Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*	(i)		N = number of molecules **and** m = mass of molecule	1			1		
		(ii)		Use of $\rho = \frac{Nm}{V}$ or equivalent clearly distinguishable (1) Statement that Nm is mass of gas or that ρ is density (1)	2			2	1	
		(iii)		$\sqrt{c^2}$ should be α $\sqrt{\frac{1}{\rho}}$ **or** equivalent e.g. ρc^2 calculated **or** $p = \frac{1}{3}\rho\overline{c^2}$ = 53 000 [Pa] (1) Quoting of data points e.g. (1,400) and (4,200) (1) When ρ is 4×, $\sqrt{c^2}$ is halved **or** ρc^2 constant **or** ρ = constant (1)			3	3	2	
	(b)	(i)		Substitution of $\overline{c^2} = \frac{3\text{x}3.0\text{x}10^5}{0.5}$ (1) c_{rms} = 1.34 × 10^3 [m s^{-1}] (1)	1	1		2	2	
		(ii)		**Either:** Use of $n = \frac{0.025}{4\text{x}10^{-3}} = 6.25$ (1) N = 6.25 × 6.02 × 10^{23} = 3.76 × 10^{24} (1) Mass of molecule = $\frac{0.025}{3.76\text{x}10^{24}}$ = 6.6 × 10^{-27} [kg] (1) Mean KE per molecule = ½ × 6.6 × 10^{-27} × (1.34 × 10^3)^2 = 5.9 × 10^{-21} [J] (1) **Or:** Use of $pV = nRT$ (1) $T = \frac{3\text{x}10^5\text{x}0.05\text{x}4\text{x}10^{-3}}{0.025\text{x}8.3}$ (1) = 289 [K] (1) Mean KE per molecule = $\frac{3}{2}$ × 1.38 × 10^{-23} × 289 = 5.9 × 10^{-21} [J] (1)	1	1 1 1		4	4	
				Question 1 total	**5**	**4**	**3**	**12**	**9**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*			Attempt to use: Electrical energy supplied = power × time (e.g. 2 × 7) (1) 50.4 [MJ] (1) Use of $\Delta U = mc\Delta T$. Tolerate mistakes such as ΔT = 320, 573 (1) ΔU = 40.3 [MJ] (1) Statement or clear implication that 10.1 [MJ] **(ecf)** has escaped from the bricks as heat (1) Clear conclusion that statement is true **(ecf)** available, but if electrical energy < ΔU a comment on its impossibility is needed (1)			6	6	2	
	(b)	(i)		Calculation of one pV **or** T (1) Calculation of second pV **or** T (1) Correct value of T obtained 289 [± 5K] (1) Calculation of third pV **or** T (1) Correct conclusion regarding agreement of values (their data) (1)		1 1 1 1	1	5	4	
		(ii)		Work done = area (1) Method clear (e.g. rectangle + triangle, counting squares) (1) W between 135 [J] and 225 [J] if correct from method used (1) W in range 166 ± 20 [J], **or** if outside, comment on whether likely to be too high or too low (1)	1	1 1 1		4	2	
		(iii)		ΔU = increase (accept *change*) in internal energy **and** Q = heat *in* **and** W = work *out* (**or** work done by system)	1			1		
		(iv)		ΔU = 0 [since gas is ideal and ΔT = 0] (1) Q = answer to *(b)*(ii) so in range 166 ± 20 [J] (1)		2		2		
				Question 2 total	**2**	**9**	**7**	**18**	**8**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*			Use of $\omega = 2\pi f$ tolerate mistakes over units but not attempts to incorporate 0.45 m or omission of 2π (1) 251 [rad s^{-1}] (1)	1	1		2	2	
	(b)	(i)		Use of $mr\omega^2$ **or** $\frac{mv^2}{r}$ with $v = \omega r$ (1) 2 270 [N] **(ecf)** from *(a)* (1)	1	1		2	2	
		(ii)		For the sock, mg = 0.8 [N] (1) Comment that mg << [resultant] force or equivalent (1)			2	2		
	(c)	(i)		Towards cylinder axis (accept circle centre)	1			1		
		(ii)		Straight line towards top of page	1			1		
				Question 3 total	**4**	**2**	**2**	**8**	**4**	**0**

Question				Marking details	Marks available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
4	*(a)*	(i)		0.3 [s]		1		1		
		(ii)		0.9 [s]		1		1		
	(b)	(i)		0.045 [m]	1			1		
		(ii)		T = 0.80 s **or** by implication (1) $\omega =$ 7.85 [rad s^{-1}] tolerate error due to misreading of T (1)		2		2	1	
		(iii)		0 **or** zero		1		1		
	(c)	(i)		Reasonable attempt at sinusoid with period of 0.8 s (1) Inverted displacement-time graph (1)	2			2	2	
		(ii)		Acceleration = $\omega^2 A$ at lowest point (1) So a = (7.85)^2 × 0.045 (1) a = 2.77 [m s^{-2}] (1) **(ecf)** on A and ω $a < g$ so therefore it will not separate (1) **(ecf)**			4	4	2	
				Question 4 total	**3**	**5**	**4**	**12**	**5**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*			System [capable of oscillation] subjected to ['driving'] force (1) Maximum amplitude of oscillation [accept maximum response] at one frequency [of driving force] (1)	2			2		
