RECOGNISING ACHIEVEMENT

GCE

Physics B (Advancing Physics)

Advanced GCE

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

Mark Scheme for June 2013

Oxford Cambridge and RSA Examinations

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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.

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

Annotations available in Scoris

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
✗	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
✓	Correct response
AE	Arithmetic error
?	Wrong physics or equation

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

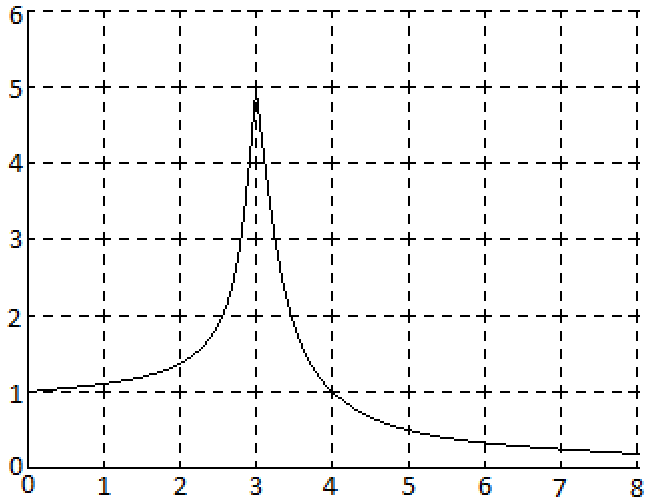
Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential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

- Annotations should be made as follows:
  - For both QWC questions put × next to pencil icon if QWC not awarded
  - in any question where part marks are awarded, put ✓ at point of award for each mark awarded so that ticks = marks total for that part for any question with a candidate response which does not gain marks, put × or ^ as appropriate
  - additional blank pages (16) should be annotated if there is no working on them and if marked with ^ if they are blank. These pages are appended to the bottom of 13(b)(ii) and are easily accessed if you click the 'fit vertically' icon (11^{th} on the icon bar).

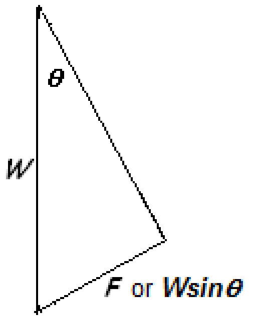
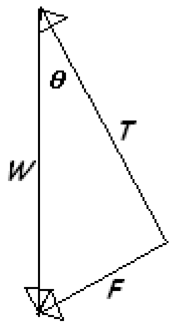
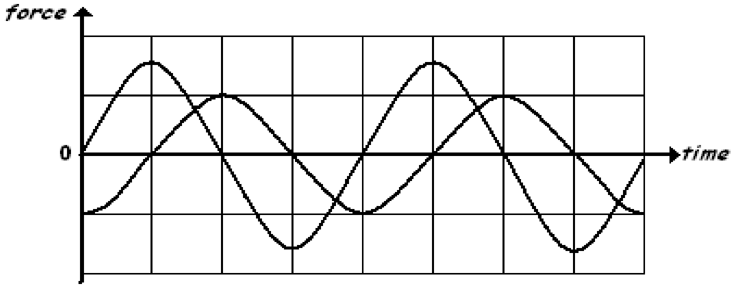
- Calculated answers are shown to 3 significant figures for the convenience of markers. Candidates are expected to express answers to an appropriate number of significant figures, (2 unless specified in mark scheme). Excessive number of sig. figs. Is not penalised

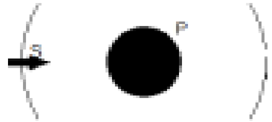
- 'Show that' calculations need evidence of evaluation but rounding error should not be penalised. Accept reverse argument.

Question			Answer	Marks	Guidance
1	**(a)**		J kg^{-1}	1	
	(b)		N m	1	
2			probability that a <u>nucleus</u> decays/fraction of <u>nuclei</u> which decay; in unit time/1s;	1 1	**not** atom, particle for nucleus
3			The outward and returning pulses travel for the same time.	1	
4	**(a)**		momentum before = 0.280 (kg m s^{-1}); momentum after = 0.235 (kg m s^{-1});	1 1	
	(b)		any of the following • friction or air resistance slows down the trolleys • track may not be level • light gates may act differently to each other • (kinetic) energy (of trolley) lost due to friction	1	**reject** references to energy transfers in collisions **not just** system was not isolated / other forces acted
5	**(a)**		R (= V/I)= $3.0/5.0\times10^{-6}$ = (6.0×10^{5} Ω)	1	**look for** evidence of correct values of V and I as well as correct rule for calculating R **not** 3/5μ
	(b)		time constant τ = RC is • time for current to drop by 1/e • half-life / ln2 • t / (lnI_0 - ln$I$) τ (RC) = 14 $\pm$ 1s; C = $\tau / 6.0\times10^{5}$ = 2.3 $\pm$ 0.2 $\times10^{-5}$ F;	 1 1	 graph gives 15 s half-life from graph is 10 s ecf on any incorrect τ for [1] e.g. τ = 10 s gives C = 1.67×10^{-5} F correct answer for C without a value of τ for [1]

