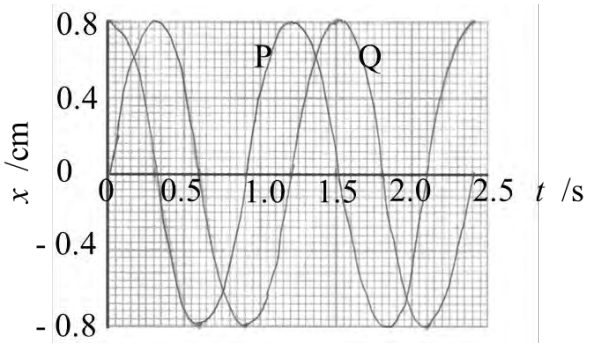
PH4

Question			Marking details	Marks Available
1	*(a)*	(i)	Any 4 from the following (1 mark for each): - the oxygen molecules move at random / in all directions - the molecules strike [the walls of] the container [and rebound] - rate of change of momentum of the molecules when they strike the wall is equal to the force exerted by the wall on the molecules (Newton's second law of motion). - force on the wall is equal and opposite to the force on the molecules (Newton's third law of motion). - pressure is the force per unit area on the walls of the container. **Award a maximum of 2 marks** if no reference made to Newton's laws	4
		(ii)	I. N: number of molecules [in the container] (1) II. m: mass of one molecule (1) III. $\overline{c^2}$: mean square speed [of the molecules] (1)	3
	(b)	(i)	$n = \frac{pV}{RT} = \frac{(4\times10^5)(0.7)}{(8.31)(288)}$ (substitution (1)) $= 117$ [mol] (1)	2
		(ii)	$pV = \frac{1}{3}Nm\overline{c^2}$ $\sqrt{\overline{c^2}} = \sqrt{\frac{3pV}{Nm}}$ (rearrange (1)) $\sqrt{\overline{c^2}} = \sqrt{\frac{3pV}{n(32\times10^{-3})}}$ correct incorporation of relative mol. mass (1) $\sqrt{\overline{c^2}} = \sqrt{\frac{3(4\times10^5)(0.7)}{(117)(32\times10^{-3})}} = 473.7$ m s^{-1} (1) **UNIT mark**	3
	(c)		One of the following (or equivalent) …….(1): Volume of molecules not negligible. Force exerted on walls less due to the attraction by other molecules. Intermolecular forces not negligible. Accept: oxygen diatomic / density too high Collisions not elastic PE not zero	1
			Question 1 Total	**[13]**

Question			Marking details	Marks Available
2	*(a)*		Acceleration is - [directly] proportional to the displacement [from a fixed point] (1) - directed towards the fixed point (1)	2
	(b)		$T = \frac{24}{20} = 1.2$ [s]	1
	(c)		$\omega = 2\pi f = 2\pi\left(\frac{20}{24}\right)$ (formula and subs. **ecf** from (b)(1)) $= 5.2$ [rad s^{-1}] (1)	2
	(d)		$x = 0.8$ (amplitude (1)) $\sin\left(5.2\ (\omega\,(1))t + \frac{\pi}{2}\ (\text{phase (1)})\right)$ cm [or use ω = 5 rad s^{-1} or phase = 90°]	3
	(e)		$0.4 = 0.8\sin\left(5.2t_1 + \frac{\pi}{2}\right)$ $\quad -0.3 = 0.8\ \sin\left(5.2t_2 + \frac{\pi}{2}\right)$ $t_1 = [-]0.201$ [s] (1) $\quad t_2 = [-]0.376$ [s] (1) $\Delta t = t_2 - t_1 = 0.376 - 0.201 = 0.175$ [s] (1) **ecf** from (d) [If using ω = 5 rad s^{-1}, $t_1 = 0.209$ [s] (1) $t_2 = 0.391$ [s] (1) $\Delta t = t_2 - t_1 = 0.391 - 0.209 = 0.182$ [s] (1)]	3
	(f)		 Curve for P (1) Curve for Q relative to P (1) Axes labelled with units and scales (1) **ecf** for *A*, phase and *T*	3
	(g)		$x = 0.8\sin 5.2t$ [cm] (or equivalent) Allow **ecf** if curve in *(f)* is incorrect, but consistent with *(g)*	1
			Question 2 Total	**[15]**

Question			Marking details	Marks Available
3	*(a)*			

	Temperature T /K	Internal Energy U /J
A	*369.7*	*9217*
B	*317.7*	*7920*
C	278.[0]	6931/ 6930
D	*323.5*	*8065*

