GCE

Physics B (Advancing Physics)

Advanced GCE

Unit **G494:** Rise and Fall of the Clockwork Universe

Mark Scheme for January 2011

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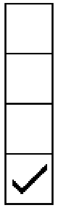
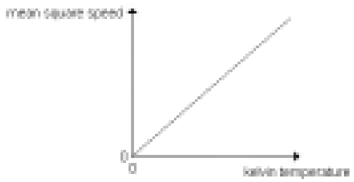
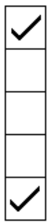
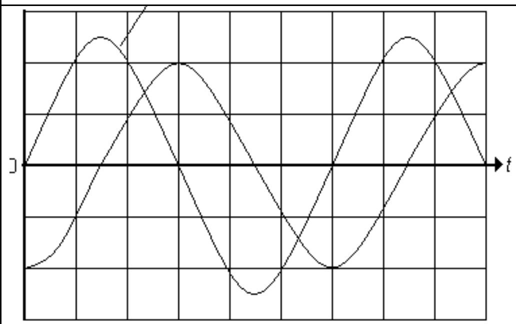
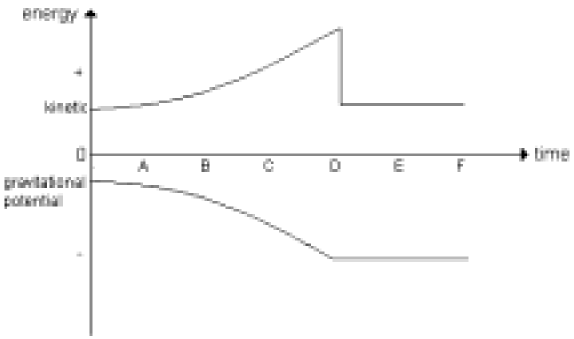
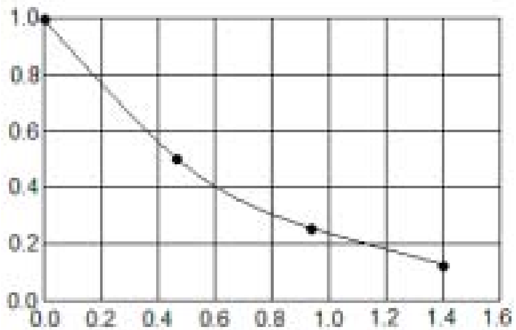
Question			Expected Answers	Marks	Rationale
1	**a**		kg m s^{-2}	1	
	b		m s^{-1}	1	
2				1	
3	**a**		$V = \frac{Q}{C}$	1	not just $Q = CV$
	b		$I = -\frac{dQ}{dt}$	1	
	c		$\frac{V}{R} = -\frac{dQ}{dt} = \frac{Q}{RC}$	1	look for correct substitution for I into answer for (b) (allow ecf) AND correct substitution for V from (a) (allow ecf) **accept** final incorrect answer which matches incorrect answers to (a) and (b)
4	**a**		$\frac{1.1\times10^{-2}}{2.9\times10^{-2}}\times6.0\times10^{23} = 2.28\times10^{23}$ or 2.3×10^{23}	1	2×10^{23} particles gives 9.7×10^{-3} kg for [1]
	b		$\overline{c^2} = \frac{3pV}{Nm}$; $m_{air} = \frac{2.9\times10^{-2}}{6.0\times10^{23}} = 4.83\times10^{-26}$ kg $\overline{c^2} = 2.5\times10^5$ m^2 s^{-2} $N = 2\times10^{23}$ gives 2.9×10^5 m^2 s^{-2} for [2]	1 1	correct substitution into equation for $\overline{c^2}$, perhaps with $m = 1.1\times10^{-2}$ kg or 2.9×10^{-2} kg for [1]; correct evaluation of m and $\overline{c^2}$ for [1] $m_{air} = 2.9\times10^{-2}$ kg gives $4.1(7)\text{X}10^{-19}$ / $4.7(5)\times10^{-19}$ m^2 s^2 for [1] $m_{air} = 1.1\times10^{-2}$ kg gives 1.1×10^{-18} / $1.2(5)\times10^{-18}$ m^2 s^{-2} for [1]
4	**c**			1	look for a straight line through the origin line does not have to be drawn with a ruler

Question			Expected Answers	Marks	Rationale
5	**a**		(shift of) wavelength of (absorption) lines in spectrum of a galaxy	1	**accept** wavelength / frequency
5	**b**		(redshift means) universe is expanding / galaxies are moving away from each other / velocity away us increases with increasing distance; therefore universe / galaxies / stars were at the same point far enough back in time;	1 1	 not just closer together in the past
6			C	1	
7	**a**		16(.43)	1	**not** 20, 115/7
7	**b**		7.3×10^{-8} / 7.5×10^{-8}	1	accept 1.1×10^{-7} from e/kT = 16 accept full ecf from (a)
7	**c**			1	accept any clearly unambiguous correct response
8				1	look for • cosine curve of any constant amplitude • correct period • correct phase amplitude can change by half a square across the graph maxima and minima within the red lines zero crossings within the green lines
9	**a**		$E = 0.5 \times 4700\times10^{-6} \times 20^2 = 0.9(4)$ J	1	must see calculated value
9	**b**		40 W	1	

