

GCE

Physics A

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

Advanced GCE

Mark Scheme for June 2017

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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.

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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 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	i	<u>Force</u> is in the direction of the motion / field The particle accelerates (AW)	B1 B1	Allow: 'to the right'
		ii	<u>Force</u> is in the opposite direction to the motion / field The particle decelerates (AW)	B1 B1	Allow: 'to the left' Allow: 'slows down'
		ii	There is no force on the particle / its speed remains constant (AW)	B1	Allow: 'particle is unaffected by the field'
	b	i	<u>Out</u> of the plane of paper (AW)	B1	Not 'up'
		ii	$BQv = \frac{mv^2}{r}$ or $mv = BQr$ momentum = $0.012 \times 1.6 \times 10^{-19} \times 0.018$ momentum = 3.5×10^{-23} (kg m s ⁻¹)	C1 C1 A1	Allow credit for alternative methods Note answer to 3 s.f. is 3.46×10^{-23} (kg m s ⁻¹) Allow 2 marks for 3.5×10^{-21} ; 1.8 used instead of 0.018 (m)
		iii	$E_k = \frac{p^2}{2m} = \frac{(3.46 \times 10^{-23})^2}{2 \times 9.1 \times 10^{-31}}$ kinetic energy = 6.56×10^{-16} (J) kinetic energy = 4100 (eV)	C1 A1	Possible ecf from (ii) Note: using $p = 3.5 \times 10^{-23}$ leads to $E_k = 4200$ (eV)
		iv	speed = $\frac{3.46 \times 10^{-23}}{9.1 \times 10^{-31}}$ or speed = 3.8×10^7 (m s ⁻¹) time = $\frac{1}{6} \times \frac{2\pi \times 0.018}{3.8 \times 10^7}$ time = 5.0×10^{-10} (s)	C1 C1 A1	Possible ecf from (ii) Allow 1 mark for 3.0×10^{-9} (s); the time for one orbit Allow 1 sf answer
Total				14	

Question		Answer	Marks	Guidance	
2	a	The atom has a (positive) nucleus which is surrounded by electrons	B1		
		The nucleus has protons and neutrons	B1		
		The nucleus is $10^4 / 10^5$ times smaller than the atom (AW)	B1		
	b	$\left({}_{86}^{222}\text{Rn} \rightarrow \right) {}_{84}^{218}\text{Po} + {}_2^4\text{He}$	B1		
			B1	Allow ${}_2^4\alpha$ for ${}_2^4\text{He}$	
		ii	$\lambda = \frac{0.693}{3.8 \times 24 \times 3600} \quad \text{or} \quad \lambda = 2.11 \times 10^{-6} \text{ (s}^{-1}\text{)}$ $40 = 2.11 \times 10^{-6} \times N$ $N = 1.9 \times 10^7$	C1	
		iii	Number of air molecules / $\text{m}^3 = 40 \times 6.02 \times 10^{23} = (2.41 \times 10^{25})$ $\text{ratio} = \frac{1.9 \times 10^7}{2.41 \times 10^{25}}$ $\text{ratio} = 7.9 \times 10^{-19}$	C1	Note $N = 219$ scores 2 out of 3 (3.8 used for T)
			Total	10	Possible ecf from (ii)

Question		Answer	Marks	Guidance	
3	a	Force is proportional to product of charges and inversely proportional to separation ² . Mention of point charges / particles	M1 A1	Allow 'distance <u>between</u> ' Allow: word equation or equation with symbols defined Not 'radius' or 'distance' in place of separation.	
	b	i	$F = \frac{(1.6 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12} \times (3.0 \times 10^{-10})^2}$ force = <u>2.56</u> × 10 ⁻⁹ (N)	C1 A1	Allow use of 9.0 × 10 ⁹ in place of $\frac{1}{4\pi \times 8.85 \times 10^{-12}}$ Note answer must be to more than 2 s.f. to score this mark
		ii	resultant force ² = (2.56 × 10 ⁻⁹) ² + (2.56 × 10 ⁻⁹) ² resultant force = 3.6 × 10 ⁻⁹ (N)	C1 A1	Possible ecf from (i) Note using 2.6 × 10 ⁻⁹ gives an answer of 3.7 × 10 ⁻⁹ (N)
		iii	acceleration = $\frac{3.6 \times 10^{-9}}{9.1 \times 10^{-31}}$ acceleration = 4.0 × 10 ²¹ (m s ⁻²)	B1	Possible ecf from (ii) Allow answer given to 1 s.f. Note using 3.7 × 10 ⁻⁹ gives an answer of 4.1 × 10 ²¹ (m s ⁻²)
		iv	An arrow pointing to the left and parallel to the line AB	B1	
Total			8		

