## GCE

# Physics B (Advancing Physics) 

Advanced GCE
Unit G494: Rise and Fall of the Clockwork Universe

## Mark Scheme for January 2011

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| Question |  |  | Expected Answers | Marks | Rationale |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | a |  | $\mathrm{kg} \mathrm{m} \mathrm{s}^{-2}$ | 1 |  |
|  | b |  | $\mathrm{m} \mathrm{s}^{-1}$ | 1 |  |
| 2 |  |  | $\begin{array}{\|l\|} \hline \square \\ \hline \\ \hline \\ \hline \\ \hline \end{array}$ | 1 |  |
| 3 | a |  | $V=\frac{Q}{C}$ | 1 | not just $Q=C V$ |
|  | b |  | $I=-\frac{d Q}{d t}$ | 1 |  |
|  | C |  | $\frac{V}{R}=-\frac{d Q}{d t}=\frac{Q}{R C}$ | 1 | look for correct substitution for I into answer for (b) (allow ecf) AND correct substitution for $V$ from (a) (allow ecf) accept final incorrect answer which matches incorrect answers to (a) and (b) |
| 4 | a |  | $\frac{1.1 \times 10^{-2}}{2.9 \times 10^{-2}} \times 6.0 \times 10^{23}=2.28 \times 10^{23} \text { or } 2.3 \times 10^{23}$ | 1 | $2 \times 10^{23}$ particles gives $9.7 \times 10^{-3} \mathrm{~kg}$ for [1] |
|  | b |  | $\begin{aligned} & \overline{c^{2}}=\frac{3 p V}{N m} \\ & m_{\text {air }}=\frac{2.9 \times 10^{-2}}{6.0 \times 10^{23}}=4.83 \times 10^{-26} \mathrm{~kg} \\ & \overline{c^{2}}=2.5 \times 10^{5} \mathrm{~m}^{2} \mathrm{~s}^{-2} \end{aligned}$ <br> $N=2 \times 10^{23}$ gives $2.9 \times 10^{5} \mathrm{~m}^{2} \mathrm{~s}^{-2}$ for [2] | 1 <br> 1 | correct substitution into equation for $\overline{c^{2}}$, perhaps with $m=1.1 \times 10^{-2} \mathrm{~kg}$ or $2.9 \times 10^{-2} \mathrm{~kg}$ for $[1]$; <br> correct evaluation of $m$ and $\overline{c^{2}}$ for [1] $\begin{aligned} & m_{\text {air }}=2.9 \times 10^{-2} \mathrm{~kg} \text { gives } 4.1(7) \times 10^{-19} / 4.7(5) \times 10^{-19} \mathrm{~m}^{2} \mathrm{~s}^{2} \text { for }[1] \\ & m_{\text {air }}=1.1 \times 10^{-2} \mathrm{~kg} \text { gives } 1.1 \times 10^{-18} / 1.2(5) \times 10^{-18} \mathrm{~m}^{2} \mathrm{~s}^{-2} \text { for }[1] \end{aligned}$ |
| 4 | C |  |  | 1 | look for a straight line through the origin line does not have to be drawn with a ruler |


| Question |  |  | Expected Answers | Marks | Rationale |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 5 | a |  | (shift of) wavelength of (absorption) lines in spectrum of a galaxy | 1 | accept wavelength / frequency |
| 5 | b |  | (redshift means) universe is expanding / galaxies are moving away from each other / velocity away us increases with increasing distance; <br> therefore universe / galaxies / stars were at the same point far enough back in time; | 1 <br> 1 | not just closer together in the past |
| 6 |  |  | C | 1 |  |
| 7 | a |  | 16(.43) | 1 | not 20, 115/7 |
| 7 | b |  | $7.3 \times 10^{-8} / 7.5 \times 10^{-8}$ | 1 | accept $1.1 \times 10^{-7}$ from $e / k T=16$ accept full ecf from (a) |
| 7 | C |  |  | 1 | accept any clearly unambiguous correct response |
| 8 |  |  |  | 1 | look for <br> - cosine curve of any constant amplitude <br> - correct period <br> - correct phase <br> amplitude can change by half a square across the graph maxima and minima within the red lines zero crossings within the green lines |
| 9 | a |  | $E=0.5 \times 4700 \times 10^{-6} \times 20^{2}=0.9(4) \mathrm{J}$ | 1 | must see calculated value |
| 9 | b |  | 40 W | 1 |  |


