OCR
RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE

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

Mark Scheme for June 2012

Oxford Cambridge and RSA Examinations

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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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Annotations

Annotation Available in Scoris	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 or ‘reading error’
	Error in number of significant figures
	Correct response
	Arithmetic error
	Wrong physics or equation

Annotation Used in Mark Scheme	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

Subject-specific Marking Instructions

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:

Q2(d), Q6(b), Q7(d), Q8(a)(b), Q9(a)(b), Q10(c).

Note about significant figures:

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.

Question			Answer	Marks	Guidance
1	(a)		(farad = 1) coulomb per (unit) volt	B1	**Allow**: C V^{-1}
	(b)	(i)	1/C	B1	**Allow**: 'inverse of *C*'
		(ii)	work (done) / energy	B1	
	(c)		**Diagram**: All 3 capacitors connected in **series** $\frac{1}{C}=\frac{1}{100}+\frac{1}{200}+\frac{1}{500}$ / $\frac{1}{C}=1.7\times10^{-2}$ capacitance = 59 (μF)	B1 C1 A1	**Note**: Correct symbol must be used for capacitor and at least one of the capacitance values (without the unit) must be shown **Allow**: Answer to 1 sf **Note**: Answer to 3sf is 58.8 (μF) **Allow**: 1.7 × 10^{-2} (μF) scores 1 mark from the C1A1
	(d)	(i)	Q = 0.040 × 60 charge = 2.4 (C)	C1 A1	**Allow**: 1 mark for 2.4 × 10^{n}, n ≠ 0 (POT error)
		(ii)	energy = $\frac{1}{2}\times\frac{2.4^2}{0.10}$ energy = 29 (J)	C1 A1	Possible ecf from **(d)(i)** **Note**: Answer to 3 sf is 28.8 (J) Allow full credit for correct use of ½ *VQ* or ½ V^2C; the final p.d is 24 (V)
			Total	**10**	

Question			Answer	Marks	Guidance
2	(a)	(i)	Correct direction of force at **A** (and marked **F**)	B1	
		(ii)	The force is perpendicular to velocity / motion (hence no work done on the electron) or No (component of) acceleration / force in direction of velocity / motion (hence no work done on electron) or No distance moved in the direction of the force	B1	
	(b)		$F = \frac{mv^2}{r}$ force = $\frac{9.11\times10^{-31}\times(6.0\times10^{7})^2}{0.24}$ force = 1.4×10^{-14} (N)	C1 A1	**Note**: Answer to 3sf is 1.37×10^{-14} (N) **Allow**: 1 mark for 1.4×10^{n}; $n \neq -14$ (POT error)
	(c)		$F = BQv$ $1.37\times10^{-14} = B\times1.60\times10^{-19}\times6.0\times10^{7}$ B = 1.4×10^{-3} (T)	C1 A1	Possible ecf from **(b)** **Note**: Answer to 3 sf is 1.43×10^{-3} (T) for 1.37×10^{-14} (N) **Note**: Using 1.4×10^{-14} (N) gives 1.46×10^{-3} (T) **Note**: Using $B = mv/Qr$ gives 1.42×10^{-3} (T)
	(d)		Using $(E =) mc^2$ and $(E =) \frac{hc}{\lambda}$ **(QWC)** $2\times mc^2 = 2\times\frac{hc}{\lambda}$ or $mc^2 = \frac{hc}{\lambda}$ or $mc = \frac{h}{\lambda}$ Correct substitution (any subject) λ = 2.4×10^{-12} (m)	B1 C1 A1	Eg: $2\times9.11\times10^{-31}\times(3.0\times10^{8})^2 = 2\times\frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda}$ Answer to 3 sf is 2.43×10^{-12} (m) **Allow**: 1 mark for 1.21×10^{-12} (m) or 4.86×10^{-12} (m) for the C1A1 marks
			Total	**9**	

