

GCE

Physics B (Advancing Physics)

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

Advanced GCE

Mark Scheme for June 2016

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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.

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

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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
	Blank page

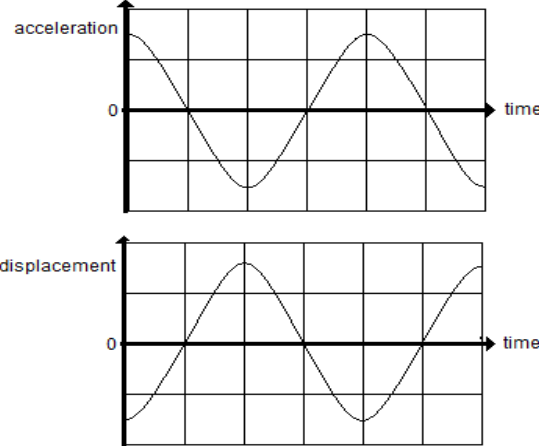
Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

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
EOR	Evidence Of (the) Rule

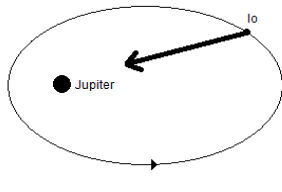
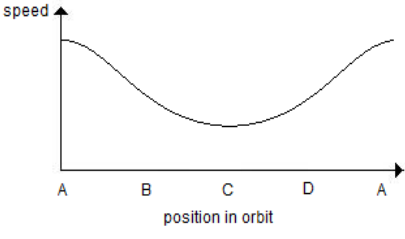
The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:

7, 10(b)(iii), 11(c)(ii), 11(c)(iii), 12(a)(i), 12(b), 13(c)(ii).

Question	Answer	Marks	Guidance																
1 a	N kg^{-1}	1	Accept '/' for '-1' e.g., N/kg instead of N kg^{-1} Reject: <i>n</i> for <i>N</i> .																
b	N s and kg m s^{-1}	1																	
2		1																	
3 a	0.5	1	Accept $\frac{1}{2}$ instead of 0.5																
b	8	1																	
4	<table border="1"> <thead> <tr> <th>T / K</th> <th>V / ml</th> <th>p / kPa</th> <th>pV/T</th> </tr> </thead> <tbody> <tr> <td>283</td> <td>5.5</td> <td>100</td> <td>1.94</td> </tr> <tr> <td>270</td> <td>2.2</td> <td>230</td> <td>1.87</td> </tr> <tr> <td>373</td> <td>6.0</td> <td>120</td> <td>1.93</td> </tr> </tbody> </table>	T / K	V / ml	p / kPa	pV/T	283	5.5	100	1.94	270	2.2	230	1.87	373	6.0	120	1.93	3	<p>evidence of calculating pV/T or an appropriate equivalent ... e.g., pV/kT, T/pV, kT/pV for [1]</p> <p>correct evaluation to at least 2 s.f. for all three rows [1]</p> <p>correct conclusion with reason: yes, because all same value to 2 s.f. set by V for [1]</p> <p>Note: If the student uses pV/kT with $k=1.4 \times 10^{-23}$, the values are not the same to 2SF (1.4, 1.3, 1.4) but accept a sensible conclusion based on the SF set by V. The focus here, is on SF so IGNORE any reference to decimal places.</p>
T / K	V / ml	p / kPa	pV/T																
283	5.5	100	1.94																
270	2.2	230	1.87																
373	6.0	120	1.93																

Question	Answer	Marks	Guidance
5	$T = 3/5 = 0.60 \text{ s} / f = 1.67\text{Hz} / \omega = 10.5 \text{ rad/s};$ $k = \frac{4\pi^2 m}{T^2} / k = 4\pi^2 m f^2 / k = m\omega^2;$ 13(.2) $\text{N m}^{-1};$	1 1 1	correct period / correct frequency / correct angular frequency [1] correct rule transposed correctly or EOR [1] Accept any final answer that rounds to 13 for [3] No ECF for incorrect T
6		1 1	correct acceleration graph (Cosine) for [1] Correct displacement graph (-Cosine) for [1]. Accept ECF for acceleration graph reflected about time axis. Note: The tolerance on both graphs is... Time axis: To within $\frac{1}{4}$ square for the peaks, troughs and zero points. y-axis: to within $\frac{1}{4}$ square for the amplitudes. THE LINE MUST COVER THE FULL WIDTH OF THE x-axis.
7	There are two ways to get the first marking point: red shift suggests that all (distant) galaxies are moving away (from us / each other). Recessional velocity of (distant) galaxies increases (linearly) with increasing distance; so at some time in the past all galaxies / matter / everything would have been at one point / singularity;	1 1	The reference to galaxies needs to be plural so ... <i>a galaxy is moving away from us</i> , would not trigger the mark. IGNORE all references to an explanation of what redshift is. Reject: Close together / at the same place / position. Reject: The universe started at a single point. The emphasis here, is on the matter / galaxies, not the whole universe.

