RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE

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

Mark Scheme for January 2012

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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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PO Box 5050
Annesley
NOTTINGHAM
NG15 0DL

Telephone: 0870 770 6622
Facsimile: 01223 552610
E-mail: publications@ocr.org.uk

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 **Not**: *F*/*Q*
	(b)	(i)	$E = V / d$ $3.0 \times 10^{6} = V / 1.3 \times 10^{-3}$	C1	**Note**: This mark is for correct substitution
			V = 3900 (V)	A1	**Allow**: 1 mark if answer is 3.9×10^{n} (V), $n \neq 3$ – POT error
		(ii)1	$Q = It$ $Q = 2.7 \times 10^{-9} \times 4.0 \times 10^{-2}$	C1	**Note**: This mark is for correct substitution
			charge = 1.1×10^{-10} (C) or 1.08×10^{-10} (C)	A1	
		(ii)2	number = $1.08 \times 10^{-10} / 1.6 \times 10^{-19}$ number = 6.8×10^{8} or 6.75×10^{8}	B1	Possible ecf from **(b)(ii)1**
		(iii)	energy = *VQ* energy = $3900 \times 1.08 \times 10^{-10}$	C1	**Note**: No credit for using ½ *QV* Possible ecf from **(b)(ii)1**
			energy = 4.2×10^{-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 force = 2.7×10^{-5} (N)	B1	
		(ii)2	torque = $2.7 \times 10^{-5} \times 0.015$ torque = 4.1×10^{-7} (N m) or 4.05×10^{-7} (N m)	C1 A1	Possible ecf from **(b)(ii)1** Do not allow 4.0×10^{-7} (N m) - rounding error
	(c)	(i)	$F = BQv$ $2.0 \times 10^{-13} = 0.14 \times Q \times 4.5 \times 10^{6}$ charge = 3.2×10^{-19} (C) or 3.17×10^{-19} (C)	C1 A1	**Allow**: Any subject
		(ii)	$F = mv^2 / r$ $2.0 \times 10^{-13} = \frac{2.7 \times 10^{-26} \times (4.5 \times 10^{6})^2}{r}$ radius = 2.7 (m) or 2.73 (m)	C1 C1 A1	**Allow**: Any subject
		(iii)	$BQv = mv^2/r$ Hence, radius ∝ mass	B1 B1	**Allow**: $r \propto m$
			Total	**12**	

Question			Answers	Marks	Guidance
3	(a)		magnetic flux = (magnetic) flux density × (cross-sectional) area Idea of (magnetic) field normal to the plane of the area	M1 A1	Allow full credit for magnetic flux = *BA*, where *B* = magnetic flux density normal to area 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 e.m.f. = $\frac{1.4\times10^{-2}\times\pi\times(3.2\times10^{-2})^2\times180}{2.5}$ e.m.f. = 3.2×10^{-3} (V) or 3.24×10^{-3} (V)	C1 C1 A1	**Allow**: $E=\frac{\Delta N\phi}{\Delta t}$ Deduct 1 mark if *B* is misread from the graph and then ecf **Allow**: 2 marks for an answer 3.24×10^{n} (if $n\neq-3$) **Allow**: 2 marks for 1.78×10^{-5} (when 180 has been missed out)
	(c)	(i)	*P* = *VI* current in secondary = 15/6 or 2.5 (A) primary voltage = 6.0 × turn ratio = 6.0 × 40 = 240 (V) V_p = 240 (V) or I_s = 2.5 (A) primary current = 2.5/40 or 15/240 input current = 6.3×10^{-2} (A) or 6.25×10^{-2} (A)	 C1 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. or capacitance = charge per (unit) p.d.	B1	**Allow**: voltage instead of p.d. **Note**: Do not allow mixture of quantity and unit, e.g. 'charge per (unit) volt'
	(b)	(i)	$C_{parallel}$ = 240 (μF) C_T = (240 × 120)/(240 +120) or $C_T = (240^{-1} + 120^{-1})^{-1}$ total capacitance = 80 (μF)	C1 C1 A0	**Allow** :1 mark if C_T is not the subject, e.g: $\frac{1}{C_T} = \frac{1}{240} + \frac{1}{120}$
		(ii)	$E = \frac{1}{2}V^2C$ $E = \frac{1}{2} \times 6.0^2 \times 80 \times 10^{-6}$ energy = 1.4×10^{-3} (J) or 1.44×10^{-3} (J)	C1 A1	Possible ecf **Allow**: 1 mark for an answer 1.44×10^n ($n \neq -3$)
		(iii)1	6.0/*e* = 2.2 (V) (as on graph) Or 6.0 × 0.37 = 2.2 (V) (as on graph) Or 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 $R = \frac{20}{80 \times 10^{-6}}$ $R = 2.5 \times 10^5$ (Ω)	C1 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) gravitational (force)	B1 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* or d $\rightarrow$ u (+ electron + antineutrino)
	(d)	(i)	0.16 MeV = $0.16 \times 10^6 \times 1.6 \times 10^{-19}$ $\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 2.56 \times 10^{-14}$ speed = 2.4×10^8 (m s^{-1}) or 2.37×10^8 (m s^{-1})	C1 A1	**Allow**: 1 mark for using 9.8 MeV; answer is equal to 1.86×10^9 (m s^{-1})
		(ii)	The mass of the electron increases / greater than 'rest mass'	B1	
	(e)	(i)	$\lambda = 0.693/T$ $\lambda = 0.693/(5560 \times 3.16 \times 10^7)$ $\lambda = 3.9 \times 10^{-12}$ (s^{-1}) or 3.94×10^{-12} (s^{-1})	C1 A1	**Allow**: 1 mark for 1.25×10^{-4} (if 5560 y used)
		(ii)	number = $\frac{1.0 \times 10^{-3}}{14} \times 6.02 \times 10^{23}$ number = 4.3×10^{19}	M1 A0	**Note**: This step must be seen to score 1 mark
		(iii)	activity = λN activity = $3.94 \times 10^{-12} \times 4.3 \times 10^{19}$ activity = 1.7×10^8 (Bq) or 1.69×10^8 (Bq)	 C1 A1	Possible ecf from **(e)(i)** and **(e)(ii)**