Question			Answer	Marks	Guidance
3	(a)	(i)	$f = \frac{1}{T} = \frac{1}{10 \times 10^{-3}}$ frequency = 100 (Hz)	B1	
		(ii)	$2.0 \times 10^{-2} = B \times 1.6 \times 10^{-3} \times 400$ $B = \frac{2.0 \times 10^{-2}}{1.6 \times 10^{-3} \times 400}$ $B = 3.1 \times 10^{-2}$ (T)	C1 C1 A1	**Allow**: 2 mark for 3.1×10^{n}; $n \neq -2$ (POT error) Answer to 3 sf is 3.13×10^{-2} (T) **Special case**: 12.5 scores 1 mark; number of turns omitted
		(iii)	(e.m.f. = -) rate of change of flux <u>linkage</u> <u>Tangent</u> drawn on Fig. 3.1 at 2.5 (ms) or 7.5 (ms) or 12.5 (ms) Values substituted to determine the gradient. The gradient must be 12.5 ± 1.0 (V)	B1 B1 B1	**Allow**: $E = (-)\frac{\Delta(N\phi)}{\Delta t}$ or (e.m.f. =) gradient **Alternative**: maximum e.m.f. = $2\pi f \times$ maximum flux linkage C1 maximum e.m.f. = $2\pi \times 100 \times 2 \times 10^{-2}$ C1 maximum e.m.f. = 12.6 (V) or 4π (V) A1
	(b)		$P = \frac{V^2}{R}$ $P = \frac{12^2}{150}$ power = 0.96 (W)	C1 A1	Possible ecf from **(a)(iii)**
			Total	**9**	

Question			Answer	Marks	Guidance
4	(a)		Any <u>two</u> from: 1. There is a repulsive (electrical) force (between the gold nucleus and the alpha particle) 2. Momentum is conserved (because there are no external forces) / initial momentum of alpha particle = final momentum of gold nucleus (because there are no external forces) 3. KE of alpha particle transformed into (electrical) PE	B1×2	**Allow**: (The gold nucleus and alpha particle experience) forces in opposite directions
	(b)		Correct directions of field shown on lines from **A** and **B** Correct curved field lines from **A** and **B**	B1 B1	
	(c)		$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ Q = 79e and q = 2e force = $\frac{79 \times 2 \times (1.60 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12} \times (6.0 \times 10^{-14})^2}$ force = 10.1 (N)	C1 C1 C1 A0	**All** values must be substituted for this mark
	(d)		Correctly shaped curve with F decreasing as r increases Value of F is between 2 to 3 (N) at r = 12 × 10^{-14} m	M1 A1	**Note**: $F \propto 1/r^2$, hence F should be about 2.5 (N)
			Total	**9**	

Question			Answer	Marks	Guidance
5	(a)		no: of neutrons = 142	B1	
	(b)	(i)	(5.6 MeV =) $5.6 \times \underline{10^6} \times \underline{1.6 \times 10^{-19}}$ energy = 8.96×10^{-13} (J)	M1 A0	**Allow**: $5.6 \times \underline{1.6 \times 10^{-13}}$
		(ii)	$\frac{1}{2} \times 6.65 \times 10^{-27} \times v^2 = 8.96 \times 10^{-13}$ $v = \sqrt{\frac{2 \times 8.96 \times 10^{-13}}{6.65 \times 10^{-27}}}$ speed = 1.6×10^7 (m s^{-1})	C1 A1	Answer to 3 sf is 1.64×10^7 (m s^{-1}) **Note**: The answer is 1.65×10^7 (m s^{-1}) if 9×10^{-13} (J) is used
	(c)	(i)	activity = $\frac{62}{8.96 \times 10^{-13}}$ activity = 6.92×10^{13} (Bq)	C1 A0	**Allow**: activity = $\frac{62}{9 \times 10^{-13}}$ (= 6.89×10^{13} Bq) Possible ecf from **(b)(i)**
		(ii)	$\lambda = \frac{0.693}{T}$ $\lambda = \frac{0.693}{88 \times 3.16 \times 10^7}$ decay constant = 2.49×10^{-10} (s^{-1}) or 2.5×10^{-10} (s^{-1})	 C1 A1	 **Note**: ln2 = 0.693 **Allow**: 1 mark for using 88 years and getting an answer of 7.9×10^{-3}
		(iii)	**1** $A = \lambda N$ $N = \frac{6.92 \times 10^{13}}{2.49 \times 10^{-10}}$ number = 2.78×10^{23} or 2.8×10^{23} **2** mass = $\frac{2.78 \times 10^{23}}{6.02 \times 10^{23}} \times 0.24$ mass = 0.11 (kg)	 C1 A1 B1	 Possible ecf from **(c)(ii)** **Note**: '$7 \times 10^{13}/2.5 \times 10^{-10} = 2.8 \times 10^{23}$' Possible ecf for mass from incorrect value for number of nuclei
			Total	**10**	

