OCR
Oxford Cambridge and RSA

GCE

Physics B (Advancing Physics)

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

Advanced GCE

Mark Scheme for June 2014

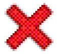
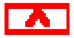
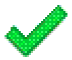
This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

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.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

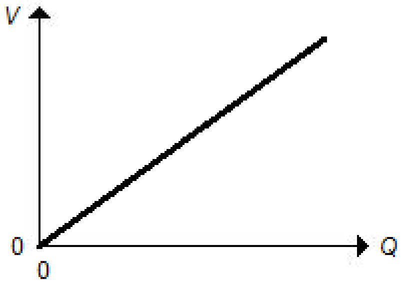
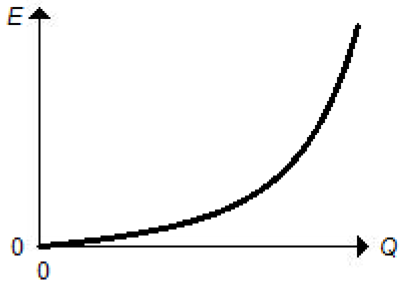
Annotations available in Scoris

Annotation	Meaning
	Blank Page – this annotation **must** be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response
	Arithmetic error
	Wrong physics or equation

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

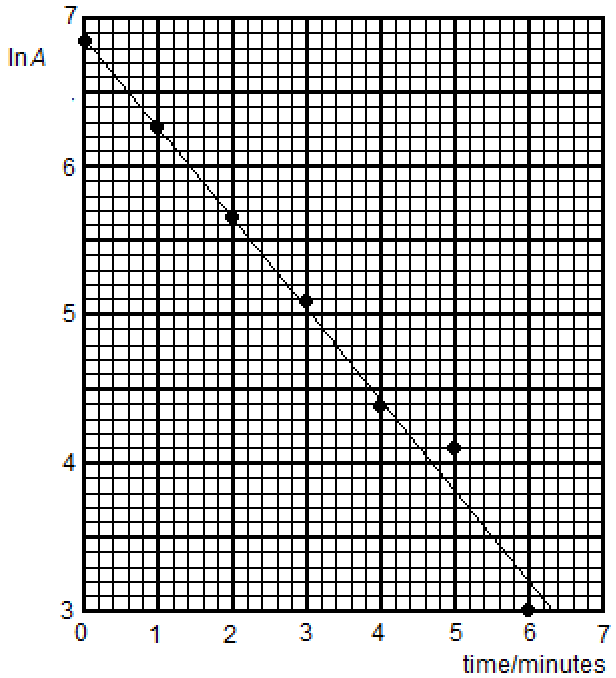
For all calculations, an answer which agrees with the one in the mark scheme to 2 s.f. earns the marks

Question		Answer	Marks	Guidance
1	**a**	kg m s^{-1}	**1**	
	b	kg m^{-1} s^{-2}	**1**	
2	**a**		**1**	any straight line through the origin
	b		**1**	any curve with increasing gradient through the origin
3	**a**	frequency of support equals/matches natural frequency of mass-spring system	**1**	**accept** driving frequency/vibration frequency as frequency of support **accept** resonant frequency as natural frequency
	b	reduces amplitude of oscillations; by transferring energy from it / applying friction;	**1** **1**	**accept** reduces resonant frequency **accept** broadens the peak of the amplitude-frequency (accept graph with labelled axes) **accept** lose energy

