

GCE

Physics B (Advancing Physics)

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

Advanced GCE

Mark Scheme for June 2015

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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
	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

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

Unless stated otherwise in the mark scheme, accept calculations which round to the mark scheme answer for full marks.

Question	Answer	Marks	Guidance
1 a	N kg^{-1}	1	
b	N m kg^{-1}	1	
2	EITHER red shift of light/radiation from (distant) <u>galaxies</u> ; because galaxies are moving away from each other / have recessional velocity owtte ; OR (uniform) microwave background; which is red-shifted light from early universe;	1 1	ignore references to expansion of the universe accept increase/stretching of wavelength as red shift accept galaxies moving away from Earth accept cosmological microwaves accept radiation for light
3	$\gamma = 42/18 = 2.33$; $v = c \sqrt{1 - \frac{1}{\gamma^2}}$ $v = 3.0 \times 10^8 \sqrt{1 - \frac{1}{5.44}} = 2.7 \times 10^8 \text{ ms}^{-1}$	1 1 1	 look for evidence of correct transposition of data sheet formula no ecf for incorrect γ
4 a	initial KE = $\frac{1}{2} 50 \times 200^2 = 1.00 \times 10^6 \text{ J}$; final KE = $\frac{1}{2} (350 + 50) \times 25^2 = 1.25 \times 10^5 \text{ J} \approx 1.3 \times 10^5 \text{ J}$; initil momentum: $50 \times 200 = 1.0 \times 10^4 \text{ kg m s}^{-1}$, final momentum = $(350 + 50) \times 25 = 1.0 \times 10^4 \text{ kg m s}^{-1}$	1 1 1	accept $1 \times 10^6 \text{ J}$ look for full working in calculations, not just final value accept 400 as final mass if 350 + 50 shown elsewhere look for words like initial/before and final/after as labels to calculations of energy or momentum accept alphabetic suffixes e.g. i , b , f or a to <i>p</i> and <i>E</i> as labels
	work done deforming the spacecraft;	1	accept transfer to heat or thermal energy, ignore sound
5 b	C	1	
6 a	-0.3(0); -0.3(0); (0.015 - 0.05 × 0.45 =) -0.0075 ≈ -0.008	1 1 1	allow ecf if $v =$ incorrect Δv no ecf for incorrect v
6 b	any of the following: - formula has effectively infinite number of steps - not enough steps in the iterative calculation - time interval too long in iterative calculation - each iteration assumes constant speed	1	accept step-widths of zero time ignore constant acceleration other than zero acceleration

Question	Answer	Marks	Guidance
7	evidence of suitable test e.g. is ρT constant; test applied to all data to 2 s.f. or 3 s.f.; $273 \times 1.29 = 352$ (350) $283 \times 1.25 = 354$ (350) $293 \times 1.20 = 352$ (350) $303 \times 1.16 = 351$ (350)	1 1	accept calculations to more than 3 s.f with a conclusion which mentions that numbers are either not the same to 3 s.f. or the same to 2 s.f. ignore any conclusion about the truth of the relationship
8	EITHER measure time for half the sample to decay ($t_{1/2}$), use $\lambda = \frac{\ln 2}{t_{1/2}}$; OR take a known number of atoms, measure activity and use equation given; OR measure gradient ($-\lambda$) of a $\ln(\text{activity})$ -time graph;	1	accept measure half-life from activity-time graph
9	B	1	
	Section A Total	20	

Question	Answer	Marks	Guidance
10 a	$\frac{mv^2}{r} = \frac{GMm}{r^2}$; evidence of $v = \frac{2\pi r}{T}$; algebraic manipulation to final formula;	1	accept $mr\omega^2$ as $\frac{mv^2}{r}$ not $\frac{mv^2}{r} = -\frac{GMm}{r^2}$
		1	accept $\omega = \frac{2\pi}{T}$, $v = r\omega$, $\omega = 2\pi f$
		1	look for clear steps ignore loss of minus sign in final manipulation
b	$V = \frac{4}{3}\pi r^3 = 1.098 \times 10^{21} \text{ m}^3$; $M = \rho V = 2.7 \times 10^3 \times 1.098 \times 10^{21} = 2.96 \times 10^{24} \text{ kg}$	1	look for correct formula or evaluation
		1	accept 3.0×10^{24} with full working for [2] accept $V = 1.1 \times 10^{21} \text{ m}^3$ gives $2.97 \times 10^{24} \text{ kg}$ for [2]
c i	any two points from: - time for pulse to reach moon = time for pulse to return; - radius of Moon / Earth is comparably negligible; - speed of pulse is constant (throughout the journey) or Earth's atmosphere does not affect speed of pulse or pulse travels at speed of light in a vacuum ($3 \times 10^8 \text{ m s}^{-1}$) or speed of light is constant;	2	not distance for time, accept (laser) light for pulse not just travels at the speed of light
ii	$r = \frac{3.0 \times 10^8 \times 2.5}{2} = 3.75 \times 10^8 \text{ m}$; $G = \left(\frac{4\pi^2}{3.0 \times 10^{24}} \right) \frac{(3.75 \times 10^8)^3}{(2.4 \times 10^6)^2} = 1.2 \times 10^{-10} \text{ N m}^2 \text{ kg}^{-2}$;	1	no ecf for incorrect value of r $r = 3.8 \times 10^8 \text{ m}$ gives $G = 1.25 \times 10^{-10}$ or 1.3×10^{-10}
		1	
iii	density / mass of Earth incorrect; need to use density of whole Earth / core and mantle are made of different material / density increases with increasing depth;	1 1	accept mass / density is too great accept orbit may not be circular for [1] ignore references to radius of Earth and Moon
Total		11	

