Oxford Cambridge and RSA

GCE

Physics A

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

Advanced GCE

Mark Scheme for June 2014

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.

1. These are the annotations, (including abbreviations), including those used in scoris, which are used when marking

Annotation	Meaning of annotation
BP	Blank Page – this annotation **must** be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
✓	correct response
✗	incorrect response
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)
FT	follow through
SF	error in number of significant figures
POT	error in the power of 10 in calculation
AE	arithmetic or calculation error
NAQ	not answered question
?	wrong physics
RE	reading error

Abbreviations, annotations and conventions used in the detailed Mark 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 word (or the equivalent) must be present in answer to score a mark
ecf	=	error carried forward
AW	=	alternative wording
ora	=	or reverse argument

Subject-specific Marking Instructions

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.
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.
(***Note**: Significant figures are thoroughly assessed in G483 and G486 components of Physics A.)

Question			Answers	Marks	Guidance
1	(a)		Correct direction of the electric field. A minimum of 5 field lines shown. Correct shape of field lines.	B1 B1	 Expect a minimum of 3 field lines to be normal (by eye) to the plate - ignore the angles made by the field lines at the sphere. Also there must not be any field lines within the sphere.
	(b)	(i)	($E \propto Q/r^2$ and the magnitude of E is the same due to each charge **A** and **B** at **X**. Therefore) **B** has a greater charge because **X** is further away from **B**.	B1	
		(ii)	Curve showing E = 0 at position of **X**. <u>Curve</u> showing E is positive between **A** and **X** and negative between **X** and **B** (or vice versa). The magnitude of E is small close to **A** <u>and</u> large close to **B**.	B1 M1 A1	**Allow** any graph, including a straight line. Tolerance for E = 0: ± ½ large square about **X.** **Note**: The curve must be continuous and pass through position of **X**. Ignore any curve to the right of **B** and to the left of **A**. **Note**: This mark can only be scored if the previous M1 has been awarded.
	(c)		Both E and g vary with 1/distance^2. (Hence the ratio is independent of the distance.)	B1	**Allow**: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ <u>and</u> $g = \frac{GM}{r^2}$ **or** $E \propto \frac{1}{r^2}$ <u>and</u> $g \propto \frac{1}{r^2}$ **Allow** 'both are inverse square laws'.
			Total	**7**	

Question			Answers	Marks	Guidance
2	(a)	(i)	A (constant) force acts at right angles to the velocity / motion (of the helium nucleus).	B1	**Note**: The answer must be in terms of force and not acceleration. **Allow '**force is towards the centre of the circle'. **Not** 'there is a *centripetal* force' - unless explained. **Not** 'force is right angles to <u>speed</u>'.
	(a)	(ii)	No work done (by the force) / no acceleration in the direction of motion / no force in direction of motion	B1	**Allow** force / acceleration is at right angles to velocity / motion.
	(b)		$BQv = \frac{mv^2}{r}$ or $mv = BQr$ momentum = $0.20 \times 10^{-3} \times 3.2 \times 10^{-19} \times 0.15$ momentum = 9.6×10^{-24} (kg m s^{-1})	C1 C1 A1	**Allow** $v = 1.45.. \times 10^3$ (m s^{-1}); $p = 1.45.. \times 10^3 \times 6.6 \times 10^{-27}$
	(c)		$v = 9.6 \times 10^{-24}/6.6 \times 10^{-27}$ or $v = 1.45... \times 10^3$ (m s^{-1}) KE = $½ \times 6.6 \times 10^{-27} \times (1.45... \times 10^3)^2$ KE =7.0×10^{-21} (J)	C1 A1	Possible ecf from **(b)** **Allow** 1 sf answer **Alternative**: ($E = p^2/2m$); KE = $\frac{(9.6\times10^{-24})^2}{2\times6.6\times10^{-27}}$ C1 KE = 7.0×10^{-21} (J) A1
	(d)		The helium nucleus moves to the <u>right.</u> The path is a clockwise curve / looped (in the plane of the paper).	B1 B1	**Not** if the path is shown as a straight line. **Allow** 2 marks for clockwise curve / loop to the right. **Allow** 1 mark for a sketch showing an 'upward curve to the right'
			Total	**9**	

