GCE
Physics A

Unit G485: Fields, Particles and Frontiers of Physics
Advanced GCE

Mark Scheme for June 2014
OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today’s society.

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.

© OCR 2014
1. These are the annotations, (including abbreviations), including those used in scoris, which are used when marking

<table>
<thead>
<tr>
<th>Annotation</th>
<th>Meaning of annotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BP</td>
<td>Blank Page – this annotation <strong>must</strong> be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.</td>
</tr>
<tr>
<td>✓</td>
<td>correct response</td>
</tr>
<tr>
<td>✗</td>
<td>incorrect response</td>
</tr>
<tr>
<td>BOD</td>
<td>benefit of the doubt (where professional judgement has been used)</td>
</tr>
<tr>
<td>NBOB</td>
<td>benefit of the doubt <strong>not</strong> given</td>
</tr>
<tr>
<td>ECF</td>
<td>error carried forward</td>
</tr>
<tr>
<td>▲</td>
<td>information omitted</td>
</tr>
<tr>
<td>CON</td>
<td>contradiction (in cases where candidates contradict themselves in the same response)</td>
</tr>
<tr>
<td>FT</td>
<td>follow through</td>
</tr>
<tr>
<td>SF</td>
<td>error in number of significant figures</td>
</tr>
<tr>
<td>POT</td>
<td>error in the power of 10 in calculation</td>
</tr>
<tr>
<td>AE</td>
<td>arithmetic or calculation error</td>
</tr>
<tr>
<td>NAQ</td>
<td>not answered question</td>
</tr>
<tr>
<td>?</td>
<td>wrong physics</td>
</tr>
<tr>
<td>RE</td>
<td>reading error</td>
</tr>
</tbody>
</table>
Abbreviations, annotations and conventions used in the detailed Mark Scheme.

/ = alternative and acceptable answers for the same marking point
(1) = separates marking points
allow = answers that can be accepted
not = answers which are not worthy of credit
reject = answers which are not worthy of credit
ignore = statements which are irrelevant
() = words which are not essential to gain credit
__ = underlined word (or the equivalent) must be present in answer to score a mark
ecf = error carried forward
AW = alternative wording
ora = or reverse argument
Subject-specific Marking Instructions

CATEGORISATION OF MARKS
The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a B-mark to be scored, the point to which it refers must be seen specifically in the candidate’s answers.

M marks: These are method marks upon which A-marks (accuracy marks) later depend. For an M-mark to be scored, the point to which it refers must be seen in the candidate’s answers. If a candidate fails to score a particular M-mark, then none of the dependent A-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a C-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the C-mark is given.

A marks: These are accuracy or answer marks, which either depend on an M-mark, or allow a C-mark to be scored.

Note about significant figures*:

If the data given in a question is to 2 sf, then allow answers to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.

Any exception to this rule will be mentioned in the Guidance.
(*Note: Significant figures are thoroughly assessed in G483 and G486 components of Physics A.)
<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (a)</td>
<td>Correct direction of the electric field. A minimum of 5 field lines shown. Correct shape of field lines.</td>
<td>B1</td>
<td>B1 Expect a minimum of 3 field lines to be normal (by eye) to the plate - ignore the angles made by the field lines at the sphere. Also there must not be any field lines within the sphere.</td>
</tr>
<tr>
<td>(b) (i)</td>
<td>( E \propto \frac{Q}{r^2} ) and the magnitude of ( E ) is the same due to each charge ( A ) and ( B ) at ( X ). Therefore ( B ) has a greater charge because ( X ) is further away from ( B ).</td>
<td>B1</td>
<td></td>
</tr>
<tr>
<td>(ii)</td>
<td>Curve showing ( E = 0 ) at position of ( X ). Curve showing ( E ) is positive between ( A ) and ( X ) and negative between ( X ) and ( B ) (or vice versa). The magnitude of ( E ) is small close to ( A ) and large close to ( B ).</td>
<td>B1</td>
<td>Allow any graph, including a straight line. Tolerance for ( E = 0 ): ( \pm \frac{1}{2} ) large square about ( X ). Note: The curve must be continuous and pass through position of ( X ). Ignore any curve to the right of ( B ) and to the left of ( A ). Note: This mark can only be scored if the previous M1 has been awarded.</td>
</tr>
<tr>
<td>(c)</td>
<td>Both ( E ) and ( g ) vary with ( 1/distance^2 ). (Hence the ratio is independent of the distance.)</td>
<td>B1</td>
<td>Allow: ( E = \frac{Q}{4\pi\varepsilon_0 r^2} ) and ( g = \frac{GM}{r^2} ) or ( E \propto \frac{1}{r^2} ) and ( g \propto \frac{1}{r^2} ) Allow ‘both are inverse square laws’.</td>
</tr>
</tbody>
</table>