Question			Answer	Marks	Guidance
6	(a)		The neutrons interact with other uranium (nuclei) / the neutrons cause further (fission) reactions	B1	**Not**: neutrons interact with uranium <u>atoms</u> / <u>molecules</u> / <u>particles</u>
	(b)		**Fuel rod**: Contain the <u>uranium</u> (nuclei) / fissile material **Control rods**: Absorb (some of the) neutrons *Controlled chain reaction*: The control rods are inserted into the reactor so as to allow (on average) one neutron from previous reaction to cause subsequent fission (AW) **Moderator**: Slows down the (fast-moving) neutrons / lowers the KE of (fast moving) neutrons / makes the (fast moving) neutrons into thermal neutrons Slow moving neutrons have a greater chance of causing fission / of being absorbed (by U-235) / sustaining chain reaction	B1 B1 B1 B1 B1	**Show annotation on Scoris** **Not** 'contains fuel' **QWC mark** **Allow**: Fast moving neutrons are captured (easily) by uranium-238 (nuclei leaving insufficient number of nuclei for fission / chain reaction) for the last B1 mark
	(c)	(i)	power = $3.0 \times 10^9/0.22$ power = 1.36×10^{10} (W) or 1.4×10^{10} (W)	B1	
		(ii)	energy = $1.36 \times 10^{10} \times 8.64 \times 10^4$ energy = 1.18×10^{15} (J) or 1.2×10^{15} (J)	B1	Possible ecf from **(c)(i)**
		(iii)	(number of reactions per day) = $\frac{1.18\times10^{15}}{3.2\times10^{-11}}$ mass = $\frac{1.18\times10^{15}}{3.2\times10^{-11}}\times3.9\times10^{-25}$ mass = 14.4 (kg) or 14 (kg)	C1 A1	Possible ecf from **(c)(ii)** **Note**: Using 1.2×10^{15} (J) gives an answer of 14.6 (kg); allow 15 (kg)
	(d)		Nuclear waste is (radio)active for a long time (AW) Causes ionisation	B1 B1	**Allow**: '*Nuclear waste can have long* half *life'*
			Total	**12**	

Question			Answer	Marks	Guidance
7	(a)		Any <u>two</u> from: (X-rays) are EM waves Travel at speed of light / 3×10^8 <u>m s^{-1}</u> (in a vacuum) Travel in a vacuum / empty space Transverse waves Can cause ionisation Have wavelength of about 10^{-10} <u>m</u> (X-rays are high energy) photons (AW)	B1×2	**Allow**: reference to diffraction / interference / refraction / reflection / polarisation for 1 mark
	(b)		(X-ray) <u>photon</u> interacts with an (orbital) <u>electron</u> The (scattered) photon has a longer wavelength / lower frequency / lower energy **AND** The electron is ejected (from the atom at high speed)	B1 B1	**Allow**: 'X-rays' instead of 'photons' for the second B1 mark
	(c)	(i)	Initial / original / incident <u>intensity</u>	B1	**Allow**: Initial / original / incident <u>power</u> <u>per</u> (unit) <u>area</u>
		(ii)	$0.5 = e^{-(3.3x)}$ $\ln(0.5) = -3.3x$ $x = \ln(0.5)/(-3.3)$ $x = 0.21$ (cm)	C1 C1 A1	**Allow**: $\ln(2) = 3.3x$ **Allow**: 2 marks for 2.1×10^n; $n \neq -1$ (POT error)
	(d)		A contrast material has large attenuation coefficient / large atomic number / large Z (and hence easily absorbs X-rays) Idea of revealing tissue	B1 B1	
			Total	**10**	

