OCR
Oxford Cambridge and RSA

GCE

Physics A

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

Advanced GCE

Mark Scheme for June 2016

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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

Annotation	Meaning
BOD	Benefit of doubt given
BP	Blank Page
CON	Contradiction
	Incorrect Response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct Response
AE	Arithmetic error
	Wrong physics or equation

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 and rounding errors:

If the data given in a question is to 2 sf, then allow to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Penalise a rounding error once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

Question			Answers	Marks	Guidance
1	(a)		$(B = \frac{F}{IL})$ $F \rightarrow$ kg m s^{-2} / $I \rightarrow$ C s^{-1} and $L \rightarrow$ m T $\rightarrow$ kg C^{-1} s^{-1}	C1 A1	**Alternative:** $B = \frac{F}{Qv}$ $F \rightarrow$ kg m s^{-2} / $Q \rightarrow$ C and $v \rightarrow$ m s^{-1} C1 T $\rightarrow$ kg C^{-1} s^{-1} A1 **Allow** $\frac{\text{kg}}{\text{C s}}$, $\frac{\text{kg C}^{-1}}{\text{s}}$, etc.
	(b)	(i)	$F = \frac{9.11\times10^{-31}\times(7.0\times10^{6})^{2}}{2.5\times10^{-2}}$ / $F = 1.79 \times 10^{-15}$ (N) $(F = BQv)$ $1.79 \times 10^{-15} = B \times 1.6 \times 10^{-19} \times 7.0 \times 10^{6}$ (Any subject) $B = 1.6 \times 10^{-3}$ (T)	C1 C1 A1	**Alternative**: Allow *e* instead of *Q* $BQv = \frac{mv^2}{r}$ or $BQ = \frac{mv}{r}$ C1 $B = \frac{9.11\times10^{-31}\times7.0\times10^{6}}{1.6\times10^{-19}\times2.5\times10^{-2}}$ (Any subject) C1 $B = 1.6 \times 10^{-3}$ (T) A1 **Allow**: 2 marks for 7.97×10^{-4} (T); 5.0 cm used instead of 2.5 cm (Allow 8×10^{-4} T)
	(b)	(ii)	(period = $\frac{2\pi\times2.5\times10^{-2}}{7.0\times10^{6}}$) period = 2.2×10^{-8} (s)	B1	**Allow**: 1 mark for 4.5×10^{-8} (s) as ECF if 5.0 cm was used in **(i)**.
	(b)	(iii)	$BQ = mv/r$ (Allow any subject) or $\frac{v}{r} =$ constant T = distance/speed or $T = 2\pi r/v$ or $T \propto r/v$ (hence T is constant)	M1 A1	**Allow** other alternatives, e.g: $T = 2\pi m/QB$ M1 m, Q and B are constants (hence T is constant) A1 or The distance / circumference / r doubles M1 T = distance/speed or $T = 2\pi r/v$ or $T \propto r/v$ (hence T is constant) A1
			Total	**8**	

Question			Answers	Marks	Guidance
2	(a)		Any **two** from: • Direction of the field (is incorrect) (AW) • The field lines should be curved / not straight (lines) • The field line(s) should be perpendicular at the plate(s) • The separation between the field lines cannot be the same / diagram shows a uniform field	B1×2	**Allow** answers on Fig. 2.1
	(b)	(i)	gradient = 1.25 ($\times 10^{-7}$) (Q = gradient $\times 4\pi \times 8.85 \times 10^{-12}$) charge = 1.4×10^{-17} (C)	C1 A1	**Ignore** POT **Allow** gradient in the range 1.20 to 1.30 ($\times 10^{-7}$) **Allow** full credit for substitution method ECF from incorrect value of calculated gradient
	(b)	(ii)	The gradient decreases Explanation: Q decreases / there are fewer protons	B1 B1	**Allow** E is smaller for the same r
	(c)	(i)	(E =) $\frac{1.5(\times 10^{3})}{2.10(\times 10^{-2})}$ or 7.14 ($\times 10^{4}$) (mass of droplet = $\frac{4}{3}\pi r^{3} \times \rho$ =) 8.15×10^{-15} (kg) (electrical force = weight / $EQ = mg$) $7.14 \times 10^{4} \times Q = 8.15 \times 10^{-15} \times 9.81$ (Any subject) and hence charge = $1.1(2) \times 10^{-18}$ (C)	C1 C1 A1	**Allow** other correct methods **Ignore** POT **Note** there is no ECF for incorrect E or mass values **Allow** 1 mark for a bald $1.1\underline{2} \times 10^{-18}$ (C); answer to 3 SF or more but a bald 1.1×10^{-18} C scores zero
	(c)	(ii)	(number of electrons = $\frac{1.12 \times 10^{-18}}{1.6 \times 10^{-19}}$ =) 7 (An integer)	B1	**Note** there is no ECF from **(i)** since 1.1×10^{-18} C is given **Not** 6.88 or 6.9 when using 1.1×10^{-18} C, but allow either of the integers 7 or 6
			Total	**10**	

