OCR
RECOGNISING ACHIEVEMENT

GCE

# Physics A

Advanced GCE

Unit **G485:** Fields, Particles and Frontiers of Physics

# Mark Scheme for January 2012

Oxford Cambridge and RSA Examinations

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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 |

**Annotations in detailed mark scheme**

| 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 |

**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.

(Significant figures are rigorously assessed in the practical skills.)

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| 1 | (a) | | electric field strength = force per unit (positive) charge | B1 | **Allow**: force/charge<br>**Not**: *F*/*Q* |
| | (b) | (i) | $E = V / d$<br>$3.0 \times 10^{6} = V / 1.3 \times 10^{-3}$ | C1 | **Note**: This mark is for correct substitution |
| | | | *V* = 3900 (V) | A1 | **Allow**: 1 mark if answer is $3.9 \times 10^{n}$ (V), n ≠3 – POT error |
| | | (ii)1 | *Q* = *It*<br>$Q = 2.7 \times 10^{-9} \times 4.0 \times 10^{-2}$ | C1 | **Note**: This mark is for correct substitution |
| | | | charge = $1.1 \times 10^{-10}$ (C) or $1.08 \times 10^{-10}$ (C) | A1 | |
| | | (ii)2 | number = $1.08 \times 10^{-10} / 1.6 \times 10^{-19}$<br>number = $6.8 \times 10^{8}$ or $6.75 \times 10^{8}$ | B1 | Possible ecf from **(b)(ii)1** |
| | | (iii) | energy = *VQ*<br>energy = $3900 \times 1.08 \times 10^{-10}$ | C1 | **Note**: No credit for using ½ *QV*<br>Possible ecf from **(b)(ii)1** |
| | | | energy = $4.2 \times 10^{-7}$ (J) | A1 | |
| | | | **Total** | **8** | |

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| 2 | (a) | | torque = one of the forces × <u>perpendicular</u> distance (between the forces) | B1 | |
| | (b) | (i) | Into (plane of) paper | B1 | **Not**: 'down' |
| | | (ii)1 | force = *BIL* = 0.060 × 0.03 × 0.015<br>force = $2.7 \times 10^{-5}$ (N) | B1 | |
| | | (ii)2 | torque = $2.7 \times 10^{-5} \times 0.015$<br><br>torque = $4.1 \times 10^{-7}$ (N m) or $4.05 \times 10^{-7}$ (N m) | C1<br><br>A1 | Possible ecf from **(b)(ii)1**<br><br>Do not allow $4.0 \times 10^{-7}$ (N m) - rounding error |
| | (c) | (i) | *F*= *BQv*<br>$2.0 \times 10^{-13} = 0.14 \times Q \times 4.5 \times 10^{6}$<br>charge = $3.2 \times 10^{-19}$ (C) or $3.17 \times 10^{-19}$ (C) | C1<br>A1 | **Allow**: Any subject |
| | | (ii) | $F = mv^2 / r$<br>$2.0 \times 10^{-13} = \frac{2.7 \times 10^{-26} \times (4.5 \times 10^{6})^2}{r}$<br>radius = 2.7 (m) or 2.73 (m) | C1<br><br>C1<br><br>A1 | **Allow**: Any subject |
| | | (iii) | $BQv = mv^2/r$<br>Hence, radius ∝ mass | B1<br>B1 | **Allow**: $r \propto m$ |
| | | | **Total** | **12** | |

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| 3 | (a) | | magnetic flux = (magnetic) flux density × (cross-sectional) area<br>Idea of (magnetic) field normal to the plane of the area | M1<br>A1 | Allow full credit for magnetic flux = *BA*,<br>where *B* = magnetic flux density normal to area<br>and *A* = (cross-sectional) area |
| | (b) | (i) | constant rate of change of (magnetic) flux / flux density | B1 | **Not**: 'graph has constant gradient' |
| | | (ii) | e.m.f. = rate of change of flux linkage<br>e.m.f. = $\frac{1.4\times10^{-2}\times\pi\times(3.2\times10^{-2})^2\times180}{2.5}$<br>e.m.f. = $3.2\times10^{-3}$ (V) or $3.24\times10^{-3}$ (V) | C1<br>C1<br>A1 | **Allow**: $E=\frac{\Delta N\phi}{\Delta t}$<br>Deduct 1 mark if *B* is misread from the graph and then ecf<br>**Allow**: 2 marks for an answer $3.24\times10^{n}$ (if $n\neq-3$)<br>**Allow**: 2 marks for $1.78\times10^{-5}$ (when 180 has been missed out) |
| | (c) | (i) | *P* = *VI*<br>current in secondary = 15/6 or 2.5 (A)<br>primary voltage = 6.0 × turn ratio = 6.0 × 40 = 240 (V)<br>$V_p$ = 240 (V) or $I_s$ = 2.5 (A)<br>primary current = 2.5/40 or 15/240<br>input current = $6.3\times10^{-2}$ (A) or $6.25\times10^{-2}$ (A) | C1<br>A1 | The C1 mark is for either of these values |
| | | (ii) | There is no change in flux density / (magnetic) flux / (magnetic) flux linkage | B1 | **Not**: 'There is no change in the magnetic field' |
| | | | **Total** | **9** | |