Question		Answer	Marks	Guidance	
4	a	Capacitor is connected to a power supply / cell	B1		
		The power supply / cell is disconnected	B1	Allow 'discharge the capacitor (through resistor)	
		The p.d. across the capacitor is measured using a voltmeter and the time of discharge is measured using a stop-watch	B1	Allow data-logger / computer	
		The time taken for the p.d. to decrease to $0.37 / \frac{1}{e}$ of its initial p.d. is the time constant / CR of the circuit	B1	This can be done using a $V-t$ graph Allow plot a $\ln V - t$ graph and time constant = $1/\text{gradient}$ Allow substitute values into $V = V_0 e^{-t/CR}$ to find CR	
	b	i	energy = $\frac{1}{2} \times 1.5^2 \times 1200 \times 10^{-6}$		
			energy = 1.4×10^{-3} (J)	B1	Note answer to 3.s.f. is 1.35×10^{-3} (J)
		ii	charge = $1.5 \times 1200 \times 10^{-6}$ or charge = 1.8×10^{-3} (C)	C1	
			number of electrons = $\frac{1.8 \times 10^{-3}}{1.6 \times 10^{-19}}$	A1	
		number of electrons = 1.1×10^{16}			
	c	i	power = $\frac{1.5^2}{5000}$		
			power = 4.5×10^{-4} (W)	B1	
		ii	Time constant = $CR = 5000 \times 1200 \times 10^{-6}$ (= 6.0)	C1	
			$1.0 = 1.5 e^{-t/6.0}$	C1	
			$\ln\left(\frac{1.0}{1.5}\right) = -\frac{t}{6.0}$		
			$t = 2.4$ (s)	A1	Note answer to 3.s.f. is 2.43 (s)
			Total	11	

Question		Answer	Marks	Guidance
5	a	positron and (electron) neutrino	B1	
	b	The total mass of the protons is <u>greater</u> than the total mass of the 'product' particles (ora) energy released = change in mass $\times c^2$	B1 B1	
	c	High temperatures / quoted value of $T \sim 10^7$ K This allows the protons to come close together (to enable strong nuclear force to act) High pressure / density The ensures that there is a greater rate of fusion reactions (AW)	M1 A1 M1 A1	Allow: protons to overcome (electrostatic) repulsive force
	d	Gravitational collapse (of the dust cloud) increases the temperature of the cloud Fusion (of hydrogen) generates energy or A stable star is produced when gravitational pressure is balanced by pressure from gas / radiation When there is no more hydrogen, the outer layers of the star expand / (super) red giant formed Eventually the <u>core</u> collapses resulting in a supernova The remnant core is either a neutron star or a black hole The sequence of gravitational collapse, fusion / star formed, supernova and neutron star/black hole is correctly set out in the text.	B1 B1 B1 B1 B1	
		Total	13	

Question		Answer	Marks	Guidance
6	a	The X-ray photon disappears and creates an electron-positron pair	B1	
	b	$\frac{hc}{\lambda} = eV$ <p>potential difference = $\frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{18 \times 10^{-12} \times 1.60 \times 10^{-19}}$</p> <p>potential difference = 6.9×10^4 (V)</p>	C1 C1 A1	
	c	<p>Use of $I = I_0 e^{-\mu x}$ with $I_0 = 2.0 \times 10^8$</p> $I = 2.0 \times 10^8 e^{-1.1 \times 5.0}$ <p>intensity = $8.174... \times 10^5$ (W m⁻²)</p> <p>power = $8.174... \times 10^5 \times 6.0 \times 10^{-6}$ or power = 4.9 (W)</p> <p>energy = $4.9 \times 2.0 \times 60$</p> <p>energy = 590 (J)</p>	C1 C1 C1 A1	<p>Allow other correct methods</p> <p>Allow FT for their value of intensity</p>
Total			8	