Total 7
<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
</table>
| 2 (a) (i) | A (constant) force acts at right angles to the velocity / motion (of the helium nucleus). | B1 | **Note**: The answer must be in terms of force and not acceleration. 
Allow ‘force is towards the centre of the circle’.
Not ‘there is a *centripetal* force’ - unless explained.
Not ‘force is right angles to speed’. |
| 2 (a) (ii) | No work done (by the force) / no acceleration in the direction of motion / no force in direction of motion | B1 | Allow force / acceleration is at right angles to velocity / motion. |
| 2 (b) | \[ BQv = \frac{mv^2}{r} \text{ or } mv = BQr \] 
momentum = \(0.20 \times 10^{-3} \times 3.2 \times 10^{-19} \times 0.15\)  
momentum = \(9.6 \times 10^{-24}\) (kg m s\(^{-1}\)) | C1 | Allow \(v = 1.45.. \times 10^{3}\) (m s\(^{-1}\))\(; \rho = 1.45.. \times 10^{3} \times 6.6 \times 10^{-27}\) |
| 2 (c) | \(v = 9.6 \times 10^{-24}/6.6 \times 10^{-27}\) or \(v = 1.45\ldots \times 10^{3}\) (m s\(^{-1}\))  
KE = \(\frac{1}{2} \times 6.6 \times 10^{-27} \times (1.45\ldots \times 10^{3})^2\)  
KE = \(7.0 \times 10^{-21}\) (J) | C1 | Possible ecf from (b) |
| 2 (d) | The helium nucleus moves to the right.  
The path is a clockwise curve / looped (in the plane of the paper). | B1 | Not if the path is shown as a straight line. |
| | | | Allow 2 marks for clockwise curve / loop to the right. 
Allow 1 mark for a sketch showing an ‘upward curve to the right’ |