Question	Answer	Marks	Guidance
8 a	$v = \frac{3 \times 10^{-9} \times 3 \times 10^8}{5 \times 10^{-9}} = \underline{1.8} \times 10^8 \text{ m s}^{-1};$	1	At least 2SF required in the final answer. Note: $2.4 \times 10^8 \text{ m s}^{-1} = [0]$
b	$\gamma = \sqrt{\frac{1}{1 - 0.6^2}} = 1.25 \quad / \quad \frac{5}{4};$ life time = $5.0/1.25 = 4 \text{ ns};$	1 1	$v = 2 \times 10^8$ gives $\gamma = 1.34$, lifetime = 3.7 ns for [2] Accetable values are between 3.7ns and 4.0ns. Allow ECF ONLY for a value calculated in 8(a) that rounds to $2 \times 10^8 \text{ ms}^{-1}$ e.g., $v = 2.4 \times 10^8$ gives $\gamma = \frac{5}{3}$ and lifetime of 3ns. Allow ECF on any value for γ greater than 1. Watch out for mistakes in the calc of γ , and the subsequent calc for lifetime, that give 4ns e.g., $\gamma = \sqrt{1 - \frac{v^2}{c^2}} = 0.8$ followed by ... $0.8 \times 5 = 4$
9	A correct test clearly stated for [1]; Note: This could be implied in the comments made e.g., calculations for two gradients at two stated voltages, is followed by ... <i>the $\frac{\text{gradient}}{\text{voltage}}$ is NOT a constant value.</i> Evidence from graph that it isn't [1] e.g. 6 V to 3 V in 2 minutes, but 3 V to 1.5 V in 4 minutes;	1 1	e.g., ... <ul style="list-style-type: none">• an exponential then should have a constant half-life (of $0.7RC$);• The ratio of voltages in equal time intervals should be the same.• $\frac{\Delta \text{Ln}(V)}{\Delta t} = \text{const}$• A plot of $\text{Ln}(V)$ vs t would be a straight line.• $\frac{\text{gradient of curve}}{\text{voltage}} = \text{const}$• Correct use of $V = V_0 e^{-t/RC}$ There should be a minimum of two data points from the graph. An incorrect test would not allow this second mark to be obtained. Candidate must not simply state two pieces of data.
Section A Total		20	

Question	Answer	Marks	Guidance
10 a (i)	$v = \frac{2\pi \times r}{T} / v = \frac{2\pi \times 4.2 \times 10^8}{43 \times 3600};$ $= 1.7 \times 10^4 \text{ m s}^{-1}$	1 1	EOR Accept $1.8 \times 10^4 \text{ m s}^{-1}$ produced by $T = 1.5 \times 10^5 \text{ s}$ i.e., 2SF.
a (ii)	$\frac{GMm}{r^2} = \frac{mv^2}{r};$ clear rearrangement to $M = \frac{rv^2}{G};$	1 1	If a '-' sign is used for $\frac{GMm}{r^2}$, this must also be used with $\frac{mv^2}{r}$. If not, zero marks. If the student begins with the equations for a and not F (i.e., $\frac{GM}{r^2} = \frac{v^2}{r}$), they score zero. There should be at least 1 line of correct working. Watch out for correct and clear cancelling. M and m should be clearly distinguished in the working.
a (iii)	$M = \frac{4.2 \times 10^8 \times (1.7 \times 10^4)^2}{6.7 \times 10^{-11}} = 1.8 \times 10^{27} \text{ kg}$	1	20 kms^{-1} gives $2.5 \times 10^{27} \text{ kg}$ for [1] 18 kms^{-1} gives $2.0(3) \times 10^{27} \text{ kg}$ for [1] Allow an ECF from 10(a)(i) ONLY if the value rounds to 2×10^4
b (i)		1	Arrow of any length from Io to Jupiter. NOT by eye. An acceptable extended straight line would pass through Io and Jupiter. Possibly use a transparent ruler to check.
(ii)		1	look for minimum at C, maximum at A The points for A must be the same speed within $\frac{1}{4}$ of a square. The minima must be within $\frac{1}{4}$ of a square of C AND must NOT touch the x-axis. Reject a U shaped curve (there should be inflection points).