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| 4 | (a) | | capacitance = charge/p.d.<br>or capacitance = charge per (unit) p.d. | B1 | **Allow**: voltage instead of p.d.<br>**Note**: Do not allow mixture of quantity and unit, e.g. 'charge per (unit) volt' |
| | (b) | (i) | $C_{parallel}$ = 240 (μF)<br>$C_T$ = (240 × 120)/(240 +120) or $C_T = (240^{-1} + 120^{-1})^{-1}$<br>total capacitance = 80 (μF) | C1<br>C1<br>A0 | **Allow** :1 mark if $C_T$ is not the subject, e.g:<br>$\frac{1}{C_T} = \frac{1}{240} + \frac{1}{120}$ |
| | | (ii) | $E = \frac{1}{2}V^2C$<br>$E = \frac{1}{2} \times 6.0^2 \times 80 \times 10^{-6}$<br>energy = $1.4 \times 10^{-3}$ (J) or $1.44 \times 10^{-3}$ (J) | C1<br>A1 | Possible ecf<br>**Allow**: 1 mark for an answer $1.44 \times 10^n$ ($n \neq -3$) |
| | | (iii)1 | 6.0/*e* = 2.2 (V) (as on graph)<br>Or<br>6.0 × 0.37 = 2.2 (V) (as on graph)<br>Or<br>At 20 (s), *V* = 2.2 (V), 2.2/6.0 = 0.37 (or $e^{-1}$) | B1 | **Allow**: Graph reading within ± 0.2 V |
| | | (iii)2 | *CR* = 20<br>$R = \frac{20}{80 \times 10^{-6}}$<br>$R = 2.5 \times 10^5$ (Ω) | C1<br>A1 | **Allow**: Follow through with *CR* value from **(iii)1** |
| | | | **Total** | **8** | |

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| 5 | (a) | | Same charge / number of protons | B1 | **Not**: 'same chemical property' |
| | (b) | | strong (nuclear force / interaction)<br>gravitational (force) | B1<br>B1 | **Allow**: 'gravity' |
| | (c) | (i) | $^{15}_{7}\text{N}$ | B1 | |
| | | (ii) | (u d d) $\rightarrow$ (u u d) | B1 | **Allow**: *One down quark becomes up quark*<br>or d $\rightarrow$ u (+ electron + antineutrino) |
| | (d) | (i) | 0.16 MeV = $0.16 \times 10^6 \times 1.6 \times 10^{-19}$<br>$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 2.56 \times 10^{-14}$<br>speed = $2.4 \times 10^8$ (m s$^{-1}$) or $2.37 \times 10^8$ (m s$^{-1}$) | C1<br><br>A1 | **Allow**: 1 mark for using 9.8 MeV; answer is equal to $1.86 \times 10^9$ (m s$^{-1}$) |
| | | (ii) | The mass of the electron increases / greater than 'rest mass' | B1 | |
| | (e) | (i) | $\lambda = 0.693 / T$<br>$\lambda = 0.693/(5560 \times 3.16 \times 10^7)$<br>$\lambda = 3.9 \times 10^{-12}$ (s$^{-1}$) or $3.94 \times 10^{-12}$ (s$^{-1}$) | C1<br><br>A1 | **Allow**: 1 mark for $1.25 \times 10^{-4}$ (if 5560 y used) |
| | | (ii) | number = $\frac{1.0 \times 10^{-3}}{14} \times 6.02 \times 10^{23}$<br>number = $4.3 \times 10^{19}$ | M1<br>A0 | **Note**: This step must be seen to score 1 mark |
| | | (iii) | activity = $\lambda N$<br>activity = $3.94 \times 10^{-12} \times 4.3 \times 10^{19}$<br>activity = $1.7 \times 10^8$ (Bq) or $1.69 \times 10^8$ (Bq) | <br>C1<br>A1 | Possible ecf from **(e)(i)** and **(e)(ii)** |