Question			Answers	Marks	Guidance
3	(a)	(i)	(magnetic flux linkage = magnetic) flux × (number of) turns	B1	**Allow**: BAN, where *B* is (perpendicular magnetic) flux density / (perpendicular magnetic) field strength, *A* is (cross-sectional) area and *N* is (the number of) turns
	(a)	(ii)1	$N = \frac{L}{2\pi r}$ (Any subject)	B1	
	(a)	(ii)2	(magnetic flux linkage =) *BAN* (magnetic flux linkage =) $B \times \pi r^2 \times \frac{L}{2\pi r}$ (magnetic flux linkage =) $\frac{BrL}{2}$	C1 A0	No ECF from **(ii)1**
	(b)	(i)	e.m.f. (induced) ∝ rate of change of (magnetic) flux linkage	B1	**Allow** an 'equal sign' **Allow** $E = (-)\Delta N\phi/\Delta t$ where *E* is e.m.f. (induced), $N\phi$ is (magnetic) flux linkage and *t* is time **Not** voltage induced **Not** 'cutting *of* flux'
	(b)	(ii)	*E* is zero only at 1.0 ms, 3.0 ms and 5 ms Correct shape of graph	M1 A1	**Ignore** 'inversion' of the sinusoidal curve
	(c)		There is an alternating (magnetic) flux / flux density / field (in primary coil) Idea of flux / flux density / field within iron / core and The secondary coil is linked by an alternating (magnetic) flux (density / linkage)	M1 A1	**Allow** changing / varying for alternating throughout **Not** *alternating current in supply*
			Total	**8**	

Question			Answers	Marks	Guidance
4	(a)		The charge / Q on each capacitor is the same $V \propto C^{-1}$	M1 A1	 **Allow** $Q = VC$ and some explanation
	(b)		(total resistance =) 27 (kΩ) or 27000 (Ω) (total capacitance =) 100 (μF) or 1.0×10^{-4} (F) (time constant =) $27 \times 10^3 \times 100 \times 10^{-6}$ time constant = 2.7 (s)	C1 C1 A1	 **Allow** 10^{-4} (F) **Note** 2.7×10^n with $n \neq 0$ scores 2 marks
	(c)	(i)	$(V =) 1.5 \times 10^{-4} \times 40 \times 10^3$ or 6 (V) $(Q =) 6.0 \times 1200 \times 10^{-6}$ charge = 7.2×10^{-3} (C)	C1 A1	**Allow** I in the range 1.50 to 1.55 **Allow** other correct methods Possible POT error **Not** C and R values from **(b)**
	(c)	(ii)	Current starts at 3.0 ($\times 10^{-4}$ A) Graph showing shorter time constant	B1 B1	**Allow** $\pm 0.05 \times 10^{-4}$ (A)
			Total	**9**	