Question			Answers	Marks	Guidance
3	(a)	(i)	One proton / (same) charge / (same) element <u>and</u> (same) chemical property / one electron	B1	**Allow** (same) number of protons. **Allow** (same) number of electrons.
		(ii)	mass of nucleus < (total) mass of nucleons Energy must be supplied to the nucleus to free the nucleons / energy released when nucleons combine (to form the nucleus). $(\Delta)E = (\Delta)mc^2$ and $(\Delta)E$ is the (binding) energy and $(\Delta)m$ is the mass defect or the difference in mass.	B1 B1 B1	 **Allow** nucleus has binding energy.
	(b)	(i)	${}^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + {}^{0}_{-1}\text{e} + \bar{\nu}_{(e)}$	B1,B1	**Allow** proton or ${}^{1}_{1}$H or H^+ or p <u>and</u> (electron) antineutrino.
		(ii)	(Average) time taken for half of the neutrons (in a sample) to decay.	B1	**Note**: Must have reference to 'half' and 'neutron<u>s</u>' **Allow** 'the time taken for the activity of neutron<u>s</u> to halve'.
	(c)	(i)	$F = \dfrac{1.6\times10^{-19}\times1.6\times10^{-19}}{4\pi\varepsilon_0\times(10^{-14})^2}$ force = 2.3 (N)	C1 A1	**Not** $Q = q = 1$
		(ii)	$E = 7.0\times10^{4}\times1.6\times10^{-19}$ (= 1.12×10^{-14} J) ($E = \frac{3}{2}kT$); $7.0\times10^{4}\times1.6\times10^{-19} = \frac{3}{2}\times1.38\times10^{-23}\times T$ temperature = 5.4×10^{8} (K)	C1 C1 A1	 **Allow** any subject. Also, allow $E \approx kT$ since it is an estimate. **Allow** 1 sf answer.
		(iii)	Some nuclei will be travelling faster / have greater (kinetic) energy (to overcome electrostatic repulsion and hence cause fusion).	B1	**Allow** the pressures are high (enough to cause fusion). **Not** 'nuclei get close enough'.
		(iv)	($\Delta E = \Delta mc^2$); $18 \times 10^{6} \times 1.6 \times 10^{-19} = \Delta m \times (3.0 \times 10^{8})^2$ change in mass = 3.2×10^{-29} (kg)	C1 A1	**Allow** any subject **Allow** a maximum of 1 mark for 18MeV ± 70 keV.
		(v)	Helium (nucleus) has greater charge / more protons. The (electrostatic) <u>repulsive</u> force (between the deuterium and helium nuclei) is greater (hence smaller chance of fusion).	B1 B1	 Do **not** award this mark if 'helium nuclei are moving slower' is also given as the reason for smaller probability for fusion.
			Total	**17**	

Question			Answers	Marks	Guidance
4	(a)		The time taken for the p.d / current / charge to decrease to 1/*e* of its (initial) value.	B1	**Allow** 37% instead of 1/*e*. **Not** time constant = *CR* on its own.
	(b)		Any suitable values with units, eg: 5 MΩ and 1 μF.	B1	
	(c)	(i)	$R = \dfrac{4.9\times10^{-7}\times5.0}{\pi\times(0.06\times10^{-3})^2}$ or *R* = 217 (Ω) time constant = 0.010 × 217 time constant = 2.2 (s)	C1 C1 A1	**Note**: An incorrect equation here for *A* prevents this and any subsequent marks. **Allow** 2 marks for 0.54 (s) – diameter of 0.12 mm used instead of radius 0.06 mm.
		(ii)	Electrons are removed from **X** or electrons are deposited on **Y**. **X** becomes positive or **Y** becomes negative (The size of charge is the same because) an equal number of electrons are removed and deposited (on the plates).	B1 B1 B1	**Allow** electrons move anticlockwise (in the circuit). There is no ecf from the previous B1 mark.
		(iii)	$E = ½ \times 0.010 \times 12^2$ or *E* = 0.72 (J) $m = 8900 \times [\pi \times (0.06 \times 10^{-3})^2 \times 5.0]$ or $5.0(3) \times 10^{-4}$ (kg) $5.03 \times 10^{-4} \times 420 \times \Delta\theta = 0.72$ increase in temperature = 3.4 (°C)	C1 C1 C1 A1	**Note**: An incorrect equation here for *m* or *V* prevents this and any subsequent marks. Correct substitution into $mc\Delta\theta = 0.72$; **allow** any subject. **Note**: Do not penalise using diameter here again if already penalised in **(c)(i)**.
		(iv)	Energy or V^2 increases by a factor of 4. The (change in temperature) increases by a factor of 4 (because $\Delta\theta \propto E$).	B1 B1	**Allow** the label *E* or *W* for energy. **Allow** $\Delta\theta$ = 13.6 (°C) for this B1 mark - possible ecf from **(iii)**.
			Total	**14**	