**Total** 9
<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (a) (i)</td>
<td>One proton / (same) charge / (same) element and (same) chemical property / one electron</td>
<td>B1</td>
<td>Allow (same) number of protons. Allow (same) number of electrons.</td>
</tr>
<tr>
<td>(ii)</td>
<td>mass of nucleus &lt; (total) mass of nucleons</td>
<td>B1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Energy must be supplied to the nucleus to free the nucleons / energy released when nucleons combine (to form the nucleus).</td>
<td>B1</td>
<td>Allow nucleus has binding energy.</td>
</tr>
<tr>
<td></td>
<td>$(\Delta)E = (\Delta)mc^2$ and $(\Delta)E$ is the (binding) energy and $(\Delta)m$ is the mass defect or the difference in mass.</td>
<td>B1</td>
<td></td>
</tr>
<tr>
<td>(b) (i)</td>
<td>$^1n \rightarrow ^1p + ^0e + \bar{\nu}_e$</td>
<td>B1, B1</td>
<td>Allow proton or $^1H$ or $H^+$ or p and (electron) antineutrino.</td>
</tr>
<tr>
<td>(ii)</td>
<td>(Average) time taken for half of the neutrons (in a sample) to decay.</td>
<td>B1</td>
<td>Note: Must have reference to 'half' and 'neutrons'. Allow 'the time taken for the activity of neutrons to halve'.</td>
</tr>
<tr>
<td>(c) (i)</td>
<td>$F = \frac{1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{4\pi \epsilon_0 \times (10^{-14})^2}$ force = 2.3 (N)</td>
<td>C1</td>
<td>Not $Q = q = 1$</td>
</tr>
<tr>
<td></td>
<td>$E = 7.0 \times 10^4 \times 1.6 \times 10^{-19} (= 1.12 \times 10^{-14} \text{ J})$</td>
<td>C1</td>
<td>Allow any subject. Also, allow $E \approx kT$ since it is an estimate.</td>
</tr>
<tr>
<td></td>
<td>$(E = \frac{1}{2}kT)$; $7.0 \times 10^4 \times 1.6 \times 10^{-19} = \frac{1}{2} \times 1.38 \times 10^{-23} \times T$ temperature = $5.4 \times 10^8$ (K)</td>
<td>C1, A1</td>
<td>Allow 1 sf answer.</td>
</tr>
<tr>
<td>(iii)</td>
<td>Some nuclei will be travelling faster / have greater (kinetic) energy (to overcome electrostatic repulsion and hence cause fusion).</td>
<td>B1</td>
<td>Allow the pressures are high (enough to cause fusion). Not 'nuclei get close enough'.</td>
</tr>
<tr>
<td>(iv)</td>
<td>$(\Delta E = \Delta mc^2)$; $18 \times 10^8 \times 1.6 \times 10^{-19} = \Delta m \times (3.0 \times 10^8)^2$ change in mass = $3.2 \times 10^{-29}$ (kg)</td>
<td>C1, A1</td>
<td>Allow any subject Allow a maximum of 1 mark for 18 MeV ± 70 keV.</td>
</tr>
<tr>
<td>(v)</td>
<td>Helium (nucleus) has greater charge / more protons.</td>
<td>B1</td>
<td>Do not award this mark if 'helium nuclei are moving slower' is also given as the reason for smaller probability for fusion.</td>
</tr>
</tbody>
</table>

