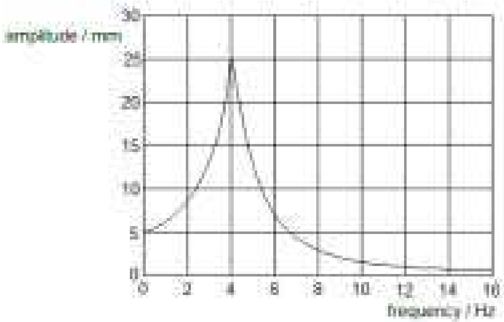
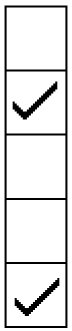
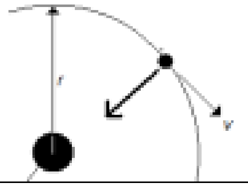
G494 Rise and Fall of the Clockwork Universe

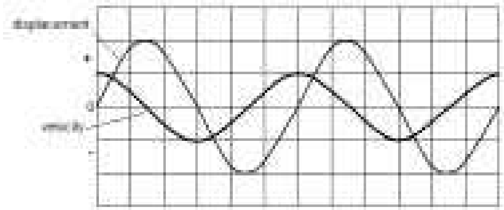
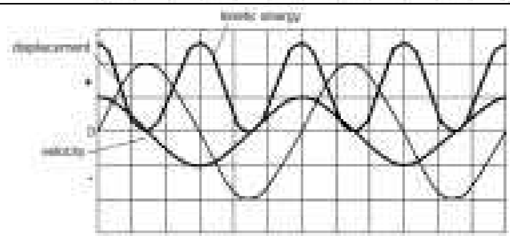
Question			Expected Answers	Marks	Additional Guidance
1	(a)		J kg^{-1}	1	
	(b)		N s	1	look for capital n, not lower case
2	(a)		$\lambda = 1.3\times10^{-5}$	1	accept 1.28×10^{-5} but not 1.2×10^{-5} (incorrect rounding)
	(b)		the probability per second; of a decay / change of a (single) nucleus/atom	1 1	accept chance per second / unit time look for mention of nucleus or atom, but not particle / sodium-24 ... accept alternative answer: fraction of nucleii / atoms for [1] decaying per second for [1]
3	(a)		$\Delta p = (0.15 \times 5) \times 700 = 525$ kg m s^{-1}	1	accept correct reverse calculation: e.g. 500 kg m s^{-1} gives 4.8 s for [1]
	(b)		$p_{initial}$ = 120 x 60 = +720 Ns p_{final} = +720 - 525 = 195 Ns v_{final} = +195 / 120 = 1.6(3) m s^{-1}	2	evidence of correct calculation of initial momentum (±) for [1] ecf: 500 kg m s^{-1} gives 1.8(3) m s^{-1} for [2] ignore sign of final answer alternative method for [2]: change of velocity = 525/120 = 4.38 m s^{-1} final velocity = 6.0 – 4.38 = 1.6(3) m s^{-1} allow [1] for correct change of velocity allow final mass of astronaut = 119.25 kg to give 1.6(4) m s^{-1}
4	(a)		$\gamma = 1.3\underline{4}$	1	look for more than just 1.3
	(b)		1.1×10^{-6} s	1	
5	(a)		minus (-); 4.9×10^{9} J	1 1	look for minus sign with their final answer (from whatever formula)
	(b)		A	1	
6	(a)		A	1	
	(b)		C	1	remember **All** **A**ble **C**andidates

Question			Expected Answers	Marks	Additional Guidance
7			25 mm peak at 4 Hz; tends towards zero above 4 Hz; 5 mm at 0 Hz; 	1 1 1	look for maximum at 4 Hz, sharpness of peak is not important must be at or below 2.5 mm at 16 Hz (by eye) must be at 5 mm at 0 Hz (by eye)
8			Microwave radiation from the universe can be detected in all directions. The red-shift of lines in a galaxy's spectrum is proportional to its distance from our galaxy. 	1 1	correct pattern of ticks for [2] one mistake for [1] a mistake is: • a tick in the wrong place • a missing tick • an extra tick accept any unambiguous correct response
			Total Section A	**20**	