Question	Answer	Marks	Guidance
(iii)	EITHER less GPE at A / as moon approaches planet; so more KE as energy conserved; OR There is a component / part of the force along orbit path / (gravitational) force is not perpendicular to the velocity; accelerates moon as it approaches planet / decelerates moon as it goes away from planet;	1 1	Accept: The GPE becomes more negative as Io approaches the planet. Do not accept <i>speed</i> , since this has no direction.
	Total	9	

Question	Answer	Marks	Guidance
11 a	$GPE = -\frac{GMm}{R}$ at surface of planet; $KE + GPE > 0$ for atom to escape gravitational field;	1 1	Without a statement about the surface of the planet, accept R to indicate the surface of the planets, not r . The GPE MUST have the '-' sign. We are looking for a statement about the total energy OR the decrease in $KE =$ gain in GPE OR $KE > \Delta GPE$ so the removal of the negative sign can be explained. Accept $KE + GPE = 0$
b	$m = 4.0 \times 10^{-3} / 6.0 \times 10^{23} = 6.67 \times 10^{-27}$ kg; $E_k = \frac{6.7 \times 10^{-11} \times 6.0 \times 10^{24} \times 6.67 \times 10^{-27}}{6.4 \times 10^6} = 4.2 \times 10^{-19}$ J	1 1	no ECF for incorrect calculation of m There must be evidence that E_k has been calculated
c i	$T = 273 + 15 = 288$ K; $kT = 1.4 \times 10^{-23} \times (288) = 4.0 \times 10^{-21}$ J	1 1	Only accept ECF for incorrect $T = 15$ K gives 2.1×10^{-22} J Accept $1.5kT = 6.0 \times 10^{-21}$ J for [2] Accept 1 SF for the final answer.
ii	Particles / helium atoms / molecules collide with other particles; (in the collisions) there is an exchange of energy; the exchange of energy in a collision is random;	1 1 1	It needs to be clear that the particles are colliding with other articles, not inferred from the argument. ignore changes of GPE ignore changes of temperature Reject: in collisions there is a <i>change</i> of energy QWC award third mark only if random fluctuations of energy clear from answer.
iii	BF for helium is $e^{-4.2 \times 10^{-19} / 4.0 \times 10^{-21}} = 5 \times 10^{-46}$; BF is the proportion / fraction / probability of atoms which have enough energy to escape (after a collision); chances of escape small unless enough collisions are considered / lots of collisions needed owtte;	1 1 1	calculation [1] Accept any BF that looks reasonable and produces an answer around 10^{-46} to 10^{-44} . what BF represents [1] Accept BF is <i>related</i> to / determines / defines / gives / the probability conclusion [1]
	Total	11	