Question			Answers	Marks	Guidance
5	(a)	(i)	$2\,{}^{1}_{0}\mathrm{n}$	B1	**Allow** answer in words, e.g. 'two neutrons' **Allow** $2 \times {}^{1}_{0}\mathrm{n}$
	(a)	(ii)	${}^{0}_{-1}\mathrm{e}$ / ${}^{0}_{-1}\beta^{(-)}$	B1	**Not** e / e^- / β / β^- **Allow** electron
			${}^{(o)}_{(0)}\bar{\nu}_{(e)}$	B1	**Allow** (electron) anti-neutrino
	(b)	(i)	(activity =) $\frac{2000}{9.0\times10^{-13}}$	C1	**Allow** other correct methods **Note** 2.22×10^{15} scores this C1 mark
			$(\lambda =) \frac{0.693}{88\times3.16\times10^{7}}$	C1	**Note** 2.49×10^{-10} (s^{-1}) scores this C1 mark
			($A = \lambda N$) $2.22\times10^{15} = 2.49 \times 10^{-10} \times N$ (Any subject)	C1	**Note** $N = 8.91 \times 10^{24}$ scores all three C1 marks Possible ECF for incorrect value(s) of activity and or λ
			(mass =) $\frac{8.91\times10^{24}}{6.02\times10^{23}}\times0.238$		
			mass = 3.5 (kg)	A1	**Allow** 3 marks for 0.21 (kg) if 120 W is used
	(b)	(ii)	(energy =) 0.120 (kW) × 24 (h)	C1	
			energy = 2. 9 (kW h)	A1	**Allow** 1 mark for 48 (kW h); 2 kW used instead of 0.12 kW **Allow** 1 mark for 2900; 120 used instead of 0.12
			Total	**9**	

Question			Answers	Marks	Guidance
6	(a)		Hadrons are made of quarks / they experience the strong (nuclear) force / interaction	B1	**Not** 'they are baryons' **Allow** 'held together by gluons' (AW) **Ignore** the number of quarks mentioned
	(b)		$\frac{2}{3}$ (e); $-\frac{1}{3}$ (e)	B1	**Allow** 0.67 (e) and – 0.33 (e)
	(c)		(proton =) u u d	B1	**Allow** up up down
	(d)		($p + n \rightarrow p + p + \pi^-$) $uud + udd \rightarrow uud + uud + \pi^-$ (left-hand side = d and right-hand side = u + π^-) π^- has one down quark or π^- has d and one anti-up quark or π^- has $\bar{u}$	C1 A1 A1	**Allow** other correct methods **Note:** This mark is for *substitution* **Note**: Any more than 2 quarks does not score the A1 marks **Allow** 3 marks for d $\bar{u}$
	(e)	(i)	$\Delta E = \Delta m\, c^2$ where ΔE is (change in) energy, Δm is (change in) mass and c is speed of light (in a vacuum)	B1	**Allow** energy = mass × speed of light^2 **Not** <u>binding</u> energy = mass <u>defect</u> × speed of light^2 **Not** energy = mass <u>defect</u> × speed of light^2
	(e)	(ii)	(KE =) $1.4 \times 10^8 \times 1.6 \times 10^{-19}$ or 2.24×10^{-11} (J) (mass of π^- =) $\frac{2.24\times10^{-11}}{(3.0\times10^8)^2}$ mass = 2.5×10^{-28} (kg)	C1 A1	
			Total	**9**	