(1 for value of T; 1 for value of U) **ecf** for U if T incorrect — 2

(b) (i) Work done by gas A→B = 0

(ii) Work done by gas B→C = -660 [J]

(iii) Work done by gas C→D = 0

(iv) Work done by gas D→A = 768 [J]

(v) Work done by gas A→B→C→D→A (net work done during cycle) = 768 – 660 = 108 [J] **ecf**

1 mark each for (ii), (iv) and (v); 1 mark for both (i) and (iii) — 4

(c) $\Delta U = Q - W$ i.e. application of equation for the first law of thermodynamics (1)

C→D $8\,065 - 6\,931 = Q_{CD} - 0$ $Q_{CD} = 1\,134$ [J] / 1 135
D→A $9\,217 - 8\,065 = Q_{DA} - 768$ $Q_{DA} = 1\,920$ [J]
Either of these two lines correct (1)

Heat absorbed = 1 134 + 1 920 = 3 054 [J] / 3 055 (1) — 3

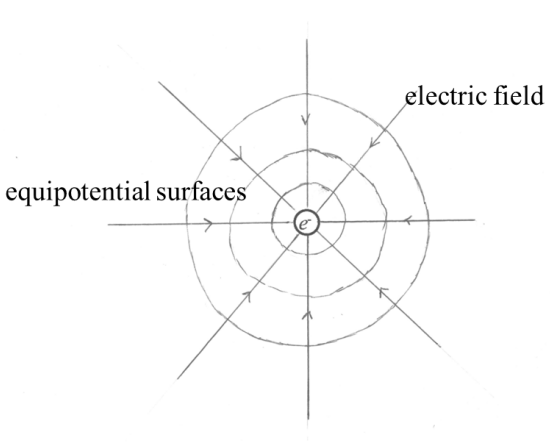
(d) Efficiency $= \frac{108}{3054} \times 100\%$ (substitution (1)) $= 3.54[\%]$ (1) **ecf** on 108

[If using heat absorbed = 3 000 J; Efficiency = 3.60%] — 2

Question 3 Total — **[11]**

Question			Marking details	Marks Available
4	*(a)*	(i)	Application of conservation of momentum (1) $(0.36 + 0.18)v = (0.36 \times 0.40) + \big(0.18 \times (-0.10)\big)$ correct eqn(1) $0.54v = 0.126$ $v = 0.23$ [m s^{-1}] to the right (1) – direction may be by implication	3
		(ii)	Initial KE $= \frac{1}{2}(0.36)(0.4)^2 + \frac{1}{2}(0.18)(-0.10)^2 = 0.0297$ [J] (1) Final KE $= \frac{1}{2}(0.36 + 0.18)(0.23)^2 = 0.0143$ [J] (1) KE lost $= 0.0297 - 0.0143 = 0.0154$ [J] as percentage: $\frac{0.0154}{0.0297} \times 100\% = 51.85[\%]$ (1)	3
	(b)	(i)	$hf = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3\times10^{8})}{(633\times10^{-9})}\big(\text{subs. (1)}\big) = 3.14 \times 10^{-19}$ [J] (1)	2
		(ii)	$N = \frac{(1\times10^{-3})}{(3.14\times10^{-19})}$(substitution (1)) $= 3.18 \times 10^{15}$ (1)	2
		(iii)	component of momentum $= \frac{h}{\lambda}\cos 30°$ $= \frac{(6.63\times10^{-34})}{(633\times10^{-9})}\cos 30° = 9.07 \times 10^{-28}$ kg m s^{-1} **or** N s **UNIT mark**	1
		(iv)	$-N\frac{h}{\lambda}\cos30° - \left(N\frac{h}{\lambda}\cos30°\right) = F \times 1$ (application of N 2nd law (1)) $F = -2(3.18 \times 10^{15})(9.07 \times 10^{-28}) = -5.8 \times 10^{-12}$ N Force on photon = 5.8×10^{-12} [N] (1) Allow **ecf** from (*b*) (iii) for the component of momentum	2
			Question 4 Total	**[13]**

