RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE **G485**

Fields, Particles and Frontiers of Physics

Mark Scheme for June 2010

Oxford Cambridge and RSA Examinations

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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.

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CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as <u>independent</u> 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 <u>method</u> 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 <u>compensatory</u> 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 <u>answer</u> marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Convention used when marking scripts

WRONG PHYSICS OR EQUATION – indicate by **?** on scoris
No credit is given for correct substitution, or subsequent arithmetic, in a physically incorrect equation.

ERROR CARRIED FORWARD – indicate by **ECF** on scoris
Answers to later sections of numerical questions may be awarded up to full credit provided they are consistent with earlier incorrect answers.

ARITHMETIC ERROR – indicate by **AE** on scoris
Deduct 1 mark for the error and then follow through the working/calculation giving full credit for subsequent marks if there are no further errors. The ruling also includes power of ten (POT).

TRANSCRIPTION ERROR – indicate by **^** on scoris
This error is when there is incorrect transcription of data from the question, formulae booklet or previous answer. For example 1.6×10^{-19} has been written down as 6.1×10^{-19} or 1.6×10^{19}. Deduct the relevant mark and then follow through the working giving full credit for subsequent marks.

SIGNIFICANT FIGURES – indicate by **SF** on scoris
Where more SFs are given than is justified by the question, do not penalise. Fewer significant figures than necessary will be considered within the mark scheme. An error in significant figures is penalised only once per paper.

BENEFIT OF DOUBT – indicate by **BOD** on scoris
This mark is awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done.

RUBRIC INFRINGEMENT
If the candidate crosses out an answer but does not make any other attempt, then the work that is crossed out should be marked and the marks awarded without penalty.

CONTRADICTION – indicate by **CON** on scoris No mark can be awarded if the candidate contradicts himself or herself in the same response. For example, '… t*he mass of the particle increases and decreases*.'

Question			Expected Answers	Marks	Additional Guidance
1	a		Capacitance = charge per (unit) potential difference	B1	Allow: capacitance = charge / potential difference, charge/pd, charge/voltage but not charge / volt, coulomb /pd (no mixture of quantities and units. Allow 'over' instead of per
	b	(i)	Q = CV = 4.5 μ x 6.3 = 28.(35) (μC)	B1	Allow: 28 (≥ 2 sf)
		(ii)	E = ½ CV^2 = 0.5 x 4.5 x μ x $(6.3)^2$ = 8.9(3) x 10^{-5} (J) / 89.3 μ(J)	C1 A1	Allow use of E = ½ QV and the Q value from **(b)(i)** Q=28 E= 8.82 and Q=28.4 E=8.946 Allow ecf from **(b)(i)** penalise power of ten error (-1)
	c	(i)	Electrons / they move in an anticlockwise direction Charge on plates decreases / electrons neutralise positive charge p.d. decreases <u>exponentially</u>	B1 B1 B1	Alternatives for anticlockwise: from / lower plate around the circuit, from / lower plate through the resistor to top plate implied Capacitor discharges / loses charge
		(ii)	(dissipated as heat) in the resistor / wires	B1	
	d	(i)	Total capacitance = 1.5 + 4.5 = 6(.0) (μF)	A1	Allow one SF
		(ii)	Original charge on 4.5 μF capacitor is conserved (28.35 μC) V = (28.35 μ) / (1.5 + 4.5) μ = 4.7 (V)	C1 A1	ecf from **(b)(i) and (d)(i)**
			Total	**[11]**	

Question			Expected Answers	Marks	Additional Guidance
2	a		static / homogeneous infinite / infinite number of stars	B1 B1	Uniform (density) Do not allow isotropic or fixed
	b	(i)	gradient of graph = H_0 value $H_0 = 66 \pm 4$ (km s^{-1} Mpc^{-1})	C1 A1	
		(ii)	age = $1 / H_0$ ($H_0 = 2.1 \times 10^{-18}$ s^{-1}) = $(1 / 66 \times 3.2 \times 10^{-20} \times 3.2 \times 10^{7})$ = 1.5×10^{10} (1.48×10^{10}) (year)	C1 C1 A1	ecf from H_0 value Or correct age in seconds (4.7×10^{17} s) Answer will depend on H_0 value in **(b)(i)** Minus one if Mega or kilo omitted
	c	(i)	$\rho_c = 3H_0^2 / 8\pi G$ $= [3 \times (2.1 \times 10^{-18})^2] / (8 \times \pi \times 6.67 \times 10^{-11})$ $= 7.9 \times 10^{-27}$ (kg m^{-3})	C1 A1	If units of H_0 not converted or converted incorrectly then maximum one out of two ecf from H_0 value in **(b)(i)**
		(ii)	if average density of the Universe is less than critical then it will be too small to stop it expanding / it goes on forever if the average density of the Universe is greater than the critical value it will cause the contraction (and produce a big crunch) close to critical value and therefore a universe expands that will go towards a limit / expands at an ever decreasing rate asymptotic	B1 B1 B1	do not allow answers open, closed and flat

2	**d**		galaxies are moving apart / universe is expanding	**(B1)**	Allow stars for galaxies
			if galaxies have always been moving apart then at some stage they must have been closer together / or started from a point	**(B1)**	allow from a singularity
			evidence in red shift either optical / microwave	**(B1)**	allow statement that red shift is observed or that blue light becomes red or gamma from big bang has become microwave
			further away the galaxy the faster the speed of recession	**(B1)**	
			the existence of a (2.7 K) <u>microwave</u> background radiation	**(B1)**	
			there is more helium in the universe than expected	**(B1)**	
			MAX 4	**B4**	
			Total	**[16]**	

Question			Expected Answers	Marks	Additional Guidance
3	a	(i)	uniformly spaced, vertical parallel lines must begin and end on the plates with a minimum of three lines arrow in the correct direction down	 B1 B1	ignore any edge effects
		(ii)	E = V / d E = 60 / 5 x 10^{-3} = 12000 (V m^{-1})	 A1	
	b	(i)	Use of energy qV and kinetic energy = ½ mv^2 v = $[(2qV)/m]^{1/2}$ v = $[(2 \times 3.2 \times 10^{-19} \times 400)/6.6 \times 10^{-27}]^{1/2}$ v = 1.97 x 10^5 (m s^{-1})	M1 M1 A0	
		(ii)	a = F / m a = Eq / m a = (12000 x 3.2 x 10^{-19}) / 6.6 x 10^{-27}) = 5.82 x 10^{11} (m s^{-2})	C1 A1	Both required for the mark
		(iii)	**1** t = $\underline{(16 \times 10^{-3}) / 2 \times 10^5}$ = 8 x 10^{-8} (s) **2** s = ½ a x t^2 = ½ [5.82 x10^{11} x (8 x $10^{-8})^2$] = 1.86 x 10^{-3} (m)	M1 A0 C1 A1	Answer will depend on number of sf used by candidate. Using u = 2 x 10^5 scores 0/2 Allow slight variation in answers that follow from the candidates working

	c		Eq = Bqv B = E / v = 12000 / 2 x 10^5 = 0.060 (T)	C1 C1 A1	 Allow one sf unless answer is 0.061 when using v =1.97 x 10^5
	d		velocity (produced by p.d / 400 V) is less force due the magnetic field is reduced / Bqv is less / force due to the electric field is unchanged hence beam deflects <u>down</u>	B1 B1	 Allow the resultant force is downward Allow towards the lower plate
			Total	**[15]**	

