OCR
Oxford Cambridge and RSA

GCE

Physics A

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

Advanced GCE

Mark Scheme for June 2015

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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.

1. Annotations

Annotation	Meaning
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.
BOD	Benefit of doubt given
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 or reading/transcription error (*dual purpose*)
SF	Error in number of significant figures
✓	Correct response
AE	Arithmetic error
?	Wrong physics or equation

Abbreviations used in detailed mark scheme

Abbreviation	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

12. 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)		A region in which a charged particle experiences a force / acceleration	B1	**Allow**: Where a charge experiences a force **Allow**: Force per (unit positive) charge **Note**: Must have reference to charge and force/acceleration for the mark
	(b)		Difference: Any one from • gravitational field / force is attractive (AW) • electric field / force can be either attractive or repulsive (AW)	B1	**Allow**: Gravitational force is in the direction of the field / towards the mass **Note**: For the second bullet point, must have reference to both attractive and repulsive or 'towards charge' and 'away from charge'
			Similarity: Any one from: • Force / field (strength) inversely proportional to distance squared • Radial fields	B1	**Allow**: (Both) obey the inverse-square law (with distance) or (Both) have $F \propto 1/r^2$ or $g \propto 1/r^2$ and $E \propto 1/r^2$ **Allow**: 'radius or separation' for 'distance'
	(c)		Any three from: • The electron is repelled by **B** / attracted by **A** / experience a force to the left • (Initially the) electron decelerates / slows down • It does not reach plate **B** / It reverses direction • When it returns to **A** it has 4 eV (of KE) • It stops 2/3 of the distance across the plates (AW)	B1 × 3	
	(d)	(i)	$E = 60 \times 10^3 \div 0.25$ / $E = 2.4 \times 10^5$ (V m^{-1}) $F = 2.4 \times 10^5 \times 1.5 \times 10^{-13}$ force = 3.6×10^{-8} (N)	C1 A1	**Allow**: $F = [1.5 \times 10^{-13} \times 60 \times 10^3]/0.25$ for the first C1 mark **Allow**: 1 mark for 7.2×10^{-8} (N); d = 12.5 cm used

Question			Answer	Marks	Guidance
		(ii)	t = 1.8/1.2 (= 1.5 s) **or** $a = \frac{3.6\times10^{-8}}{8.0\times10^{-7}}$ (= 4.5 × 10^{-2} m s^{-2}) ($s = ut + \frac{1}{2}at^2$ and u = 0)	C1	Possible ecf from **(d)(i)**
			s = $\frac{1}{2}\times4.5\times10^{-2}\times1.5^2$	C1	**Note**: No ecf within calculation if $t \neq$ 1.8/1.2
			displacement = 5.1 × 10^{-2} (m)	A1	**Note**: Answer to 3 sf is 5.06 × 10^{-2} (m)
			Total	**11**	

Question			Answer	Marks	Guidance
2	(a)	(i)	(weight = *BIL*) $6.8\times10^{-5} = 0.070\times I\times0.01$ (Any subject) I = 0.097 (A)	C1 A1	
		(ii)	The force on the cables will keep changing direction	B1	
	(b)	(i)	$BQv = mv^2 / r$ $r = \dfrac{mv}{BQ}$	M1 A1	**Allow** *e*, *q* instead of *Q* **Note**: *r* must be the subject of this equation
		(ii)	($p = mv = BQr$; KE = ½ p^2/m) KE $\propto r^2$ ratio = $\dfrac{4.8^2}{1.2^2}$ ratio = 16	C1 A1	**Allow** full credit for correct alternative approaches **Allow** 16 : 1
			Total	**7**	

Question			Answer	Marks	Guidance
3	(a)		They are not fundamental particles because they consist of <u>quarks</u>	B1	**Not**: They can be sub-divided
	(b)		Any <u>two</u> from: electron / positron / neutrino / antineutrino	B1	**Allow**: muon / tau
	(c)	(i)	${}^{40}_{20}\text{Ca}$ ${}^{0}_{-1}\text{e} + \bar{\nu}_{(\text{e})}$ or electron + (electron) antineutrino	B1 B1	**Allow**: ${}^{0}_{-1}\beta$ but not β^- or e^- for the electron
		(ii)	There is a decrease in mass Energy (released) given by $(\Delta)E = (\Delta)mc^2$ **or** Binding energy increases Energy (released) is the difference between the binding energies (of Ca and K nuclei)	M1 A1 M1 A1	**Ignore** Δm being referred to as the 'mass defect' **Allow**: binding energy per nucleon increases
		(iii)	$\lambda = \dfrac{0.693}{4.2 \times 10^{16}}$ / $N = \dfrac{0.012}{100} \times \dfrac{4.5 \times 10^{-4}}{0.040} \times 6.02 \times 10^{23}$ $A = 1.65 \times 10^{-17} \times 8.127 \times 10^{17}$ activity = 13 (Bq)	C1 C1 A1	**Allow**: 1 mark for either λ = 1.65 × 10^{-17} s^{-1} or N = 8.127 × 10^{17} **Note**: Answer to 3 sf is 13.4 (Bq) **Note**: 1.3 × 10^3 (Bq) scores 2 marks; division by 100 omitted
			Total	**9**	