Question			Answers	Marks	Guidance
7	(a)		Any **two** from: • A nucleus is split / broken up in a fission reaction **OR** In a fusion reaction nuclei combine / fuse • High temperatures / pressures / (kinetic) energy required for fusion reaction • More energy per reaction produced in a fission reaction (ORA) • A neutron causes fission reaction • Chain reaction possible in fission • 'Larger' nuclei produced in fusion **OR** 'Smaller' nuclei produced in fission	B1×2	**Allow** alternative wording (AW) **Not** 'neutrons are produced in a fission reaction' because neutrons can also be produced in some fusion reactions
	(b)		There is repulsion (between nuclei) (At high temperatures nuclei) move fast / have more KE (At high temperature / pressure the nuclei) have greater chance of fusion / collision / interaction (AW) At high temperatures nuclei get close (enough) to experience the strong force **OR** At high pressures nuclei are close	B1 B1 B1 B1	**Allow** reference to 'particles' or protons instead of 'nuclei' **Not** 'enough / sufficient' KE …… **Allow** fuse / collide / interact more frequently **Allow** At high pressures … high density / greater number of nuclei per unit volume
	(c)	(i)	Mention of slow / thermal neutron(s) The nucleus splits up into two nuclei / smaller nuclei / daughter nuclei / smaller fragments (and neutrons)	B1 B1	 **Not** 'nucleus undergoes fission / decay / becomes unstable '
	(c)	(ii)	$\frac{3}{2}kT$ and $\frac{1}{2}mv^2$ $3\times1.38\times10^{-23}\times573=1.7\times10^{-27}\times v^2$ (Any subject) speed = 3.7×10^3 (m s^{-1})	C1 C1 A1	 **Allow** 1 mark for 2.7×10^3 (m s^{-1}); 300 used instead of 573 **Allow** 3 marks for 3.8×10^3 m s^{-1}; 1.675×10^{-27} kg or 1.673×10^{-27} kg (mass of proton) from Data Booklet used
			Total	**11**	

Question			Answers	Marks	Guidance
8	(a)		Any **three** from: **Photoelectric effect:** Photon ejects / removes an electron (from the atom / metal) **Compton (scattering):** Photon emerges with less energy / longer wavelength / lower frequency and an electron escapes / ejected (from the atom) **Pair-production:** Photon produces an electron-positron (pair) **Scattering** : Photon is scattered by an electron ✎ **QWC:** (Intensity decreases in the original direction because) there are fewer photons	B1×3 B1	**Allow** consistent use of plurals throughout, e.g: Photons eject electrons
	(b)	(i)	($E = \frac{hc}{\lambda}$) (E =) $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{1.4\times10^{-11}}$ or (f =) 2.14×10^{19} (Hz) energy = 1.4×10^{-14} (J)	C1 A1	
	(b)	(ii)	gradient = (-) μ μ = 0.20 (cm^{-1})	C1 A1	**Allow** correct substitution into $\ln I = \ln I_0 - \mu x$; coordinates read to ± ½ small square **Allow** 1 SF answer of 0.2 (cm^{-1}) **Allow** answer in the range 0.19 to 0.21 (cm^{-1}) **Ignore** sign
			Total	**8**	

Question			Answers	Marks	Guidance
9	(a)		$2\pi f = 4.0 \times 10^8$ / $f = 6.37 \times 10^7$ (Hz) $(\lambda = \frac{c}{f})$ $\lambda = \frac{3.0 \times 10^8}{6.37 \times 10^7}$ (Any subject) wavelength = 4.7 (m)	C1 C1 A1	**Allow** 1 mark for 0.75 (m); $f = 4.0 \times 10^8$ Hz used **Not** 1.5π **Allow** other correct methods, e.g: $\omega = 2\pi c/\lambda$ C1 $\lambda = 2\pi \times 3.0 \times 10^8/4.0 \times 10^8$ C1 wavelength = 4.7 (m) A1
	(b)		The (mean) time taken by the nuclei / protons to return to low / original / initial energy state. (AW)	B1	**Allow** 'the time taken for the number of excited nuclei / protons to decrease to 37% of the original value'
			Total	**4**	

Question			Answers	Marks	Guidance
10	(a)		Applying a p.d across the material makes it expand / compress / deform / strain (ORA)	B1	**Allow**: Applying a varying p.d. produces vibrations / ultra-sound **Allow**: Ultrasound hitting the material produces a varying e.m.f. **Allow**: voltage or p.d. instead of e.m.f. **Not** current
	(b)	(i)	(acoustic impedance =) speed (of ultrasound in the material) × density (of material)	B1	**Not** $Z = \rho c$
	(b)	(ii)	Any **one** from: • Speed / wavelength is different • Travel slow(er) in air (ORA) • Ultrasound has short(er) wavelength in air (ORA) • Reflection(s) occur inside patient (ORA) • Greater attenuation (of ultrasound) inside patient (ORA)	B1	Penalise wrong physics, e.g 'travel faster in air' **Not** frequency **Not** acoustic impedance
	(c)		($Z_{(m)}$ =) 1.38×10^6 / ($Z_{(f)}$ =) 1.69×10^6 $\frac{(1.38-1.69)^2}{(1.38+1.69)^2}$ or 0.01(02) intensity transmitted = 99 %	C1 C1 A1	 **Note**: 1.0(2)% scores 2 marks
			Total	**6**	