<p>| Total | 17 |</p>
<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 (a)</td>
<td>The time taken for the p.d / current / charge to decrease to $1/e$ of its (initial) value.</td>
<td>B1</td>
<td>Allow 37% instead of $1/e$. Not time constant $= CR$ on its own.</td>
</tr>
<tr>
<td>(b)</td>
<td>Any suitable values with units, eg: $5 , M\Omega$ and $1 , \mu F$.</td>
<td>B1</td>
<td></td>
</tr>
<tr>
<td>(c) (i)</td>
<td>$R = \frac{4.9 \times 10^{-2} \times 5.0}{\pi \times (0.06 \times 10^{-3})^2}$ or $R = 217 , (\Omega)$</td>
<td>C1</td>
<td>Note: An incorrect equation here for A prevents this and any subsequent marks.</td>
</tr>
<tr>
<td></td>
<td>time constant $= 0.010 \times 217$</td>
<td>C1</td>
<td>Allow 2 marks for 0.54 (s) – diameter of 0.12 mm used instead of radius 0.06 mm.</td>
</tr>
<tr>
<td></td>
<td>time constant $= 2.2 , (s)$</td>
<td>A1</td>
<td></td>
</tr>
<tr>
<td>(ii)</td>
<td>Electrons are removed from $X$ or electrons are deposited on $Y$.</td>
<td>B1</td>
<td>Allow electrons move anticlockwise (in the circuit).</td>
</tr>
<tr>
<td></td>
<td>$X$ becomes positive or $Y$ becomes negative</td>
<td>B1</td>
<td>There is no ecf from the previous B1 mark.</td>
</tr>
<tr>
<td></td>
<td>(The size of charge is the same because) an equal number of electrons are removed and deposited (on the plates).</td>
<td>B1</td>
<td></td>
</tr>
<tr>
<td>(iii)</td>
<td>$E = \frac{1}{2} \times 0.010 \times 12^2$ or $E = 0.72 , (J)$</td>
<td>C1</td>
<td>Note: An incorrect equation here for $m$ or $V$ prevents this and any subsequent marks.</td>
</tr>
<tr>
<td></td>
<td>$m = 8900 \times [\pi \times (0.06 \times 10^{-3})^2 \times 5.0]$ or $5.0(3) \times 10^{-4} , (kg)$</td>
<td>C1</td>
<td>Correct substitution into $mc\Delta \theta = 0.72$; allow any subject.</td>
</tr>
<tr>
<td></td>
<td>$5.03 \times 10^{-4} \times 420 \times \Delta \theta = 0.72$</td>
<td>A1</td>
<td>Note: Do not penalise using diameter here again if already penalised in (c)(i).</td>
</tr>
<tr>
<td></td>
<td>increase in temperature $= 3.4 , (^{\circ}\text{C})$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(iv)</td>
<td>Energy or $V^2$ increases by a factor of 4.</td>
<td>B1</td>
<td>Allow the label $E$ or $W$ for energy.</td>
</tr>
<tr>
<td></td>
<td>The (change in temperature) increases by a factor of 4 (because $\Delta \theta \propto E$).</td>
<td>B1</td>
<td>Allow $\Delta \theta = 13.6 , (^{\circ}\text{C})$ for this B1 mark - possible ecf from (iii).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answers</td>
<td>Marks</td>
<td>Guidance</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>5 (a)</td>
<td>The induced e.m.f. is (directly) proportional / equal to the rate of change of (magnetic) flux linkage.</td>
<td>B1</td>
<td><strong>Allow</strong> $E = \frac{\Delta \Phi}{\Delta t}$ with all terms defined; $E =$ induced e.m.f., $\Phi =$ (magnetic) flux linkage and $t =$ time.</td>
</tr>
<tr>
<td>(b)</td>
<td>North / N (pole). There is a repulsive force (between magnet and coil and the work done against this repulsive force is transferred to electrical energy in the coil).</td>
<td>B1</td>
<td><strong>Allow</strong> - A south (pole) would cause attraction (between the coil and magnet) or there is gain in KE (of magnet which cannot happen hence it must be north pole).</td>
</tr>
<tr>
<td>(c) (i)</td>
<td>There is no change in (magnetic) flux (linkage) or there is no change in the (magnetic) flux density.</td>
<td>B1</td>
<td><strong>Allow</strong> 'no change in (magnetic) field strength'.</td>
</tr>
<tr>
<td>(ii)</td>
<td>$E = 0$ between 0 to 3 cm, 5 – 8 cm and 10 - 12 cm. Two ‘pulses’ where $B$ is changing. The pulses have opposite signs.</td>
<td>B1</td>
<td><strong>Tolerance:</strong> ± ¼ large square</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M1</td>
<td><strong>Note:</strong> The pulses must have $E = 0$ at 3 cm, 5 cm, 8 cm and 10 cm; tolerance ± ¼ large square.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A1</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answers</td>
<td>Marks</td>
<td>Guidance</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>6 (a) (i)</td>
<td>C</td>
<td>B1</td>
<td></td>
</tr>
<tr>
<td>(ii)</td>
<td>Zero</td>
<td>B1</td>
<td></td>
</tr>
<tr>
<td>(b) (i)</td>
<td>proton / $^1\text{H}$ / $^1\text{p}$ / p</td>
<td>B1</td>
<td></td>
</tr>
<tr>
<td>(ii)</td>
<td>$\lambda = \frac{0.693}{5700 \times 3.16 \times 10^7}$ or $\lambda = 3.847... \times 10^{-12}$ (s$^{-1}$)</td>
<td>C1</td>
<td>Allow any subject</td>
</tr>
<tr>
<td></td>
<td>$(A = \lambda N); N = \frac{1.1 \times 10^{19}}{3.847... \times 10^{-12}}$ or $N = 2.859.. \times 10^{30}$</td>
<td>C1</td>
<td>Allow ecf within the calculation for an incorrect $\lambda$.</td>
</tr>
<tr>
<td></td>
<td>mass $= \frac{2.859... \times 10^{30}}{6.02 \times 10^{23}} \times 0.014$</td>
<td>A1</td>
<td>Allow $6.7 \times 10^4$ (kg)</td>
</tr>
<tr>
<td>(c)</td>
<td>A (thermal / slow-moving) neutron splits the nucleus into two (smaller) nuclei and (fast-moving) neutron(s).</td>
<td>B1</td>
<td>Allow ‘fast neutron’; allow ‘decays’ instead of ‘splits’. Not ‘splitting the atom’. Not ‘particles’ or ‘fragments’ in place of ‘(smaller) nuclei’.</td>
</tr>
</tbody>
</table>
| (d)      | Any three from:  
1. Fission reactions produce fast neutrons.  
2. The moderator / water slows down (the fast-moving) neutrons.  
3. Slow-moving neutrons have a greater chance of causing fission (of U-235). (ora)  
4. The control rods absorb (some of the) neutrons.  
5. (On average) one neutron survives between successive (fission) reactions.  

