RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE

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

Mark Scheme for June 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 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)
RE	rounding error
SF	error in the number of significant figures
POT	error in the power of 10 in a calculation
?	wrong physics or equation
NAQ	not answered question
FT	follow through

The following annotations are available on the marking scheme:

Annotation	Meaning
/	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

Subject-specific Marking Instructions
One tick per mark. All questions must have appropriate annotation.

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)		Series branch: Using $(100^{-1} + 300^{-1})^{-1}$ and C = 75 (μF) capacitance = 500 + 75 capacitance = 575 (μF)	C1 A1	 Possible ecf, if capacitance of series branch is incorrect
	(b)	(i)	**Time constant method:** 37% of 6.0 V is 2.2 V. The time taken to reach 2.2 V is equal to the time constant time constant = 60 (s) / CR = 60 (s) $500 \times 10^{-6} \times R = 60$ $R = \frac{60}{500 \times 10^{-6}}$ resistance = 1.2×10^5 (Ω) **Substitution method:** Correct values for p.ds and t substituted into $V = V_0 e^{-\frac{t}{CR}}$ Correct values substituted into $\ln(V / V_0) = -\frac{t}{CR}$ resistance = 1.2×10^5 (Ω)	 C1 C1 A1 C1 C1 A1	**Note**: Allow full credit for other correct methods **Allow**: time constant in the range 58 s to 62 s Deduct 1 mark for misreading graph followed by ecf **Note**: If C value from **(a)** is used, then deduct 1 mark followed by ecf **Eg**: $2.2 = 6.0e^{-\frac{60}{CR}}$ - values read to ± 1 small square **Eg:** $\ln(2.2/6.0) = -\frac{60}{500 \times 10^{-6} \times R}$ **Note**: If C value from **(a)** is used, then deduct 1 mark followed by ecf. Using 575 (μF) gives 1.04×10^5 (Ω)
		(ii)	Correct p.ds from graph: 6 (V) and 3.6 (V) $\frac{1}{2} \times 500 \times 10^{-6} \times 6.0^2$ or $\frac{1}{2} \times 500 \times 10^{-6} \times 3.6^2$ energy is 9.00×10^{-3} (J) and 3.24×10^{-3} (J) energy lost = 5.76×10^{-3} (J) or 5.8×10^{-3} (J)	C1 C1 A1	**Allow** V value to be in the range 3.5 V to 3.7 at 30s **Note**: Do not penalise 10^n error from **(b)(ii)** again here **Allow** 1 mark for: $\frac{1}{2} \times 500 \times 10^{-6} \times (6.0 - 3.6)^2 = 1.44 \times 10^{-3}$ (J) **Note**: Do not penalise use of 575 μF again. This gives a value of 6.62×10^{-3} (J)
			Total	**8**	

Question			Answer	Marks	Guidance
2	(a)		number = $\frac{2.8\times10^{-9}}{1.6\times10^{-19}}$ number = 1.75×10^{10} or 1.8×10^{10}	B1	Ignore a negative sign
	(b)		$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ $F = \frac{2.8\times10^{-9}\times2.8\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(2.0\times10^{-2})^2}$ force = 1.76×10^{-4} (N) or 1.8×10^{-4} (N)	C1 A1	**Note**: No credit for using charge equal to *e*
	(c)	(i)	Tension and weight	B1	**Allow**: force provided by the string / force in the string instead of tension **Not**: 'gravity' for weight **Allow**: force due to gravity **Allow**: gravitational (force)
		(ii)	(weight =) $6.5 \times 10^{-5} \times g$ $\tan\theta = 1.76 \times 10^{-4}/6.38 \times 10^{-4}$ θ =15° Or Scale drawing of triangle of force θ in the range 13° to 18° θ in the range 14° to 16°	C1 C1 A1 C1 A1 A1	Deduct 1 mark for the use of 10 (m s^{-2}) followed by ecf **Note** that getting to this stage scores both C1 marks Possible ecf from **(b)** **Note**: No marks if mass is used instead of the weight
			Total	**7**	

