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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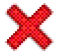
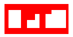
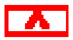
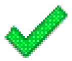
This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

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

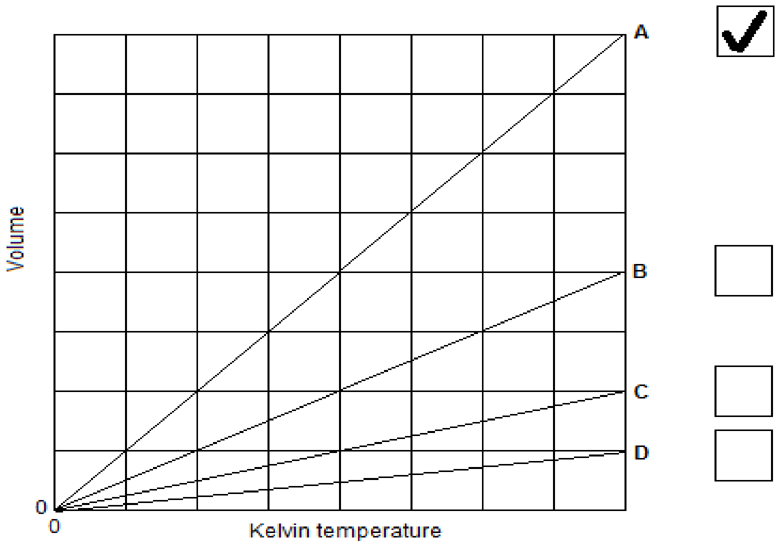
Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response
	Arithmetic error
	Wrong 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:

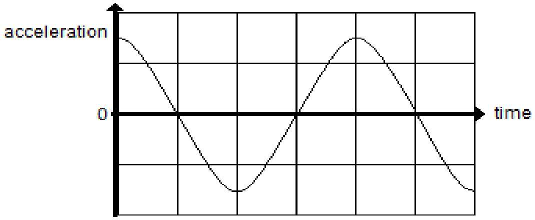
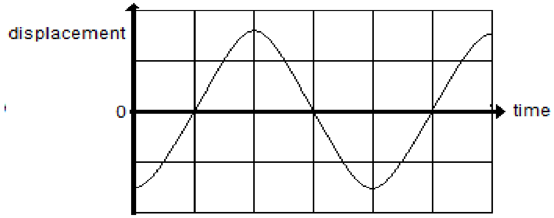
7, 10(b)(iii), 11(c)(ii), 11(c)(iii), 12(a)(i), 12(b), 13(c)(ii).

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1 a</td><td>N kg^{-1}</td><td>1</td><td rowspan="2">Accept '/' for '$^{-1}$' e.g., N/kg instead of N kg^{-1}
Reject: n for N.</td></tr>
<tr><td>b</td><td>N s and kg m s^{-1}</td><td>1</td></tr>
<tr><td>2</td><td>
</td><td>1</td><td></td></tr>
<tr><td>3 a</td><td>0.5</td><td>1</td><td>Accept ½ instead of 0.5</td></tr>
<tr><td>b</td><td>8</td><td>1</td><td></td></tr>
<tr><td>4</td><td><table>
<tr><th>T / K</th><th>V / ml</th><th>p / kPa</th><th>pV/T</th></tr>
<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>
</table></td><td>3</td><td>evidence of calculating pV/T or an appropriate equivalent …
e.g., pV/kT, T/pV, kT/pV for [1]

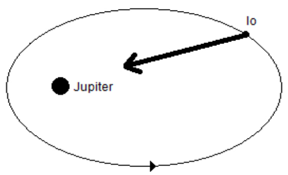
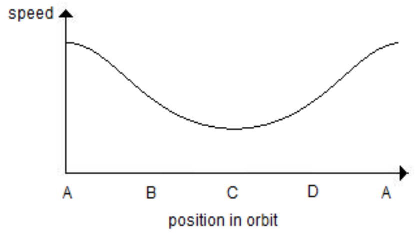
correct evaluation to at least 2 s.f. for all three rows [1]

correct conclusion with reason:
yes, because all same value to 2 s.f. set by V for [1]

Note: If the student uses pV/kT with k=1.4 x 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.</td></tr>
</table>