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

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

Question			Answers	Marks	Guidance
7	(a)		Any **two** from: 1. Electrons are accelerated through high voltage 2. (High speed) electron(s) hit metal 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 Or $E = hf$ and X-rays have higher frequency	B1	
	(c)		(KE of electron =) $1.6\times10^{-19}\times120\times10^{3}$ $eV = \frac{hc}{\lambda}$ $1.6\times10^{-19}\times120\times10^{3} = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda}$ wavelength = 1.0×10^{-11} (m) or 1.04×10^{-11} (m)	C1 C1 A1	**Allow**: 2 marks for $1.0(4)\times10^{-n}$ (m) ($n \neq 11$ - powers of ten error) **Allow**: 1×10^{-11} (m)
	(d)		Compton (scattering) Incoming photon collides with an electron, the electron is ejected and the photon is scattered / has lower energy Or Pair production Incoming photon (disappears and) produces electron-positron pair	M1 A1 --- M1 A1	**Must use ticks on Scoris to show where the marks are awarded** **Allow**: (Simple) scatter(ing) M1 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 Lower risk of infection / less trauma	B1 B1	
	(b)		Radioactive substance that is ingested / injected (into patient) Technetium(-99m) / Iodine(-131) / fluorine(-18)	B1 B1	 **Not**: barium
	(c)		**Collimator** – gamma (ray photons) travel along the axis of lead tubes or allows parallel gamma (ray photons travel to the scintillator) Having thin / long / narrow (lead) tubes makes the image sharper / less blurred (**QWC mark**) **Scintillator** – gamma ray photon produces many/thousands of photons of (visible) light **Photomultiplier** - An electrical pulse is / electrons are produced from the light (photons) **Computer** – Signals (from photomultiplier tubes) are used to produce an image	B1 B1 B1 B1 B1	**Must use ticks on Scoris to show where the marks are awarded**
	(d)	(i)	$v = f\lambda$ $1500 = 2.0 \times 10^{6} \times \lambda$ wavelength = 7.5×10^{-4} (m)	C1 A1	
		(ii)	Ultrasound is reflected by (moving) blood (cells) The frequency / wavelength (of ultrasound) is changed (AW) The change of frequency is related to speed of blood / change of wavelength is related to speed of blood / 'Δfrequency $\propto$ speed of blood'	B1 B1 B1	**Must use ticks on Scoris to show where the marks are awarded** **Not**: Doppler effect mentioned
			Total	**14**	

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

Question			Answers	Marks	Guidance
		(iii)	number = $9.24 \times 10^{-27}/1.7 \times 10^{-27}$ number = 5.4 (Allow 5)	C1 A1	Possible ecf from **(c)(ii)** **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 $\propto \sqrt{T}$ ratio = $\sqrt{\frac{10^8}{2.7}}$ ratio = 6.1×10^3 or 6.09×10^3	C1 A1	
			Total	**15**	

OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

OCR Customer Contact Centre

Education and Learning
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

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