Question			Answers	Marks	Guidance
5	(a)		The induced e.m.f. is (directly) proportional / equal to the rate of change of (magnetic) flux linkage.	B1	**Allow** $E = \frac{\Delta\Phi}{\Delta t}$ with all terms defined; E = induced e.m.f., Φ = (magnetic) flux linkage and t = time.
	(b)		North / N (pole). There is a repulsive force (between magnet and coil and the work done against this repulsive force is transferred to electrical energy in the coil).	B1	**Allow** - A south (pole) would cause attraction (between the coil and magnet) or there is gain in KE (of magnet which can-not happen hence it must be north pole).
	(c)	(i)	There is no change in (magnetic) flux (linkage) or there is no change in the (magnetic) flux density.	B1	**Allow** 'no change in (magnetic) field strength'.
		(ii)	E = 0 between 0 to 3 cm, 5 – 8 cm and 10 - 12 cm. Two 'pulses' where B is changing. The pulses have opposite signs.	B1 M1 A1	Tolerance: ± ¼ large square **Note**: The pulses must have E = 0 at 3 cm, 5 cm, 8 cm and 10 cm; tolerance ± ¼ large square.
			Total	**6**	

Question			Answers	Marks	Guidance
6	(a)	(i)	**C**	B1	
		(ii)	Zero	B1	
	(b)	(i)	proton / ${}^{1}_{1}$H / ${}^{1}_{1}$p / p	B1	
		(ii)	$\lambda = \dfrac{0.693}{5700 \times 3.16 \times 10^{7}}$ or λ = 3.847... × 10^{-12} (s^{-1}) ($A = \lambda N$); $N = \dfrac{1.1 \times 10^{19}}{3.847... \times 10^{-12}}$ or N = 2.859.. × 10^{30} mass = $\dfrac{2.859... \times 10^{30}}{6.02 \times 10^{23}} \times 0.014$ mass = 6.649... × 10^{4} (kg) or 6.6 × 10^{4} (kg)	C1 C1 A1	 **Allow** any subject **Allow** ecf within the calculation for an incorrect λ. **Allow** 6.7 × 10^{4} (kg)
	(c)		A (thermal / slow-moving) neutron splits the <u>nucleus</u> into two (smaller) nuclei and (fast-moving) neutron(s).	B1 B1	**Allow** 'fast neutron'; **allow** 'decays' instead of 'splits'. **Not** 'splitting the atom'. **Not** 'particles' or 'fragments' in place of '(smaller) nuclei'.
	(d)		Any **three** from: 1. Fission reactions produce fast neutrons. 2. The moderator / water slows down (the fast-moving) neutrons. 3. Slow-moving neutrons have a greater chance of causing fission (of U-235). (ora) 4. The control rods absorb (some of the) neutrons. 5. (On average) one neutron survives between successive (fission) reactions. QWC: The neutrons make collisions with the (moderator) nuclei <u>and</u> transfer (some of) their (kinetic) energy.	B1×3 B1	**Allow** boron / cadmium instead of control rods in 4. **Not** graphite for 4. **Allow** atoms / molecules instead of nuclei.
			Total	**12**	

Question			Answers	Marks	Guidance
7	(a)	(i)	Discrete energy (of electrons in an atom) / quantised energy (of electrons in an atom) / permitted energy (states of electrons in an atom).	B1	
		(ii)	($E = \frac{hc}{\lambda}$) $E = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{7.2\times10^{-11}}$ or $E = 2.763 \times 10^{-15}$ (J) value of energy level = - $(3.2 - 2.763) \times 10^{-15}$ (J) value of energy level = - 4.4×10^{-16} (J)	C1 C1 A1	**Note**: The answer must be <u>negative</u> to score the A1 mark **Note:** 4.4×10^{-16} (J) scores 2 marks
		(iii)	(λ_0 is) halved. Explanation: Reference to (photon / electron kinetic) energy doubled <u>and</u> $E = hc/\lambda$ or $E \propto 1/\lambda$.	M1 A1	**Allow** explanation in terms of $eV = hc/\lambda$.
	(b)	(i)	($I = I_0 e^{-\mu x}$) fraction transmitted = $e^{-(0.96\times2.3)}$ fraction transmitted = 0.11 fraction absorbed or scattered = 1 – 0.11 fraction absorbed or scattered = 0.89	C1 C1 A1	**Allow** 3 marks for 89%. **Allow** 89/100
		(ii)	Bone and muscle have different (values for) μ hence better contrast. or Muscle and fat have similar (values for) μ hence poor contrast.	B1	
			Total	**10**	

