RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE

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

Mark Scheme for January 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.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

Annotations

The following annotations are available on the marking 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 words must be present in answer to score a mark
ecf = error carried forward
AW = alternative wording
ora = or reverse argument

The following annotations are available in SCORIS.

Annotation	Meaning
✓	correct response
✗	incorrect response
AE	arithmetic error
BOD	benefit of the doubt (where professional judgement has been used)
NBOD	benefit of the doubt **not** given
ECF	error carried forward
^	information omitted
CON	contradiction (in cases where candidates contradict themselves in the same response)

Annotation	Meaning
	rounding error
	error in the number of significant figures
	error in the power of 10 in a calculation
	wrong physics or equation
	not answered question
	follow through

Highlighting is also available to highlight any particular points on the script.

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:
Q5(e), 6(d), 7(a), 8(a) and Q9(a)

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 and rounding errors:

If the data given in a question is to 2 sf, then allow answers to 2 or more sf. 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.
Penalise a rounding error once only in the entire paper.

Question			Answer	Marks	Guidance
1	(a)	(i)	Any <u>two</u> from: Correct direction of movement of electrons Electrons deposited on **Y** / removed from **X** An equal number of electrons removed and deposited on plates (AW)	B1 × 2	
		(ii)1	$Q = 40 \times 10^{-6} \times 100$ (= 4.0×10^{-3} C) $4.0 \times 10^{-3} = 1.6 \times C$ $C = 2.5 \times 10^{-3}$ (F)	C1 C1 A1	**Allow**: 2 marks for 2.5×10^{n} (F), where $n \neq -3$ (POT error)
		(ii)2	Graph starts at <u>origin</u> and has positive gradient A straight line graph that passes between 1-2 V at 100 s	M1 A1	
	(b)	(i)	$CR = 4.7 \times 10^{-6} \times 220$ (= 1.03×10^{-3} s) $4.00 = 6.00e^{-\frac{t}{1.03\times10^{-3}}}$ $t = -\ln(4.00/6.00) \times 1.03 \times 10^{-3}$ time = 4.2×10^{-4} (s)	C1 C1 A1	**Note**: Answer to 3 sf is 4.19×10^{-4} (s) **Allow**: 2 marks for $t = -lg(4.00/6.00) \times 1.03 \times 10^{-3} = 1.8 \times 10^{-4}$ s
		(ii)	speed = $\dfrac{0.100}{4.2 \times 10^{-4}}$ speed = 240 (m s^{-1})	B1	Possible ecf from **(b)(i)**
			Total	**11**	

Question			Answer	Marks	Guidance
2	(a)		force per unit (positive) charge	B1	**Allow**: $E = \frac{F}{Q}$, where F = force on (a positive) charge Q
	(b)	(i)	The direction is different (AW)	B1	
		(ii)	$E \propto 1/r^2$ or distance is doubled $\therefore$ E decreases by a factor of 4 electric field strength = 2.0×10^5 (N C^{-1})	C1 A1	**Not**: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ on its own **Allow** 1 sf answer
	(c)	(i)	$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ $F_E = \frac{1.6\times10^{-19}\times1.6\times10^{-19}}{4\pi\varepsilon_0\times(5.0\times10^{-11})^2}$ $F_E = 9.2 \times 10^{-8}$ (N)	C1 C1 A1	 **Allow**: 1 mark if $Q = q = 1$ giving an answer of 3.6×10^{30} (N)
		(ii)	$F_G = \frac{6.67\times10^{-11}\times1.67\times10^{-27}\times9.11\times10^{-31}}{(5.0\times10^{-11})^2}$ $F_G = 4.06 \times 10^{-47}$ (N) ratio = $9.2 \times 10^{-8}/4.06 \times 10^{-47}$ ratio = 2.3×10^{39}	C1 A1	**Note**: Deduct 1 mark if mass of two electrons or two protons is used, then ecf Possible ecf from **(c)(i)**
		(iii)1	wavelength = 2.0×10^{-10} (m) $\lambda = h/mv$ $p = \frac{6.63\times10^{-34}}{2.0\times10^{-10}}$ $p = 3.3 \times 10^{-24}$ (kg m s^{-1})	C1 C1 A1	 Possible ecf for incorrect wavelength **Note**: Answer to 3 sf is 3.32×10^{-24} (kg m s^{-1}) **Allow**: 1 sf answer