Question	Answer	Marks	Guidance
5	T = 3/5 = 0.60 s / f = 1.67Hz / ω = 10.5 rad /s ; $k=\dfrac{4\pi^2 m}{T^2}$ / $k=4\pi^2 mf^2$ / $k=m\omega^2$ **;** 13(.2) 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 ¼ square for the peaks, troughs and zero points. *y*-axis: to within ¼ 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 ... *a galaxy is moving away from us*, 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	$v = \frac{3\times10^{-9}\times3\times10^{8}}{5\times10^{-9}}$ = <u>1.8</u> x 10^8m s^{-1};	1	At least 2SF required in the final answer. Note: 2.4 x 10^8m s^{-1} = [0]
	b	$\gamma = \sqrt{\frac{1}{1-0.6^2}} = 1.25$ / $\frac{5}{4}$; life time = 5.0/1.25 = 4 ns;	1 1	v = 2×10^8 gives γ = 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 x 10^8ms^{-1} e.g., v = 2.4 x 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 x 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 ... *the* $\frac{gradient}{voltage}$ *is NOT a constant value*. 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., ... • an exponential then should have a constant half-life (of 0.7*RC*); • The ratio of voltages in equal time intervals should be the same. • $\frac{\Delta Ln(V)}{\Delta t} = const$ • A plot of Ln(V) vs *t* would be a straight line. • $\frac{gradient\ of\ curve}{voltage} = const$ • 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 1.8×10^4 m s^{-1} produced by $T = 1.5 \times 10^5$ 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)	$M = \frac{4.2 \times 10^8 \times (1.7 \times 10^4)^2}{6.7 \times 10^{-11}} = 1.8 \times 10^{27}$ kg	1	20 kms^{-1} gives 2.5×10^{27} kg for [1] 18 kms^{-1} gives 2.0(3) $\times 10^{27}$ 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 ¼ of a square. The minima must be within ¼ 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 *speed*, 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*>Δ*GPE*... ... so the removal of the negative sign can be explained. Accept *KE*+*GPE*=0
	b		*m* = 4.0×10^{-3} / 6.0×10^{23} = 6.67×10^{-27} kg; $E_K = \frac{6.7\times10^{-11}\times6.0\times10^{24}\times6.67\times10^{-27}}{6.4\times10^{6}} = 4.2\times10^{-19}$ 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; $kT = 1.4\times10^{-23}\times(288) = 4.0\times10^{-21}$ J	1 1	Only accept **ECF** for incorrect *T* = 15 K gives 2.1×10^{-22} J **Accept** $1.5kT = 6.0\times10^{-21}$ 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 *change* of energy QWC award third mark only if random fluctuations of energy clear from answer.
		iii	BF for helium is $e^{-4.2\times10^{-19}/4.0\times10^{-21}} = 5\times10^{-46}$; 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 *related* 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	$F = mg = 0.2 \times 9.8 = 1.96$N;
			
			pressure (difference) = $F/A = 1.96/\pi \times (6\times10^{-3})^2 = 1.7\times10^4$ Pa;
			
			net pressure = 100 - 17 = 83 kPa;
			
			Alternative answer: based on forces:
			$F = mg = 0.2 \times 9.8 = 1.96$N;
			
			($F_{up}=100\text{x}10^3\ \pi\ (6\text{x}10^{-3})^2 =$ 11.3N)
			$\Delta F = 11.3 - 1.96 = 9.35$N;
			
			net pressure = $\dfrac{9.35}{\pi(6\text{x}10^{-3})^2}$ = 83 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 $1.1\text{x}10^{-4}\text{m}^2$ gives 18kPa leading to 82kPa[3]
					
					Note: If diameter is used as the radius, the net pressure = 96kPa [2] max
					
					Accept 100-20 = 80kPa for [1]max
					
					No ECF on incorrect *F*.

	b		The ratio of the areas = $\dfrac{30^2}{12^2}$ / = 6(.25) OR the ratio of the masses is $\dfrac{1.2}{0.2}$ / 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 $1.7\times10^4 \times \pi \times (15\times10^{-3})^2$ / 9.8 = 1.2.kg Full **ECF** on pressure calculated in (a)(ii) [1]max available for a qualitative argument along the lines: • 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	$m = 8.0\times10^{-2} + 1.0\times10^{-3}$ (= 8.1 x 10^{-2} / 0.081kg); KE = $8.1\times10^{-2}\times 9.8 \times 2.3\times10^{-1} = 1.83\times10^{-1}$ J; Assumption: $KE_{initial} = GPE_{final}$ / $KE_{lost} = GPE_{gained}$ / KE+GPE=constant / $\Delta KE = \Delta GPE$; (= 8.1×10^{-2});	1 1 1	**ECF** incorrect $m = 8.0\times10^{-2}$ 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 / KE = 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; $u = 0.172/ 1.0\times10^{-3} = 1.7\times10^{2}$ m s^{-1};	1 1 1	Allow **ECF** for incorrect value of *v*. For example, if v = 4.5(08)m s^{-1} leads to u = 365m s^{-1}.[2] Using KE = 0.2J v = 2.22 m s^{-1} final momentum = 0.18 Ns u = 180m s^{-1} [3]
	c i	initial KE of pellet = $\frac{1}{2}mv^2 = 14.5$ J; which is (much) greater than 2×10^{-1} 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 ... • ... 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 *transferred to heat.* **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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