Question			Answer	Marks	Guidance
6				3	starts 0,1.0 [1] rises with increasing gradient to a maximum value at 3.0,5.0 [1] then falls with decreasing gradient to below 1.0 by 8.0 [1] **accept** rounded or sharp peak
7			A	1	
8			$pV = NkT = \frac{Nm\overline{c^2}}{3}$; $\overline{c^2}$ = 8.40×10^4 m^2 s^{-2}; $\sqrt{\overline{c^2}}$ = 290 m s^{-1};	1 1 1	method [1] evaluation of $\overline{c^2}$ [1] answer [1] **accept** $\frac{1}{2}m\overline{c^2} = kT$ [1] gives $\sqrt{\overline{c^2}}$ = 237 m s^{-1} [1]
9			any two of the following, [1] each: 1. there is a <u>microwave</u> background radiation; 2. which is red-shifted light from earlier universe; 3. due to expansion of space since big bang;	2	**accept** increased wavelength or decreased frequency for red-shift
			Total	**20**	

Question			Answer	Marks	Guidance
10	(a)	(i)	T = 273 + 20 = 293 K; $N = \frac{pV}{kT} = \frac{1.1\times10^5 \times 4.5\times10^{-3}}{1.4\times10^{-23}\times 293}$; $N = 1.21\times10^{23}$;	1 1 1	conversion to kelvin [1] transposition and substitution [1] evaluation [1] **ecf** on any incorrect value of T T = 20 K gives $N = 1.77\times10^{24}$ for [2]
		(ii)	$m = \frac{1.21\times10^{23}}{6.0\times10^{23}}\times4.0\times10^{-3} = 8.07\times10^{-4}$ kg	1	**accept** ecf from (i) $N = 1.77\times10^{24}$ gives 1.18×10^{-2} kg for [1] **accept** 8.0×10^{-4} kg, 8×10^{-4} kg
	(b)		particles bounce off balloon; exerting outwards force/pressure; because of change of momentum of particles / transfer of momentum to balloon;	1 1 1	**accept** collide with / hit the balloon **accept** particles push out / balance force from outside **ignore** references to energy transfer QWC: third mark only for reference to momentum change of particles / balloon
	(c)		EITHER density of helium = 0.177 kg m^{-3} from $\rho = \frac{M}{V}$; number of hydrogen molecules = 2.42×10^{23} from $\rho = \frac{Nm}{V}$; OR $\rho = \frac{Nm}{V}$ so $\rho V = Nm$; if $m \rightarrow \frac{m}{2}$ then $N \rightarrow 2N$ = 2.42×10^{23}; THEN pressure = 2.20×10^5 Pa from $pV = NkT$;	 1 1 1	use of constant density [1] calculation of number of particles [1] calculation of pressure [1] **ecf** for calculation of p from incorrect calculation of N or M from part (a). **ecf** for calculation of p from incorrect number of H molecules **accept** correct answer for [3] **accept** algebra e.g. use of $p = \frac{Nm\overline{c^2}}{3V}$ and $\rho = \frac{Nm}{V}$ to show that $p \propto \overline{c^2}$; $\frac{1}{2}m\overline{c^2} = kT$ so $m\overline{c^2} = \text{constant}$; if $m \rightarrow \frac{m}{2}$ then $\overline{c^2} \rightarrow 2\overline{c^2}$ so p doubles to 2.2×10^5 Pa;
			Total	**10**	

Question			Answer	Marks	Guidance
11	(a)		$l = g\left(\frac{T}{2\pi}\right)^2$; l = 0.993 m	1 1	evidence transposition [1] evaluation [1] **accept** reverse calculation: use of $T = 2\pi\sqrt{\frac{l}{g}}$ [1]: EITHER l = 1.0 m gives T = 2.01 s [1] OR T = 2.0 s and l = 1.0 m gives g = 9.87 N kg^{-1} [1]
	(b)		$g = l\frac{4\pi^2}{T^2}$; calculated value of g will be low (because l used will be low);	1 1	**look** for use of $T = 2\pi\sqrt{\frac{l}{g}}$ to show $g \propto l$ **ignore** references to wrong value of T
	(c)		 [1]  [2]	2	Look for: • arrows in correct direction • all three sides labelled • angle θ opposite F. • right angle between T and F. right angle triangle (by eye) with θ, W and F or $W\sin\theta$ correctly labelled [1] and all three arrows and T in correct direction for [2] **accept** any orientation of the triangle
	(d)			2	sinusoid with any constant amplitude and period of four squares all the way across for [1] **accept** one error in amplitude, crossing point or turning point correct phase for [1]
			Total	**8**	

