

# **Physics B (Advancing Physics)**

Advanced GCE

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

## **Mark Scheme for June 2013**

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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

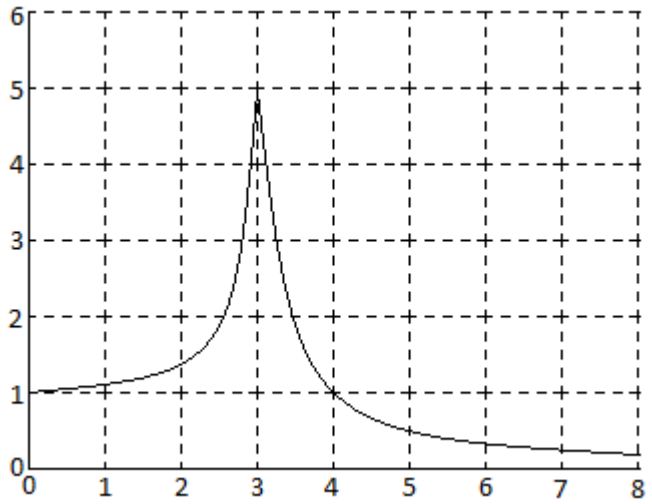
| Annotation                                                                          | Meaning                                |
|-------------------------------------------------------------------------------------|----------------------------------------|
|    | Benefit of doubt given                 |
|    | 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).**

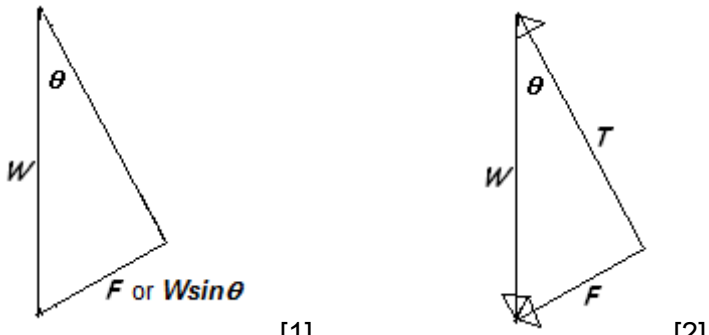
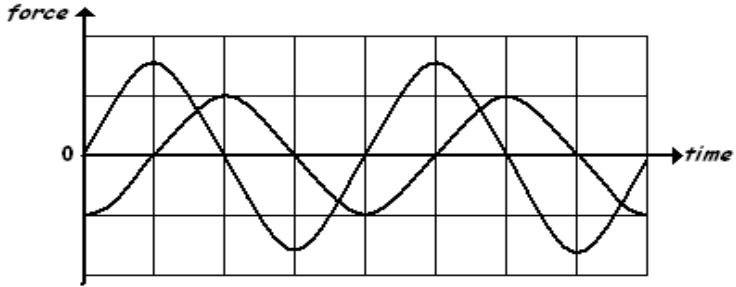
| <b>Annotation</b> | <b>Meaning</b>                                                |
|-------------------|---------------------------------------------------------------|
| /                 | alternative and acceptable answers for the same marking point |
| (1)               | Separates marking points                                      |
| <b>reject</b>     | Answers which are not worthy of credit                        |
| <b>not</b>        | Answers which are not worthy of credit                        |
| <b>IGNORE</b>     | Statements which are irrelevant                               |
| <b>ALLOW</b>      | Answers that can be accepted                                  |
| ( )               | Words which are not essential to gain credit                  |
| —                 | Underlined words must be present in answer to score a mark    |
| <b>ecf</b>        | Error carried forward                                         |
| <b>AW</b>         | Alternative wording                                           |
| <b>ORA</b>        | Or reverse argument                                           |
| <b>owtte</b>      | 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<sup>th</sup> 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) |  | $\text{J kg}^{-1}$                                                                                                                                                                                                                                                                                                              | 1      |                                                                                                                                                                                                                                 |
|          | (b) |  | $\text{N m}$                                                                                                                                                                                                                                                                                                                    | 1      |                                                                                                                                                                                                                                 |
| 2        |     |  | probability that a <u>nucleus</u> decays/fraction of <u>nuclei</u> which decay;<br>in unit time/1s;                                                                                                                                                                                                                             | 1<br>1 | <b>not</b> atom, particle for nucleus                                                                                                                                                                                           |
| 3        |     |  | The outward and returning pulses travel for the same time.                                                                                                                                                                                                                                                                      | 1      |                                                                                                                                                                                                                                 |
| 4        | (a) |  | momentum before = $0.280 \text{ (kg m s}^{-1}\text{)}$ ;<br>momentum after = $0.235 \text{ (kg m s}^{-1}\text{)}$ ;                                                                                                                                                                                                             | 1<br>1 |                                                                                                                                                                                                                                 |
|          | (b) |  | any of the following <ul style="list-style-type: none"> <li>• friction or air resistance slows down the trolleys</li> <li>• track may not be level</li> <li>• light gates may act differently to each other</li> <li>• (kinetic) energy (of trolley) lost due to friction</li> </ul>                                            | 1      | <b>reject</b> references to energy transfers in collisions<br><br><b>not just</b> system was not isolated / other forces acted                                                                                                  |
| 5        | (a) |  | $R (= V/I) = 3.0/5.0 \times 10^{-6} = (6.0 \times 10^5 \Omega)$                                                                                                                                                                                                                                                                 | 1      | <b>look for</b> evidence of correct values of $V$ and $I$ as well as correct rule for calculating $R$<br><b>not</b> $3/5\mu$                                                                                                    |
|          | (b) |  | time constant $\tau = RC$ is <ul style="list-style-type: none"> <li>• time for current to drop by <math>1/e</math></li> <li>• half-life / <math>\ln 2</math></li> <li>• <math>t / (\ln I_0 - \ln I)</math></li> </ul> $\tau (RC) = 14 \pm 1\text{s}$ ;<br>$C = \tau / 6.0 \times 10^5 = 2.3 \pm 0.2 \times 10^{-5} \text{ F}$ ; | 1<br>1 | graph gives 15 s<br>half-life from graph is 10 s<br><br>ecf on any incorrect $\tau$ for [1]<br>e.g. $\tau = 10 \text{ s}$ gives $C = 1.67 \times 10^{-5} \text{ F}$<br>correct answer for $C$ without a value of $\tau$ for [1] |