Question			Expected Answers	Marks	Rationale
10	**a**		force proportional to displacement; force and displacement in opposite directions / force always towards equilibrium position;	1 1	accept force increases with increasing displacement / distance ... accept acceleration for force throughout not just restoring force or minus sign accept wtte for equilibrium position e.g. centre, midpoint ...
10	**b**	**i**	$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = 26(.39)$	1 1	evidence of correct formulae for [1] e.g $T = 2\pi\sqrt{\frac{m}{k}}, f = \frac{1}{T}$ evidence of correct calculation for [1]
10	**b**	**ii**	largest amplitude at 26 / 30 Hz / resonant frequency / natural frequency; amplitude decreases with increasing frequency (above resonance);	1 1	allow ecf from (b)(i) if within 20 Hz to 50 Hz accept small amplitude away from resonance / 26 Hz / 30 Hz ignore sketch graph, award marks for the accompanying words marks are independent, so second mark can be earned if the response doens't mantion resonance.
10	**c**		any of the following [1] each, maximum [3] air acts like a spring because: • as volume decreases pressure increases • because pV is constant (= NkT) • more collisions as particles pushed together • increased transfer of momentum to cone from particles • force from particle impacts restores cone to equilibrium position any of the following [1] each, maximum [3] effects on the frequency: • total k increases • spring and air act in parallel • frequency of free oscillations increases • because $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ or $f \alpha \sqrt{k}$	4	must have correct technical terms throughout for the fourth mark to be awarded. overall mark cannot exceed [4]

Question			Expected Answers	Marks	Rationale
11	**a**			4	one mark for each point, maximum [4]: • KE rises from A to D with correct shape • KE drops suddenly at D to constant value from D to F • GPE drops from A to D with correct shape • total energy constant from A to D (by eye) • GPE constant from D to F • KE is -0.5 GPE (and constant) from D to F use the overlay to help you make judgements vertical part of overlay must pass though D
11	**b**		$\Delta p = 1.2\times10^3 \times 1.8\times10^3 - 9.5\times10^2 \times 1.5\times10^3$ $\Delta p = 7.35\times10^5$ Ns $m_{gas} = 2.5\times10^2$ kg $v = 7.35\times10^5 / 2.5\times10^2$ kg $= 2.9\times10^3$ m s^{-1}	 1 1 1	 correct value of Δp for [1] correct m_{gas} for [1] ecf incorrect Δp, m_{gas} for ecf must have calculated a **change** of momentum
11	**c**	**i**	$\frac{mv^2}{r} = \frac{GMm}{r^2}$ cancellation and rearrangement as required	1 1	not just separate statement of both forces working to final formula must be clear ignore minus signs
11	**c**	**ii**	$r = 1.9(36)\times10^7$ m	1	must have correct rounding to earn mark, but not 2×10^7

Question			Expected Answers	Marks	Rationale
12	**a**		T = 273 + 20 = 293 K $N = \frac{pV}{kT} = 3.17 \times 10^{27}$ accept 3.2×10^{27}	1 1	 ecf incorrect T: e.g. T = 20 K gives 4.6×10^{28} for [1]
12	**b**		energy per particle ≈ kT $\Delta E = 3.2\times10^{27} \times 1.4\times10^{-23} \times (20 - 5) = 6.7\times10^{5}$ J $P = 6.7\times10^{5} / 3600$ = 187 W or 190 W	1 1 1	accept anything from kT to $3kT$ 3×10^{27} particles gives 175 W 3.17×10^{27} particles gives 185 W
12	**c**		EITHER particles have more energy / move faster; particles collide more (often) / greater impact force; particles get further apart / occupy a larger volume; reducing density; OR assuming ideal gas behaviour; V increase as T increases (at constant p, N); so same number of particles occupy larger volume; reducing density; OR $p = \frac{1}{3}\rho\overline{c^2}$ for ideal gas; particles have more energy; $\overline{c^2}$ increases with increasing energy; (p constant) so density reduces	 1 1 1 1	 accept increased rate of change of momentum at impact accept $pV = NkT$ instead of ideal gas behaviour accept volume increases as particle energy increases accept same mass instead of number of particles

Question			Expected Answers	Marks	Rationale
13	**a**	**i**	probability of decay; of a single nucleon in one second;	1 1	accept proportion of nucleons [1] which decay per second [1] accept muon / electron / particle / nucleus / atom for nucleon accept rate of decay as decays per second
13	**a**	**ii**	$0.693/1.5\times10^{-6} = 4.6(2)\times10^{5}\ s^{-1}$	1	
13	**b**	**i**	three half-lives to reduce to one eighth; $t = 3 \times 1.5\times10^{-6} = 4.5\times10^{-6}$ s; $s = 4.5\times10^{-6} \times 3.0\times10^{8} = 1.35\times10^{3}$ m;	1 1 1	accept use of $N = N_0e^{-\lambda t}$ to find t accept working backwards e.g.: 1.4 km gives 4.67×10^{-6} s [1] $e^{-\lambda t} = 0.116$ [1] 1/0.116 = 8.6 [1] 1.4 km gives 3.11 half-lives for [3]
13	**b**	**ii**		1 1	correct shape (falling with decreasing gradient all the way from 0.0 to 1.4 km) for [1] passing through points for [1] (by eye) use overlay for guidance
13	**b**	**iii**	$\gamma = 4/1.35 = 2.96$ / 3.0; time dilation occurs / muon time runs slower than laboratory time / effective half-life longer for muons / effective half-life now 4.4 μs; γ formula to find $v = 2.8\times10^{8}\ m\ s^{-1}$ / $v/c = 0.94(1)$;	1 1 1	1.4 km gives $\gamma = 2.86$ / 2.9

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