Question			Answers	Marks	Guidance
8	(a)		Ultrasound reflected at boundary (between materials). B-scan takes place in different directions. QWC: The <u>intensity</u> of the reflected ultrasound depends on the acoustic impedances of the materials (and this is greater when the difference between the acoustic impedances is greater).	B1 B1 B1	 **Allow** B-scan is 'multiple A-scans'. **Allow** *Z* instead of acoustic impedance. **Not** attenuation coefficient for *Z*.
	(b)		Any **four** from: 1. The brain / body is surrounded by a ring of (gamma) detectors /gamma camera(s). 2. The positrons (from the F-18 nuclei) annihilate electrons. 3. The annihilation of a positron and an electron produces <u>two</u> (identical gamma) <u>photons</u> travelling in opposite directions. 4. The delay time between these two photons / gamma rays is used to determine the location of the annihilation / F-18 / tracer. 5. Computer connected to detectors / gamma camera <u>and</u> an image is formed by the computer (using the electrical signals from the detectors).	B1×4	**Not** positron<u>**s**</u> and electron<u>**s**</u> annihilate to produce photons travelling in opposite directions for 3. **Allow** an answer in terms of arrival times.
			Total	**7**	

Question			Answers	Marks	Guidance
9	(a)		$V = \frac{4}{3}\pi \times (6\times10^3)^3$ or $V = 9.05 \times 10^{11}$ (m^3) density = $\dfrac{2.0\times10^{30}}{\frac{4}{3}\pi\times(6\times10^3)^3}$ density = 2.2×10^{18} <u>kg m^{-3}</u>	C1 C1 A1	**Note**: An incorrect equation here for *V* prevents this and any subsequent marks. The correct unit must also be included to score this A1 mark. **Allow** 2 marks for $2.76.... \times 10^{17}$ <u>kg m^{-3}</u> – 12 km used instead of 6 km for the radius.
	(b)		$g \propto 1/r^2$ ratio = $\left(\dfrac{1.4\times10^9}{12\times10^3}\right)^2$ or ratio = $\left(\dfrac{0.7\times10^9}{6\times10^3}\right)^2$ ratio = 1.4×10^{10}	C1 A1	**Note**: The answer to 3 sf is 1.36×10^{10}. **Allow** 1 mark for 7.3×10^{-11} – inverse of the ratio.
	(c)		($p = 1/d$) $d = \dfrac{8.6\times9.5\times10^{15}}{3.1\times10^{16}}$ (pc) or $d = 2.64$ (pc) $p = 0.38$ (arc seconds)	C1 A1	**Allow** full credit for alternative methods.
	(d)		$(\dfrac{\Delta\lambda}{\lambda} = \dfrac{v}{c})$ fractional change = $\dfrac{7600}{3.0\times10^8}$ percentage change = 2.5×10^{-3} %	C1 A1	**Allow** 1 mark for 2.5×10^{-5} (factor of 100 missed out).
	(e)		The suggestion is incorrect because Hubble's law applies to (distant receding) galaxies. or The suggestion is incorrect because Hubble's law does not apply to stars in our own galaxy.	B1	Do **not** allow this mark if 'Sirius / star is moving <u>towards</u> us' is also included.
			Total	**10**	

Question			Answers	Marks	Guidance
10	(a)		The universe is homogeneous. and isotropic (on a large scale).	B1 B1	
	(b)		The <u>intensity</u> of the microwaves is the same in all directions.	B1	**Allow** the microwave (background radiation) is <u>isotropic</u>.
			These microwaves correspond to a temperature of 2.7 K or The temperature of the universe is 2.7 K.	B1	**Allow** 3 K
			The expansion of the universe following the big bang led to cooling and hence we observe microwaves rather than short wavelength e.m. waves / gamma waves.	B1	**Allow** - The short e.m. / gamma waves during the early stages of the universe have been 'stretched out' / 'red-shifted' to microwaves by the expansion.
	(c)		($\rho = \frac{3H_0^{\ 2}}{8\pi G}$) $H_0 = \sqrt{\frac{8\pi \times 6.67 \times 10^{-11} \times 9.7 \times 10^{-27}}{3}}$ $H_0 = 2.328 \times 10^{-18}$ (s^{-1})	C1	**Allow** any subject
			(age = $1/H_0$) age = $\frac{1}{2.328 \times 10^{-18}}$ or age = 4.3×10^{17} (s)	C1	
			age = 1.4×10^{10} (y)	A1	Answer to 3 sf is 1.36×10^{10} (y)
			Total	**8**	

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