Question			Answer	Marks	Guidance
		(iii)2			Possible ecf from **(iii)1**
			$v = \dfrac{3.32 \times 10^{-24}}{9.11 \times 10^{-31}}$ (= 3.64×10^{6} m s^{-1})	C1	**Note**: Deduct 1 mark if mass of proton is used, then ecf
			$E_k = ½ \times 9.11 \times 10^{-31} \times (3.64 \times 10^{6})^2$	C1	
			$E_k = 6.0 \times 10^{-18}$ (J)	A1	**Note**: Answer to 3 sf is 6.05×10^{-18} (J) **Allow**: 1 sf answer
			or		
			$E_k = ½\, p^2/m$	C1	**Note**: Deduct 1 mark if mass of proton is used, then ecf
			$E_k = ½ \times (3.32 \times 10^{-24})^2/9.11 \times 10^{-31}$	C1	
			$E_k = 6.0 \times 10^{-18}$ (J)	A1	
			Total	**15**	

Question			Answer	Marks	Guidance
3	(a)		(Fleming's) left-hand rule	B1	
	(b)		The force is at right angles to the velocity (hence no work is done on the ions) / no (component of) force in the direction of motion / no (component of) acceleration in the direction of motion (AW)	B1	**Allow**: 'force is right angles to the motion'
	(c)	(i)	$F = \frac{mv^2}{r}$ force = $\frac{1.2\times10^{-26}\times(4.0\times10^{5})^2}{0.15}$ force = 1.3×10^{-14} (N)	C1 A1	**Note**: Answer to 3 sf is 1.28×10^{-14} (N)
		(ii)	$F = BQv$ $1.28 \times 10^{-14} = B \times 1.6 \times 10^{-19} \times 4.0 \times 10^{5}$ $B = 0.20$ (T)	C1 A1	Possible ecf from **(c)(i)** **Allow**: 1 sf answer of 0.2 (T)
		(iii)	number per second = $\frac{4.8\times10^{-9}}{1.6\times10^{-19}}$ number per second = 3.0×10^{10} (s^{-1})	C1 A1	**Allow**: 1 sf answer of 3×10^{10} (s^{-1})
	(d)		(height is smaller) hence less abundance (than lithium-7) position suggests that the ions are less massive / lighter fewer neutrons (than lithium-7)	B1 B1	**Allow**: fewer / less (than lithium-7)
			Total	**10**	

Question			Answer	Marks	Guidance
4	(a)	(i)	momentum / mass-energy / charge / proton number / baryon number / nucleon number	B1	**Not**: 'energy' on its own
		(ii)	Some basic labelling of neutron(s), Xe and Sr Correct extension of diagram showing at least one of the neutrons interacting with <u>U-235</u> nucleus and producing neutron(s) and 'fragments'	B1 B1	
	(b)	(i)	initial m = 6.686 × 10^{-27} (kg) or final m = 6.681 × 10^{-27} (kg) or $\Delta m = 0.005 \times 10^{-27}$ (kg) $\Delta E = 0.005 \times 10^{-27} \times (3.0 \times 10^{8})^{2}$ energy = 4.5 × 10^{-13} (J)	C1 C1 A1	
		(ii)	kinetic (energy)	B1	**Not**: heat / sound **Allow**: (gamma) photons / EM radiation
		(iii)	KE = $\frac{3}{2}kT$ KE = $\frac{3}{2} \times 1.38 \times 10^{-23} \times 10^{9}$ KE = 2.1 × 10^{-14} (J)	C1 A1	**Allow**: 1 sf answer or 10^{-14} (J) because the temperature is given as 10^{9} K
		(iv)	Some nuclei will have KE greater than the mean KE (and hence cause fusion) (AW)	B1	
			Total	**10**	