| Question |  |  | Expected Answers | Marks | Rationale |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 10 | a |  | force proportional to displacement; force and displacement in opposite directions / force always towards equilibrium position; | $1$ $1$ | accept force increases with increasing displacement / distance ... accept acceleration for force throughout <br> not just restoring force or minus sign accept wtte for equilibrium position e.g. centre, midpoint ... |
| 10 | b | i | $f=\frac{1}{2 \pi} \sqrt{\frac{k}{m}}=26(.39)$ | $\begin{aligned} & 1 \\ & 1 \end{aligned}$ | evidence of correct formulae for [1] e.g $T=2 \pi \sqrt{\frac{m}{k}}, f=\frac{1}{T}$ evidence of correct calculation for [1] |
| 10 | b | ii | largest amplitude at $26 / 30 \mathrm{~Hz} /$ resonant frequency / natural frequency; amplitude decreases with increasing frequency (above resonance); | $1$ $1$ | allow ecf from (b)(i) if within 20 Hz to 50 Hz <br> accept small amplitude away from resonance / $26 \mathrm{~Hz} / 30 \mathrm{~Hz}$ ignore sketch graph, award marks for the accompanying words marks are independent, so second mark can be earned if the response doens't mantion resonance. |
| 10 | C |  | any of the following [1] each, maximum [3] air acts like a spring because: <br> - as volume decreases pressure increases <br> - because $p V$ is constant (= NkT) <br> - more collisions as particles pushed together <br> - increased transfer of momentum to cone from particles <br> - force from particle impacts restores cone to equilibrium position <br> any of the following [1] each, maximum [3] effects on the frequency: <br> - total $k$ increases <br> - spring and air act in parallel <br> - frequency of free oscillations increases <br> - because $f=\frac{1}{2 \pi} \sqrt{\frac{k}{m}}$ or $f \alpha \sqrt{k}$ | 4 | must have correct technical terms throughout for the fourth mark to be awarded. <br> overall mark cannot exceed [4] |


| Question |  |  | Expected Answers | Marks | Rationale |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 11 | a |  |  | 4 | one mark for each point, maximum [4]: <br> - KE rises from A to D with correct shape <br> - KE drops suddenly at $D$ to constant value from $D$ to $F$ <br> - GPE drops from A to D with correct shape <br> - total energy constant from A to D (by eye) <br> - GPE constant from D to F <br> - KE is -0.5 GPE (and constant) from D to F <br> use the overlay to help you make judgements vertical part of overlay must pass though D |
| 11 | b |  | $\begin{aligned} & \Delta p=1.2 \times 10^{3} \times 1.8 \times 10^{3}-9.5 \times 10^{2} \times 1.5 \times 10^{3} \\ & \Delta p=7.35 \times 10^{5} \mathrm{Ns} \\ & m_{\text {gas }}=2.5 \times 10^{2} \mathrm{~kg} \\ & v=7.35 \times 10^{5} / 2.5 \times 10^{2} \mathrm{~kg}=2.9 \times 10^{3} \mathrm{~m} \mathrm{~s}^{-1} \end{aligned}$ | $\begin{aligned} & 1 \\ & 1 \\ & 1 \end{aligned}$ | ```correct value of }\Deltap\mathrm{ for [1] correct mgas for [1] ecf incorrect }\Deltap,\mp@subsup{m}{\mathrm{ gas}}{ for ecf must have calculated a change of momentum``` |
| 11 | C | i | $\frac{m v^{2}}{r}=\frac{G M m}{r^{2}}$ <br> cancellation and rearrangement as required | $1$ $1$ | not just separate statement of both forces <br> working to final formula must be clear ignore minus signs |
| 11 | c | ii | $r=1.9(36) \times 10^{7} \mathrm{~m}$ | 1 | must have correct rounding to earn mark, but not $2 \times 10^{7}$ |


