

GCE

Physics A

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

Advanced GCE

Mark Scheme for June 2016

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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.

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

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Annotations

Annotation	Meaning
	Benefit of doubt given
	Blank Page
	Contradiction
	Incorrect Response
	Error carried forward
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct Response
	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)	$(B = \frac{F}{IL})$ $F \rightarrow \text{kg m s}^{-2} / I \rightarrow \text{C s}^{-1} \text{ and } L \rightarrow \text{m}$ $T \rightarrow \text{kg C}^{-1} \text{ s}^{-1}$	<p>C1</p> <p>A1</p>	<p>Alternative: $B = \frac{F}{Qv}$</p> <p>$F \rightarrow \text{kg m s}^{-2} / Q \rightarrow \text{C and } v \rightarrow \text{m s}^{-1}$ C1</p> <p>$T \rightarrow \text{kg C}^{-1} \text{ s}^{-1}$ A1</p> <p>Allow $\frac{\text{kg}}{\text{Cs}}, \frac{\text{kgC}^{-1}}{\text{s}}$, etc.</p>
	(b) (i)	$F = \frac{9.11 \times 10^{-31} \times (7.0 \times 10^6)^2}{2.5 \times 10^{-2}} / F = 1.79 \times 10^{-15} \text{ (N)}$ $(F = BQv)$ $1.79 \times 10^{-15} = B \times 1.6 \times 10^{-19} \times 7.0 \times 10^6 \text{ (Any subject)}$ $B = 1.6 \times 10^{-3} \text{ (T)}$	<p>C1</p> <p>C1</p> <p>A1</p>	<p>Alternative: Allow e instead of Q</p> <p>$BQv = \frac{mv^2}{r}$ or $BQ = \frac{mv}{r}$ C1</p> <p>$B = \frac{9.11 \times 10^{-31} \times 7.0 \times 10^6}{1.6 \times 10^{-19} \times 2.5 \times 10^{-2}}$ (Any subject) C1</p> <p>$B = 1.6 \times 10^{-3} \text{ (T)}$ A1</p> <p>Allow: 2 marks for $7.97 \times 10^{-4} \text{ (T)}$; 5.0 cm used instead of 2.5 cm (Allow $8 \times 10^{-4} \text{ T}$)</p>
	(b) (ii)	$\text{(period} = \frac{2\pi \times 2.5 \times 10^{-2}}{7.0 \times 10^6} \text{)}$ $\text{period} = 2.2 \times 10^{-8} \text{ (s)}$	B1	<p>Allow: 1 mark for $4.5 \times 10^{-8} \text{ (s)}$ as ECF if 5.0 cm was used in (i).</p>
	(b) (iii)	$BQ = mv/r \text{ (Allow any subject) or } \frac{v}{r} = \text{constant}$ $T = \text{distance/speed or } T = 2\pi r/v \text{ or } T \propto r/v \text{ (hence } T \text{ is constant)}$	<p>M1</p> <p>A1</p>	<p>Allow other alternatives, e.g:</p> <p>$T = 2\pi m/QB$ M1</p> <p>m, Q and B are constants (hence T is constant) A1</p> <p>or</p> <p>The distance / circumference / r doubles M1</p> <p>$T = \text{distance/speed or } T = 2\pi r/v \text{ or } T \propto r/v \text{ (hence } T \text{ is constant)}$ A1</p>
Total			8	