Question			Expected Answers	Marks	Additional Guidance
4	a		magnetic flux = magnetic flux density x area (perpendicular to field direction)	B1	Allow equation with the symbols identified correctly Do not allow magnetic field or magnetic field strength
	b		Φ = NBA = 500 x 0.035 x 2.5 x 10^{-3} = 0.044 (0.04375) unit: Wb	C1 A1 B1	[allow for one mark 8.75 x 10^{-5} (Wb) i.e. B x A] Allow: Wb turns and T m^2 and V s
	c	(i)	The component of B perpendicular to the area changes / the idea that the area changes relative to the field direction detail of how it varies / depends on cos θ / maximum when field is perpendicular to B / zero when area is parallel to B	B1 B1	Allow the idea that the direction of the field relative to the area of the coil varies with the orientation of the coil Do not allow reference to cutting of the flux by the coil
		(ii)	Induced / e.m.f is proportional / to <u>the rate</u> of change of (magnetic) flux	B1	Allow the emf produced is equal to the rate of change of flux or flux cutting
		(iii)	e.m.f. **max** when ϕ is **zero** or at 0.005 /0.015 /0.025 s e.m.f **zero** when ϕ is a **max** or at 0.0 / 0.01/ 0.02 s e.m.f. and ϕ have the same frequency allow e.m.f and ϕ out of phase by $\pi/2$/ emf follows a sin curve emf is the gradient of the graph **MAX 3**	(B1) (B1) (B1) (B1) (B1) B3	

4		(iv)	ε = (change in flux linkage) / time = 0.04375 / 0.005 (8.8 x 10^{-5} x 500) / 0.005 = 8.75 (V)	C1 A1	[if N omitted then give one mark (ε = 0.0175)] [if 10^{-5} omitted then minus 1] [reading error from graph is penalised -1 (should be 8.8 and not 8.4)]
		(v)	Max e.m.f. is twice the original value as the rate of flux change is twice the original	B1 B1	Do not allow just larger Allow: the change in magnetic flux occurs in half the time Allow the max gradient will double
			Total	**[14]**	

Question			Expected Answers	Marks	Additional Guidance
5	a		Magnetic resonance: **some <u>nuclei</u> behave as small magnets / certain <u>nuclei</u> possess a net spin / <u>nuclei</u>** line up in the magnetic field **Need for a strong magnetic field** the frequency of precession is known as Lamor frequency (1) **Application of RF pulses** produces resonance / flip energy states (1) **RF pulse turned off nuclei relax / flip back (and emit RF signal)** RF detected (by coil receiver) and processed (1) Use of non-uniform field / gradient field (1) To locate position of nuclei in body (1) **QWC mark: difference in the relaxation times for hydrogen in different tissues / materials** MAX (3) **MAX 8**	**B1** **B1** **B1** **B1** **B1** **MAX B8**	Allow protons instead of nuclei in the context of hydrogen nuclei or a single proton instead of nuclei There are 5 essential marks **(in bold)** and a maximum of THREE extra marks (1) Maximum of **8 marks** Do not allow ‘atoms’ for nuclei but penalise once only **Please annotate scripts as follows:** **Essential marks: ✓(ticks) on left hand side of candidate’s work** **Extra marks: ✓(ticks) on right hand side of candidate’s work**

5	**b**		Advantage: not ionising radiation (as with X-rays) / better soft tissue contrast Disadvantage: heating effect of metal objects /effect on cardiac pacemakers / takes a long time to perform MRI scan	**B1** **B1**	Accept can view soft tissue in brain / skull Do not allow not harmful Do not allow no side effects
			Total	**[10]**	

Question			Expected Answers	Marks	Additional Guidance
6	a	(i)	$A = \lambda N_0 = 4.5 \times 10^{23} \times 0.693 / (12 \times 3600)$ $= 7.22 \times 10^{18}$ (s^{-1})	C1 A1	allow one mark if the 12 hours is not converted into seconds. Answer is 2.6×10^{22} Allow one mark if the 12 hours is converted into minutes Answer 4.33×10^{20}
		(ii)	3 half lives $N = 5.6 \times 10^{22}$	A1	
		(iii)	$N = N_0 e^{-\lambda t}$ $= 4.5 \times 10^{23} \times e^{-(0.693 \times 50/12)}$ or use of 2^n $= 2.5 \times 10^{22}$	C1 A1	use of 2^n 50/12 half lives
	b		material with large λ / short half life have initial high activity hence precautions needed <u>for initial period</u> of disposal OR material with small λ / long half life activity will last for a long period hence need for long term disposal MAX 2	(B1) (B1) (B1) (B1) B2	
			Total	**[7]**	

Question			Expected Answers	Marks	Additional Guidance
7	a	(i)	e: 0 and –1 N: 15 and 7 + (antineutrino)	**B1**	
		(ii)	e: 0 and +1 Si: 30 and 14 + (neutrino) correct 'neutrino' <u>in each case</u>	**B1** **B1**	Allow 1 for +1 Correct symbols required for the neutrinos: ν and $\bar{\nu}$ Allow ν_e and $\bar{\nu}_e$
	b	(i)	uud $\rightarrow$ udd	**B1**	Allow u $\rightarrow$ d
		(ii)	udd $\rightarrow$ uud	**B1**	Allow d $\rightarrow$ u
	c		weak(nuclear force)	**B1**	
			Total	**[6]**	

Question			Expected Answers	Marks	Additional Guidance
8	a	(i)	mass of uranium is greater than (the sum of) the mass of the products $E = \Delta mc^2$ OR binding energy of the products is greater than that of uranium energy available is the difference between the binding energies of uranium and the sum of the products	M1 A1 M1 A1	
		(ii)	kinetic energy	B1	
	b	(i)	the neutron is a single nucleon / cannot be split further / no binding has occurred	B1	The neutron is not bound to anything
		(ii)	binding energy of uranium = 235 x 7.6 =1786 binding energy of products = 141 x 8.3 + 92 x 8.7 = 1170.3 + 800.4 energy available = 184.7 (MeV)	C1 A1	An answer of 9.4 (not using the number of nucleons) scores zero Allow ≥ 2 sf (180, 185, 184.7) Penalise 184 as an AE
			Total	**[6]**	

Question			Expected Answers	Marks	Additional Guidance
9	a		$F = Q_1Q_2 / 4\pi\varepsilon_0 r^2$ $= (1.6 \times 10^{-19} \times 1.6 \times 10^{-19}) / 4\pi\varepsilon_0 (2 \times 10^{-15})^2$ $= 57.5$ (N)	C1 A1	Allow use of 9×10^9 instead of $1 / 4\pi\varepsilon_0$ (using this gives 57.6) Allow ≥ 2sf (58) If correct formula quoted and then AE (e.g. not squaring r <u>or</u> not squaring Q) then allow ecf in final answer for 2/3
	b		<u>attractive</u> strong (nuclear force)	B1	Do not it holds them together
	c		as the proton travels towards the stationary proton it experiences a repulsive force that slows it down. (It needs a high velocity) to get close enough (to the proton) / for the (attractive) <u>short range</u> force to have any effect	B1 B1	
			Total	**[5]**	