Question	Answer	Marks	Guidance
11 a	molecules bounce off the ground; any two of the following - each bounce transfers momentum to ground - force on ground is rate of transfer of momentum - pressure is force per unit area	3	accept collide with the ground accept impulse as momentum transfer / change ignore algebraic formulae e.g. $F = \frac{\Delta p}{\Delta t}$, $P = \frac{F}{A}$, $\Delta p = mv - mu$ QWC: first marking point
b i	$NkT = \frac{1}{3} Nmc^2$; $T = 293 \text{ K}$; $\sqrt{c^2} = \sqrt{\frac{3kT}{m}} = 512 \text{ ms}^{-1} \approx 510 \text{ m s}^{-1}$	1 1 1	not $kT = \frac{1}{2} mc^2$ ecf $T := 20 \text{ K}$ gives 134 ms^{-1} for [2] allow $c^2 = 2.62 \times 10^5$ for [2]
ii	any one of the following assumptions - elastic collisions - molecules impact surface at right angles to it - all molecules moving at rms speed evidence of use of $F = PA$ ($= 1.0 \times 10^5 \times 0.56 = 5.6 \times 10^4 \text{ N}$); EITHER $F = \frac{\Delta p}{\Delta t} = \frac{2nm\sqrt{c^2}}{1}$ and $n = 1.2 \times 10^{27} \text{ s}^{-1}$; (2) OR $F = \frac{\Delta p}{\Delta t} = \frac{nm\sqrt{c^2}}{1}$ and $n = 2.3 \times 10^{27} \text{ s}^{-1}$; (1)	1 1 2	$\sqrt{c^2} = 500 \text{ m s}^{-1}$ gives $2.4 \times 10^{27} \text{ s}^{-1}$
	Total	10	

Question	Answer	Marks	Guidance
12 a i	$(R = \frac{V}{I} =) \frac{6.0}{2.7 \times 10^{-3}} = 2.2(2) \times 10^3 \Omega$	1	
ii	EITHER use of half-life = $0.69RC = 33 \pm 1 \text{ s} / 53 \pm 1 \text{ s}$; OR use of $RC = 1/e$ drop time = $49 \pm 1 \text{ s} / 69 \pm 1 \text{ s}$; OR data from graph, use of $I = I_0 e^{-t/RC}$; $C = 2.2 \pm 0.3 \times 10^{-2} \text{ F}$	1 1	evidence of method [1] correct answer [1]
b i	$\Delta Q = C\Delta V = 470 \times 10^{-6} \times 0.12 = 5.64 \times 10^{-5} \text{ C}$; $I = \frac{\Delta Q}{\Delta t} = \frac{5.64 \times 10^{-5}}{60} = 9.4 \times 10^{-7} \text{ A} = 0.94 \mu\text{A}$;	1 1	 no ecf on incorrect ΔQ
ii	energy required; for an electron to break free (from an atom) / enter the conduction band / become a free electron / move freely within the insulator;	1 1	 not just to get from one plate to the other
iii	use of $\ln I = \ln A - \frac{\varepsilon}{kT}$ to eliminate A ; $\varepsilon = 3.9 \times 10^{-20} \text{ J}$;	1 1	look for method which will eliminate A [1] correct answer for [2]
	Total	9	

Question	Answer	Marks	Guidance
13 a	large amplitude (vertical) oscillations; make it dangerous/unpleasant for occupants of lift ;	1 1	ignore references to sideways oscillations / swinging accept break cables
b	i use of $k = \frac{F}{x}$ or $F = kx$;	1	accept $k = \frac{F}{\Delta L}$
	use of $\frac{F}{A} = E \frac{x}{L}$ to obtain required expression	1	
ii	$k = \frac{2.0 \times 10^{11} \times 2.5 \times 10^{-4}}{300} = 1.67 \times 10^5 \text{ Nm}^{-1}$	1	no ecf on incorrect k allow ecf if mass is just 1500 kg (1.7 Hz) or 640 kg (2.6 Hz) for [2]
	$T = (2\pi \sqrt{\frac{m}{k}} = 2\pi \sqrt{\frac{1500 + 640}{1.67 \times 10^5}}) = 0.711 \text{ s}$	1	
	$f = \frac{1}{T} = \frac{1}{0.711} = 1.4 \text{ Hz}$	1	
c i	idea that damping requires friction / energy transfer from lift AND slowing down the lift / reducing efficiency of lift	1	
ii	EITHER reducing L (to increase k); raising f_0 (above 2 Hz); OR increasing mass of load / cage; lowering f_0 (below 0.2 Hz); OR decreasing mass of load / cage raising f_0 (above 2 Hz) OR increasing csa of cables (to increase k) raising f_0 (above 2 Hz); OR use a cable material which is stiffer / increased E ; raising f_0 (above 2 Hz)	1 1	any realistic modification [1] which is explained [1] not increasing L not reducing csa of cables not more elastic material QWC against second marking point (organise information clearly)
Total		10	

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