Question			Expected Answers	Marks	Additional Guidance
9	(a)	(i)	$N = PV/kT$; $T_A = 27 + 273 = 300$ K; $N = 1.1(4)\times10^{22}$	1 1 1	evidence of this rule (as algebra or subsitution of numbers) [1] accept $PV = NkT$ or nkT or nRT or NRT as the rule correct conversion of °C to K for [1] ecf incorrect conversion of °C to K e.g. T_A = 27 K gives 1.3×10^{23} for [2] correct reverse calculation for [3]: $N = 1\times10^{22}$ gives T = 343 K for [2] and therefore 70°C for [1] $N = 1\times10^{22}$ and T = 300 K gives $V = 4.2\times10^{-4}$ m^3 for [3] $N = 1\times10^{22}$ and T = 300 K gives $P = 8.8\times10^4$ Pa for [3] use of $k = 1.38\times10^{-23}$ gives $N = 1.16\times10^{22}$ for [3]
		(ii)	$P_B = 20\times10^5$ Pa; full value N from (i) gives T_B = 750 - 273 = 477 °C; accept answers rounded to 2 sig fig	1 1	evidence of correct reading off graph for [1] allow P_B = 17 to 21×10^5 Pa for [1] and subsequent calculation for [1] no ecf for P_B = 20 $N = 1\times10^{22}$ gives T_B = 857 K and 584°C for [2] $N = 1.1\times10^{22}$ gives T_B = 779 K and 506°C for [2] $N = 1.14\times10^{22}$ gives T_B = 752 K and 479°C for [2] accept correct reverse calculation for [2] e.g. T = 273 + 500 = 773 K and $N = 1\times10^{22}$ gives $V = 5.4\times10^{-5}$ m^3 [1] comparable to 6×10^{-5} m^3 [1] e.g. T = 273 + 500 = 773 K and $N = 1\times10^{22}$ gives $P = 1.8\times10^6$ Pa [1] comparable to 20×10^5 Pa [1]

Question			Expected Answers	Marks	Additional Guidance
	(b)	(i)	increased their speed/velocity; greater momentum change per collision (with the walls); increases rate of collisions (with walls)	1 1 1	not just increase of kinetic energy look for complete statement for [1] not just more collisions QWC should include the full story for the third mark
		(ii)	number of molecules / particles doesn't change; $T = \frac{PV}{Nk} = \frac{35\times10^{5}\times0.5\times10^{-4}}{1.14\times10^{22}\times1.4\times10^{-23}} = 1096$ K	1 1	NOT just ideal gas *N*: 1×10^{22} gives 1250 K for [1] *V* = 0.6×10^{-4} m^3 gives 1316 K or 1500 K for [1] look for correct method with sensible values and answer between 1522 K and 1090 K
	(c)		work done by gas; equals decrease in internal energy	1 1	for example: gas does work on the piston for [1] work done by gas equals decrease in internal energy for [2]
			Total Q9	**12**	

Question			Expected Answers	Marks	Additional Guidance
10	(a)	(i)	pulses of light/microwaves from Earth reflect from the Moon; speed of light × half the pulse-echo time = distance (owtte); assumes: speed of light same all the way through the journey / same time for both halves of journey	1 1 1	accept EM waves instead of light / microwaves (not IR, UV ...) look for pulses of radiation from Earth to Moon and back to Earth look for how to calculate the distance for [1] accept a formula e.g. $d = ct/2$ accept effect of atmosphere is negligible (on speed of EM wave) QWC candidates who cannot spell correctly cannot earn more than [2]
		(ii)	$t = 27 \times 24 \times 3600 = 2.3\times10^6$ s $v = \frac{2\pi r}{t} = \frac{2\pi \times 3.8\times10^8}{2.3\times10^6} = 1.02\times10^3$ m s^{-1}	1 1	look for correct method of conversion to seconds for [1] accept ecf from incorrect t for [1] e.g. 27 s gives 8.8×10^7 m s^{-1} for [1] 27 × 24 s gives 3.7×10^6 m s^{-1} for [1] 27× 24 ×60 s gives 6.1×10^4 m s^{-1} [1] accept correct reverse calculation for [2] e.g. v = 1000 m s^{-1} gives 2.4×10^6 s [1] which is 27.6 days [1]
	(b)	(i)		1	arrow from centre of Moon towards centre of Earth for [1] accept arrow pushing Moon towards centre of Earth look for extrapolated arrow passing through Earth.
		(ii)	acceleration / force is at right angles to displacement / velocity so no work is done	1	look for complete argument to award [1]
		(iii)	$F = \frac{mv^2}{r} = \frac{GMm}{r^2}$ v = 1000 m s^{-1} gives 5.7×10^{24} kg v = 1023 m s^{-1} gives 5.9×10^{24} kg	1 1	use of this rule for [1]
			Total Q10	**9**	