| Question | Answer                                                                                                                                                                                                                                                       | Marks       | Guidance                                                                                                                                                                                                            |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6        |                                                                                                                                                                            | 3           | <p>starts 0,1.0 [1]<br/> rises with increasing gradient to a maximum value at 3.0,5.0 [1]<br/> then falls with decreasing gradient to below 1.0 by 8.0 [1]</p> <p><b>accept</b> rounded or sharp peak</p>           |
| 7        | A                                                                                                                                                                                                                                                            | 1           |                                                                                                                                                                                                                     |
| 8        | $pV = NkT = \frac{Nmc^2}{3};$ $\overline{c^2} = 8.40 \times 10^4 \text{ m}^2 \text{ s}^{-2};$ $\sqrt{\overline{c^2}} = 290 \text{ m s}^{-1};$                                                                                                                | 1<br>1<br>1 | <p>method [1]<br/> evaluation of <math>\overline{c^2}</math> [1]<br/> answer [1]</p> <p><b>accept</b> <math>\frac{1}{2}mc^2 = kT</math> [1] gives <math>\sqrt{\overline{c^2}} = 237 \text{ m s}^{-1}</math> [1]</p> |
| 9        | <p>any two of the following, [1] each:</p> <ol style="list-style-type: none"> <li>there is a <u>microwave</u> background radiation;</li> <li>which is red-shifted light from earlier universe;</li> <li>due to expansion of space since big bang;</li> </ol> | 2           | <p><b>accept</b> increased wavelength or decreased frequency for red-shift</p>                                                                                                                                      |
|          | <b>Total</b>                                                                                                                                                                                                                                                 | <b>20</b>   |                                                                                                                                                                                                                     |