Question			Answer	Marks	Guidance
3	(a)		Arrow to the left	B1	
	(b)	(i)	1500 (eV)	B1	**Note**: 2.4×10^{-16} (J) on the answer line scores zero
		(ii)	(KE =) $1500 \times 1.6 \times 10^{-19}$ (= 2.4×10^{-16} J)	C1	Possible ecf from **(b)(i)**
			$2.4\times10^{-16} = \frac{1}{2}\times 9.11\times10^{-31}\times v^2$ (Allow any subject)	C1	
			$v = 2.3 \times 10^{7}$ (m s^{-1})	A1	**Allow**: 2 marks for 5.3×10^{14} (answer not square-rooted) **Note**: $v = \sqrt{\frac{2\times1500}{9.11\times10^{-31}}} = 5.74\times10^{16}$ (m s^{-1}) does not score
	(c)	(i)	$F_{(E)} = Eq$ and $F_{(M)} = Bqv$		
			$Eq = Bqv$ (This mark is for equating the two equations)	M1	**Allow** an equivalent approach
			(Hence) $v = \frac{E}{B}$	A1	**Allow** any subject
		(ii)	Force due to magnetic field > force due to electric field	B1	**Allow**: magnetic force > electric force or $F_M > F_E$ or $Bqv > Eq$ or magnetic force is bigger and electric force is the same
			Electrons drift 'downwards'	B1	**Note**: This mark can be scored on Fig. 3.2
			Total	**9**	

Question			Answer	Marks	Guidance
4	(a)		magnetic flux = magnetic flux density × area <u>normal</u> to the field	B1	**Allow**: $\phi = BA$, with terms defined; B = magnetic flux density or magnetic field strength and A = area <u>normal</u> to the field **Note**: If angle is used in the definition then it must be defined correctly
	(b)	(i)	$R = \frac{1.7\times10^{-8}\times130}{\pi\times(4.6\times10^{-4})^2}$ (Any subject) R = 3.3(2) (Ω) current = $\frac{24}{3.32}$ current = 7.2 (A)	C1 C1 A1	**Allow**: Possible ecf if value for R is incorrect after attempted use of the equation $R = \frac{\rho L}{\pi r^2}$.
		(ii)	e.m.f. = rate of change of magnetic flux linkage (initial ϕ =) 0.090 × 1.3 × 10^{-3} or 1.17 × 10^{-4} 150 = $\frac{1100\times0.090\times1.3\times10^{-3}}{t}$ (Any subject) time = 8.6 × 10^{-4} (s)	 C1 C1 A1	**Allow**: (initial $N\phi$ =) 0.090 × 1.3 × 10^{-3} × 1100 or 0.129 **Allow**: 2 marks for 7.8 × 10^{-7} (s) if 1100 turns omitted
			Total	**7**	

Question			Answer	Marks	Guidance
5	(a)	(i)	Any number in the range: 10^4 to 10^5	B1	
		(ii)1	$10^{-14} = \frac{h}{mv}$ momentum = $\frac{6.63 \times 10^{-34}}{10^{-14}}$ momentum = 6.6×10^{-20} (kg m s^{-1})	C1 A1	**Allow** 1 sf answer of 7×10^{-20} (kg m s^{-1})
		(ii)2	The mass of the electron is greater (than its rest mass / 9.11×10^{-31} kg)	B1	**Allow**: Dividing (momentum) by 9.11×10^{-31} (kg) would give a speed of 7.3×10^{10} (m s^{-1}) which is greater than the speed of light / *c* (this is not possible) (AW)
	(b)	(i)	Different number of <u>neutrons</u>	B1	**Not**: different number of nucleons / different mass number / different A
		(ii)	u u d	B1	
		(iii)	u $\rightarrow$ d + positron + neutrino	M1 A1	**Allow**: u u d $\rightarrow$ u d d **Allow**: symbols for positron (e^+ / β^+ / $^0_{+1}e$) and neutrino (υ) **Allow** full marks for an answer in words **Allow** 1 mark for p $\rightarrow$ n + e^+ + υ
		(iv)	Any <u>two</u> from: charge or proton number / momentum / mass-energy / nucleon number / lepton number / strangeness / baryon number / spin	B1	**Not**: <u>mass</u> on its own or <u>energy</u> on its own, but **allow** mass <u>and</u> energy
		(v)	β^+ when there are fewer neutrons / β^+ for lighter nuclei or β^- when there are more neutrons / β^- for heavier nuclei	B1	**Allow**: Alternative correct answers in terms of ratio of protons to neutrons
			Total	**10**	