Question		Answer	Marks	Guidance
7	a	<p>Any four from:</p> <p>Nuclei / proton behave like tiny magnets / have 'spin' (AW)</p> <p>The nuclei precess about the magnetic field (at the Larmor frequency)</p> <p>Radio waves of frequency equal to the Larmor frequency are used to excite / resonate the nuclei</p> <p>The nuclei absorb energy (from the radio waves) and flip into higher energy state and eventually flip back to the lower energy state by emitting radio wave (photons)</p> <p>The relaxation time depends on the (surrounding) tissues</p>	B1×4	Allow answers in terms of 'alignment and anti-alignment of protons in the external magnetic field'
	b	<p>MRI scanning is non-ionising (AW)</p> <p>Better 3D <u>contrast</u> of soft-tissues</p>	<p>B1</p> <p>B1</p>	
Total			6	

Question		Answer	Marks	Guidance
8	a	emf / voltage produced when a material is expanded / compressed / changes shape or When a p.d. is applied across the material it expands / contracts / changes shape	B1	Allow material oscillates / vibrates only if applied p.d. is alternating.
	b	i	B1	
		ii1	C1 A1	Allow 1 mark for 3.2×10^{-2} (m); twice the distance
		ii2	C1 A1	Note answer to 3 sf is 1.06×10^3 (kg m ⁻³)
	b	iii	C1 C1 A1	Note answer to 3.s.f. is 7.55×10^6 (kg m ⁻² s ⁻¹)
			Total	8

Question		Answer	Marks	Guidance
9	a	energy = $3.3 \times 10^{27} \times 1.0 \times 10^6 \times 3.2 \times 10^7$	C1	
		change in mass = $\frac{3.3 \times 10^{27} \times 10^6 \times 3.2 \times 10^7}{(3.0 \times 10^8)^2}$	C1	
		change in mass = 1.2×10^{24} (kg)	A1	
	b	$g \propto M/r^2$; $g = 270 \times \frac{1.8}{1.8^2}$ gravitational field strength = 150 (N kg ⁻¹)	C1 A1	
	c	density $\propto M/r^3$; ratio = $\frac{1.8}{1.8^3}$ ratio = 0.31	C1 A1	
	d	distance = $\frac{6.0 \times 10^{17}}{3.1 \times 10^{16}}$ or distance = 19.35... (pc) parallax = $\frac{1}{19.35}$ parallax = 0.052 (arc second)	C1 A1	
Total			9	

Question		Answer	Marks	Guidance	
10	a	Reference to $d\sin\theta = (n)\lambda$	B1		
		Reference to the Doppler equation $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$	B1		
		Determination of wavelength of a spectral line from receding galaxy and of an identical line in the laboratory and correct description of how $\Delta\lambda$ is calculated	B1		
	b	i	Hubble constant = $\frac{740}{11}$	C1	
			Hubble constant = $67 \text{ (km s}^{-1} \text{ Mpc}^{-1}\text{)}$	A1	
		ii	Hubble constant = $\frac{67 \times 10^3}{10^6 \times 3.1 \times 10^{16}}$ or $2.16 \times 10^{-18} \text{ (s}^{-1}\text{)}$	C1	Possible ecf from (i)
		age = $\frac{1}{2.161 \times 10^{-18}} = 4.63 \times 10^{17} \text{ (s)}$			
		age = $1.446 \times 10^{10} \text{ (y)}$	C1		
		uncertainty = $\left(\frac{2}{11} + \frac{20}{740}\right) \times 1.446 \times 10^{10}$	C1		
		age = $(1.4 \pm 0.3) \times 10^{10} \text{ (y)}$	A1		
		iii	Determine the gradient from the v - d graph which is (an average value for) Hubble constant.	B1	
			The age of the universe is the inverse of this gradient	B1	
		iv	distance = $4.63 \times 10^{17} \times 3.0 \times 10^8$	C1	Possible ecf from (ii)
			distance = $1.4 \times 10^{26} \text{ (m)}$	A1	
			Total	13	

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