QWC: The neutrons make collisions with the (moderator) nuclei and transfer (some of) their (kinetic) energy. | B1 $\times 3$ | Allow boron / cadmium instead of control rods in 4. Not graphite for 4. Allow atoms / molecules instead of nuclei. |
<p>|          | Total 12 |       |          |</p>
<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 (a) (i)</td>
<td>Discrete energy (of electrons in an atom) / quantised energy (of electrons in an atom) / permitted energy (states of electrons in an atom).</td>
<td>B1</td>
<td></td>
</tr>
</tbody>
</table>
| (ii) | \( E = \frac{\hbar c}{\lambda} \) \[
E = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{7.2 \times 10^{-11}} \text{ or } E = 2.763 \times 10^{-15} \text{ (J)}
\]
value of energy level = \(- (3.2 - 2.763) \times 10^{-15} \text{ (J)}\)
value of energy level = \(- 4.4 \times 10^{-16} \text{ (J)}\) | C1 | Note: The answer must be negative to score the A1 mark. Note: 4.4 \times 10^{-16} \text{ (J)} scores 2 marks |
| (iii) | \( \lambda_0 \) is halved.
Explanation: Reference to (photon / electron kinetic) energy doubled and \( E = h\omega/\lambda \) or \( E \propto 1/\lambda \). | M1 | Allow explanation in terms of \( eV = h\omega/\lambda \). |
| (b) (i) | \( I = I_0 e^{-\mu x} \)
fraction transmitted = \( e^{-0.96 \times 2.3} \)
fraction transmitted = 0.11
fraction absorbed or scattered = 1 – 0.11
fraction absorbed or scattered = 0.89 | C1 | Allow 3 marks for 89%. Allow 89/100 |
| (ii) | Bone and muscle have different (values for) \( \mu \) hence better contrast.
or
Muscle and fat have similar (values for) \( \mu \) hence poor contrast. | B1 | |
<p>| | | | Total 10 |</p>
<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 (a)</td>
<td>Ultrasound reflected at boundary (between materials). B-scan takes place in different directions. QWC: The intensity of the reflected ultrasound depends on the acoustic impedances of the materials (and this is greater when the difference between the acoustic impedances is greater).</td>
<td>B1 B1 B1</td>
<td>Allow B-scan is ‘multiple A-scans’. Allow Z instead of acoustic impedance. Not attenuation coefficient for Z.</td>
</tr>
<tr>
<td>(b)</td>
<td>Any four from: 1. The brain / body is surrounded by a ring of (gamma) detectors / gamma camera(s). 2. The positrons (from the F-18 nuclei) annihilate electrons. 3. The annihilation of a positron and an electron produces two (identical gamma) photons travelling in opposite directions. 4. The delay time between these two photons / gamma rays is used to determine the location of the annihilation / F-18 / tracer. 5. Computer connected to detectors / gamma camera and an image is formed by the computer (using the electrical signals from the detectors).</td>
<td>B1×4</td>
<td>Not positrons and electrons annihilate to produce photons travelling in opposite directions for 3. Allow an answer in terms of arrival times.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answers</td>
<td>Marks</td>
<td>Guidance</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>9(a)</td>
<td>( V = \frac{4}{3} \pi (6 \times 10^3)^3 ) or ( V = 9.05 \times 10^{11} ) (m³) &lt;br&gt; density = ( \frac{2.0 \times 10^{30}}{\frac{4}{3} \pi (6 \times 10^3)^3} ) &lt;br&gt; density = ( 2.2 \times 10^{18} ) kg m⁻³</td>
<td>C1</td>
<td><strong>Note</strong>: An incorrect equation here for ( V ) prevents this and any subsequent marks. &lt;br&gt; C1</td>
</tr>
<tr>
<td>9(b)</td>
<td>( g \propto \frac{1}{r^2} ) &lt;br&gt; ratio = ( \left( \frac{1.4 \times 10^9}{12 \times 10^3} \right)^2 ) or ratio = ( \left( \frac{0.7 \times 10^9}{6 \times 10^3} \right)^2 )</td>
<td>C1</td>
<td><strong>Note</strong>: The answer to 3 sf is ( 1.36 \times 10^{10} ). <strong>Allow</strong> 1 mark for ( 7.3 \times 10^{-11} ) – inverse of the ratio.</td>
</tr>
<tr>
<td>9(c)</td>
<td>((\rho = 1/d)) &lt;br&gt; ( d = \frac{8.6 \times 9.5 \times 10^{15}}{3.1 \times 10^{16}} ) (pc) or ( d = 2.64 ) (pc) &lt;br&gt; ( \rho = 0.38 ) (arc seconds)</td>
<td>C1</td>
<td><strong>Allow</strong> full credit for alternative methods.</td>
</tr>
<tr>
<td>9(d)</td>
<td>( \frac{\Delta \lambda}{\lambda} = \frac{v}{c} ) &lt;br&gt; fractional change = ( \frac{7600}{3.0 \times 10^8} ) &lt;br&gt; percentage change = ( 2.5 \times 10^{-3} ) %</td>
<td>C1</td>
<td><strong>Allow</strong> 1 mark for ( 2.5 \times 10^{-5} ) (factor of 100 missed out).</td>
</tr>
<tr>
<td>9(e)</td>
<td>The suggestion is incorrect because Hubble’s law applies to (distant receding) galaxies. &lt;br&gt; or &lt;br&gt; The suggestion is incorrect because Hubble’s law does not apply to stars in our own galaxy.</td>
<td>B1</td>
<td><strong>Do not</strong> allow this mark if ‘Sirius / star is moving towards us’ is also included.</td>
</tr>
</tbody>
</table>