| Question |     |      | Answer                                                                                                                                                                                                                                                                                                                                                                        | Marks       | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------|-----|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 10       | (a) | (i)  | $T = 273 + 20 = 293 \text{ K};$<br>$N = \frac{pV}{kT} = \frac{1.1 \times 10^5 \times 4.5 \times 10^{-3}}{1.4 \times 10^{-23} \times 293};$<br>$N = 1.21 \times 10^{23};$                                                                                                                                                                                                      | 1<br>1<br>1 | conversion to kelvin [1]<br>transposition and substitution [1]<br>evaluation [1]<br><br><b>ecf</b> on any incorrect value of $T$<br>$T = 20 \text{ K}$ gives $N = 1.77 \times 10^{24}$ for [2]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|          |     | (ii) | $m = \frac{1.21 \times 10^{23}}{6.0 \times 10^{23}} \times 4.0 \times 10^{-3} = 8.07 \times 10^{-4} \text{ kg}$                                                                                                                                                                                                                                                               | 1           | <b>accept</b> ecf from (i)<br>$N = 1.77 \times 10^{24}$ gives $1.18 \times 10^{-2} \text{ kg}$ for [1]<br><b>accept</b> $8.0 \times 10^{-4} \text{ kg}$ , $8 \times 10^{-4} \text{ kg}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|          | (b) |      | particles bounce off balloon;<br>exerting outwards force/pressure;<br>because of change of momentum of particles / transfer of momentum to balloon;                                                                                                                                                                                                                           | 1<br>1<br>1 | <b>accept</b> collide with / hit the balloon<br><b>accept</b> particles push out / balance force from outside<br><b>ignore</b> references to energy transfer<br>QWC: third mark only for reference to momentum change of particles / balloon                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|          | (c) |      | EITHER<br>density of helium = $0.177 \text{ kg m}^{-3}$ from $\rho = \frac{M}{V};$<br>number of hydrogen molecules = $2.42 \times 10^{23}$ from $\rho = \frac{Nm}{V};$<br>OR<br>$\rho = \frac{Nm}{V}$ so $\rho V = Nm;$<br>if $m \rightarrow \frac{m}{2}$ then $N \rightarrow 2N = 2.42 \times 10^{23};$<br>THEN<br>pressure = $2.20 \times 10^5 \text{ Pa}$ from $pV = NkT;$ | 1<br>1<br>1 | use of constant density [1]<br>calculation of number of particles [1]<br>calculation of pressure [1]<br><br><b>ecf</b> for calculation of $p$ from incorrect calculation of $N$ or $M$ from part (a).<br><b>ecf</b> for calculation of $p$ from incorrect number of H molecules<br><b>accept</b> correct answer for [3]<br><br><b>accept</b> algebra e.g.<br>use of $p = \frac{Nmc^2}{3V}$ and $\rho = \frac{Nm}{V}$ to show that $p \propto \overline{c^2};$<br>$\frac{1}{2} m \overline{c^2} = kT$ so $m \overline{c^2} = \text{constant};$<br>if $m \rightarrow \frac{m}{2}$ then $\overline{c^2} \rightarrow 2\overline{c^2}$ so $p$ doubles to $2.2 \times 10^5 \text{ Pa};$ |
|          |     |      | <b>Total</b>                                                                                                                                                                                                                                                                                                                                                                  | <b>10</b>   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

| Question | Answer                                                                                          | Marks      | Guidance                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----------|-------------------------------------------------------------------------------------------------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11 (a)   | $l = g \left( \frac{T}{2\pi} \right)^2;$ $l = 0.993 \text{ m}$                                  | 1<br><br>1 | evidence transposition [1]<br>evaluation [1]<br><b>accept</b> reverse calculation:<br>use of $T = 2\pi \sqrt{\frac{l}{g}}$ [1]:<br>EITHER $l = 1.0 \text{ m}$ gives $T = 2.01 \text{ s}$ [1]<br>OR $T = 2.0 \text{ s}$ and $l = 1.0 \text{ m}$ gives $g = 9.87 \text{ N kg}^{-1}$ [1]                                                                                                                                                                                    |
| (b)      | $g = l \frac{4\pi^2}{T^2};$ calculated value of $g$ will be low (because $l$ used will be low); | 1<br>1     | <b>look</b> for use of $T = 2\pi \sqrt{\frac{l}{g}}$ to show $g \propto l$<br><b>ignore</b> references to wrong value of $T$                                                                                                                                                                                                                                                                                                                                             |
| (c)      |               | 2          | Look for: <ul style="list-style-type: none"> <li>arrows in correct direction</li> <li>all three sides labelled</li> <li>angle <math>\theta</math> opposite <math>F</math>.</li> <li>right angle between <math>T</math> and <math>F</math>.</li> </ul> right angle triangle ( by eye) with $\theta$ , $W$ and $F$ or $W \sin \theta$ correctly labelled [1]<br>and all three arrows and $T$ in correct direction for [2]<br><b>accept</b> any orientation of the triangle |
| (d)      |             | 2          | sinusoid with any constant amplitude and period of four squares all the way across for [1]<br><b>accept</b> one error in amplitude, crossing point or turning point<br>correct phase for [1]                                                                                                                                                                                                                                                                             |
| Total    |                                                                                                 | 8          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

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

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

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