Question	Answer	Marks	Guidance
12 a i	Particles collide (with the surface) and exert a force; More particles collide with the bottom surface (per second) than the top surface; There is a net upwards force / $F_{up} > F_{down}$;	1 1 1	Accept there is a force generated by the colliding particles not particles move slower on top Reject no collisions on the top surface or no downward force. Reject The outside force > inside force (direction needed). QWC: award third mark only if reason for net upwards force clearly linked to particles.
ii	$F = mg = 0.2 \times 9.8 = 1.96\text{N};$ pressure (difference) = $F/A = 1.96/\pi \times (6 \times 10^{-3})^2 = 1.7 \times 10^4 \text{ Pa};$ net pressure = $100 - 17 = 83 \text{ kPa};$ <hr/> Alternative answer: based on forces: $F = mg = 0.2 \times 9.8 = 1.96\text{N};$ $(F_{up} = 100 \times 10^3 \pi (6 \times 10^{-3})^2 = 11.3\text{N})$ $\Delta F = 11.3 - 1.96 = 9.35\text{N};$ net pressure = $\frac{9.35}{\pi(6 \times 10^{-3})^2} = 83 \text{ kPa};$	1 1 1	accept any mass from 0.20 kg to 0.29 kg e.g. 0.25 kg for 2.45 N and 21 kPa for [1] Rounding the area to $1.1 \times 10^{-4} \text{ m}^2$ gives 18kPa leading to 82kPa[3] Note: If diameter is used as the radius, the net pressure = 96kPa [2] max Accept $100 - 20 = 80\text{kPa}$ for [1]max No ECF on incorrect F .
b	The ratio of the areas = $\frac{30^2}{12^2} / = 6(.25)$ OR the ratio of the masses is $\frac{1.2}{0.2} / 6(.25);$ With the same absolute uncertainty in mass (e.g., 0.1), the precision in the pressure measurement improves by 6(.25);	1 1 1	new mass is $1.7 \times 10^4 \times \pi \times (15 \times 10^{-3})^2 / 9.8 = 1.2 \text{ kg}$ Full ECF on pressure calculated in (a)(ii) [1]max available for a qualitative argument along the lines: <ul style="list-style-type: none"> • Larger area leads to ... • Larger load ... • And a greater precision on the measurement of P Allow ECF from the area / mass calculation.
Total	9		

Question	Answer	Marks	Guidance
13 a	$m = 8.0 \times 10^{-2} + 1.0 \times 10^{-3} (= 8.1 \times 10^{-2} / 0.081 \text{kg});$ $\text{KE} = 8.1 \times 10^{-2} \times 9.8 \times 2.3 \times 10^{-1} = 1.83 \times 10^{-1} \text{ J};$ Assumption: $\text{KE}_{\text{initial}} = \text{GPE}_{\text{final}} / \text{KE}_{\text{lost}} = \text{GPE}_{\text{gained}} / \text{KE} + \text{GPE} = \text{constant} /$ $\Delta \text{KE} = \Delta \text{GPE};$ $(= 8.1 \times 10^{-2});$	1 1 1	ECF incorrect $m = 8.0 \times 10^{-2} \text{ kg}$ for [1] 0.183 = [2] 0.18: Check to ensure the masses were added for [2] Reject any reference to a collision or energy lost in the collision or energy lost when the gun is fired. Accept no air resistance / no transfer to heat in the air / surroundings Ignore: Energy is conserved / $\text{KE} = \text{GPE}$ / no energy lost as heat.
b	$v = \sqrt{\frac{2E_K}{m}} = 2.12 \text{ m s}^{-1};$ final momentum = 0.172 N s; $u = 0.172 / 1.0 \times 10^{-3} = 1.7 \times 10^2 \text{ m s}^{-1};$	1 1 1	Allow ECF for incorrect value of v . For example, if $v = 4.5(08) \text{ m s}^{-1}$ leads to $u = 365 \text{ m s}^{-1}$. [2] Using $\text{KE} = 0.2 \text{ J}$ $v = 2.22 \text{ m s}^{-1}$ final momentum = 0.18 Ns $u = 180 \text{ m s}^{-1}$ [3]
c i	initial KE of pellet = $\frac{1}{2}mv^2 = 14.5 \text{ J};$ which is (much) greater than $2 \times 10^{-1} \text{ J}$ final KE;	1 1	Accept any value for KE between 14J and 16J ECF: From u in (b). There must be a comparison between the (correct) initial and final KE values. Reject: The two KEs are different / unequal / not the same.
ii	any two of the following, [1] each KE (of the pellet) is lost due to ... <ul style="list-style-type: none"> ... raises temperature of pellet/blutak / heat transferred to pellet/blutac; ... deforming / changing shape of the pellet / bluetac ... sound / vibrations (in the pellet / blutac) 	2	Ignore: references to friction. Reject: bald <i>transferred to heat</i> . Accept: pellet embedding in the blutac. ANY reference to energy losses that occur before the collision itself (e.g., sound from the gun) scores 0/2. PLEASE REMEMBER TO PUT A BP ANNOTATION ON PAGE 16 to show it has been seen.
	Total	10	

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