**Total** 10
<table>
<thead>
<tr>
<th>Question</th>
<th>Answers</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10 (a)</strong></td>
<td>The universe is homogeneous. and isotropic (on a large scale).</td>
<td>B1</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>(b)</strong></td>
<td>The intensity of the microwaves is the same in all directions.</td>
<td>B1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>These microwaves correspond to a temperature of 2.7 K or The temperature of the universe is 2.7 K.</td>
<td>B1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The expansion of the universe following the big bang led to cooling and hence we observe microwaves rather than short wavelength e.m. waves / gamma waves.</td>
<td>B1</td>
</tr>
<tr>
<td><strong>(c)</strong></td>
<td>( \rho = \frac{3H_0^2}{8\pi G} )</td>
<td>C1</td>
<td>Allow any subject</td>
</tr>
<tr>
<td></td>
<td>( H_0 = \sqrt{\frac{8\pi \times 6.67 \times 10^{-11} \times 9.7 \times 10^{-27}}{3}} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( H_0 = 2.328 \times 10^{-18} \text{ (s}^{-1}) )</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \text{age} = \frac{1}{H_0} )</td>
<td>C1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>age = ( \frac{1}{2.328 \times 10^{-18}} ) or age = ( 4.3 \times 10^{17} \text{ (s)} )</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>age = ( 1.4 \times 10^{10} \text{ (y)} )</td>
<td>A1</td>
<td>Answer to 3 sf is ( 1.36 \times 10^{10} \text{ (y)} )</td>
</tr>
</tbody>
</table>

**Total** | **8** | |