Question			Answer	Marks	Guidance
5	(a)		$\lambda = \dfrac{0.693}{6.6\times10^{3}}$ or $\lambda = \dfrac{\ln 2}{6.6\times10^{3}}$	C1	
			decay constant = 1.1 × 10^{-4} (s^{-1})	A1	**Note**: Answer to 3sf is 1.05 × 10^{-4} (s^{-1})
	(b)		$A = \lambda N$ $N = \dfrac{250\times10^{6}}{1.05\times10^{-4}}$	C1	Possible ecf from **(a)**
			number = 2.38 × 10^{12} or 2.4 × 10^{12}	A0	**Allow** full credit for bald 2.4 × 10^{12}
	(c)		mass of F-18 = $\dfrac{2.38\times10^{12}}{6.02\times10^{23}}\times0.018$ (= 7.116 × 10^{-14} kg)	C1	Possible ecf from **(b)**
			mass of FDG= $7.116\times10^{-14}/0.099$	C1	
			mass of FDG = 7.2 × 10^{-13} (kg)	A1	**Allow** full credit for using 2 × 10^{12}; answer is 6.04 × 10^{-13} (kg)
	(d)		$A = 250\times e^{-(1.05\times10^{-4}\times20\times60)}$	C1	
			activity = 220 (MBq)	A1	Possible ecf from **(a)** **Allow**: 1 mark for 249 (MBq); factor of 60 omitted
	(e)		(FDG/positron-emitting substance is injected into the patient) Any <u>three</u> from: 1. Annihilation of electron and positron 2. Positron-electron annihilation produces <u>two</u> gamma photons 3. The gamma photons travels in opposite directions 4. The patient is surrounded by (a ring of) gamma detectors 5. A 3-D image is created (using the detector-signals with the aid of computer software)	B1 × 3	**Allow**: rays / waves instead of photons in 2 and 3
			QWC: The arrival times / delay times of the photons (at diametrically opposite detectors) are used to pinpoint areas of increased activity (AW)	B1	
			Total	**12**	

Question			Answer	Marks	Guidance
6	(a)		(Fast-moving) electrons hit a metal / an anode The kinetic energy of the electrons is transferred into X-rays / photons / EM waves	B1 B1	**Allow**: (X-rays are produced by large) deceleration of electrons
	(b)		An X-ray photon interacts an electron (within the atom) The electron is ejected and the energy / frequency of the (scattered) photon is reduced	B1 B1	**Allow**: The electron is ejected and the wavelength of the (scattered) photon is increased
	(c)	(i)	$I = I_0 e^{-\mu x}$ $I = 3.0 \times 10^9 \times e^{-(6.5 \times 1.7)}$ intensity = 4.8×10^4 (W m^{-2})	C1 C1 A0	
		(ii)	power of beam = $4.8 \times 10^4 \times 5.0 \times 10^{-6}$ (= 0.24 W) power absorbed by tumour = 0.24/10 = 0.024 (W) time = 200/0.024 time = 8.3×10^3 (s)	C1 C1 A1	Possible ecf from **(c)(i)** **Allow**: 2 marks for 8.3×10^2 (s) if 10% is omitted **Note**: Using 5×10^4 (W m^{-2}) gives an answer of 8000 (s)
	(d)		X-ray beam passes through the patient at different angles / X-ray tube rotates around the patient A <u>thin</u> fan-shaped beam is used (AW) Images of 'slices' through the patient (in one plane are produced with the help of computer software) X-ray tube / detectors are moved along (the patient for the next slice through the patient) Advantage: 3D image / better contrast between different (soft) tissues	B1 B1 B1 B1 B1	
			Total	**14**	

