OCR
Oxford Cambridge and RSA

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.

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 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	Force is in the direction of the motion / field The particle accelerates (AW)	B1 B1	**Allow:** 'to the right'
		ii	Force 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	Out 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 The nucleus has protons and neutrons The nucleus is 10^4 / 10^5 times smaller than the atom (AW)	B1 B1 B1	
	b	i	$(^{222}_{86}\text{Rn} \rightarrow)$ $^{218}_{84}\text{Po}$ + $^{4}_{2}\text{He}$	B1 B1	**Allow** $^{4}_{2}\alpha$ for $^{4}_{2}\text{He}$
		ii	$\lambda = \frac{0.693}{3.8 \times 24 \times 3600}$ or $\lambda = 2.11 \times 10^{-6}$ (s^{-1}) $40 = 2.11 \times 10^{-6} \times N$ $N = 1.9 \times 10^{7}$	C1 C1 A1	Note N = 219 scores 2 out of 3 (3.8 used for T)
		iii	Number of air molecules / m³ = $40 \times 6.02 \times 10^{23} = (2.41 \times 10^{25})$ ratio = $\frac{1.9 \times 10^{7}}{2.41 \times 10^{25}}$ ratio = 7.9×10^{-19}	C1 A1	Possible ecf from **(ii)**
			Total	**10**	

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	$F = \frac{(1.6\times10^{-19})^2}{4\pi\times8.85\times10^{-12}\times(3.0\times10^{-10})^2}$ force = 2.<u>56</u> $\times 10^{-9}$ (N)	C1 A1	**Allow** use of 9.0×10^9 in place of $\frac{1}{4\pi\times8.85\times10^{-12}}$ **Note** answer must be to more than 2 s.f. to score this mark
		ii	resultant force^2 = $(2.56 \times 10^{-9})^2 + (2.56 \times 10^{-9})^2$ 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 = $\frac{3.6\times10^{-9}}{9.1\times10^{-31}}$ 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 stopwatch	B1	**Allow** data-logger / computer
			The time taken for the p.d. to decreases to 0.37 / $1/e$ 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/gradient **Allow** substitute values into $V = V_o e^{-t/CR}$ to find CR
	b	i	energy = ½ × 1.5^2 × 1200 × 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 × 1200 × 10^{-6} or charge = 1.8 × 10^{-3} (C)	C1	
			number of electrons = $\frac{1.8\times10^{-3}}{1.6\times10^{-19}}$	A1	
			number of electrons = 1.1 × 10^{16}		
	c	i	power = $\frac{1.5^2}{5000}$	B1	
			power = 4.5 × 10^{-4} (W)		
		ii	Time constant = CR = 5000 x 1200 x 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 B1	
			Total	**13**	

Question			Answer	Marks	Guidance
6	a		The X-ray photon disappears and creates an electron-positron pair	B1	
	b		$\frac{hc}{\lambda} = eV$	C1	
			potential difference = $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{18\times10^{-12}\times1.60\times10^{-19}}$	C1	
			potential difference = 6.9×10^4 (V)	A1	
	c		Use of $I = I_o e^{-\mu x}$ with $I_o = 2.0 \times 10^8$ $I = 2.0\times10^{8}\ e^{-1.1\times5.0}$	C1	**Allow** other correct methods
			intensity = $8.174... \times 10^5$ (W m^{-2})	C1	
			power = $8.174... \times 10^5 \times 6.0 \times 10^{-6}$ or power = 4.9 (W)	C1	**Allow FT** for their value of intensity
			energy = $4.9 \times 2.0 \times 60$ energy = 590 (J)	A1	
			Total	**8**	

Question			Answer	Marks	Guidance
7	a		Any **four** from: Nuclei / proton behave like tiny magnets / have 'spin' (AW) The nuclei precess about the magnetic field (at the Larmor frequency) Radio waves of frequency equal to the Larmor frequency are used to excite / resonate the nuclei 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) The relaxation time depends on the (surrounding) tissues	B1×4	**Allow** answers in terms of 'alignment and anti-alignment of protons in the external magnetic field'
	b		MRI scanning is non-ionising (AW) Better 3D contrast of soft-tissues	B1 B1	
			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	Reflection of ultrasound from the bone (and muscle boundary)	B1	
		ii1	$x = ½ \times 20 \times 10^{-6} \times 1600$ $x = 1.6 \times 10^{-2}$ (m)	C1 A1	**Allow** 1 mark for 3.2×10^{-2} (m); twice the distance
		ii2	density = $\frac{1.7 \times 10^6}{1600}$ density = 1.1×10^3 (kg m^{-3})	C1 A1	Note answer to 3 sf is 1.06×10^3 (kg m^{-3})
	b	iii	$0.40 = \left(\frac{Z - 1.7 \times 10^6}{Z + 1.7 \times 10^6}\right)^2$ $0.6325 = \left(\frac{Z - 1.7 \times 10^6}{Z + 1.7 \times 10^6}\right)$ $Z = 7.6 \times 10^6$ (kg m^{-2} s^{-1})	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 = $3.3 \times 10^{27} \times 1.0 \times 10^{6} \times 3.2 \times 10^{7}$ change in mass = $\frac{3.3\times10^{27}\times10^{6}\times3.2\times10^{7}}{(3.0\times10^{8})^{2}}$ change in mass = 1.2×10^{24} (kg)	C1 C1 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 = $\frac{6.0\times10^{17}}{3.1\times10^{16}}$ 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 $d\sin\theta = (n)\lambda$ Reference to the Doppler equation $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ 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 B1 B1	
	b	i	Hubble constant = $\frac{740}{11}$ Hubble constant = 67 (km s^{-1} Mpc^{-1})	C1 A1	
		ii	Hubble constant = $\frac{67\times10^3}{10^6\times3.1\times10^{16}}$ or 2.16×10^{-18} (s^{-1}) age = $\frac{1}{2.161\times10^{-18}} = 4.63\times10^{17}$ (s) age = 1.446×10^{10} (y) uncertainty = $\left(\frac{2}{11}+\frac{20}{740}\right)\times1.446\times10^{10}$ age = $(1.4\pm0.3)\times10^{10}$ (y)	C1 C1 C1 A1	Possible ecf from **(i)**
		iii	Determine the gradient from the *v*-*d* graph which is (an average value for) Hubble constant. The age of the universe is the inverse of this gradient	B1 B1	
		iv	distance = $4.63\times10^{17}\times3.0\times10^8$ distance = 1.4×10^{26} (m)	C1 A1	Possible ecf from **(ii)**
			Total	**13**	

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