Question		Answers	Marks	Guidance
2	(a)	Any two from: <ul style="list-style-type: none"> • 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 = $1.25 (\times 10^{-7})$ ($Q = \text{gradient} \times 4\pi \times 8.85 \times 10^{-12}$) 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) <u>and</u> 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 1.12×10^{-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 <u>integer</u>)	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 \times (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) \propto rate of change of (magnetic) flux <u>linkage</u>	B1	Allow an 'equal sign' Allow $E = (-)\Delta N\phi/\Delta t$ where E is e.m.f. (induced), $N\phi$ is (magnetic) flux <u>linkage</u> 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 <u>iron</u> / <u>core</u> <u>and</u> The secondary coil is linked by an alternating (magnetic) <u>flux</u> (density / linkage)	M1 A1	Allow changing / varying for alternating throughout Not <i>alternating current in supply</i>
		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 (k Ω) or 27000 (Ω) (total capacitance =) 100 (μ F) 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 3.0×10^{-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)	$2\text{}^1_0\text{n}$	B1	Allow answer in words, e.g. 'two neutrons' Allow $2 \times \text{}^1_0\text{n}$
	(a)	(ii)	$\text{}^0_{-1}\text{e} / \text{}^0_{-1}\beta^{(-)}$ $\overset{(0)}{\underset{(0)}{\bar{\nu}}}_{(e)}$	B1 B1	Not $\text{e} / \text{e}^- / \beta / \beta^-$ Allow electron Allow (electron) anti-neutrino
	(b)	(i)	(activity =) $\frac{2000}{9.0 \times 10^{-13}}$ (λ =) $\frac{0.693}{88 \times 3.16 \times 10^7}$ ($A = \lambda N$) $2.22 \times 10^{15} = 2.49 \times 10^{-10} \times N$ (Any subject) (mass =) $\frac{8.91 \times 10^{24}}{6.02 \times 10^{23}} \times 0.238$ mass = 3.5 (kg)	C1 C1 C1 A1	Allow other correct methods Note 2.22×10^{15} scores this C1 mark Note $2.49 \times 10^{-10} \text{ (s}^{-1}\text{)}$ scores this C1 mark Note $N = 8.91 \times 10^{24}$ scores all three C1 marks Possible ECF for incorrect value(s) of activity and or λ Allow 3 marks for 0.21 (kg) if 120 W is used
	(b)	(ii)	(energy =) $0.120 \text{ (kW)} \times 24 \text{ (h)}$ energy = 2.9 (kW h)	C1 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 + π^-) u u d + u d d \rightarrow u u d + u u d + π^- (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 <i>substitution</i> 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 \times speed of light ² Not <u>binding</u> energy = mass <u>defect</u> \times speed of light ² Not energy = mass <u>defect</u> \times 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^- =) $\frac{2.24 \times 10^{-11}}{(3.0 \times 10^8)^2}$ mass = 2.5×10^{-28} (kg)	C1 A1	
Total			9	

Question		Answers	Marks	Guidance
7	(a)	<p>Any two from:</p> <ul style="list-style-type: none"> • A <u>nucleus</u> is split / broken up in a fission reaction OR In a fusion reaction <u>nuclei</u> 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' <u>nuclei</u> produced in fusion OR 'Smaller' <u>nuclei</u> produced in fission 	B1×2	<p>Allow alternative wording (AW)</p> <p>Not 'neutrons are produced in a fission reaction' because neutrons can also be produced in some fusion reactions</p>
	(b)	<p>There is repulsion (between nuclei)</p> <p>(At high temperatures nuclei) move fast / have more KE</p> <p>(At high temperature / pressure the nuclei) have <u>greater</u> chance of fusion / collision / interaction (AW)</p> <p>At high temperatures nuclei get close (enough) to experience the strong force OR At high pressures nuclei are close</p>	<p>B1</p> <p>B1</p> <p>B1</p> <p>B1</p>	<p>Allow reference to 'particles' or protons instead of 'nuclei'</p> <p>Not 'enough / sufficient' KE</p> <p>Allow fuse / collide / interact more frequently</p> <p>Allow At high pressures ... high density / greater number of nuclei per unit volume</p>
	(c) (i)	<p>Mention of slow / thermal neutron(s)</p> <p>The nucleus splits up into two nuclei / smaller nuclei / daughter nuclei / smaller fragments (and neutrons)</p>	<p>B1</p> <p>B1</p>	<p>Not 'nucleus undergoes fission / decay / becomes unstable'</p>
	(c) (ii)	<p>$\frac{3}{2}kT$ <u>and</u> $\frac{1}{2}mv^2$</p> <p>$3 \times 1.38 \times 10^{-23} \times 573 = 1.7 \times 10^{-27} \times v^2$ (Any subject)</p> <p>speed = 3.7×10^3 (m s⁻¹)</p>	<p>C1</p> <p>C1</p> <p>A1</p>	<p>Allow 1 mark for 2.7×10^3 (m s⁻¹); 300 used instead of 573</p> <p>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</p>
Total			11	