Question		Answer	Marks	Guidance
4		T = 273 + {-63} = (210 K); EITHER $(pV) = NkT = \frac{Nm\overline{c^2}}{3}$ $\sqrt{\overline{c^2}}$ = 348 m s^{-1} OR $\frac{1}{2}mv^2 = kT$ v = 284 m s^{-1}	1 1 1	correct conversion to kelvin [1] use of correct relationships [1] evaluation [1] **allow** ecf from incorrect conversion to kelvin for [2] $\frac{1}{2}mv^2 = \frac{3}{2}kT$ gives 348 m s^{-1} for [3]
5		initial momentum = 1.6 × 0.56 - 2.4 × 0.41 = -0.088 N s; final momentum = - 1.6 × 0.55 + 2.4 × 0.33 = -0.088 N s;	1 1	**look for** some working as well as value (2 s.f.) for each mark **accept** either direction as positive **accept** 11/125 as value of total momentum
6		C	1	
7	a	collides with other molecules; then any one of: results in a random/unpredictable change of ▪ velocity ▪ momentum ▪ direction ▪ path length;	1 1	**accept** particles / atoms **accept** interacts as collides **ignore** collisions with walls **look for** randomness clearly associated with change of direction not the timing of collisions **ignore** description of a random walk
	b	distance $\propto \sqrt{N}$ so distance$^2 \propto N$; $N \propto t$ so distance $\propto \sqrt{t}$ so $\frac{\text{distance}}{\sqrt{\text{time}}}$ = constant so $\frac{5}{\sqrt{1}} = \frac{50}{\sqrt{100}}$;	1 1	**accept** just mention of distance $\propto \sqrt{N}$ rule for first mark [1] **accept** argument without algebra e.g 50 mm is 10 x 5 mm, so it needs 10^2 =100 times as many steps so takes 100 times as long;
8		age of universe = $14\times10^9 \times 3.2\times10^7 = 4.48\times10^{17}$ s; distance = $3.5\times10^6 \times 4.48\times10^{17} = 1.6\times10^{24}$ m**;** assumption: • steady expansion of universe • constant (recessional) velocity of galaxy • constant value for H_0;	1 1 1	ecf: award [1] for 1.6×10^{21} m
		Section A Total	**20**	

Question			Answer	Marks	Guidance
9	a		$\frac{mv^2}{r} = \frac{GMm}{r^2}$ then rearrangement and cancellation to $v = \sqrt{\frac{GM}{r}}$	1 1	**look for** $v^2 = \frac{GM}{r}$ as the smallest intermediate step in rearangement and cancellation
	b	i	$v = 1.93\times10^4$ m s^{-1} / $v^2 = 3.72\times10^8$ m^2 s^{-2}; $\frac{1}{2}mv^2 = 9.31\times10^{10}$ J;	1 1	look for correct use of $v = \sqrt{\frac{GM}{r}}$ for first mark **allow ecf** on incorrect value of *v* for second mark **accept** 9×10^{10} J
		ii	EITHER $\Delta E_{GPE} = 6.7\times10^{-11}\times2.0\times10^{30}\times5.0\times10^2\left(\frac{1}{1.5\times10^{11}} - \frac{1}{3.6\times10^{11}}\right)$ ΔE_{GPE} = -2.61×10^{11} J; $E_{KE} = 9.31\times10^{10} + 2.61\times10^{11}$ J = 3.54×10^{11} J; OR total *E* in original orbit = -9.31×10^{10} J; E_{GPE} in Earth orbit = -4.47×10^{11} J; E_{KE} in Earth orbit = $-9.31\times10^{10} + 4.47\times10^{11} = 3.54\times10^{11}$ J; THEN $v = \sqrt{\frac{2E_{KE}}{m}} = 3.76\times10^4$ m s^{-1};	1 1 1 1	use of $V_g = -\frac{GM}{r}$ or $E_{GPE} = -\frac{GMm}{r}$ for [1] calculation of GPE drop for [1] calculation of KE at Earth orbit for [1] calculation of speed at Earth orbit for [1] **no ecf** from one stage to the next **allow ecf** from incorrect E_{KE} in (b)(i)
	c		send a pulse of EM waves (radio, microwaves, light) towards the asteroid (and detect its reflection); $\text{distance} = \frac{(\text{pulse time} - \text{echo time})}{2}\times\text{speed of light}$; EITHER speed of EM waves constant (throughout journey) OR time out same as time back;	1 1 1	**ignore** radar **accept** equivalent in algebra e.g. $d = \frac{\Delta t}{2}c$ with defined Δt QWC for correct assumption **accept** travels at the speed of light throughout the journey **ignore** references to motion of asteroid **not** distance out same as distance back
			Total	**11**	