| Question |  | Expected Answers | Marks | Rationale |
| :---: | :---: | :---: | :---: | :---: |
| 12 | a | $\begin{aligned} & T=273+20=293 \mathrm{~K} \\ & N=\frac{p V}{k T}=3.17 \times 10^{27} \text { accept } 3.2 \times 10^{27} \end{aligned}$ | 1 <br> 1 | ecf incorrect $T$ : e.g. $T=20 \mathrm{~K}$ gives $4.6 \times 10^{28}$ for [1] |
| 12 | b | $\begin{aligned} & \text { energy per particle } \approx k T \\ & \Delta E=3.2 \times 10^{27} \times 1.4 \times 10^{-23} \times(20-5)=6.7 \times 10^{5} \mathrm{~J} \\ & P=6.7 \times 10^{5} / 3600=187 \mathrm{~W} \text { or } 190 \mathrm{~W} \end{aligned}$ | $\begin{aligned} & 1 \\ & 1 \\ & 1 \end{aligned}$ | accept anything from $k T$ to $3 k T$ <br> $3 \times 10^{27}$ particles gives 175 W <br> $3.17 \times 10^{27}$ particles gives 185 W |
| 12 | C | EITHER <br> particles have more energy / move faster; particles collide more (often) / greater impact force; particles get further apart / occupy a larger volume; reducing density; <br> OR <br> assuming ideal gas behaviour; <br> $V$ increase as $T$ increases (at constant $p, N$ ); <br> so same number of particles occupy larger volume; reducing density; <br> OR <br> $p=\frac{1}{3} \rho \overline{c^{2}}$ for ideal gas; <br> particles have more energy; <br> $\overline{c^{2}}$ increases with increasing energy; <br> ( $p$ constant) so density reduces | $\begin{aligned} & 1 \\ & 1 \\ & 1 \\ & 1 \end{aligned}$ | accept increased rate of change of momentum at impact <br> accept $p V=N k T$ instead of ideal gas behaviour accept volume increases as particle energy increases accept same mass instead of number of particles |


| Question |  |  | Expected Answers | Marks | Rationale |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 13 | a | i | probability of decay; of a single nucleon in one second; | $\begin{aligned} & 1 \\ & 1 \end{aligned}$ | accept proportion of nucleons [1] which decay per second [1] accept muon / electron / particle / nucleus / atom for nucleon accept rate of decay as decays per second |
| 13 | a | ii | $0.693 / 1.5 \times 10^{-6}=4.6(2) \times 10^{5} \mathrm{~s}^{-1}$ | 1 |  |
| 13 | b | i | three half-lives to reduce to one eighth; $\begin{aligned} & t=3 \times 1.5 \times 10^{-6}=4.5 \times 10^{-6} \mathrm{~s} ; \\ & s=4.5 \times 10^{-6} \times 3.0 \times 10^{8}=1.35 \times 10^{3} \mathrm{~m} \end{aligned}$ | $\begin{aligned} & 1 \\ & 1 \\ & 1 \end{aligned}$ | accept use of $N=N_{0} e^{-\lambda t}$ to find $t$ <br> accept working backwards e.g.: 1.4 km gives $4.67 \times 10^{-6} \mathrm{~s}$ [1] $\begin{gathered} e^{-\lambda t}=0.116[1] \\ 1 / 0.116=8.6[1] \end{gathered}$ <br> 1.4 km gives 3.11 half-lives for [3] |
| 13 | b | ii |  | $\begin{aligned} & 1 \\ & 1 \end{aligned}$ | correct shape (falling with decreasing gradient all the way from 0.0 to 1.4 km ) for [1] passing through points for [1] (by eye) <br> use overlay for guidance |
| 13 | b | iii | $\gamma=4 / 1.35=2.96 / 3.0 ;$ <br> time dilation occurs / muon time runs slower than laboratory time / effective half-life longer for muons / effective half-life now $4.4 \mu \mathrm{~s}$; <br> $\gamma$ formula to find $v=2.8 \times 10^{8} \mathrm{~m} \mathrm{~s}^{-1} / v / c=0.94(1)$; | $\begin{aligned} & 1 \\ & 1 \\ & 1 \end{aligned}$ | 1.4 km gives $\gamma=2.86 / 2.9$ |

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