

Physics B (Advancing Physics)

Advanced GCE

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

Mark Scheme for June 2012

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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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Any enquiries about publications should be addressed to:

OCR Publications
PO Box 5050
Annesley
NOTTINGHAM
NG15 0DL

Telephone: 0870 770 6622
Facsimile: 01223 552610
E-mail: publications@ocr.org.uk

Annotations in scoris

Annotation	Meaning
	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

Annotations in Mark Scheme

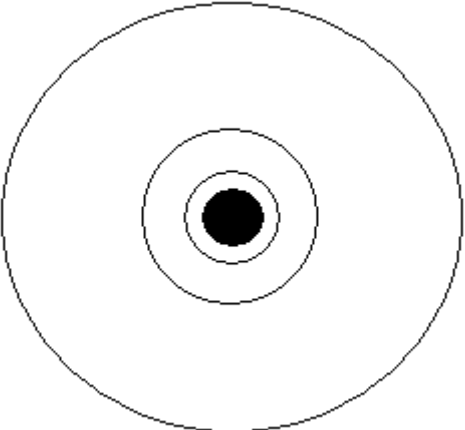
Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
()	Words which are not essential 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

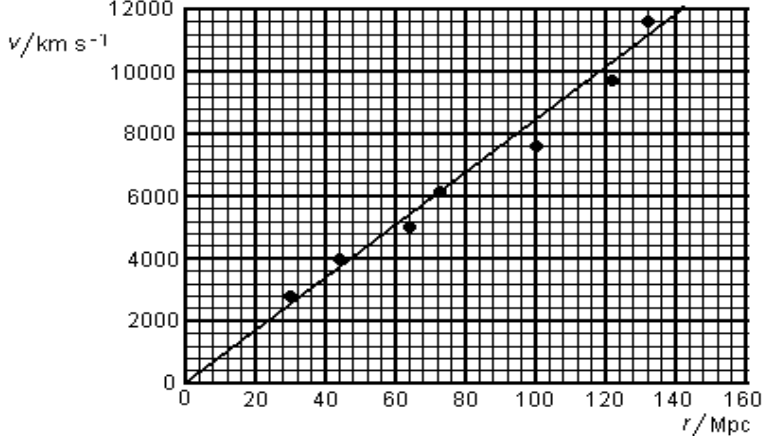
Subject Specific Marking Instructions

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:

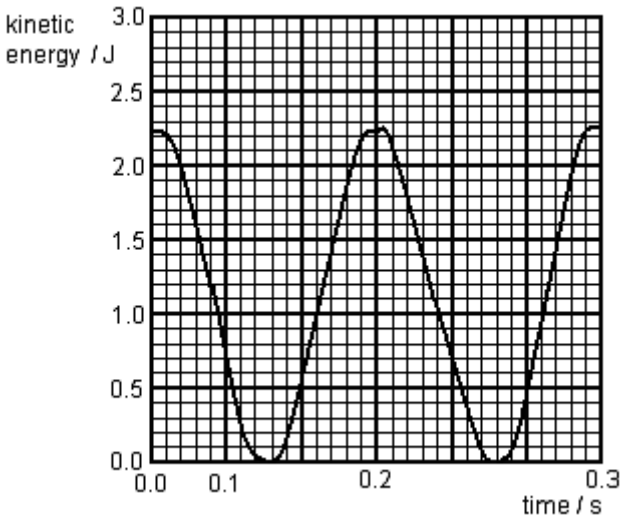
Question			Answer	Marks	Guidance															
1	(a)		J kg ⁻¹	1																
	(b)		N s	1																
2	(a)		1.8(23)×10 ⁴ J	1																
	(b)		B	1																
3			$\gamma = \frac{1}{\sqrt{1 - \left(\frac{2.8 \times 10^8}{3.0 \times 10^8}\right)^2}} = 2.79$ half-life = 2.79 × 10 = 27.9 or 28 μs	2	evaluation of γ; ecf incorrect calculated value of γ from correct substitution into formula															
4	(a)		Probability of decay of a nucleus per unit time. ✓	1																
	(b)		<table><tr><td>t / s</td><td>N</td><td>ΔN</td></tr><tr><td>0</td><td>100</td><td>-21</td></tr><tr><td>10</td><td>79</td><td>-17</td></tr><tr><td>20</td><td>62</td><td>-13</td></tr><tr><td>30</td><td>49</td><td></td></tr></table>	t / s	N	ΔN	0	100	-21	10	79	-17	20	62	-13	30	49		2	79 correct for (1) accept 79.0 all rest completely correct for (1) only accept whole numbers of nuclei for the rest no ecf on incorrect first value (79) ignore contents of bottom r.h. cell
t / s	N	ΔN																		
0	100	-21																		
10	79	-17																		
20	62	-13																		
30	49																			
	(c)		Use a smaller time interval / more steps in same time	1	not just more steps															