Question			Answers	Marks	Guidance
11	(a)		angle = $\tan^{-1}(1.3\times10^{20}/2.4\times10^{22})$ angle = 0.31 (°)	B1	**Note**: Using $\sin^{-1}$ is correct; it gives the same answer of 0.31°
	(b)		$(\frac{\Delta\lambda}{\lambda}=\frac{v}{c})$ $\frac{\Delta\lambda}{656.3}=\frac{2.5\times10^{5}}{3.0\times10^{8}}$ (Any subject) $\Delta\lambda$ = 0.55 (nm)	C1 A1	**Note**: Answer to 3 sf is 0.547 (nm) **Note**: 5.5×10^{-10} on the answer line scores 1 mark
	(c)		$\frac{GMm}{r^2}=\frac{mv^2}{r}$ or $\frac{GM}{r}=v^2$ $\frac{GM}{0.65\times10^{20}}=(2.5\times10^{5})^2$ (Any subject) mass = 6.09×10^{40} (kg) (number of stars = $6.09\times10^{40}/2.0\times10^{30}$) number of stars = 3.0×10^{10}	C1 C1 C1 A1	**Allow** other correct methods. **Allow** the following for the first two C1 marks: $F=\frac{2.0\times10^{30}\times(2.5\times10^{5})^2}{0.65\times10^{20}}$ or 1.92×10^{21} (N) C1 $\frac{GM\times2.0\times10^{30}}{(0.65\times10^{20})^2}=1.92\times10^{21}$ (Any subject) C1 **Allow**: 2 out of 3 marks for use of 1.3×10^{20} (m); this gives an answer of 1.2×10^{41} (kg) Possible ECF from incorrect mass of galaxy **Allow** 1 SF answer for the estimation
			Total	**7**	

Question			Answers	Marks	Guidance
12	(a)		Any **four** from: (The forces are separated) 1. Expansion / cooling 2. Creation of matter / pair production 3. More matter than antimatter 4. Quarks <u>and</u> leptons (soup) 5. Quarks combine to form hadrons / baryons / nucleons / protons / neutrons 6. Imbalance of neutrons and protons / (primordial) helium / lithium /beryllium (nuclei) produced 7. Hadrons / baryons / (neutrons and) protons / combine to form nuclei (Atoms formed) ✎ **QWC**: Correct sequencing of two steps from 4, 5 and 7	B1 × 4 B1	Annotation by the pencil icon
	(b)		(Recession) speed / velocity of <u>galaxy</u> is (directly) proportional to its distance (from us)	B1	
	(c)	(i)	(ρ =) $8 \times 1.673 \times 10^{-27}$ (kg m^{-3}) or 1.34×10^{-26} (kg m^{-3}) ($\rho = \frac{3H_0^2}{8\pi G}$) $H_0 = \sqrt{\frac{8\pi \times 6.67 \times 10^{-11} \times 1.34 \times 10^{-26}}{3}}$ (Any subject) $H_0 = 2.7 \times 10^{-18}$ (s^{-1})	C1 C1 A1	**Allow** 1.7×10^{-27} kg or 1.675×10^{-27} kg (neutron) or 1.661×10^{-27} kg (u) **Note**: Answer is 2.8×10^{-18} (s^{-1}) when 1.7×10^{-27} kg is used
	(c)	(ii)	(age =) $\frac{1}{2.7 \times 10^{-18}}$ or 3.7×10^{17} (s) age = 1.2×10^{10} (y)	C1 A1	Possible ECF from **(c)(i)** **Allow** use of 1 y = 3.15×10^7 (s) or 3.16×10^7 (s) **Note**: Answer is 1.1×10^{10} (y) when 2.8×10^{-18} (s^{-1}) and 3.16×10^7 are used
			Total	**11**	

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