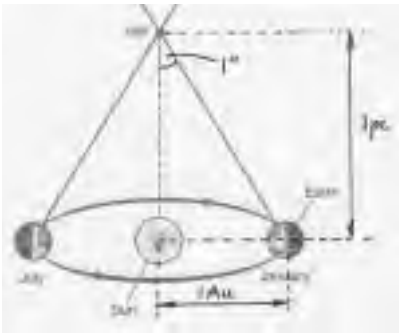
Question			Answer	Marks	Guidance
6	(a)		Impossible to predict when a nucleus will decay or impossible to predict which nucleus will decay	B1	
	(b)		$N = N_0 e^{-\lambda t}$ (λ =) 0.693/7.1 ×10^8 λ = 9.76 × 10^{-10} y^{-1} $0.011 = e^{-(9.76\times10^{-10}\times t)}$ (age =) $\frac{\ln(0.011)}{-9.76\times10^{-10}}$ age = 4.6 × 10^9 (y)	C1 C1 A1	**Alternatives:** $N = N_0 e^{-\lambda t}$ (λ =) 0.693/[7.1 ×10^8 × 3.16 × 10^7] C1 λ =3.089 × 10^{-17} s^{-1} $0.011 = e^{-(3.089\times10^{-17}\times t)}$ C1 (age =) $\frac{\ln(0.011)}{-3.089\times10^{-17}}$ age = 1.46... × 10^{17} (s) age = 4.6 × 10^9 (y) A1 Or $0.011 = \frac{1}{2^n}$ C1 $n = -\frac{\ln(0.011)}{\ln 2}$ or n = 6.5 C1 age = 6.5 × 7.1 × 10^8 (y) age = 4.6 × 10^9 (y) A1
	(c)	(i)	number in the range 50 to 70	B1	
		(ii)	Correct reference to binding energy. Eg: The BE per nucleon will decrease for fusion (which is impossible unless external energy is supplied) (AW)	B1	

Question			Answer	Marks	Guidance
		(iii)	(mass of nucleons =) $4 \times 1.673 \times 10^{-27} + 4 \times 1.675 \times 10^{-27}$	C1	**Allow**, due to misinterpretation of Data, Formulae and Relationship Booklet, the following (though incorrect):
			(Δm =) $[4 \times 1.673 \times 10^{-27} + 4 \times 1.675 \times 10^{-27}] - 1.329 \times 10^{-26}$	C1	(nucleon mass =) $8 \times 1.661 \times 10^{-27}$ (kg) C1 (Δm =) $[8 \times 1.661 \times 10^{-27}] - 1.329 \times 10^{-26}$ (kg) C1
			(mass defect =) 1.020×10^{-28} (kg)		(BE =) (-) $2.0 \times 10^{-30} \times (3.0 \times 10^{8})^2$ (= 1.8×10^{-13} J) C1 (BE per nucleon =) $1.8 \times 10^{-13}/8$
			BE = mass defect $\times c^2$		BE per nucleon = 2.25×10^{-14} (J) A1
			(BE =) $1.020 \times 10^{-28} \times (3.0 \times 10^{8})^2$ (= 9.180×10^{-12} J)	C1	
			(BE per nucleon) = $9.180 \times 10^{-12}/8$		
			BE per nucleon =1.148×10^{-12} (J)	A1	**Allow** 2 sf or 3 sf answer
			Total	**10**	