Question			Answer	Marks	Guidance
4	(a)	(i)	Correct shape of (exponential) decay curve (labelled **L**)	B1	**Note**: The curve must show a gradient of decreasing magnitude as time increases and appear to have a finite value of V at $t = 0$ **Ignore** any levelling of the curve or $V = 0$ towards the end
		(ii)	Correct shape of curve (labelled **H**)	B1	**Note**: As **(i)** and this curve must show a smaller time constant than **(i)**; the initial V can be different **Note**: One of the curves must be labelled
		(iii)	Correct explanation in terms of constant-ratio for V values for <u>fixed</u> intervals of t	B1	**Allow** V is halved every half-life; V decreases to 0.37 (of its initial value) after every time constant **Note**: This can be scored on a suitably labelled sketch graph in either **(iii)** or Fig. 4.1
	(b)	(i)	(time constant = $6.9 \times 10^{-6} \times 240$) time constant = 1.7×10^{-3} (s)	B1	**Note**: Answer to 3 sf 1.66×10^{-3} (s)
		(ii)	charge = $6.9 \times 10^{-6} \times 1.4$ (= 9.66×10^{-6} C) (Δt = 1/120 = 0.0083 s) current = $\dfrac{6.9\times10^{-6}\times1.4}{0.0083}$ current = 1.2×10^{-3} (A)	C1 C1 A1	Possible ecf from **(b)(i)** for value of total capacitance **Note**: Answer to 3 sf 1.16×10^{-3} (A) **Allow**: 2 marks for $9.66 \times 10^{-6} \times 60 = 5.8 \times 10^{-4}$ (A); Δt = 1/60 s used **Allow**: 2 marks for $9.66 \times 10^{-6} \times 240 = 2.3 \times 10^{-3}$ (A); Δt = 1/240 s used
		(iii)	The capacitors do not fully discharge (AW) Any <u>one</u> from: • Period (of switching) is (halved to) 4.2×10^{-3} (s) (and this time is comparable to the time constant) • The time constant (of the circuit) and period of mechanical switch are comparable / similar	B1 B1	
			Total	**9**	

Question			Answer	Marks	Guidance
5	(a)		Observations: 1. <u>Most</u> of the alpha particles went straight / un-deflected through (the atom(s) / foil) (AW) 2. (Some of the) alpha particles were scattered / repelled / deflected through large angles (AW) Conclusions (QWC mark): • 1 showed that most of the <u>atom</u> is empty space **and** • 2 showed the existence of small / dense / positive nucleus	M1 M1 A1	 **Not** 'reflected' **Allow**: The QWC mark even if 'alpha <u>reflected</u> at large angles' is mentioned in 2
	(b)	(i)	The aluminium nucleus has velocity / accelerates / moves to the right There is a repulsive force on the (aluminium) nucleus (to the right) / According to conservation of momentum the (aluminium) nucleus must move (to the right)	B1 B1	**Allow**: Moves away from the alpha particle
		(ii)	$8.0\times10^{6}\times1.6\times10^{-19}=\frac{1}{2}\times6.6\times10^{-27}\times v^{2}$ (Any subject) speed = 2.0×10^{7} (m s^{-1})	C1 A1	**Note**: Answer to 3 sf is 1.97×10^{7} (m s^{-1}) **Allow** 1 sf answer 2×10^{7} (m s^{-1})
		(iii)	Q = 13e or q = 2e or $F=\dfrac{Qq}{4\pi\varepsilon_0 r^2}$ $270=\dfrac{13\times1.6\times10^{-19}\times2\times1.6\times10^{-19}}{4\pi\times8.85\times10^{-12}\times r^{2}}$ (Any subject) distance = 4.7×10^{-15} (m)	C1 C1 A1	**Allow**: $F=k\dfrac{Qq}{r^2}$, where $k = 9\times10^{9}$ **Note**: No credit for using Q and q as 13 and 2

Question			Answer	Marks	Guidance
		(iv)	The strong force is attractive Correct explanation of size / direction of resultant force	M1 A1	**Allow**: The strong force is repulsive M1 Correct explanation of size / direction of resultant force A1
			Total	**12**	