	(b)			Natural frequency = 2.0 [Hz] (1) Substitution into $T = 2\pi\sqrt{\frac{m}{k}}$ (1) $k = 4\pi^2 mf^2$ **or** $k = \frac{4\pi^2 m}{T^2}$ **or** equivalent re-arrangement of equation at any stage (1) k = 15.8 N m^{-1} **unit mark** (1)	1 1	1 1		4	3	
	(c)			Peak lower and at same frequency or lower (1) Low frequency amplitude unaffected, high frequency amplitude lower or unaltered, so curve blunter (1)	2			2		
				Question 5 total	**6**	**2**	**0**	**8**	**3**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*	(i)		Mass number = 206 (1) Atomic number = 82 (1)		2		2		
		(ii)		**Any 3 × (1) from:** • More data on radon dosage • More data on types of cancer • Safe dosage known • Measurable life of lab rate • Killing animals to get data • Encourages animal terrorism	3			3		
	(b)			Use of $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$ e.g. λ = 0.182 day^{-1} (2.11 × 10^{-6} s^{-1}) or $t = nT_{\frac{1}{2}}$ (1) Logs taken correctly e.g. $\ln A = \ln A_0 - \lambda t$ **or** $\ln A = \ln A_0 - n\ln 2$ (1) Algebra correct e.g. $t = \frac{1}{\lambda}\ln\frac{A_0}{A}$ **or** $n = \frac{1}{\ln 2}\ln\frac{A_0}{A}$ **or** implied (1) Correct answer 13.2 days **unit mark** (1.14 × 10^6 s) (1)	1	1 1 1		4	4	
	(c)			Product nuclei give added activity		1		1		
	(d)			Current = rate of flow of charge **or** equivalent (1) 250 × 1.15 × 10^6 × 1.6 × 10^{-19} = 4.6 × 10^{-11} [A] (1) Assumption – all charges contribute to the current **or** all ions are single charges (1)	1	1 1		3	1	
	(e)			Subtraction of masses (221.9773 – 4.0015 = 217.9758) (1) Conversion of 5.59 MeV to mass (i.e. 0.0060 u **o**r 9.9671 × 10^{-31} kg) (1) Answer = 217.9698 [u] (**or** 3.618299 × 10^{-25} kg depends on u) (1)	1	1 1		3	2	
				Question 6 total	**6**	**10**	**0**	**16**	**7**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*			Alpha present because significant drop after paper (1) Beta not present because no **additional** drop after Al (1) Gamma present because significant **after** Al **or** Pb (1) Absorbers **explained** e.g. paper stops alpha, beta stopped by ~1 mm of Al, 15 cm of Pb for gamma (1)	1		1 1 1	4		4
	(b)			As a check/ensure fair test **or** equivalent (1) In case source activity changing/distance changed/apparatus disturbed etc (1)			2	2		2
				Question 7 total	**1**	**0**	**5**	**6**	**0**	**6**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*			**Factor explanations** F0 – Energy required α mass or $E = mc\Delta T$. F1 – Heat in α surface area. F2 – Increasing thickness – heat must travel further or smaller temperature gradient. **Time** T0 – Energy α time or energy = power $\times$ time (of oven). T1 – Time α mass. T2 – Time α 1/area. T3 - Time increases as thickness increases. **5-6 marks** All of F0 – F2 are present. At least 3 from T0 – T3 are present. There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3-4 marks** Expect 2 from F0 – F2. Expect 2 from T0 – T3. There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure. **1-2 marks** 1 from F0 – F2 is present. 1 from T0 – T3 is present. There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure. **0 marks** No attempt made or no response worthy of credit.		6		6		

	(b)			Per unit mass is missing	1			1		
	(c)			$22 \times 1{\cdot}26 = 27{\cdot}7$ [cm]		1		1		
	(d)			$\frac{0.46}{1.59} = 0.29\,[\text{m}^2]$		1		1		
	(e)	(i)		$E = mc\Delta T$ used e.g. = $9 \times 3\,200 \times 90$ (1) Answer = $9 \times 3\,200 \times 90 = 2{\cdot}59$ [MJ] (1)	1	1		2	2	
		(ii)		$P = \frac{E}{t}$ [or by implication] (1) $t = \frac{2\,590\,000}{2200} = 1200\,\text{s}$ (1)	1	1		2	2	
		(iii)		Some detailed account of the 'lost' energy (1) e.g. All the oven and air also need rise in temperature Heat escapes from the oven to the kitchen/room/surroundings Energy goes to change of state of fat/water Clear statement that most of the energy is lost (1)			1 1	2		
		(iv)		Electrical energy used: $2\,200 \times 6.4 \times 60^2$ (1) [=50 688 000 J] Efficiency = 2 590 000 / 50 688 000 **(ecf)** = 0.051 **or** 5.1% (1)		1 1		2	2	
		(v)		Less than (1) Thermal energy required is only ½ that of 9.0 kg turkey (1) But cooking time >½ that required (1)			1 1 1	3		
				Question 8 total	**3**	**12**	**5**	**20**	**6**	**0**