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| | (f) | | Any **three** from:<br>1. Plants / living things take in carbon(-dioxide) or plants / living things stop taking in carbon after death<br>2. The ratio of carbon-14 to carbon-12 (nuclei) for the relic sample is determined<br>3. The current ratio of carbon-14 to carbon-12 nuclei is determined<br>4. The age of the relic is found using '$x = x_0 e^{-\lambda t}$'<br>Limitation: The ratio of carbon-14 to carbon-12 is assumed to be constant / count(-rate) from relic may be comparable to background count(-rate) | B1×3<br><br>B1 | **Must use ticks on Scoris to show where the marks are awarded**<br><br>**Allow**: Any other valid comment for the limitation |
| | | | **Total** | **17** | |

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| 6 | (a) | | (Minimum) energy to separate<br>(all) nucleons / protons <u>and</u> neutrons (of a nucleus) | M1<br>A1 | **Alternative**:<br>B.E. = mass <u>defect</u> $\times c^2$ M1<br>mass defect = mass of nucleons – mass of nucleus A1 |
| | (b) | (i) | BE of $^{2}$H = $2 \times 1.8 \times 10^{-13}$ (J)<br>or BE of $^{4}$He = $4 \times 1.1 \times 10^{-12}$ (J)<br><br>energy = $(4 \times 1.1 \times 10^{-12}) - 2 \times (2 \times 1.8 \times 10^{-13})$<br><br>energy = $3.68 \times 10^{-12}$ (J) / $3.7 \times 10^{-12}$ (J) | C1<br><br>C1<br><br>A0 | **Note**: Ignore signs |
| | | (ii)1 | total surface area = $4\pi \times (1.5 \times 10^{11})^2$<br>power = $1400 \times (2.83 \times 10^{23})$<br>power = $3.96 \times 10^{26}$ (W) / $4.0 \times 10^{26}$ (W) | C1<br>C1<br>A0 | |
| | | (ii)2 | number = $4.0 \times 10^{26} / 3.7 \times 10^{-12}$<br>number = $1.1 \times 10^{38}$ ($s^{-1}$) or $1.08 \times 10^{38}$ ($s^{-1}$) | C1<br>A1 | **Allow**: $10^{38}$ ($s^{-1}$) because the question is about an estimate |
| | | | **Total** | **8** | |

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| 7 | (a) | | Any **two** from:<br>1. Electrons are accelerated through high voltage<br>2. (High speed) electron(s) hit metal<br>3. kinetic energy of electron(s) 'produces' X-ray (photons) | B1×2 | **Allow**: X-rays are produced by (large) deceleration of electrons |
| | (b) | (i) | Packet /quantum of (electromagnetic) energy | B1 | **Allow**: 'particle of (electromagnetic) energy' |
| | | (ii) | $E = hc/\lambda$ and X-rays have shorter wavelength<br>Or<br>$E = hf$ and X-rays have higher frequency | B1 | |
| | (c) | | (KE of electron =) $1.6\times10^{-19}\times120\times10^{3}$<br>$eV = \frac{hc}{\lambda}$<br>$1.6\times10^{-19}\times120\times10^{3} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda}$<br>wavelength = $1.0\times10^{-11}$ (m) or $1.04\times10^{-11}$ (m) | C1<br>C1<br>A1 | **Allow**: 2 marks for $1.0(4)\times10^{-n}$ (m) ($n \neq 11$ - powers of ten error)<br>**Allow**: $1\times10^{-11}$ (m) |
| | (d) | | Compton (scattering)<br>Incoming photon collides with an electron, the electron is ejected and the photon is scattered / has lower energy<br><br>Or<br><br>Pair production<br>Incoming photon (disappears and) produces electron-positron pair | M1<br>A1<br>---<br><br><br>M1<br>A1 | **Must use ticks on Scoris to show where the marks are awarded**<br><br>**Allow**:<br>(Simple) scatter(ing) M1<br>The photon is absorbed and re-emitted without change in energy/wavelength/frequency A1 |
| | | | **Total** | **9** | |