Question			Answer	Marks	Guidance
8	(a)		Any <u>seven</u> from: 1. Protons / nuclei have spin / behave like (tiny) magnets 2. Protons / nuclei precess about the magnetic field (provided by the strong electromagnet) 3. Transmitting coils provide (pulses of) radio waves of frequency equal to the Larmor frequency 4. The protons / nuclei absorb energy / radio waves / resonate and flip into a higher energy state 5. When protons / nuclei flip back to a lower energy state they emit (photons of) radio waves 6. The relaxation time (of the protons/nuclei) depends on the (surrounding) tissues 7. The radio waves are picked up by the receiving coils 8. The gradient coils alter the magnetic flux density (through the body) 9. The Larmor frequency (of the protons / nuclei) varies through the body 10. The computer (processes all the signals from the receiving coils and) generates the image(s)	B1 × 7	**Show annotation on Scoris** **Not**: Atoms / particles for nuclei /protons. **Allow**: The protons / nuclei absorb energy / radio waves / resonate and get excited **Allow**: When protons / nuclei relax they emit (photons of) radio waves
	(b)		Ay <u>two</u> from: 1. PET scan: uses radioactive substance / uses positron-emitting substance / uses F(-18) / mention of gamma rays / mention of gamma photons 2. PET scan reveal the 'function' of the brain (AW) 3. MRI scan show variation in tissues (in the brain) (AW)	B1×2	**Allow**: MRI scan: no radioactive substance is required / mention of radio waves **Allow**: PET scans are used to diagnose dyslexia / Alzheimer (disease)
			Total	**9**	

Question			Answer	Marks	Guidance
9	(a)		Any <u>four</u> from: 1. (Fusion is the) joining / fusing together of ('lighter') <u>nuclei</u> / <u>protons</u> (to make 'heavier' nuclei) 2. Mass decreases in the reaction and this is transformed into energy OR the products have greater binding energy 3. High temperatures / ~10^7 K needed for fusion 4. High pressure / density (required in the core) 5. The protons / nuclei repel (each other because of their positive charge) 6. The strong (nuclear) force comes into play when the protons / nuclei are close to each other	B1×4	**Not**: Atoms / particles for nuclei /protons.
	(b)		(When hydrogen / helium runs out) the outer layers of the star expands / a (super) red giant is formed The core (of the star) collapses (rapidly) / a <u>supernova</u> is formed (Depending on the initial mass of the star the remnant is either a) <u>neutron star</u> or a <u>black hole</u>	B1 B1 B1	
			Total	**7**	

Question			Answer	Marks	Guidance
10	(a)		$F = \frac{GMm}{r^2}$ force = $\frac{6.67\times10^{-11}\times(10^{41})^2}{(4\times10^{22})^2}$ force = 4.2×10^{26} (N)	C1 C1 A1	**Allow**: 4×10^{26} (N) or 10^{26} since this is an estimation **Allow**: 2 marks for 4.2×10^{n}; $n \neq 26$ (POT error)
	(b)		Allow any <u>one</u> from: • The galaxies are receding / moving away from each other (because of the big bang) • Other galaxies may be pulling them in opposite direction • The acceleration is too small to collapse (other than over a very long period of time)	B1	
	(c)		Any <u>six</u> from: 1. (At the start it was) very hot / extremely dense / singularity 2. All forces were unified 3. Expansion led to cooling 4. Quarks / leptons (soup) 5. More matter than antimatter 6. Quarks combine to form hadrons / protons / neutrons 7. Imbalance of neutrons and protons / (primordial) helium produced 8. Atoms formed 9. Idea of gravitational force responsible for formation of stars / galaxies 10. Temperature becomes 2.7 K / 3 K or (the universe is saturated with cosmic) microwave background radiation	B1×6	**Show annotation on Scoris**
	(d)	(i)	Dark lines / bands against a background of <u>continuous</u> <u>spectrum</u>	M1 A1	

Question			Answer	Marks	Guidance
		(ii)	$\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$		
			speed = $\frac{86.6}{393.4} \times 3.0 \times 10^8$ (Any subject)	C1	
			speed = 6.6×10^7 (m s^{-1}) or 66000 (km s^{-1})	C1	**Allow**: 1 mark for $\frac{86.6}{480.0} \times 3.0 \times 10^8 = 5.41 \times 10^7$ (m s^{-1})
			$v = H_0 d$		
			$66000 = 50 \times d$		
			distance = 1300 (Mpc)	A1	**Allow**: 2 marks for 1.3×10^n; $n \neq 3$ (POT error) **Note**: Answer is 1080 (Mpc) if 5.4×10^7 (m s^{-1}) is used; this value will score 2 marks
			Total	**15**	

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