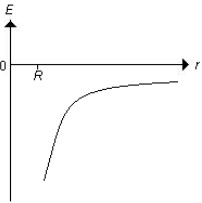
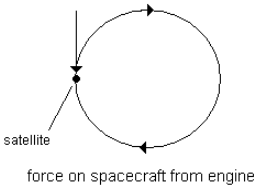
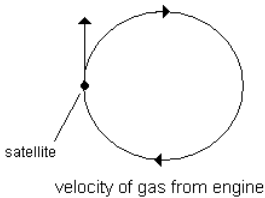
Question			Answer	Marks	Guidance
5	(a)		change of KE = $0.5 \times 1.8 (2.9^2 - 0.52^2) = 7.3(3)$ J	1	look for correct method as well as correct answer to at least 1 d.p.
	(b)		change of GPE = $1.8 \times 9.8 \times (0.73 - 0.11) = 10.9 / 11$ J; work done = $10.9 - 7.3 = 3.6$ J;	2	no ecf from incorrect GPE change KE change = 7.0 J gives 3.9 / 4(.0) J for (2) not -3.6 J
6			EITHER initial $p = 1200 \times 2.3 - 830 \times 3.7 = -3.1 \times 10^2$ Ns; OR $1200 \times 2.3 - 830 \times 3.7 = (1200 + 830) \times v$; THEN final velocity = $-3.1 \times 10^2 / 2030 = -0.15(3)$ m s ⁻¹ ;	3	calculation of initial momentum (1) calculation of final speed for (1) no ecf from incorrect initial p negative final velocity (1) accept to the left instead of -
7			f ε kT extra energy of particles average thermal energy of particles fraction of particles with extra energy	1	

Question			Answer	Marks	Guidance
8				1	Three circles centred on the star, with middle circle clearly closer to the inner one than the outer one. Accept freehand circles. ignore written comments
9	(a)		B (total energy)	1	
	(b)		C (acceleration)	1	
			Total	20	

Question			Answer	Marks	Guidance
10	(a)	(i)	r is distance, v is velocity / speed; of a <u>galaxy</u> (relative to Earth);	2	not r is radius not galaxy and anything else
		(ii)	$(H_0 = \frac{v}{r}) = \frac{\text{ms}^{-1}}{\text{m}} = \text{s}^{-1}$	1	accept $\text{m s}^{-1} = H_0 \times \text{m}$ etc.
	(b)		best straight line through origin (1); THEN data points from line; conversion to SI units; calculation of $H_0 = 2.7 \times 10^{-18} \text{ s}^{-1}$; look for from 2.4×10^{-18} to $2.9 \times 10^{-18} \text{ s}^{-1}$ for (3). must have some working for 2.4×10^{-18} look for from 2.4×10^{-21} to $2.9 \times 10^{-21} \text{ s}^{-1}$ for (2) look for from 7.5×10^4 to $8.8 \times 10^4 \text{ s}^{-1}$ for (2) look for from 75 to 88 s^{-1} for (1)	4	not freehand look for line whose gradient lies within limits of overlay 
	(c)	(i)	(Hubble Law) suggests galaxies are moving apart (from each other) / space is expanding; so must have been in the same place at an earlier time (Big Bang);	2	accept universe for space, stars / planets for galaxies not just speed of recession increases with distance
		(ii)	(a galaxy which has a constant velocity v) and moves a distance r since Big Bang in a time t , then $t = r/v = 1/H_0$;	1	look for complete answer to award the mark not just $t = r/v$ combined with $v = H_0 r$
		(iii)	$1.3(2) \times 10^{10} \text{ yr}$	1	
			Total	11	