Question			Answer	Marks	Guidance
7	(a)		Any <u>two</u> from: • Can travel in a vacuum • Travel at the speed of light / c / 3×10^8 <u>m s^{-1}</u> in <u>vacuum</u> • No charge / no (rest) mass • (Highly) ionising	B1 × 2	**Not**: EM radiation / wave because not *particulate* nature **Not**: Short wavelength or high frequency **Not**: High energy photons **Not**: reflect / refract / diffract
	(b)		$\frac{hc}{\lambda}$ <u>and</u> $E = mc^2$ $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda} = 2\times9.11\times10^{-31}\times(3.0\times10^{8})^{2}$ wavelength = 1.2×10^{-12} (m)	C1 C1 A1	**Allow**: $\frac{hc}{\lambda}$ and 1.02 <u>MeV</u> or 0.51 <u>MeV</u> for this first C1 mark **Allow**: Correct use of mass = 0.00055 u **Allow**: 2 marks for 2.4×10^{-12} (m) for omitting factor of 2 **Note**: Using the de Broglie equation with $v = c$, also gives an answer of 2.4×10^{-12} (m); this scores zero – see below: $\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times3.0\times10^{8}} = 2.4\times10^{-12}$ m scores zero
	(c)		Barium / iodine (Contrast medium absorbs X-rays because it) has large attenuation coefficient / has large absorption coefficient / has large Z values Ideal for imaging the <u>outline</u> (of soft tissues)	B1 B1 B1	 **Not**: X-rays are (easily) absorbed by the contrast material **Allow**: If there is a hole then the barium shows this up by flowing out / Barium is used to find blockage with explanation
			Total	**8**	

Question			Answer	Marks	Guidance
8	(a)		Rate of decay / disintegration of <u>nuclei</u> or Number of γ (photons) emitted per unit time	B1	The question has 500 Bq. Hence a**llow** the following: Number of <u>nuclei</u> decaying per second / number of γ (photons) emitted per second **Not**: Rate of decay of atoms / molecules / particles
	(b)		(rate of energy =) $500 \times 10^{6} \times 2.2 \times 10^{-14}$ rate of energy emission = 1.1×10^{-5} (J s^{-1})	C1 A1	
	(c)		**Collimator / lead tubes** <u>and</u> ..... gamma (ray photons) travel along the axis of lead tubes (AW) **Scintillator / Sodium Iodide (crystal)** <u>and</u> ..... gamma ray / gamma photon produces (many) <u>photon**s**</u> of (visible) light **Photomultiplier (tubes) / photocathode and dynodes** <u>and</u> ..... (electrical) pulse / signal / electron<u>s</u> produced by photon(s) of visible light **Computer** <u>and</u> ..... signals / pulses /electrons (from photomultiplier tubes) are used to generate an image QWC: Quality of image improved by narrower / thinner / longer collimators OR longer scanning time	B1 B1 B1 B1 B1	**Not** 'it collimates' **Allow**: parallel rays / uni-directional rays travel along the lead tubes (AW) **Not** 'information / data' in place of signals
			Total	**8**	

Question			Answer	Marks	Guidance
9	(a)		Longitudinal (wave) Frequency (sound) ≥ 20 kHz	B1 B1	**Allow**: high frequency (sound) that cannot be heard **Allow** any value of frequency ≥ 20 kHz **Not**: It is non-ionising
	(b)		Emission: (Piezoelectric film / crystal connected to an) alternating e.m.f / p.d / current making it vibrate / contract and expand / resonate (and hence emits ultrasound) (AW) Reception: (Ultrasound makes the piezoelectric film / crystal) vibrate / contract and expand / resonate and this produces (alternating) e.m.f. / p.d / current (AW)	B1 B1	**Note**: The alternating p.d. can be implied by the term *frequency* **Not** varying p.d.
	(c)		Without the gel, the ultrasound would be reflected (at the skin /air interface) or The gel allows (maximum) transmission of ultrasound (into the body) Gel and skin has similar acoustic impedance / *Z* (values) or There is a large difference between the *Z* (values) of air and skin	B1 B1	**Allow**: Gel is used for impedance matching
	(d)		Transducer placed at an angle to the artery / arm Ultrasound (pulses) are reflected by (moving) blood (cells) The frequency / wavelength (of ultrasound) is changed Change in frequency is related to the speed (of blood) or change in wavelength is related to the speed	B1 B1 B1 B1	**Allow**: The wavelength / frequency is Doppler shifted (AW) **Allow**: $\frac{\Delta f}{f} = \frac{2v\cos\theta}{c}$ where *c* is the speed of ultrasound and *v* is the speed of blood; no need to define the angle
			Total	**10**	