Question			Answer	Marks	Guidance
12	(a)	(i)		1	arrow through S pointing to centre of planet [1] **reject** if stem of arrow appears outside overlay
		(ii)	force at right angles to velocity/motion; so no work done/energy transferred;	1 1	
		(iii)	$\frac{mv^2}{r} = \frac{GMm}{r^2}$; $v^2 = \frac{GM}{r} = \frac{6.7 \times 10^{-11} \times 4.8 \times 10^{23}}{6.1 \times 10^6}$ = 5.27×10^6 $v = 2.30 \times 10^3$ m s^{-1};	1 1 1	equating centripetal force/acceleration to gravitational force/field for [1] substitution into expression for v^2 for [1]; correct evaluation for [1]
		(iv)	$GPE = -\frac{GMm}{r}$; $GPE = -\frac{6.7 \times 10^{-11} \times 4.8 \times 10^{23} \times 5.7 \times 10^3}{6.1 \times 10^6} = -3.01 \times 10^{10}$ J	1 1	**look for** evidence of correct rule, **accept** incorrect sign [1] **reject** use of *GPE* = *mgh* evaluation (including correct sign) [1] **accept** 3×10^{10} J
	(b)		EITHER use of $KE = \frac{1}{2}mv^2$ and $\frac{mv^2}{r} = \frac{GMm}{r^2}$; to show $KE = \frac{GMm}{2r}$; OR *KE* at 6.1×10^6 m = 1.50×10^{10} J; use of $v^2 = \frac{GM}{r}$ from (a)(iii) for double or half radius; THEN *KE* for S_1 is half *KE* for S_2 / doubling radius halves *KE* ;	 1 1 1	 **accept** use of $v^2 = \frac{GM}{r}$ from (a)(iii) **accept** to show $KE \propto \frac{1}{r}$ **accept** any initial radius or mass for calculation of *KE* **accept** correct answer with no justification for [1]
			Total	**11**	

Question			Answer	Marks	Guidance
13	(a)	(i)	$v^2 = \frac{2KE}{m}$ $v = 6.03\times10^4$ m s^{-1} $p = 1.33\times10^{-20}$ kg m s^{-1}	1 1 1	accept use of $KE = \frac{p^2}{2m}$ allow ecf from incorrect v for [1] reverse calculation $p = 1\times10^{-20}$ gives $KE = 2.27\times10^{-16}$J for [3]
		(ii)	$F = \frac{\Delta p}{\Delta t} = 4.79\times10^{-3}$N	1	**allow ecf** from incorrect (a)(i) $p = 1\times10^{-20}$ kg m s^{-1} gives 3.6×10^{-3} N for [1] $p = 1.3\times10^{-20}$ kg m s^{-1} gives 4.7×10^{-3} N for [1]
		(iii)	EITHER 860 × change of speed = $3.2\times10^7 \times 3.6\times10^{17} \times 1.3\times10^{-20}$; OR $a = \frac{F}{m} = 5.58\times10^{-6}$m s^{-2} and use of $v - u = at$; THEN change of speed = 1.78×10^2 m s^{-1};	1 1	correct method [1] correct answer [1] **allow ecf** from incorrect (ii) 3.6×10^{-3} N gives 134 m s^{-1} 4.7×10^{-3} N gives 175 m s^{-1}
	(b)	(i)	atoms exchange energy on each collision; EITHER high temperature means atoms have high energy / collision rate; some atoms gain enough energy to be ionised; OR proportion of ions given by BF($e^{-\varepsilon/kT}$) ; high T means large value for BF / amount of ionisation;	1 1 1	**accept** atoms can gain energy through collisions **QWC** linking temperature to atom behaviour **accept** more collisions **accept** electrons gain enough energy to escape **QWC** linking temperature to BF
		(ii)	4.83×10^{-45}; so proportion/fraction of ions will be very small;	1 1	**accept** low number of ions, low production rate ... **look for** a comment which shows understanding of meaning of BF **not just** not feasible / won't be effective ...
			Total	**11**	

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