Question			Expected Answers	Marks	Additional Guidance
10	a		ANY ONE from X-rays interact with matter by: the photoelectric effect where an (orbital) electron is ejected from atom / atom is ionised Compton scattering where X-ray scattered by the interaction with (orbital) electron Pair production where X-ray photon interacts with the nucleus / atom and an electron and positron are produced [allow one mark for statement and one for explanation] **Max 2**	 **(B2)** **(B2)** **(B2)** **B2**	 Allow electrons ejected from metal surface if reference is made to <u>free</u> electrons Allow: X-ray diffraction **B1** X-ray passes through the 'slits' / atomic gap formed by the atoms **B1**

	b		$I = I_0e^{-\mu x}$ $0.1 = e^{-\mu 3}$ $0.5 = e^{-\mu x}$ $\ln 0.5 / \ln 0.1 = x/3$ $x = 0.903$ (mm)	**C1** **C1** **A1**	Calculation of μ =0.768 C1 Substitution into second equation C1 Allow 0.9 (1sf) If question misread and 0.9 used for change μ = 0.035 and x = 19.7 (allow 20) give 2/3
10	**c**	**(i)**	Absorption of X-rays by (silver halide molecules) by a photographic film Uses of fluorescent / scintillator/ phosphor Photon releases electron (that is accelerated onto a fluorescent screen) number of electrons increased /multiplied **MAX B2** QWC: Phosphor / Intensifier/ it converts X-ray photon into increased number of 'visible' photons	**(B1)** **(B1)** **(B1)** **(B1)** **B2** **B1**	

		(ii)	Different soft body tissue produce little difference in contrast/attenuation (Contrast media with) high atomic number / Z used / iodine or barium (used to give greater contrast) liquids injected or swallowed into soft tissue areas / or examples of such **MAX B2**	**(B1)** **(B1)** **(B1)** **B2**	This method produces good contrast for soft tissue /for similar Z values
			Total	**[10]**	

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Question			Expected Answer	Mark	Additional Guidance
1	(a)	(i)	$E = \frac{V}{d} = \frac{2400}{9.4 \times 10^{-3}}$ $E = 2.55 \times 10^5$ (V m^{-1}) force = $E \times Q = 2.55 \times 10^5 \times 1.60 \times 10^{-19}$ force = 4.09×10^{-14} (N)	C1 A1	**Allow** 1 mark for 4.1×10^{-n}, $n \neq 14$ **Allow** 2sf answer of 4.1×10^{-14} (N) Alternative: $F = \frac{Ve}{d} = \frac{2400 \times 1.60 \times 10^{-19}}{9.4 \times 10^{-3}}$ C1 force = $4.08(5) \times 10^{-14}$ (N) A1 [Allow: 4.08×10^{-14} (N)]
		(ii)	KE = $e \times V$ or KE = $F \times d$ KE = $1.6 \times 10^{-19} \times 2400$ or KE = $4.09 \times 10^{-14} \times 9.4 \times 10^{-3}$ KE = 3.84×10^{-16} (J)	C1 A1	**Allow** 2 sf answer Possible ecf if answer from **(a)(i)** is used
		(iii)	KE = $\frac{1}{2}mv^2$ $v = \sqrt{\frac{2 \times 3.84 \times 10^{-16}}{9.11 \times 10^{-31}}}$ speed = $2.9(0) \times 10^7$ (m s^{-1})	B1	Possible ecf if answer from **(a)(ii)** is used
	(b)		There is no change (to the gain in KE) work done or KE = Fd, F or E is halved <u>and</u> d is doubled or work done or KE = VQ and V is the same or work done or KE = VQ and this does not depend on distance	M1 A1	
			Total	7	

Question			Expected Answer	Mark	Additional Guidance
2	(a)		coulomb <u>per</u> volt	B1	**Allow**: 1 F = 1 $\underline{CV^{-1}}$
	(b)	(i)	<u>Electrons</u> flow 'clockwise' / negative to positive These are deposited on (plate) **A** (and hence becomes negatively charged) or These are removed from (plate) **B** (and hence become positively charged)	B1 B1	**Not**: **A** becomes negative / **B** becomes positive
		(ii)1	$Q = C \times V = 5.4 \times 10^{-9} \times 12$ charge = 6.48×10^{-8} (C)	B1	
		(ii)2	energy = $\frac{1}{2}V^2C = \frac{1}{2}\times 12^2 \times 5.4\times 10^{-9}$ energy = 3.89×10^{-7} (J)	B1	Possible ecf if Q used from **(ii)1**
	(c)	(i)	$R = \dfrac{12}{3.24\times 10^{-6}}$ resistance = 3.7×10^{6} (Ω)	M1 A0	**Allow**: 'R = 12/3.24μ' (= 3.7 MΩ)
		(ii)	time constant = CR = $5.4 \times 10^{-9} \times 3.7 \times 10^{6}$ or 0.02 (s) $I = I_0 e^{-t/CR} = 3.24 \times e^{-(0.080/0.020)}$ current = 0.059 (μA)	C1 A1	**Allow**: ecf for time constant **Allow**: 1 mark for 5.9×10^{-n}
	(d)		(Total) resistance of circuit <u>halved</u> / time constant is <u>halved</u> Rate of discharge is <u>doubled</u> / (initial) current is <u>doubled</u>	B1 B1	
			Total	10	

Question			Expected Answer	Mark	Additional Guidance
3	(a)		Perpendicular out of plane of paper	B1	**Allow**: 'out of paper' **Not**: 'up the paper'
	(b)		$\frac{mv^2}{R} = BQv$ hence $v = \frac{BQR}{m}$	M1 A0	**Allow**: Use of r instead of R and e instead of Q
	(c)		speed = $\frac{2\pi \times 0.18}{2.0 \times 10^{-8}}$ or 5.66×10^7 (m s^{-1}) $5.66 \times 10^7 = \frac{B \times 1.60 \times 10^{-19} \times 0.18}{1.67 \times 10^{-27}}$ (Any subject) B = 3.28 (T)	C1 C1 A1	**Allow** : ecf for incorrect value for speed v Alternative : $t = (\frac{2\pi R}{v} =) \frac{2\pi m}{BQ}$ C1 $B = \frac{2\pi \times 1.67 \times 10^{-27}}{2.0 \times 10^{-8} \times 1.60 \times 10^{-19}}$ C1 B = 3.28 (T) A1
	(d)		The force / acceleration is perpendicular to the motion / velocity No work is done	B1 B1	**Allow**: 'speed' instead of 'velocity'
			Total	7	

Question			Expected Answer	Mark	Additional Guidance
4	(a)		The speed of recession of a galaxy is proportional to its distance (from Earth / observer)	B1	
	(b)	(i)	$v = \dfrac{\Delta\lambda}{\lambda} \times c$ $v = 0.15 \times 3.0 \times 10^8$ speed = 4.5×10^7 (m s^{-1})	M1 A0	**Allow**: '15% of $3.0 \times 10^8 = 4.5 \times 10^7$ (m s^{-1})' **Not**: '0.15*c*'
		(ii)	distance = v / H_0 (Any subject) distance = $\dfrac{4.5\times10^7 \times 3.1\times10^{22}}{65\times10^3}$ distance = 2.15×10^{25} (m)	C1 A1	Possible ecf from **(b)(i)** **Allow**: 1 mark for 2.15×10^n, $n \neq 25$
		(iii)	$H_0 = \dfrac{65\times10^3}{3.1\times10^{22}}$ (= 2.10×10^{-18} s^{-1}) age = $1/H_0$ = 4.77×10^{17} (s) age = 1.49×10^{10} (y)	C1 A1	**Allow**: 1 mark for 1.49×10^n, $n \neq 10$
	(c)		Any two from: 1. Spectra from galaxies show shift to longer wavelengths (suggests galaxies are moving away from the Earth) 2. The more distant galaxies are moving faster (than the ones closer to our galaxy) 3. Existence of microwave background radiation (which is the same in all directions) / The temperature of universe is 3 K (after cooling due to expansion) / gamma (radiation) became microwaves (as the universe expanded) 4. Existence of primordial helium (produced in the early stages of the universe) 5. Temperature fluctuations (predicted and observed)	B1 × 2	**Not** 'red-shift' for 1. **Allow**: Reference to CMB (radiation) in 3. **Not** bald 'ripples' for 5.
			Total	8	