Question			Marking details	Marks Available
5	*(a)*		$\omega = \frac{2\pi(1200)}{60}$ $\big($conversion of units (1)$\big) = 125.7$ [rad s^{-1}] (1) $F = m\omega^2 r = (0.80)(125.7)^2(0.25)\big($subs (1)$\big) = 3160.1$ [N] (1)	4
	(b)	(i)	$R - mg = 3\,160.1$ (1) $R = 3\,160.1 + (0.8)(9.81) = 3\,168$ [N] (1) **ecf** from (a)	
		(ii)	$R + mg = 3\,160.1$ $R = 3\,160.1 - (0.8)(9.81) = 3\,152$ [N] (1) **ecf** from (a)	3
	(c)		Resonance – frequency of rotation matches the natural / resonant frequency of vibration of the saucepan [lid] (1) [When the spin rate decreases,] the frequencies no longer match / so no resonance (1)	2
			Question 5 Total	**[9]**

Question			Marking details	Marks Available
6	*(a)*			
		(i) & (ii)	Correct diagram – 2 or more circles and 3 or more roughly symmetrical lines (1) Correct arrows and labels (1)	2
	(b)		$V = -\frac{1}{4\pi\varepsilon_o}\frac{q}{r} = -\frac{1}{4\pi(8.85\times10^{-12})}\frac{1.60\times10^{-19}}{2.00\times10^{-3}}$ (subs. (1))	
			$= -7.19\times10^{-7}$ [V] (1)	2
	(c)		Use of $W = q\Delta V$ (1) $= (-1.60\times10^{-19})\left(-1.20\times10^{-6} - (-7.19\times10^{-7})\right)$ $= 7.70\times10^{-26}$[J] (1)	2
	(d)		$F_C = \frac{1}{4\pi\varepsilon_o}\frac{q^2}{r^2} = \frac{1}{4\pi(8.85\times10^{-12})}\frac{(1.60\times10^{-19})^2}{(1.20\times10^{-3})^2}$ $= 1.60\times10^{-22}$ [N] $F_G = G\frac{m^2}{r^2} = (6.67\times10^{-11})\frac{(9.11\times10^{-31})^2}{(1.20\times10^{-3})^2} = 3.84\times10^{-65}$ [N] Both F_C and F_G (1) (or by implication) Gravitational force much less [by factor $\sim \frac{3.84\times10^{-65}}{1.60\times10^{-22}} = 2.40\times10^{-43}$] (or equivalent quantitative comparison or qualitative comparison such as **much** larger, **much** smaller) (1) Electrostatic force repels. Gravitational force attracts. (1) Both need to be mentioned for comparison (or equivalent statement).	3
			Question 6 Total	**[9]**

Question			Marking details	Marks Available
7	*(a)*		$27.3 \times 24 \times 60 \times 60 = 2.36 \times 10^6$ [s] (1)	
			$T = 2\pi\sqrt{\dfrac{d^3}{G(M_1 + M_2)}}$	
			$d = \sqrt[3]{\left(\frac{T}{2\pi}\right)^2 G(M_1 + M_2)}$ rearrange (1)	
			$d = \sqrt[3]{\left(\dfrac{2.36 \times 10^6}{2\pi}\right)^2 (6.67 \times 10^{-11})(6.00 \times 10^{24} + 7.34 \times 10^{22})}$ (accept 7.34×10^{22} ignored in formula) substitution (1)	
			$d = 3.85 \times 10^8$ [m] = 385 000 k[m]	3
	(b)	(i)	$x_{cm} = \dfrac{M_2}{M_1 + M_2}\, d$	
			$= \frac{7.34\times10^{22}}{(6.00\times10^{24}+7.34\times10^{22})} \times 3.85 \times 10^8$ (substitution (1))	
			$= 4.65 \times 10^6$ [m] (1) (~ 4 650 k[m])	2
		(ii)	The centre of mass is within the Earth **ecf** (~1 710 km below the surface of the Earth)	1
	(c)		$G\frac{M_1}{x^2} = G\frac{M_2}{(d-x)^2}$ (1) – equality of the two fields in terms of *x*	
			$\left(\dfrac{x}{d-x}\right)^2 = \dfrac{M_1}{M_2}$	
			$x = \left(\frac{M_1}{M_2}\right)^{1/2}(d - x)$	
			$x = \left(\frac{6.00\times10^{24}}{7.34\times10^{22}}\right)^{1/2}(3.85 \times 10^8 - x)$ substitution (1)	
			$x = \left(\dfrac{(9.04) \times (3.85 \times 10^8)}{10.04}\right)$ rearrange (1)	4
			$x = 3.47 \times 10^8$ [m from the Earth] (1)	
			Question 7 Total	**[10]**