Question			Expected Answers	Marks	Additional Guidance
11	(a)	(i)	(model has each atom at centre of a cube of side *d*, so) volume occupied by a single atom is d^3	1	accept volume of an atom/particle is d^3
		(ii)	$d = \sqrt[3]{\frac{m}{\rho}}$ $d = 2.3\times10^{-10}$ m	1 1	correct rearrangement for density with symbols or numbers for [1] award [1] for correct calculation of $d^3 = 1.2\times10^{-29}\ \text{m}^3$
	(b)	(i)	full value *d* from (ii) gives $2.312\times10^{-10} \times 1.3\times10^{11} = 30.1\ \text{N m}^{-1}$	1	$d = 2.31\times10^{-10}$ m gives 30.0 N m^{-1} for [1] $d = 2.3\times10^{-10}$ m gives 29.9 N m^{-1} for [1] $d = 2\times10^{-10}$ m gives 26 N m^{-1} for [1] accept correct reverse calculation for [1] e.g. $k = 30\ \text{N m}^{-1}$, $d = 2.3\times10^{-10}$ m gives $E = 1.30\times10^{11}$ Pa
		(ii)	k/d is $(\text{N m}^{-1})(\text{m}^{-1}) = \text{N m}^{-2}$	1	look for correct units for *k* and *d* combined correctly to give N m^{-2}
	(c)	(i)		1	accept any constant amplitude, look for correct peaks and zero-crossing points across whole timespan, cosine curve. at least one of the curves for (i) or (ii) must be clearly labelled for marks to be awarded.
		(ii)		1	any constant amplitude, must be positive, and correct pattern across timespan ecf incorrect phase of velocity-time graph - peak energy to coincide with peak speed accept full-wave rectified cosine wave
	(d)		$A = 0.15 \times 2.3\times10^{-10} = 3.5\times10^{-11}$ m; $E = kA^2 / 2 = 1.8\times10^{-20}$ J; $T_m = E/k = 1.8\times10^{-20} / 1.4\times10^{-23} = 1280$ K	1 1 1	2×10^{-10} m gives 3×10^{-11} m for [1] 2×10^{-10} m gives 1.4×10^{-20} J for [1] 2×10^{-10} m gives 960 K for [1] look for calculation of amplitude for [1], energy for [1] and T_m for [1] with ecf from one step to the next.
			Total Q11	**10**	

Question			Expected Answers	Marks	Additional Guidance
12	(a)	(i)	$E_T = 1.3\times10^{-20}$ J; $f = E/h = 2.0\times10^{13}$ Hz; $\lambda = c/f = 1.47\times10^{-5}$ m	1 1 1	correct answer for [3] allow ecf from incorrect *E* $E = kT$ gives 2.36×10^{-5} m for [2] allow ecf from incorrect *f* accept 1.5×10^{-5} m
		(ii)	infrared	1	accept any correct and unambiguous response allow ecf from incorrect (i) X-rays below 1×10^{-9} m ultraviolet from 1×10^{-9} m to 4×10^{-7} m visible from 4×10^{-7} m to 8×10^{-7} m infrared from 8×10^{-7} m to 1×10^{-3} m microwaves above 1×10^{-3} m
	(b)		current is determined by rate at which electrons leave the surface owtte; probability that an electron will (have energy ε to) be able to leave the surface (at temperature *T*) is proportional to BF ($e^{-\varepsilon/kT}$);	1 1	accept current is electrons per second owtte for [1] accept proportion of electrons able to leave the surface
	(c)	(i)	$\ln I = \ln C - \varepsilon/kT$	1	look for this formula in the response accept $\log_e$ but not log
		(ii)	gradient = $5.0\times10^4 \pm 0.5\times10^4$ $\varepsilon = 7.0\times10^{-19} \pm 0.7\times10^{-19}$ J	1 1	allow ecf only from incorrect gradient calculation for [1] e.g. $\varepsilon = 7.0\times10^{-22}$ J for [1] watch out for one point from graph instead of gradient for [0]
			Total Q12	**9**	