Question		Answers	Marks	Guidance
8	(a)	<p>Any three from:</p> <p>Photoelectric effect: Photon ejects / removes an electron (from the atom / metal)</p> <p>Compton (scattering): Photon emerges with less energy / longer wavelength / lower frequency <u>and</u> an electron escapes / ejected (from the atom)</p> <p>Pair-production: Photon produces an electron-positron (pair)</p> <p>Scattering : Photon is scattered by an electron</p> <p>QWC: (Intensity decreases in the original direction because) there are fewer <u>photons</u></p>	<p>B1×3</p> <p>B1</p>	<p>Allow consistent use of plurals throughout, e.g: Photons eject electrons</p>
	(b) (i)	$(E = \frac{hc}{\lambda})$ $(E =) \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{1.4 \times 10^{-11}} \text{ or } (f =) 2.14 \times 10^{19} \text{ (Hz)}$ <p>energy = 1.4×10^{-14} (J)</p>	<p>C1</p> <p>A1</p>	
	(b) (ii)	<p>gradient = (-) μ</p> <p>$\mu = 0.20 \text{ (cm}^{-1}\text{)}$</p>	<p>C1</p> <p>A1</p>	<p>Allow correct substitution into $\ln I = \ln I_0 - \mu x$; coordinates read to $\pm \frac{1}{2}$ small square</p> <p>Allow 1 SF answer of $0.2 \text{ (cm}^{-1}\text{)}$</p> <p>Allow answer in the range 0.19 to $0.21 \text{ (cm}^{-1}\text{)}$</p> <p>Ignore sign</p>
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 1.5 π 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 <u>varying</u> p.d. produces vibrations / ultrasound Allow: Ultrasound hitting the material produces a <u>varying</u> 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: <ul style="list-style-type: none"> • 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)	$(Z_{(m)} =) 1.38 \times 10^6$ / $(Z_{(f)} =) 1.69 \times 10^6$ $\frac{(1.38 - 1.69)^2}{(1.38 + 1.69)^2}$ 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 = $\tan^{-1}(1.3 \times 10^{20} / 2.4 \times 10^{22})$ angle = 0.31 (°)	B1	Note: Using \sin^{-1} is correct; it gives the same answer of 0.31°
(b)	$\left(\frac{\Delta\lambda}{\lambda} = \frac{v}{c}\right)$ $\frac{\Delta\lambda}{656.3} = \frac{2.5 \times 10^5}{3.0 \times 10^8} \quad (\text{Any subject})$ $\Delta\lambda = 0.55 \text{ (nm)}$	C1 A1	Note: Answer to 3 sf is 0.547 (nm) Note: 5.5×10^{-10} on the answer line scores 1 mark
(c)	$\frac{GMm}{r^2} = \frac{mv^2}{r} \quad \text{or} \quad \frac{GM}{r} = v^2$ $\frac{GM}{0.65 \times 10^{20}} = (2.5 \times 10^5)^2 \quad (\text{Any subject})$ mass = 6.09×10^{40} (kg) (number of stars = $6.09 \times 10^{40} / 2.0 \times 10^{30}$) number of stars = 3.0×10^{10}	C1 C1 C1 A1	Allow other correct methods. Allow the following for the first two C1 marks: $F = \frac{2.0 \times 10^{30} \times (2.5 \times 10^5)^2}{0.65 \times 10^{20}} \quad \text{or} \quad 1.92 \times 10^{21} \text{ (N)} \quad \text{C1}$ $\frac{GM \times 2.0 \times 10^{30}}{(0.65 \times 10^{20})^2} = 1.92 \times 10^{21} \quad (\text{Any subject}) \quad \text{C1}$ 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)	<p>Any four from: (The forces are separated)</p> <ol style="list-style-type: none"> 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 <p>(Atoms formed)</p> <p>✍ QWC: Correct sequencing of two steps from 4, 5 and 7</p>	<p>B1 × 4</p> <p>B1</p>	<p>Annotation by the pencil icon</p>
(b)	(Recession) speed / velocity of <u>galaxy</u> is (directly) proportional to its distance (from us)	B1	
(c) (i)	<p>($\rho =$) $8 \times 1.673 \times 10^{-27} \text{ (kg m}^{-3}\text{)}$ or $1.34 \times 10^{-26} \text{ (kg m}^{-3}\text{)}$</p> $\left(\rho = \frac{3H_0^2}{8\pi G}\right)$ $H_0 = \sqrt{\frac{8\pi \times 6.67 \times 10^{-11} \times 1.34 \times 10^{-26}}{3}} \quad \text{(Any subject)}$ <p>$H_0 = 2.7 \times 10^{-18} \text{ (s}^{-1}\text{)}$</p>	<p>C1</p> <p>C1</p> <p>A1</p>	<p>Allow $1.7 \times 10^{-27} \text{ kg}$ or $1.675 \times 10^{-27} \text{ kg}$ (neutron) or $1.661 \times 10^{-27} \text{ kg}$ (u)</p> <p>Note: Answer is $2.8 \times 10^{-18} \text{ (s}^{-1}\text{)}$ when $1.7 \times 10^{-27} \text{ kg}$ is used</p>
(c) (ii)	<p>(age =) $\frac{1}{2.7 \times 10^{-18}}$ or $3.7 \times 10^{17} \text{ (s)}$</p> <p>age = $1.2 \times 10^{10} \text{ (y)}$</p>	<p>C1</p> <p>A1</p>	<p>Possible ECF from (c)(i)</p> <p>Allow use of $1 \text{ y} = 3.15 \times 10^7 \text{ (s)}$ or $3.16 \times 10^7 \text{ (s)}$</p> <p>Note: Answer is $1.1 \times 10^{10} \text{ (y)}$ when $2.8 \times 10^{-18} \text{ (s}^{-1}\text{)}$ and 3.16×10^7 are used</p>
	Total	11	

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