Question			Answer	Marks	Guidance
6	(a)		The (minimum) energy needed to separate / remove all the nucleons / protons and neutrons (to infinity)	B1	**Allow**: The energy released when (stationary) nucleons combine to form the nucleus **Allow**: The (minimum) energy required to break the nucleus into its (separate) nucleons **Allow**: binding energy = mass defect $\times$ speed of light^2 **Allow**: 'Work (done)' in place of 'energy'
	(b)		BE per nucleon = $4.53 \times 10^{-12}/4$ BE per nucleon = 1.13×10^{-12} (J)	B1	**Allow** 2 sf answer of 1.1×10^{-12} (J)
	(c)		The helium nucleus has greater charge / The helium nucleus experience greater repulsive force Helium nuclei need to get close together (for the strong force to initiate fusion)	B1 B1	
	(d)		($\frac{1}{2} m v^2 = \frac{3}{2} kT$) $\frac{1}{2} \times 6.6 \times 10^{-27} \times v^2 = \frac{3}{2} \times 1.38 \times 10^{-23} \times 10^8$ speed = 7.9×10^5 (m s^{-1})	C1 A1	**Allow**: KE $\approx kT$; this gives an answer of 6.47×10^5 (m s^{-1})
			Total	**6**	

Question			Answer	Marks	Guidance
7	(a)		Quantum / packet of (electromagnetic) <u>energy</u> Any <u>one</u> from: Can travel in a vacuum / has speed of 3×10^{8} <u>m s^{-1} in a vacuum</u> / has no charge / has no (rest) mass / causes ion-isation / has momentum	B1 B1	**Allow**: Particle of <u>energy</u> **Allow**: Travels at the speed of light / *c* <u>in a vacuum</u>
	(b)	(i)	number per second = $4.8 \times 10^{-3}/1.6 \times 10^{-19}$ number per second = 3.0×10^{16} s^{-1}	M1 A0	**Note**: This must be seen to gain a mark
		(ii)	(incident power =) $150 \times 10^{3} \times 4.8 \times 10^{-3}$ or (incident power =) $3.0 \times 10^{16} \times 150 \times 10^{3} \times 1.6 \times 10^{-19}$ ($P = mc[\Delta\theta/\Delta t]$) $0.99 \times 720 = 0.0086 \times 140 \times [\Delta\theta/\Delta t]$ rate of temperature increase = 590 (°C s^{-1})	C1 C1 A1	**Note** an incident power of 720 (W) scores this C1 mark **Note**: Answer to 3 sf is 592 (°C s^{-1}) **Allow**: 2 marks for 598 (°C s^{-1}) or 600 (°C s^{-1}); 99% omitted **Allow**: 2 marks for 1.97×10^{-14} (°C s^{-1}); 3.0×10^{16} omitted
		(iii)	(photon energy = maximum KE of electron) $E = 150 \times 10^{3} \times 1.6 \times 10^{-19}$ or $E = 2.4 \times 10^{-14}$ (J) $2.4 \times 10^{-14} = \dfrac{6.63\times10^{-34}\times3.0\times10^{8}}{\lambda}$ (Allow any subject) wavelength = 8.3×10^{-12} (m)	 C1 A1	 **Allow**: $E = 720/3.0 \times 10^{16}$ **Allow**: 1 mark 8.3×10^{-10} (m); $E = 2.4 \times$ <u>10^{-16}</u> (J) used
	(c)		Contrast material / iodine is injected (into the vessels) Any <u>one</u> from: The contrast material • large attenuation / absorption coefficient • has high *Z* (atoms) (and hence reveal the outline of the blood vessels)	B1 B1	**Not**: barium for this B1 mark **Not** 'large μ'
			Total	**10**	

Question			Answer	Marks	Guidance
8	(a)		Gamma radiation will pass through the patient (and hence can be detected) / beta particles will be absorbed by the patient (and hence cannot be detected)	B1	
			Gamma radiation is not (very) ionising / gamma radiation does little damage to cells / beta particles are (very) ionising / beta particle damage cells	B1	**Allow**: 'Body' in place of 'cells'
	(b)		X-ray tube rotates around (the patient) / X-ray beam passes through the patient at different angles	B1	**Not**: Detector rotates around (the patient)
			A <u>thin</u> X-ray beam is used	B1	
			Image(s) of slice(s) / (cross) section(s) through the patient are taken	B1	
			X-ray tube moves / spirals along (the patient)	B1	**Allow**: Detectors moves / spirals along (the patient)
			The signals / information / pulses / data (from the detectors) are used by the computer (and its software) to produce a 3D image	B1	
			Total	**7**	