Question			Expected Answer	Mark	Additional Guidance
5	(a)		Diagram showing (star,) 1 AU, 1 pc and angle of 1 arc second	B1	
			Distance from a base length of 1 AU that subtends an angle of 1 (arc) second or Parsec is a distance that gives a (stellar) parallax of 1 second (of arc) / 1/3600°	B1	**Allow**: 1 pc is the distance calculated using: 1 AU/tan(1/3600°) **Not**: 1 pc = 3.26 ly **Not**: 1 pc = 3.1×10^{16} m
	(b)	(i)	distance (pc) = 1 / 0.275 distance = 3.64 (pc)	B1	
		(ii)	distance in m = $3.1 \times 10^{16} \times 3.64 = 1.127 \times 10^{17}$ (m) distance in ly = $1.127 \times 10^{17}/9.5 \times 10^{15}$ distance in ly = 11.9	C1 A1	Possible ecf from **(b)(i)** **Alternative**: 1 pc = 3.26 ly C1 distance = 3.26×3.64 distance 11.9 (y) A1
			Total	5	

Question			Expected Answer	Mark	Additional Guidance
6	(a)	(i)	Any five from: 1. Gas / dust (cloud) drawn together by gravitational forces 2. Loss in (gravitational) PE / KE increases / PE changes KE / temperature increase 3. Fusion of protons / hydrogen nuclei (produces helium nuclei and energy) 4. A stable star is formed when radiation pressure is equal to gravitational pressure 5. When hydrogen runs out the outer layers of the star expands / core shrinks 6. Red giant formed / eventually (the core becomes) a white dwarf QWC mark for '*correct sequencing of the processes from birth to death*'	B1 × 5 B1	**Allow**: 'Gravitational collapse of dust cloud'
		(ii)	Supernova followed by neutron star / black hole	B1 B1	
	(b)		$\Delta E = \Delta mc^2$ energy = $2.0 \times 10^{30} \times 10^{-6} \times (3.0 \times 10^8)^2$ or $1.8(0) \times 10^{41}$ (J) time = $1.80 \times 10^{41}/3.8 \times 10^{26}$ (= 4.74×10^{14} s) time = $4.74 \times 10^{14}/3.2 \times 10^7$ time = 1.5×10^7 (y)	 C1 C1 A1	**Alternative**: rate = 4.22×10^9 (kg s^{-1}) C1 time = $2.0 \times 10^{24}/4.22 \times 10^9$ (= 4.74×10^{14} s) C1 time = 1.5×10^7 (y) A1

Question			Expected Answer	Mark	Additional Guidance
6	(c)	(i)	Any four from: 1. Protons / hydrogen <u>nuclei</u> to produce He <u>nuclei</u> (positrons and neutrinos) 2. There is electrostatic repulsion (between the protons) / The protons repel (each other because of their positive charge) 3. High temperatures / 10^7 K needed (for fusion) 4. (At high temperatures some of the fast moving) protons come close enough to each other for the strong (nuclear) force (to overcome the electrostatic repulsion) 5. High density / pressure (in the core of the Sun) 6. There is a decrease in mass, hence energy is released / products have greater binding energy	B1 × 4	**Not**: 'heat' in place of temperature in 3.
		(ii)	Kinetic (energy) Electromagnetic / photons	B1 B1	**Not**: heat / thermal (energy) **Not**: 'radiation' / 'wave energy'' **Allow**: Gamma
		(iii)	BE = 4 × 7.2 = 28.8 (MeV) BE = $28.8 \times 1.6 \times 10^{-13}$ BE = 4.6×10^{-12} (J)	C1 A1	Possible ecf if BE value is incorrect
			Total	19	

Question			Expected Answer	Mark	Additional Guidance
7	(a)		The application of a p.d. across a material / crystal causes an expansion / contraction / vibration (ora)	B1	**Allow**: reference to 'current' instead of p.d / e.m.f
	(b)		Any <u>two</u> from: • <u>Pulses</u> of ultrasound (sent into the body) • Wave / ultrasound / pulse / signal is <u>reflected</u> (at boundary of tissue) • Time of delay used to determine depth / thickness • The fraction of <u>reflected</u> signal is used to identify the tissue	B1 × 2	**Allow**: The <u>reflected</u> signal / ultrasound /amplitude / intensity is used to identify the tissue
			A-scan in one direction only / range or distance or depth finding	B1	
			B-scan uses a number of sensors or a sensor in different positions / angles (to build up a 2D/3D image)	B1	**Not**: 'B-scan is many A-scans'
	(c)	(i)	$Z = \rho c$; density $\rightarrow$ kg m^{-3} <u>and</u> speed $\rightarrow$m s^{-1} (Hence $Z \rightarrow$ kg m^{-2} s^{-1})	M1 A0	
		(ii)	fraction = $\dfrac{(7.14-1.72)^2}{(7.14+1.72)^2}$ fraction = 0.37(4)	C1 A1	**Allow**: 37 %
		(iii)	(Acoustic) impedances of media are similar / identical No / reduced reflection (at boundary) Or The gel allows maximum transmission of ultrasound (into the body)	B1 B1	**Allow**: 'The Zs are the same'
		(iv)	$v = f\lambda$ wavelength = $\dfrac{1590}{1.2\times10^{6}}$ $(=1.33\times10^{-3}$ m) (Any subject) wavelength = 1.33 (mm)	C1 A1	**Allow**: 1 mark for '4080/1.2 × 10^{6} = 3.4 mm'
		(v)	Small wavelength means finer detail can be seen / greater resolution	B1	
			Total	13	

Question			Expected Answer	Mark	Additional Guidance
8	(a)		Any five from: 1. Intensifier used as X-ray would pass through film 2. Intensifier converts X-ray photon to many visible (light) photons (which are absorbed by film) 3. *Lower exposure / fewer X-rays needed 4. Iodine / barium (used as contrast material) 5. *High Z number / large attenuation coefficient / large absorption coefficient (used to improve image contrast) 6. Contrast media are ingested / injected into the body 7. *Scan shows outline / shape of soft tissue QWC mark is acquired from clear expression of any of the marking points 3, 5 or 7	B1 × 5	
	(b)		X-rays produce visible light or In photoelectric effect electrons are emitted	B1	
	(c)	(i)	Any two from: • Simple X-ray is one directional / produces single image • CT image(s) taken at different angles / X-ray tube is rotated • Computer processes data / image constructed from many slices	B1 × 2	
		(ii)	Any two from: 1. X-ray image is 2D / CT scan produces 3D image 2. Greater detail / definition / contrast with CT scan / 'soft tissues can be seen' 3. Image can be rotated	B1 × 2	
			Total	10	