Question			Answer	Marks	Guidance
10	a		volume = (12.0 × (1.2 + 3.2)/2) × 5.6 = 148 m^3; mass = 148 × 1000 = $1.48×10^5$ kg;	1 1	 **accept ecf** from incorrect volume for [1] **look for** 3 s.f. in correct value for mass
	b		$4.2×10^3$ × $1.48×10^5$ × (30 - 10) = $1.2(4)×10^{10}$ J; any one from • no energy transfers from the water • no energy transfers into the heater • no evaporation of water owtte • specific thermal heat capacity independent of temperature	1 1	$1.5×10^5$ m^3 gives $1.26×10^{10}$ J for [1] **accept ecf** from incorrect mass for [1] **accept** heater is 100% efficient **not** uniform temperature, or constant mass **accept** heat as energy **accept** no energy loss
	c	i	EITHER molecules per kg = $6.0×10^{23}$ / $1.8×10^{-2}$ = $3.33×10^{25}$; energy per molecule = $2.3×10^6$ / $3.33×10^{25}$ = $6.9×10^{-20}$ J OR mass of one molecule $1.8×10^{-2}$ / $6.0×10^{23}$ = $3.00×10^{-26}$ kg; energy per molecule = $2.3×10^6$ × $3.00×10^{-26}$ = $6.9×10^{-20}$ J;	 1 1	
		ii	BF is probability that a molecule / fraction of molecules; can gain enough energy to leave pool / evaporate; through (random) collisions (with other molecules);	1 1 1	**accept** proportion / ratio / percentage **not** number QWC for describing molecule collisions
		iii	$7.2\times10^{-3} = Ce^{-6.9\times10^{-20}/1.4\times10^{-23}\times(273+30)}$; C = $8.34×10^4$; $8.34\times10^4 e^{-6.9\times10^{-20}/1.4\times10^{-23}\times(273+10)} = 2.28\times10^{-3}$ kg s^{-1}	 1 1	 award [1] for method which would eliminate C or give it a value ε = $7x10^{-20}$ J gives C = $1.06x10^5$ and $2.24x10^{-3}$ kg s^{-1} for [2]
			Total	**11**	

Question	Answer	Marks	Guidance
11 a	repeat the procedure without the protoactinium; subtract result from recorded value with protoactinium;	1 1	**accept** count rate as activity but not background radiation
b	$A = -\frac{\Delta N}{\Delta t}(= \lambda N)$; $A = \lambda N_0 e^{-\lambda t}$; $\ln A = \ln(\lambda N_0) - \lambda t$;	1 1 1	look for correct use of minus sign in first step **ignore** $A = A_0 e^{-\lambda t}$ correct algebra which ignores the minus sign can earn [2]
c i		3	best straight line through points [1] **accept** any line through majority of points to meet time axis between 6.0 and 7.0 minutes gradient = -3.85 / (6.30 × 60) = -1.02×10^{-2} s^{-1} [1] **accept** from -0.90×10^{-2} s^{-1} to -1.1×10^{-2} s^{-1} half-life = 0.693 / 1.0×10^{-2} = 69 s [1] accept from 77 s to 63 s **allow ecf** on calculation of half-life from incorrect λ for [1] **accept** pair of data points from graph and use of $A = Ce^{-\lambda t}$ to obtain correct value for [2]
ii	radioactive decay is a random process;	1	
	Total	**9**	

Question			Answer	Marks	Guidance
12	a	i	any one from • collides with walls with no loss of energy • momentum after collision is equal and opposite to momentum before collision • velocity after collision is equal and opposite to velocity before collision;	1	**accept** collisions are elastic / no change of speed / no change in magnitude of momentum **not** moving at right angles to wall
		ii	$\text{time between collisions} = \frac{\text{distance to other face and back}}{\text{speed}}$	1	**accept** travels to right-hand face and back before hitting the left-hand face again owtte **not** just distance = 2*d*
	b	i	$F = (\frac{\Delta p}{\Delta t}) = \frac{mv^2}{d}$ (for one particle); three pairs of faces / three dimensions of box; so *N*/3 particles hit left-hand face;	1 1 1	 **accept** three directions in box look for explicit statement, not just algebra
		ii	particles do not collide with each other / have no interaction / have no size / *N* is a very big number;	1	**not** same temperature / energy / speed / mass / hit faces at right angles / elastic collisions
	c		temperature *T* is proportional to (average) energy of particles; kinetic energy = $\frac{1}{2}mv^2$; then correct manipulation of $\frac{1}{2}mv^2 \propto T$ to achieve $p = \frac{NkT}{V}$;	1 1 1	**accept** energy of a particle is *kT* **not just** $\frac{1}{2}mv^2 = \frac{3}{2}kT$ **or** $\frac{mv^2}{3} = kT$
			Total	**9**	

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