Question			Answer	Marks	Guidance
7	(a)		Any six from: 1. Protons / nuclei have spin or they behave like (tiny) magnets 2. Protons precess around the magnetic field (provided by the strong electromagnet) 3. The frequency of precession is known as the *Larmor frequency* 4. (Transmitting) coils provide (pulses of) radio waves (of frequency equal to the Larmor frequency) 5. The protons absorb energy (from the radio waves) / resonate and enter into a high energy state (AW) 6. When protons return back to their low energy state and they emit (photons of) radio waves 7. The *relaxation time* is the (average) time taken for the protons to return back to their normal / low energy state 8. The relaxation time depends on the tissues (A computer processes all the signals from the receiving coils and with the help of computer software generates a 3D image)	B1 × 6	**Not**: Atoms / particles **Note**: Must have reference to radio (waves) in 4 and 6 **Allow** 'excited' for 'high-energy state' **Allow**: Relaxing protons emit radio waves
	(b)		Disadvantage: Patient with metallic objects cannot be scanned / patient has to remain still (for a long time) / confined space / difficult for patient suffering from claustrophobia / or another suitable suggestion Advantage: Non-ionising /non invasive / better contrast (between soft tissues) / or another suitable suggestion	B1 B1	 **Not** '3 D image' because it is given in **(a)**
			Total	**8**	

Question			Answer	Marks	Guidance
8	(a)		Any <u>three</u> from: 1. (Interstellar dust and gas) cloud is drawn together by gravitational force / gravity 2. Loss in (gravitational) PE / KE increases / temperature increases 3. Fusion (of protons / hydrogen nuclei) takes place 4. Energy is released in fusion reactions 5. A stable star is formed when gravitational pressure is equal to internal / gas / radiation pressure QWC: The steps in the process are correctly sequenced	B1 × 3 B1	**Allow**: 'gravitational collapse'
	(b)	(i)	Any <u>two</u> from: • (extremely) dense / (very) hot / low luminosity • no fusion reactions occur • it is a remnant of a low-mass star • correct reference to Fermi pressure / electron degeneracy / Chandrasekhar's limit	B1 × 2	
		(ii)	Red giant identified (It is cooler but has) large <u>surface</u> area (and therefore radiates large amounts of energy)	B1 B1	
			Total	**8**	

Question			Answer	Marks	Guidance
9	(a)		The night sky should be bright / have uniform brightness (but it is not) The line of sight ends on (the surface of a star) or 'number of stars $\propto r^2$ and intensity $\propto 1/r^2$' Any <u>two</u> assumptions about the Universe: Infinite / uniformly distributed matter or stars throughout / static / infinite age	B1 B1 B1	
	(b)		(recessional) speed of <u>galaxy</u> $\propto$ its distance (from the Earth) The universe is finite / it is expanding / it has a beginning / visible light is red-shifted (because of expansion of space) (AW)	B1 B1	**Allow**: $v = H_0 x$, v = (recessional) speed of galaxy, x = distance and H_0 is Hubble constant / a constant
	(c)	(i)	$v = H_0 x$ $3.4 \times 10^7 = H_0 \times 1.4 \times 10^{25}$ $H_0 = 2.4 \times 10^{-18}$ unit: s^{-1}	C1 A1 B1	**Note**: This is an independent mark **Note**: Allow full credit for an Hubble constant of 75 with unit km s^{-1} Mpc^{-1}
		(ii)1	age = $\dfrac{1}{2.4 \times 10^{-18}}$ age = 4.17×10^{17} (s) age = 1.3×10^{10} (years)	C1 A1	Possible ecf from **(i)**
		(ii)2	distance = $4.17 \times 10^{17} \times 3.0 \times 10^8$ (= 1.25×10^{26} m) distance = $\dfrac{4.17 \times 10^{17} \times 3.0 \times 10^8}{3.1 \times 10^{16}}$ distance = 4.0×10^9 (pc)	C1 A1	Possible ecf from **(ii)1**
			Total	**12**	

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