Question			Expected Answer	Mark	Additional Guidance
9	(a)	(i)	composition for n and p: u d d & u u d charge for n and p: 0 & +1	B1 B1	 **Allow**: charge 'e' instead of '+1' or '1'
		(ii)	up +2/3 **(+1/3)** 0 down -1/3 +1/3 **(0)**	B1 B1	**Allow**: charges in terms of 'e'
	(b)	(i)	$^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + {}^{0}_{-1}\text{e} + \bar{\nu}$	A2	**Allow**: '→ proton + electron + <u>anti</u>neutrino' **Note**: -1 for any omission or error. Score = 0 if more than one error
		(ii)	weak (nuclear)	B1	
		(iii)	lepton(s) <u>and</u> hadron(s) / baryons(s)	B1	**Not**: Neutrons are mesons
			Total	8	

Question			Expected Answer	Mark	Additional Guidance
10	(a)		**Spontaneous**: the decay cannot be induced / occurs without external influence **Random**: cannot predict when / which (nucleus) will decay next	B1 B1	
	(b)		The probability of decay of a <u>nucleus</u> <u>per</u> unit time	M1 A1	**Allow**: $\lambda = A / N$ (Any subject) C1 A = activity and N = number of <u>nuclei</u> A1
	(c)		Living plants / animals absorb carbon(-14) Once dead, the plant does not take in any more carbon(-14) The fraction of C-14 to C-12 (nuclei) or number of C-14 (nuclei) or activity of C-14 (nuclei) measured in dead <u>and</u> living (sample) $x = x_0\, e^{-\lambda t}$ used with data above to estimate the age	B1 B1 M1 A1	
	(d)	(i)1	$\lambda = \ln 2 / T_{1/2}$ decay constant = 1.24×10^{-4} (y^{-1})	B1	
		(i)2	$A = A_0 e^{-\lambda t}$ $0.194 = 0.249 \times e^{-(1.24 \times 10^{-4} \times t)}$ $\ln(0.194/0.249) = -1.24 \times 10^{-4}\, t$ time = 2.0×10^3 (y)	C1 A1	
		(ii)	The activity is (very) small / decay is random	B1	
		(iii)	Activity so low that it cannot be differentiated from the background	B1	
			Total	13	

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RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE

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

Mark Scheme for June 2011

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.

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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:

Significant figures are rigorously assessed in the practical skills.
If the data given in a question is to 2 sf, then allow answers to 2 or more significant figures.
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 Additional Guidance.

Question			Expected Answers	Marks	Additional guidance
1	(a)		Electromotive force is the energy transferred (from one form of energy) to <u>electrical</u> <u>per</u> unit charge	B1	**Allow:** 'electrical energy (gained) per unit charge' **Not:** electrical energy per coulomb
	(b)		Magnetic flux is the product of the (magnetic) flux density and the area (normal to the field)	B1	**Allow:** $\phi = BA$, where B = (magnetic) flux density and A = area. If $\phi = BA\cos\theta$ is used, then θ must be defined as the angle (between the normal to the plane of the area and the magnetic field) **Do not allow** 'field strength' for 'flux density'
	(c)	(i)	A changing (magnetic) flux is produced (in the primary coil / in the iron core) The iron core links this (magnetic) flux /(magnetic) flux density to the secondary coils The changing (magnetic) flux / (magnetic) flux density through secondary induces e.m.f. (in secondary coils)	B1 B1 B1	**Allow:** A changing (magnetic) flux density is produced (in the primary coil) but **not** '*changing (magnetic) field*' **Allow:** The rate of change of (magnetic) flux (linkage) induces an e.m.f. (in the secondary coil)
		(ii)	Any <u>one</u> from: More coils / turns on secondary Less coils / turns on primary Laminate the core	 B1	 **Not:** Increase frequency of alternating supply
	(d)	(i)	$\dfrac{n_s}{4200} = \dfrac{12}{230}$ (Any subject) number of turns = 219 or 220	C1 A1	 **Note:** A bald answer 219 or 220 scores 2 marks
		(ii)	current = $(12.0 - 11.8)/0.35$ current = 0.57 (A) -- $P = VI$ or $P = I^2R$ or $P = V^2/R$ $P = 0.2 \times 0.57$ or $P = 0.57^2 \times 0.35$ or $P = 0.2^2/0.35$ power = 0.114 (W) or 0.11 (W)	C1 A1 C1 A1	 Possible e.c.f. from **(ii)1**
			Total	**12**	

Question			Expected Answers	Marks	Additional guidance
2	(a)		capacitance = charge / potential difference	B1	**Allow:** p.d. and voltage **Not:** charge per volt or coulombs per p.d
	(b)	(i)	$V = Q/C$ and Q = constant in series circuit $V = \frac{450}{450+150} \times 6.0$ potential difference = 4.5 (V)	C1 A1	**Allow:** 1 mark for an answer of 1.5 (V) **Note**: Using **(b)(ii)**, alternative marking scheme $V = 6.75 \times 10^{-4}/150 \times 10^{-6}$ C1 $V = 4.5$ V A1
		(ii)	charge = $150 \times 10^{-6} \times 4.5$ charge = 6.75×10^{-4} (C)	B1	Possible e.c.f. **Note**: Using **(b)(iii)** ... $Q = 6.0 \times 1.125 \times 10^{-4} = 6.75 \times 10^{-4}$ (C)
		(iii)	$\frac{1}{C} = \frac{1}{150} + \frac{1}{450}$ (working in μF) capacitance $C_T = 1.125 \times 10^{-4}$ (F) or 113 μ(F)	B1	**Possible alternative:** capacitance = $6.75 \times 10^{-4}/6.0$ capacitance = 1.125×10^{-4} (F) or 113 μ(F) Possible e.c.f. from **(ii)**
	(c)	(i)	time constant = CR time constant = $1.125 \times 10^{-4} \times 45 \times 10^{3}$ time constant = 5.06 (s)	M1 A0	**Note:** The mark is for multiplying correct C and R values Possible e.c.f. from**(b)(iii)**
		(ii)	Graph starting from 6.0 (V) Correct shaped curve Approximately correct value of V at CR	B1 B1 B1	**Note:** The (exponential decay) curve must not touch or cut the time axis **Note:** V is 2 to 2.5 (V) at $t \approx 5$ s

Question			Expected Answers	Marks	Additional guidance
		(iii)	$\frac{1}{2}\times 4.5^2 \times 150\times 10^{-6}$ <u>and</u> $\frac{1}{2}\times 1.5^2 \times 450\times 10^{-6}$ ratio = $\dfrac{0.5\times 4.5^2 \times 150\times 10^{-6}}{0.5\times 1.5^2 \times 450\times 10^{-6}}$ ratio = 3 Or ½ Q^2/C_{150} and ½ Q^2/C_{450} ratio = C_{450} / C_{150} ratio = 3	C1 A1 C1 A1	**Allow:** with or without the 10^{-6} Possible e.c.f. from **(b)(i)** and **(b)(ii)** **Allow:** full credit for correct use of either ½QV or ½ Q^2/C
		(iv)	The ratio remains constant The charge / Q is the same for both capacitors	B1 B1	
			Total	**13**	

