RECOGNISING ACHIEVEMENT

GCE

Physics B (Advancing Physics)

Advanced GCE

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

Mark Scheme for January 2011

This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by Examiners. It does not indicate the details of the discussions which took place at an Examiners' meeting before marking commenced.

All Examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the Report on the Examination.

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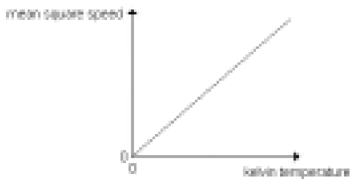
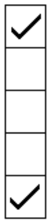
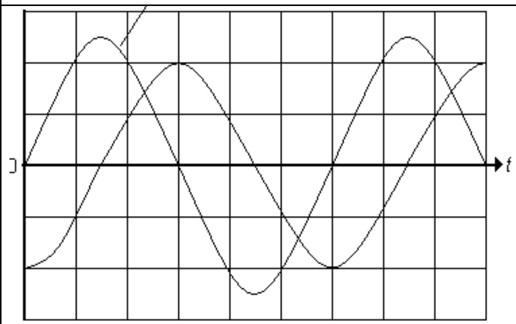
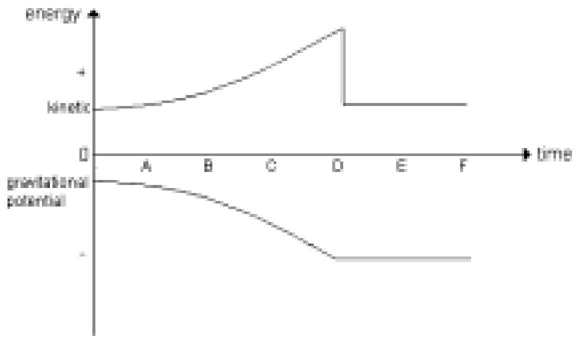
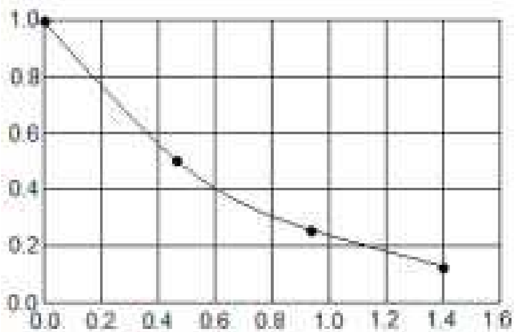
Question			Expected Answers	Marks	Rationale
1	**a**		kg m s^{-2}	1	
	b		m s^{-1}	1	
2			☐ ☐ ☐ ☑	1	
3	**a**		$V = \frac{Q}{C}$	1	not just $Q = CV$
	b		$I = -\frac{dQ}{dt}$	1	
	c		$\frac{V}{R} = -\frac{dQ}{dt} = \frac{Q}{RC}$	1	look for correct substitution for I into answer for (b) (allow ecf) AND correct 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 $9.7\text{x}10^{-3}$ 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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