Question			Answer	Marks	Guidance
11	(a)	(i)	$T = 15 + 273 = 288 \text{ K};$ $N = pV/kT = 5.7(0) \times 10^{24};$	2	ecf any incorrect T : e.g. $T = 15 \text{ K}$ gives 1.09×10^{26} for (1)
		(ii)	correct use of $\Delta E = k\Delta T$ per particle, $\Delta E = Nk\Delta T = 2.8 \times 10^3 \text{ J};$	2	$3/2NkT$ gives $4.2 \times 10^3 \text{ J}$ for (2) $N = 6 \times 10^{24}$ gives $2.9 \times 10^3 / 3 \times 10^3 / 4.4 \times 10^3 \text{ J}$ for (2) accept $4.9 \times 10^{-22} / 7.4 \times 10^{-22} \text{ J}$ for (1) ignore sign of answer
	(b)	(i)	any three of the following, (1) each - particle energy / speed / momentum decreases; - collision frequency (with surface) decreases; - momentum change per collision decreases; - force on surface is rate of change of momentum; - pressure is (average) force per unit area;	3	QWC: third mark can only awarded if answer describes changes of particle properties. not fewer collisions ignore statements linked to rise in temperature
		(ii)	use of $pV = NkT$; $8.8 \times 10^4 \text{ Pa};$	2	accept use of $P/T = \text{constant}$ $N = 6 \times 10^{24}$ gives $9(2) \times 10^4 \text{ Pa}$ for (2) otherwise no ecf on incorrect N
	(c)		$\frac{2}{500} = \frac{e^{\varepsilon/k288}}{e^{\varepsilon/k253}} = e^{\frac{\varepsilon}{k}(\frac{1}{288} - \frac{1}{253})} = e^{-3.4 \times 10^{19} \varepsilon}$ $\ln(4 \times 10^{-3}) = -3.4 \times 10^{19} \times \varepsilon$, so $\varepsilon = 1.6 \times 10^{-19} \text{ J}$	3	correct substitution of all data (1) method i.e. anything which eliminates C (1) correct evaluation - no ecf on incorrect substitution (1)
			Total	12	

Question		Answer	Marks	Guidance
12	(a)	$k = 360/1.3 \times 10^{-2} = 2.8 \times 10^4 \text{ N m}^{-1}$	1	
	(b)	$f = \frac{1}{2\pi} \sqrt{\frac{k}{m}}$ $f = 3.4 \text{ Hz}$	2	correct combination of $f = \frac{1}{T}$ and $T = 2\pi \sqrt{\frac{m}{k}}$ for (1) evaluation (1) $k = 3 \times 10^4$ gives 3.5 Hz for (2) allow ecf from incorrect k from (a)
	(c)	any three of the following, (1) each: • bumps / road vibrate spring at natural frequency (and resonance occurs); • (at resonance) the frame / rider experience large amplitude oscillations; • damping removes energy from the system; • by converting kinetic energy into heat; • reducing amplitude of oscillations;	3	QWC third mark can only be awarded if technical terms (such as amplitude, frequency, resonance, kinetic energy, heat) have been used correctly. not just resonance
	(d)	$A = 12.5 \times 10^{-3} \text{ m}$, $E = 0.5kA^2 = 2.1 \text{ J} / 2.3 \text{ J}$; correct shape and correct phase; accept evidence of gradient to measure velocity and calculate maximum KE - gives 1.6 J to 2.1 J.	2	
Total			8	

Question			Answer	Marks	Guidance
13	(a)		$\frac{GMm}{r^2} = \frac{mv^2}{r}$; cancellation / rearrangement to final formula;	2	look for cancelling down of r and m
	(b)		$E = 0.5mv^2 - GMm/r$; substitution for v^2 (and manipulation) to final formula;	2	not just $E_k = GMm/2r$
	(c)			1	anything which has E approaching zero more and more slowly from a negative value with increasing r . ignore curve for r less than R .
	(d)	(i)		1	arrow vertically down anywhere on the diagram
		(ii)		1	look for arrow in opposite direction to force arrow of previous question.
		(iii)	$-\frac{GMm}{2} \left(\frac{1}{r_f} - \frac{1}{r_i} \right)$; work = (-) 2.1×10^9 J;	2	use of $-\frac{GMm}{2r}$ for (1) correct evaluation (1) ignore sign of final answer, accept 2×10^9 J
			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

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