Question			Expected Answers	Marks	Additional guidance
3	(a)		(Electric field strength is the) force <u>per</u> (unit positive) charge	B1	**Allow:** $E = F/Q$, *F* is the force on a (positive) charge *Q*
	(b)		Parallel and equally spaced lines at right angles to plates Correct <u>upward</u> direction of field shown on at least one field line	B1 B1	
	(c)	(i)	An arrow vertically downwards at **P**	B1	
		(ii)	$E = \frac{3400}{0.050}$ or $E = 6.8 \times 10^4$ (V m^{-1}) $a = \frac{EQ}{m}$ $a = \frac{6.8\times10^4 \times 1.6\times10^{-19}}{9.11\times10^{-31}}$ or $a = \frac{1.09\times10^{-14}}{9.11\times10^{-31}}$ acceleration = 1.19×10^{16} (m s^{-2}) or 1.2×10^{16} (m s^{-2})	C1 C1 A0	**Vital:** Candidates using separation of 0.050 cm must be awarded full credit for the analysis shown below $E = \frac{3400}{0.050\times10^{-2}}$ or $E = 6.8 \times 10^6$ (V m^{-1}) C1 $a = \frac{EQ}{m}$ $a = \frac{6.8\times10^6 \times 1.6\times10^{-19}}{9.11\times10^{-31}}$ C1 acceleration = 1.19×10^{18} (m s^{-2}) A0
		(iii)	$t = \frac{0.04}{4.0\times10^7}$ time = 1.0×10^{-9} (s)	B1	**Allow:** 1×10^{-9} (s) or 10^{-9} (s)
		(iv)	initial vertical velocity = 0, final vertical velocity = *at* vertical velocity = $1.2 \times 10^{16} \times 1.0 \times 10^{-9}$ (**Allow:** $1 \times 10^{16} \times 1.0 \times 10^{-9}$) vertical velocity = 1.2×10^7 (m s^{-1})	 M1 A0	**Vital:** Candidates using separation of 0.050 cm must be awarded full credit for the analysis shown below vertical velocity = $1.2 \times 10^{18} \times 1.0 \times 10^{-9}$ M1 vertical velocity = 1.2×10^9 (m s^{-1}) A0

Question			Expected Answers	Marks	Additional guidance
		(v)	$v^2 = (4.0\times10^7)^2 + (1.2\times10^7)^2$ velocity = 4.2×10^7 (m s^{-1}) Or $v^2 = (4.0\times10^7)^2 + (1\times10^7)^2$ velocity = 4.1×10^7 (m s^{-1})	C1 A1 C1 A1	Possible ecf from **(iv)**
		(vi)	KE = ½ mv^2 KE = $0.5 \times 9.11 \times 10^{-31} \times (4.2 \times 10^7)^2$ kinetic energy = 8.04×10^{-16} (J) or 8.0×10^{-16} (J)	C1 A1	Possible ecf from **(v)** **Allow:** 1 sf answer if the answer comes out as 8.0×10^{-16} (J)
		(vii)	Graph starts at non-zero value for E_k Between 0 and 0.08 (m) the graph has increasing gradient Horizontal line after 0.080 (m)	B1 B1 B1	 **Note:** The E_k value for the horizontal line > E_k value at x = 0
			Total	**15**	

Question			Expected Answers	Marks	Additional guidance
4	(a)		$E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$	C1	
			$\dfrac{(-)4.0\times10^{-9}}{4\pi\varepsilon_0\times(1.75\times10^{-2})^2}$ and $\dfrac{5.0\times10^{-9}}{4\pi\varepsilon_0\times(1.75\times10^{-2})^2}$	C1	Ignore signs
			$E_B = 1.17\times10^5$ (N C^{-1}) and $E_A = 1.47\times10^5$ (N C^{-1})		
			field strength = $(1.17 + 1.47)\times10^5$ (N C^{-1})		
			field strength = 2.64×10^5 (N C^{-1}) or 2.6×10^5 (N C^{-1})	A1	**Allow:** 2 marks for $2.9(4)\times10^4$ (N C^{-1}) when the fields are subtracted **Allow:** 2 marks for 6.6×10^4 (N C^{-1}) for using 3.5×10^{-2} m
			direction = to the left / towards B	B1	
	(b)		$F = \dfrac{Qq}{4\pi\varepsilon_0 r^2}$	C1	
			force = $\dfrac{4.0\times10^{-9}\times5.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(3.5\times10^{-2})^2}$	C1	Ignore signs **Allow:** ε_0 in the equation
			force = 1.47×10^{-4} (N)	A0	
	(c)		(weight =) $4.5\times10^{-5}\times9.81$ or (weight =) $4.4(1)\times10^{-4}$ (N)	C1	**Allow:** weight = $4.5\times10^{-5}\times g$
			$\tan\theta = \dfrac{1.5\times10^{-4}}{4.41\times10^{-4}}$	C1	
			angle = 18.8 (°) or 19 (°) (**Allow**: Full credit when angle is determined using a scale diagram)	A1	**Note:** Using force = 1.47×10^{-4} (N) gives an angle of 18.4°; hence allow 18° **Allow:** 2 marks for θ = 71°; this is the complementary angle **Allow:** 1 mark for '$\tan\theta = \dfrac{1.5\times10^{-4}}{4.5\times10^{-5}}, \theta = 73^0$' when mass is used instead of weight.
			Total	**9**	

Question			Expected Answers	Marks	Additional guidance
5	(a)		Down(wards)	B1	**Note:** Can be on Fig. 5.1
	(b)		(Fleming's) left-hand rule	B1	**Allow:** Thumb in direction of force, first finger in direction of (magnetic) field and second finger in direction of (conventional) current
	(c)	(i)	force = $BIL = 0.080 \times 4.0 \times 5.0 \times 10^{-2}$ force = 0.016 (N)	B1	
		(ii)	reading = 2.500 – 0.016 reading = 2.484 (N) The force on core/magnets is up(wards) (According to Newton's third law) the forces (on the rod and steel core/magnets) are equal and opposite	B1 B1 B1	**Allow:** 'up and down' as equivalent to 'opposite'
	(d)		Resistance increases by a factor of 4 Current decreases by a factor of 4 The force decreases by a factor of 4 force = 0.004 (N)	C1 C1 A1	Possible e.c.f. from **(c)(i)** **Note:** force = **(c)(i)**/4 can score full marks **Special case:** Allow 1 mark for (resistance doubles, current is halved, hence) force = 0.008 (N)
			Total	**9**	

Question			Expected Answers	Marks	Additional guidance
6	(a)		Any <u>four</u> from 1 to 5: 1. Most of the alpha particles went straight through (some deviated through small angles) 2. Hence most of the atom is empty space 3. Some / a very small number of alpha particles were scattered / repelled through large angles / angles more than 90° 4. This showed the existence of (a tiny) positive nucleus 5. The size of the nucleus is about 10^{-14} <u>m</u> ✐ QWC: Award a mark for one conclusion correctly linked to an observation	B1×4 B1	**Must use ticks on Scoris to show where the marks are awarded** **Allow**: 10^{-15} <u>m</u>
	(b)		Any <u>five</u> from: Gravitational (force) This force is attractive **AND** is long-ranged / obeys '$1/r^2$ relationship' <u>Strong</u> (nuclear force/interaction) This force is attractive (at larger distances) or repulsive at short distances **AND** is short-ranged / ~ 10^{-14} m Electrostatic / electrical (force) / coulomb (force) This force is repulsive between protons / zero between neutrons / zero between protons and neutrons **AND** is long-ranged / obeys '$1/r^2$ relationship'	 M1 A1 M1 A1 M1 A1	 **Allow:** gravity **Note**: Do not allow 'inverse square law'; allow 'inverse square law with distance' **Allow:** Electromagnetic (interaction/force)