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| 8 | (a) | | No entry into body / no cutting/incision of patient / no surgery<br>Lower risk of infection / less trauma | B1<br>B1 | |
| | (b) | | Radioactive substance that is ingested / injected (into patient)<br><br>Technetium(-99m) / Iodine(-131) / fluorine(-18) | B1<br><br>B1 | <br><br>**Not**: barium |
| | (c) | | **Collimator** – gamma (ray photons) travel along the axis of lead tubes or allows parallel gamma (ray photons travel to the scintillator)<br>Having thin / long / narrow (lead) tubes makes the image sharper / less blurred (**QWC mark**)<br>**Scintillator** – gamma ray photon produces many/thousands of photons of (visible) light<br>**Photomultiplier** - An electrical pulse is / electrons are produced from the light (photons)<br>**Computer** – Signals (from photomultiplier tubes) are used to produce an image | B1<br><br>B1<br><br>B1<br><br>B1<br><br>B1 | **Must use ticks on Scoris to show where the marks are awarded** |
| | (d) | (i) | $v = f\lambda$<br>$1500 = 2.0 \times 10^6 \times \lambda$<br><br>wavelength = $7.5 \times 10^{-4}$ (m) | C1<br><br>A1 | |
| | | (ii) | Ultrasound is reflected by (moving) blood (cells)<br><br>The frequency / wavelength (of ultrasound) is changed (AW)<br><br>The change of frequency is related to speed of blood / change of wavelength is related to speed of blood / '$\Delta$frequency $\propto$ speed of blood' | B1<br><br>B1<br><br>B1 | **Must use ticks on Scoris to show where the marks are awarded**<br>**Not**: Doppler effect mentioned |
| | | | **Total** | **14** | |

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| 9 | (a) | | Any <u>four</u> from:<br>1. (Sun / star formed from) dust cloud /nebula / (hydrogen) gas<br>2. <u>Gravitational</u> collapse (AW)<br>3. Temperature of (dust) cloud increases / KE (of cloud) increases / (cloud) heats up<br>4. Fusion occurs (when temperature is about $10^7$ K)<br>5. Protons / hydrogen nuclei combine to make helium (nuclei)<br>6. Stable size star is produced when thermal / radiation pressure is equal to gravitational pressure<br><br>Steps sequenced correctly – **QWC mark** | B1× 4<br><br>B1 | **Must use ticks on Scoris to show where the marks are awarded** |
| | (b) | | Any <u>two</u> from:<br>1. Very dense star<br>2. Hot star / high surface temperature / low luminosity<br>3. No fusion reactions take place / leaks away photons (from earlier fusion reactions)<br>4. Its collapse is prevented by Fermi pressure / mass less than 1.4 solar masses (AW) | B1×2 | **Must use ticks on Scoris to show where the marks are awarded**<br><br>**Not**: small in size, but <u>allow</u> 'smaller than main sequence star / Sun' |
| | (c) | (i) | Flat<br>or universe will expand towards a (finite) limit<br>or the rate of expansion will become/tend to zero | B1 | |
| | | (ii) | Hubble constant = 1/age<br>$H_0 = 1/4.4\times10^{17}\ (=2.273\times10^{-18}\ \text{s}^{-1})$<br>density = $\frac{3H_0^{\ 2}}{8\pi G}$<br>density = $\frac{3H_0^{\ 2}}{8\pi G} = \frac{3\times(2.273\times10^{-18})^2}{8\pi\times6.67\times10^{-11}}$<br>density = $9.2\times10^{-27}$ (kg m$^{-3}$) or $9.24\times10^{-27}$ (kg m$^{-3}$)<br><br>density is about $10^{-26}$ (kg m$^{-3}$) | C1<br><br>C1<br><br>A1<br><br>A0 | **Allow**: 2 marks for a bald $9.24\times10^{-27}$ (kg m$^{-3}$) answer<br>**Note**: This mark can only be scored if working is shown |

| Question | | | Answers | Marks | Guidance |
|---|---|---|---|---|---|
| | | (iii) | number = $9.24 \times 10^{-27}/1.7 \times 10^{-27}$<br>number = 5.4 (Allow 5) | C1<br>A1 | Possible ecf from **(c)(ii)**<br>**Allow**: 2 marks for '$10^{-26}/1.7 \times 10^{-27}$ = 5.9 or 6' |
| | (d) | | $\frac{1}{2}mv^2 = \frac{3}{2}kT$ / speed $\propto \sqrt{T}$<br>ratio = $\sqrt{\frac{10^8}{2.7}}$<br>ratio = $6.1 \times 10^3$ or $6.09 \times 10^3$ | C1<br><br><br>A1 | |
| | | | **Total** | **15** | |

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