Question			Answer	Marks	Guidance
9	(a)		Change in the frequency / wavelength because of source / 'observer' moving	B1	**Allow**: There is blue / red shift because of relative motion between source and observer
	(b)		Any <u>two</u> from: 1. Ultrasound transducer / device / probe emits and detects ultrasound 2. The transducer / device / probe is placed at an angle (to the artery) 3. Ultrasound is <u>reflected</u> by the blood / cells	B1 × 2	
			QWC mark - change in frequency / wavelength (of the reflected ultrasound) is related to speed of blood	B1	**Allow**: speed of blood $\propto$ change in frequency **Allow**: $\Delta f = 2vf\cos\theta/c$, where v is the speed of blood, c = speed of ultrasound; no need to define the other labels **Note**: Do not award this mark if $\Delta f = fv/c$ is used to determine the speed v of the blood
	(c)	(i)	$Z = \rho c$ density = $1.66 \times 10^6/1570$ density = 1060 (kg m^{-3})	B1	**Allow**: 1100 (kg m^{-3})
		(ii)	$\lambda = 1570/2.4 \times 10^6$ wavelength = 6.5×10^{-4} (m)	B1	
	(d)		(fraction of intensity reflected =) $\dfrac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$	C1	
			(fraction of intensity reflected =) $3^2/5^2$ (= 0.36)	C1	
			intensity = 64%	A1	**Note**: 2 marks for 36% or 0.36
	(e)		Gel is used (between transducer and skin).	B1	
			The acoustic impedance / Z of gel is similar to that for skin hence less <u>reflection</u> (at the skin)	B1	**Allow**: There is acoustic / impedance matching so less <u>reflection</u> **Allow**: Without the gel, there is large difference between acoustic impedances of air and skin, hence large <u>reflection</u> **Note**: Must have reference to reflection
			Total	**11**	

Question			Answer	Marks	Guidance
10	(a)		A core / 'star' left behind after a red giant (has shed its outer layers)	B1	**Allow**: It is the core of a red giant **Allow**: It is the remnant of a low-mass star **Allow**: A core / 'star' • supported by Fermi pressure / electron degeneracy (pressure) • with maximum mass of 1.4(4) solar masses / 1.4(4) M_o / Chandrasekhar limit **Not**: It is a collapsing red giant
	(b)		(parallax = 1/d) $d = 0.0059^{-1}$ (pc = 169 .49 .... pc) distance = $0.0059^{-1} \times 3.26$ distance = 550 ly	C1 A1	**Allow** other correct methods
	(c)	(i)	power per (unit) area or power/area	B1	**Allow** 'energy per (unit) area per unit time' **Not**: power per m^2
		(ii)	**1** (density = mass/$\frac{4}{3}\pi r^3 \propto$ mass/r^3) ratio = $\dfrac{12}{(1.1\times10^5)^3}$ ratio = 9.0×10^{-15} **2** (power = intensity × surface area) power $\propto T^4r^2$ ratio = $\dfrac{4300^4 \times (1.1\times10^5)^2}{25000^4}$ ratio = 1.1×10^7	C1 A1 C1 C1 A1	**Allow**: 9.0×10^{-15} : 1 **Allow**: 1 sf answer of 9×10^{-15} **Note**: Answer to 3 sf is 1.06×10^7 **Allow**: 1.1×10^7 : 1
			Total	**9**	

Question			Answer	Marks	Guidance
11	(a)		recessional speed / velocity of <u>galaxy</u> is proportional to its distance (from us)	B1	**Allow**: recessional speed of <u>galaxy</u> = Hubble constant $\times$ distance
	(b)	(i)	v = 1010 (10^3 m s^{-1}) d in the range 4.47 to 4.54 (10^{23} m)	B1 B1	**Note**: Answer to 4 sf is 1014 (10^3 m s^{-1})
		(ii)	(Straight line drawn through the points gradient = Hubble constant, H_0) gradient = 2.24×10^{-18} (s^{-1}) age = $(2.24 \times 10^{-18})^{-1}$ age = 4.46×10^{17} (s) age = 1.4×10^{10} (y)	 C1 C1 A1	 **Allow**: gradient in the range 2.21 to 2.27 $\times 10^{-18}$ **Allow** ecf from incorrect value of the gradient **Allow**: A maximum of 2 marks if values from the table are used instead of the gradient of the line drawn on Fig. 11.2 **Note**: No marks for a bald 14 billion years
	(c)		Big bang: Creation / birth / expansion / evolution of the universe or The universe was very hot / very dense / singularity (at the start) Evidence: Any <u>two</u> from: • Microwave / background radiation / 3 K (or 2.7 K) • Existence of (primordial) helium / lithium / lighter elements • Tiny variation (or ripples) in (background) temperature	 B1 B1 $\times$ 2	 **Not**: More matter than antimatter / baryonic asymmetry
			Total	**9**	

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