Question			Expected Answers	Marks	Additional guidance
	(c)	(i)	mass = $235 \times 1.7 \times 10^{-27}$ (= 3.995×10^{-25} kg) volume = $\frac{4}{3}\pi \times (8.8 \times 10^{-15})^3$ (= 2.855×10^{-42} m^3) density = mass/volume density = 1.4×10^{17} (kg m^{-3})	C1 C1 A1	**Allow:** 1.66×10^{-27} kg for mass of nucleon **Allow:** 10^{17} (kg m^{-3}) for this estimation question **Note:** Omitting 235 gives 6.0×10^{14} (kg m^{-3}), allow 2 mark **Allow:** 1 mark if 92 or 143 is used to determine the mass of the nucleus; this gives a density value of 5.5×10^{16} (kg m^{-3}) and 8.5×10^{16} (kg m^{-3}) respectively
		(ii)	The nucleons / neutrons and protons are packed together with little or no empty space (AW)	B1	
			Total	14	

Question			Expected Answers	Marks	Additional guidance
7	(a)		The critical density is the density for which the universe will expand towards a (finite) limit or rate of expansion **tends** to zero / which will result in a flat universe	B1	**Not:** critical density is given by $\frac{3H_0^{\ 2}}{8\pi G}$
	(b)		Hubble constant = $\frac{65\times10^3}{10^6\times3.1\times10^{16}}$ Hubble constant = 2.1 × 10^{-18} s^{-1} critical density = $\frac{3H_0^{\ 2}}{8\pi G}$ critical density = $\frac{3\times(2.1\times10^{-18})^2}{8\pi\times6.67\times10^{-11}}$ critical density = 7.9 × 10^{-27} (kg m^{-3})	B1 C1 A1	Possible e.c.f. from value of Hubble constant within this calculation
	(c)	(i)	open: (density of universe < critical density hence) the universe will expand forever closed: (density of universe > critical density hence) the universe will (eventually stop expanding and then) contract / big crunch flat: (density of universe = critical density hence) the universe will expand towards a (finite) limit / rate of expansion **tends** to zero	B1 B1 B1	**Allow:** 'universe continues to expand' **Not:** 'The universe stops expanding' **Special case:** Award 1 mark for correct sketches if no explanation is given for open, closed and flat
		(ii)	Any one from: Existence of dark matter / black holes / neutrinos / dark energy / H_0 is not known accurately	B1	
			Total	**8**	

Question			Expected Answers	Marks	Additional guidance
8	**(a)**		Less chance of infection	B1	
	(b)		Any <u>two</u> from: 1. Tracer is injected into the body / placed inside the body / circulates the body 2. Tracer is absorbed by organ / shows blockage 3. Beta detector / gamma camera (is used to detect radiation from the body)	B1×2	**Note:** No marks for ingesting substances (e.g barium)
	(c)		Any <u>five</u> from: 1. A positron / beta-plus emitting tracer / source is used 2. The positron annihilates with an electron (inside the patient) 3. This produces <u>two</u> gamma photons 4. The photons travels in opposite directions 5. The patient is surrounded by a ring of gamma detectors 6. The arrival times of the photons / delay time indicates location (of tumour inside the body) 7. A 3-D image is created (by the computer connected to the detectors)	B1×5	
			Total	**8**	

Question			Expected Answers	Marks	Additional guidance
9	(a)		Any <u>three</u> from 1 to 4: 1. A (piezoelectric) crystal / transducer is used to send <u>pulse</u>(s) of ultrasound (into the patient) 2. Wave / ultrasound / pulse / signal is <u>reflected</u> (at the boundary of tissue) 3. The (intensity of the) <u>reflected</u> signal depends on the acoustic impedances (at the boundary) 4. The (time of) delay is used to determine the depth / thickness 🖉 QWC: Award a mark for correct sequencing of the steps in the process	B1×3 B1	**Must use ticks on Scoris to show where the marks are awarded** **Allow:** $\frac{I_{(r)}}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$ without symbols defined for the 3rd marking point **Note**: Do not allow marking points 2 or 3 for gel-skin interface
	(b)		A-scan is one directional / B-scan involves different directions or angles / B-scan consists of many A-scans / B-scan produces 2-D or 3-D image	B1	
			Total	**5**	

Question			Expected Answers	Marks	Additional guidance
10	(a)		A neutron is absorbed by a (massive / uranium) nucleus The nucleus splits into two (smaller/daughter) nuclei and (one or more) neutrons	B1 B1	
	(b)		In a fission reaction there is a decreases in the mass (According to $\Delta E = \Delta mc^2$) mass is converted into energy Or The (total) binding energy of the products / smaller nuclei is greater than the binding energy of the original nucleus The difference in the binding energies is released as energy	M1 A1 M1 A1	 **Allow:** The 'BE increases (in the reaction)'
	(c)		Moderator: water / graphite / carbon It slows down the (fast-moving) neutrons / reduces the (kinetic) energy of neutrons Slow-moving neutrons have greater chance of causing fission (than fast-moving neutrons)	B1 B1 B1	**Note**: If boron is mentioned, then do not award this B1 mark **Allow**: They become thermal neutrons
			Total	**7**	

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RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE

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

Mark Scheme for January 2012

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Facsimile: 01223 552610
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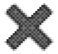
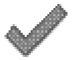
Annotations available in Scoris

Annotation	Meaning
	Benefit of doubt given
	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

Annotations in detailed mark scheme

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
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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:

If the data given in a question is to 2 sf, then allow answers to 2 or more significant figures.

(Significant figures are rigorously assessed in the practical skills.)

Question			Answers	Marks	Guidance
1	(a)		electric field strength = force per unit (positive) charge	B1	**Allow**: force/charge **Not**: *F*/*Q*
	(b)	(i)	$E = V/d$ $3.0 \times 10^6 = V/1.3 \times 10^{-3}$ *V* = 3900 (V)	C1 A1	**Note**: This mark is for correct substitution **Allow**: 1 mark if answer is 3.9×10^n (V), n ≠3 – POT error
		(ii)1	*Q* = *It* $Q = 2.7 \times 10^{-9} \times 4.0 \times 10^{-2}$ charge = 1.1×10^{-10} (C) or 1.08×10^{-10} (C)	C1 A1	**Note**: This mark is for correct substitution
		(ii)2	number = $1.08 \times 10^{-10} / 1.6 \times 10^{-19}$ number = 6.8×10^8 or 6.75×10^8	B1	Possible ecf from **(b)(ii)1**
		(iii)	energy = *VQ* energy = $3900 \times 1.08 \times 10^{-10}$ energy = 4.2×10^{-7} (J)	C1 A1	**Note**: No credit for using ½ *QV* Possible ecf from **(b)(ii)1**
			Total	**8**	

