 m s^{-1} (1)	3
		(ii)	$M_r = \frac{1.39\times10^{-25}}{1.66\times10^{-27}}$ (1) = 84 (1)[or $M_r = m/\text{g} \times N_A$] [No unit penalty] [N.B. Alternatives available: 1 mark method; 1 mark answer – factor of 10^3 error → method mark available]]	2
		(iii)	$pV = nRT$ used (1) $n = \frac{1.7\times10^{20}}{6.02\times10^{23}}$ (1) [N.B. The mark might be earned in (ii)] T = 275 K (1)	3
	(b)		Gets bigger (1) because pressure decreases [and T is ~ constant] (1). [Accept: …. because it collects dissolved gas(es) or because temperature increases as bubble rises]]	2 **[10]**
2.	*(a)*		ΔV = 0 / no change in volume	1
	(b)		Work done = area under graph or by impl. [i.e. area calc attempt] (1) Work done [= [–]1.5 × 10^5 × 4.0 × 10^{-3}]= [–] 600 J (1) Minus sign (1) [free-standing mark] [NB Any reasonable method of determining area, including counting squares ✓]	3
	(c)		ΔU: change [or increase] in internal energy of …(1) Q: heat supplied ["heat in" etc. – direction must be indicated] to ……(1) W: work done by …..(1) [NB: **not** "by or on"] [Subtract 1 mark if "gas" or "system" not mentioned at least once].	3
	(d)		Attempt at area inside the cycle or Area $_{\text{BC}}$ – Area $_{\text{DA}}$ (1) Area / W [= 0.675× 10^5 × 4.0 × 10^{-3} – 600] = – 350 J (1) ∴ Q = –350 J (1) [NB final step must be explicit – leaving answer for W doesn't gain the final mark]	3 **[10]**

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3			Sample answer: Microwave oven [although away from central resonance] (1). Driving force: the [e-m fields of the] microwaves (1) Oscillating System: rotation [accept vibration] of <u>water</u> molecules (1) Result: Increased [accept large amplitude] rotational k.e. (1) General scheme: 4 distinct points needed → 4 × (1) Diagram / statement of application [e.g. bridge, car rattle…] ✓ Description of plausible oscillating driving force ✓ Description of plausible system ✓ Large <u>amplitude</u> because of same frequency [or graph showing resonance, with labelled axes]✓	4 **[4]**
4.	*(a)*		$r_1 = \frac{m_2}{m_1 + m_2}d$ <u>used</u> [or $m_1r_1 = m_2r_2$] (1) $r_1 = 7.43 \times 10^8$ m (1)	2
	(b)		<u>Use</u> of relevant eq^n: $T = 2\pi\sqrt{\frac{d^3}{G(m_1 + m_2)}}$ or $2\pi\sqrt{\frac{d^3}{GM}}$ or $\frac{GM}{r^2} = \frac{mv^2}{r}$ (1) $T = 3.75 \times 10^8$ s (1) Division by (24 × 60 × 60 × 365[.25]) or equiv (1) [=11.88 year]	3
	(c)		$v = \frac{2\pi r}{T}$ [or $v = \omega r$ **and** $\omega = \frac{2\pi}{T}$] (1) $v = \frac{2\pi \times \text{ answer } (a)}{\text{answer } (b)}$ (1) [= 12.46 m s^{-1}]	2
	(d)		Doppler shift calculated: $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \rightarrow \Delta\lambda = \frac{v\lambda}{c} = 5.3 \times 10^{-14}$ m (1) Upper λ value labelled: 1.28 μm / $\lambda_{[0]}$ + 5.3×10^{-14} m (1) Lower λ value labelled: 1.28 μm / $\lambda_{[0]}$ – 5.3×10^{-14} m (1) [Alternatively for 2nd and 3rd marks, indication on the graph that the amplitude of the variation is 5.3×10^{-14} m, e.g. peak to peak $\Delta\lambda$ is shown as 10.6×10^{-14} m] Period labelled: 12 years / 3.75×10^8 s (1)	4 **[11]**