Question			Answer	Marks	Guidance
10	(a)		(distance =) $3.0 \times 10^8 \times 3.16 \times 10^7$ distance = 9.48×10^{15} (m) ≈ 9.5×10^{15} (m)	B1	**Allow**: (distance =) $3.0 \times 10^8 \times 365(¼) \times 24 \times 3600$ **Allow** 1 mark for bald 9.48×10^{15} (m)
	(b)		Correct labelling of 1 pc, 1 AU and 1” 	B1	**Allow**: ‘hypotenuse’ labelled as 1 pc
	(c)	(i)	(distance =) $9.5 \times 10^{15} \times 2.1 \times 10^7$ (m) or 2.0×10^{23} (m) (distance in pc =) $2.0 \times 10^{23}/3.1 \times 10^{16}$ distance = 6.4×10^6 (pc)	C1 A1	Possible ecf from **(a)**
		(ii)	(time =) $10^{44}/4 \times 10^{26}$ (s) or 2.5×10^{17} (s) (time =) $2.5 \times 10^{17}/3.16 \times 10^7$ time = 7.9×10^9 years	C1 A1	 **Allow**: 1 sf answer of 8×10^9 years
	(d)		Any <u>one</u> from: • Very dense / infinite density / very small / singularity Any <u>one</u> from: • (Very strong gravitational field therefore) light cannot escape from it / curves space / slows down time / emits Hawking radiation	B1 B1	
			Total	**8**	

Question			Answer	Marks	Guidance
11	(a)	(i)	H_0 = 1/age		
			$H_0 = 1/(13.7 \times 10^9 \times 3.16 \times 10^7)$	C1	
			$(H_0 =)\ 2.31 \times 10^{-18}\ (s^{-1})$	C1	
			$(H_0 =)\ \frac{2.31\times10^{-18}\times3.09\times10^{16}\times10^6}{10^3}$		**Allow:** 2 sf answer
			Hubble constant = 71.4 (km s^{-1} Mpc^{-1})	A1	**Special case**: Using $H_0 = 1/13.7 \times 10^9 = 7.30 \times 10^{-11}\ (y^{-1})$ gives an answer of 2.26×10^9 (km s^{-1} Mpc^{-1}) – allow 1 mark
		(ii)	$v = H_0$ d		
			$(v =)\ 71.4 \times 50$ or 3.57×10^3 (km s^{-1}) or 3.57×10^6 (m s^{-1})	C1	Possible ecf from **(a)**
			$\frac{\Delta\lambda}{\lambda} = \frac{3.57\times10^6}{3.0\times10^8} (= 1.19\times10^{-2})$	C1	
			$\Delta\lambda = 656 \times 1.19 \times 10^{-2}$ or $\Delta\lambda = 7.80$ (nm)	C1	
			wavelength = 656 + 7.80		
			wavelength = 664 (nm)	A1	**Allow**: 2sf answer
	(b)		Big bang: Creation of the universe (from which space/time evolved) (AW)	B1	
			Any <u>three</u> from: 1. (At the start) the universe was hot / infinitely dense 2. Expansion of the universe led to cooling 3. The (current) temperature of universe is 2.7 K / 3 K 4. (The universe as a black body) is associated with microwaves at this temperature (AW) or The (wavelength of the) gamma radiation stretched to microwaves (by the expansion).	B1 × 3	**Not**: The universe now has microwaves. (The microwaves must be linked with current temperature)
			QWC: (Cosmological principle is supported because) MBR is isotropic	B1	**Allow**: Microwaves have the same intensity in all directions

Question			Answer	Marks	Guidance
	(c)		(For an open / flat universe) Further expansion will lead to cooling / temperature lower than 3K / temperature tend to absolute zero (AW) The wavelength (of the EM radiation) gets longer / frequency (of the EM radiation) gets smaller / energy of photons decreases / microwaves become radio waves	B1 B1	**Alternative**: Temperature (will eventually) increases if closed universe B1 The wavelength (of EM radiation) get smaller B1
	(d)		Graph starting from origin and having a shape consistent with either open or accelerated universe	B1	**Not** a straight line
			Total	**15**	

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