

GCE

Physics B (Advancing Physics)

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

Advanced GCE

Mark Scheme for June 2014

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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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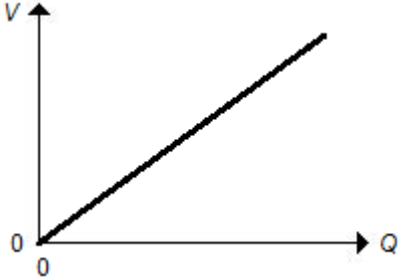
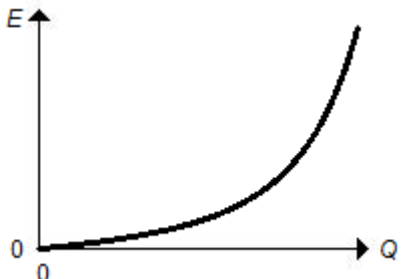
Annotations available in Scoris

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	$\text{kg m}^{-1} \text{s}^{-2}$	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	$T = 273 + \{-63\} = (210 \text{ K});$ EITHER $(pV) = NkT = \frac{Nmc^2}{3}$ $\sqrt{c^2} = 348 \text{ m s}^{-1}$ OR $\frac{1}{2}mv^2 = kT$ $v = 284 \text{ m s}^{-1}$	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 = $1.6 \times 0.56 - 2.4 \times 0.41 = -0.088 \text{ N s};$ final momentum = $-1.6 \times 0.55 + 2.4 \times 0.33 = -0.088 \text{ N s};$	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 $\frac{\text{distance}}{\sqrt{\text{time}}} = \text{constant}$ 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 = $14 \times 10^9 \times 3.2 \times 10^7 = 4.48 \times 10^{17} \text{ s};$ distance = $3.5 \times 10^6 \times 4.48 \times 10^{17} = 1.6 \times 10^{24} \text{ m};$ assumption: • steady expansion of universe • constant (recessional) velocity of galaxy • constant value for H_0;	1 1 1	ecf: award [1] for $1.6 \times 10^{21} \text{ m}$
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 rearrangement and cancellation
b i	$v = 1.93 \times 10^4 \text{ m s}^{-1} / v^2 = 3.72 \times 10^8 \text{ m}^2 \text{ s}^{-2};$ $\frac{1}{2}mv^2 = 9.31 \times 10^{10} \text{ J};$	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 $9 \times 10^{10} \text{ J}$
ii	EITHER $\Delta E_{GPE} = 6.7 \times 10^{-11} \times 2.0 \times 10^{30} \times 5.0 \times 10^2 \left(\frac{1}{1.5 \times 10^{11}} - \frac{1}{3.6 \times 10^{11}} \right)$ $\Delta E_{GPE} = -2.61 \times 10^{11} \text{ J};$ $E_{KE} = 9.31 \times 10^{10} + 2.61 \times 10^{11} \text{ J} = 3.54 \times 10^{11} \text{ J};$ OR total E in original orbit = $-9.31 \times 10^{10} \text{ J};$ E_{GPE} in Earth orbit = $-4.47 \times 10^{11} \text{ J};$ E_{KE} in Earth orbit = $-9.31 \times 10^{10} + 4.47 \times 10^{11} = 3.54 \times 10^{11} \text{ J};$ THEN $v = \sqrt{\frac{2E_{KE}}{m}} = 3.76 \times 10^4 \text{ m s}^{-1};$	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); 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
		11	

Question	Answer	Marks	Guidance
10 a	volume = $(12.0 \times (1.2 + 3.2)/2) \times 5.6 = 148 \text{ m}^3$; mass = $148 \times 1000 = 1.48 \times 10^5 \text{ kg}$;	1 1	accept ecf from incorrect volume for [1] look for 3 s.f. in correct value for mass
b	$4.2 \times 10^3 \times 1.48 \times 10^5 \times (30 - 10) = 1.2(4) \times 10^{10} \text{ J}$; 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	$1.5 \times 10^5 \text{ m}^3$ gives $1.26 \times 10^{10} \text{ J}$ 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 = $6.0 \times 10^{23} / 1.8 \times 10^{-2} = 3.33 \times 10^{25}$; energy per molecule = $2.3 \times 10^6 / 3.33 \times 10^{25} = 6.9 \times 10^{-20} \text{ J}$ OR mass of one molecule $1.8 \times 10^{-2} / 6.0 \times 10^{23} = 3.00 \times 10^{-26} \text{ kg}$; energy per molecule = $2.3 \times 10^6 \times 3.00 \times 10^{-26} = 6.9 \times 10^{-20} \text{ J}$;	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	$7.2 \times 10^{-3} = C e^{-6.9 \times 10^{-20} / 1.4 \times 10^{-23} \times (273+30)}$; $C = 8.34 \times 10^4$; $8.34 \times 10^4 e^{-6.9 \times 10^{-20} / 1.4 \times 10^{-23} \times (273+10)} = 2.28 \times 10^{-3} \text{ kg s}^{-1}$	1 1	award [1] for method which would eliminate C or give it a value $\epsilon = 7 \times 10^{-20} \text{ J}$ gives $C = 1.06 \times 10^5$ and $2.24 \times 10^{-3} \text{ kg s}^{-1}$ 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 = $-3.85 / (6.30 \times 60) = -1.02 \times 10^{-2} \text{ s}^{-1}$ [1] accept from $-0.90 \times 10^{-2} \text{ s}^{-1}$ to $-1.1 \times 10^{-2} \text{ s}^{-1}$ half-life = $0.693 / 1.0 \times 10^{-2} = 69 \text{ s}$ [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]
	radioactive decay is a random process;	1	
ii	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	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 = $2d$
b i	$F = \left(\frac{\Delta p}{\Delta t}\right) = \frac{mv^2}{d}$ (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
	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 ii	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	

OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

OCR Customer Contact Centre

Education and Learning

Telephone: 01223 553998

Facsimile: 01223 552627

Email: general.qualifications@ocr.org.uk

www.ocr.org.uk

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Head office

Telephone: 01223 552552

Facsimile: 01223 552553

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