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5.	(a)		[centripetal force =] $m\omega^2 r$ [or $\omega^2 r$ and ma] (1) $F = 32.5 \times 1.4^2 \, r$ [$= 63.7\, r$] (1) Friction [of the surface on the shoes] provides centripetal force [or is the resultant etc.] (1) [Accept $F = m\omega r^2$ for 1st and 3rd marks as F is defined in the question]	3
	(b)		$63.7\, r = 114$ [N] (1) $r = 1.79$ **and** relevant comment, e.g. if r greater, $F > 114$ N (1) [Alt: Subst $r = 1.8$ m and comment that F > 114 N]	2
	(c)		$T = \frac{2\pi}{\omega}$ [or by impl.] (1) = [$\frac{2\pi}{1.4}$ =] 4.49 s (1)	2
	(d)		$v = \omega A$ [or by impl.] (1) = [$1.4 \times 1.8 =$] 2.52 m s^{-1} (1) [If $v = A\omega \cos \omega t$, or equiv, then $\cos \omega t = 1$must be stated for 1st mark]	2
	(e)		$a = \omega^2 A$ [or by impl.] (1) = [$1.4^2 \times 1.8 =$] 3.53 m s^{-2} (1) occurs at the extremities / when $x = \pm A$ etc. (1) [If $a = A\omega^2 \cos \omega t$, or equiv, then $\cos \omega t = 1$must be stated for 1st mark]	3
	(f)		At least one cycle of wave drawn with correct amplitude [1.8 m e.c.f.] (1) Reasonable shape of sinusoid + correct period + correct phase [i.e. sin wave] (1)	2
	(g)		Use of $-1.00 = \sin \omega t$ (1) $1.4t = \sin^{-1}\left(\frac{-1}{1.8}\right)$ (1) [= – 0.59] $t = -0.42$ s (1) [Mysterious loss of – sign loses 1 mark] $t_1 = \frac{T}{2} + 0.42$ [2.42 s] **and** $t_2 = T - 0.42$ [4.07 s] (1) Max 2 marks for reading from graph ± 0.1 s, i.e 2.6, 2.7 s ✓ 4.0, 4.1 s ✓	4 **[18]**

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6.	*(a)*		$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{519.8\times10^{-9}}$ = 1.275 × 10^{-27} kg m s^{-1} / Ns ((**unit**))	1
	(b)		$p = mv$ = 9.11 × 10^{-31} × 1400 (1) = 1.275 × 10^{-27} kg m s^{-1} $\therefore$ momenta cancel or sum = 0. [Comment needed] (1)	2
	(c)		Yes – momenta cancel afterwards also. [i.e. Yes + sensible comment, e.g. reflection symmetry, e.g. wavelength and speed unchanged. Accept mention of C of M frame]	1
	(d)		Loss of photon energy (1) = gain in kinetic energy [of electron] (1) [“Photon energy decreases; Electron KE increases” → 1 mark]	2 **[6]**
7.	*(a)*		Use of $\frac{GMm}{r^2}$ (1)[or by impl.] = $\frac{6.67\times10^{-11}\times1.99\times10^{30}\times1.31\times10^{22}}{(7.38\times10^{12})^2}$ Force = 3.19 × 10^{16} N (1)	2
	(b)		$\frac{GM_1}{r_1^2} = \frac{GM_2}{r_2^2}$ (1) $\frac{r_2^2}{r_1^2} = \frac{m_2}{m_1}$ (1) $\frac{r_2}{r_1}$ = 8.11 × 10^{-5} (1) → r_2 = 6 × 10^8 m (1) Alt: $\frac{GM_1}{r_1^2} = \frac{GM_2}{(d_1 - r_1)^2}$ (1) $M_1(d - r_1)^2 = M_2 r_1^2$ (1) remaining algebra (1)	4
	(c)		GPE = [–]$\frac{GMm}{r}$ [or V = [–]$\frac{GM}{r}$ **and** GPE = $m\Delta V$] (1) Attempt at calculating 2 PEs or 2 Vs (1) [PEs: –2.36 × 10^{29} and –3.92 × 10^{29}, Vs: 1.8 × 10^7 and 3.0 × 10^7] ΔE_k = [–]ΔE_p = 1.56 × 10^{29} J (1) e.c.f. i.e. the mark is for equating the gain of KE to the loss in PE.	3 **[9]**

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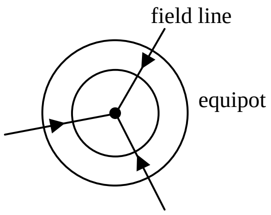
8.	*(a)*		At least 2 field lines shown with correct direction (1) At least two equipotentials surfaces shown [reasonable sketch circles centred on –Q] (1) Labelling (1)  	3
	(b)	(i)	Use of $F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$ (1) = 5.62 N (1)	2
		(ii)	Use of $V = \frac{1}{4\pi\varepsilon_0}\frac{Q_1}{r}$ **and** $\Delta E_\mathrm{p} = q\Delta V$ **or** use of $E_\mathrm{p} = \frac{1}{4\pi\varepsilon_0}\frac{Qq}{r}$ (1) ΔE_p = [–] 0.45 J (1) $\therefore E_{\mathrm{k\ [max]}}$ = 0.45 J [explicit] (1)[NB Free-standing mark – awarded if KE gain = PE loss stated]	3
	(c)		Use of $E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ (1) = 2.81 × 10^6 V m^{-1}(1) Horizontal cpts cancel $\therefore$ direction down [could be in diagram] or stated algebraically, e.g. $2E\cos\theta$ (1) E_res [= $2E\sin\theta = 2\times\frac{3}{5}\times 2.81\times 10^6$]= 8.6 × 10^6 V m^{-1} [or N C^{-1}] (1) ((**unit**))	4 **[12]**