Question			Answers	Marks	Guidance
2	(a)		torque = one of the forces × perpendicular distance (between the forces)	B1	
	(b)	(i)	Into (plane of) paper	B1	**Not**: 'down'
		(ii)1	force = BIL = 0.060 × 0.03 × 0.015 force = 2.7×10^{-5} (N)	B1	
		(ii)2	torque = $2.7 \times 10^{-5} \times 0.015$ torque = 4.1×10^{-7} (N m) or 4.05×10^{-7} (N m)	C1 A1	Possible ecf from **(b)(ii)1** Do not allow 4.0×10^{-7} (N m) - rounding error
	(c)	(i)	$F = BQv$ $2.0 \times 10^{-13} = 0.14 \times Q \times 4.5 \times 10^{6}$ charge = 3.2×10^{-19} (C) or 3.17×10^{-19} (C)	C1 A1	**Allow**: Any subject
		(ii)	$F = mv^2 / r$ $2.0\times10^{-13} = \dfrac{2.7\times10^{-26}\times(4.5\times10^{6})^{2}}{r}$ radius = 2.7 (m) or 2.73 (m)	C1 C1 A1	**Allow**: Any subject
		(iii)	$BQv = mv^2/r$ Hence, radius ∝ mass	B1 B1	**Allow**: $r \propto m$
			Total	**12**	

Question			Answers	Marks	Guidance
3	(a)		magnetic flux = (magnetic) flux density × (cross-sectional) area Idea of (magnetic) field normal to the plane of the area	M1 A1	Allow full credit for magnetic flux = *BA*, where *B* = magnetic flux density normal to area and *A* = (cross-sectional) area
	(b)	(i)	constant rate of change of (magnetic) flux / flux density	B1	**Not**: 'graph has constant gradient'
		(ii)	e.m.f. = rate of change of flux linkage e.m.f. = $\frac{1.4\times10^{-2}\times\pi\times(3.2\times10^{-2})^2\times180}{2.5}$ e.m.f. = 3.2×10^{-3} (V) or 3.24×10^{-3} (V)	C1 C1 A1	**Allow**: $E = \frac{\Delta N\phi}{\Delta t}$ Deduct 1 mark if *B* is misread from the graph and then ecf **Allow**: 2 marks for an answer 3.24×10^{n} (if $n \neq -3$) **Allow**: 2 marks for 1.78×10^{-5} (when 180 has been missed out)
	(c)	(i)	$P = VI$ current in secondary = 15/6 or 2.5 (A) primary voltage = 6.0 × turn ratio = 6.0 × 40 = 240 (V) V_p = 240 (V) or I_s = 2.5 (A) primary current = 2.5/40 or 15/240 input current = 6.3×10^{-2} (A) or 6.25×10^{-2} (A)	 C1 A1	 The C1 mark is for either of these values
		(ii)	There is no change in flux density / (magnetic) flux / (magnetic) flux linkage	B1	**Not**: 'There is no change in the magnetic field'
			Total	**9**	

Question			Answers	Marks	Guidance
4	(a)		capacitance = charge/p.d. or capacitance = charge per (unit) p.d.	B1	**Allow**: voltage instead of p.d. **Note**: Do not allow mixture of quantity and unit, e.g. 'charge per (unit) volt'
	(b)	(i)	$C_{parallel}$ = 240 (μF) $C_T = (240 \times 120)/(240 + 120)$ or $C_T = (240^{-1} + 120^{-1})^{-1}$ total capacitance = 80 (μF)	C1 C1 A0	**Allow** :1 mark if C_T is not the subject, e.g: $\frac{1}{C_T} = \frac{1}{240} + \frac{1}{120}$
		(ii)	$E = \frac{1}{2}V^2C$ $E = \frac{1}{2} \times 6.0^2 \times 80 \times 10^{-6}$ energy = 1.4×10^{-3} (J) or 1.44×10^{-3} (J)	 C1 A1	Possible ecf **Allow**: 1 mark for an answer 1.44×10^n ($n \neq -3$)
		(iii)1	$6.0/e$ = 2.2 (V) (as on graph) Or 6.0×0.37 = 2.2 (V) (as on graph) Or At 20 (s), V = 2.2 (V), 2.2/6.0 = 0.37 (or e^{-1})	B1	**Allow**: Graph reading within ± 0.2 V
		(iii)2	CR = 20 $R = \frac{20}{80 \times 10^{-6}}$ $R = 2.5 \times 10^5$ (Ω)	C1 A1	**Allow**: Follow through with CR value from **(iii)1**
			Total	**8**	

Question			Answers	Marks	Guidance
5	(a)		Same charge / number of protons	B1	**Not**: 'same chemical property'
	(b)		strong (nuclear force / interaction) gravitational (force)	B1 B1	 **Allow**: 'gravity'
	(c)	(i)	${}^{15}_{7}\mathrm{N}$	B1	
		(ii)	(u d d) $\rightarrow$ (u u d)	B1	**Allow**: *One down quark becomes up quark* or d $\rightarrow$ u (+ electron + antineutrino)
	(d)	(i)	0.16 MeV = $0.16 \times 10^{6} \times 1.6 \times 10^{-19}$ $\frac{1}{2} \times 9.11 \times 10^{-31} \times v^{2} = 2.56 \times 10^{-14}$ speed = 2.4×10^{8} (m s^{-1}) or 2.37×10^{8} (m s^{-1})	C1 A1	 **Allow**: 1 mark for using 9.8 MeV; answer is equal to 1.86×10^{9} (m s^{-1})
		(ii)	The mass of the electron increases / greater than 'rest mass'	B1	
	(e)	(i)	$\lambda = 0.693/T$ $\lambda = 0.693/(5560 \times 3.16 \times 10^{7})$ $\lambda = 3.9 \times 10^{-12}$ (s^{-1}) or 3.94×10^{-12} (s^{-1})	 C1 A1	 **Allow**: 1 mark for 1.25×10^{-4} (if 5560 y used)
		(ii)	number = $\dfrac{1.0 \times 10^{-3}}{14} \times 6.02 \times 10^{23}$ number = 4.3×10^{19}	M1 A0	**Note**: This step must be seen to score 1 mark
		(iii)	activity = λN activity = $3.94 \times 10^{-12} \times 4.3 \times 10^{19}$ activity = 1.7×10^{8} (Bq) or 1.69×10^{8} (Bq)	 C1 A1	 Possible ecf from **(e)(i)** and **(e)(ii)**

Question			Answers	Marks	Guidance
	(f)		Any **three** from: 1. Plants / living things take in carbon(-dioxide) or plants / living things stop taking in carbon after death 2. The ratio of carbon-14 to carbon-12 (nuclei) for the relic sample is determined 3. The current ratio of carbon-14 to carbon-12 nuclei is determined 4. The age of the relic is found using '$x = x_0 e^{-\lambda t}$' Limitation: The ratio of carbon-14 to carbon-12 is assumed to be constant / count(-rate) from relic may be comparable to background count(-rate)	B1×3 B1	**Must use ticks on Scoris to show where the marks are awarded** **Allow**: Any other valid comment for the limitation
			Total	**17**	

Question			Answers	Marks	Guidance
6	(a)		(Minimum) energy to separate (all) nucleons / protons <u>and</u> neutrons (of a nucleus)	M1 A1	**Alternative**: B.E. = mass <u>defect</u> $\times c^2$ M1 mass defect = mass of nucleons – mass of nucleus A1
	(b)	(i)	BE of ^{2}H = $2 \times 1.8 \times 10^{-13}$ (J) or BE of ^{4}He = $4 \times 1.1 \times 10^{-12}$ (J) energy = $(4 \times 1.1 \times 10^{-12}) - 2 \times (2 \times 1.8 \times 10^{-13})$ energy = 3.68×10^{-12} (J) / 3.7×10^{-12} (J)	C1 C1 A0	**Note**: Ignore signs
		(ii)1	total surface area = $4\pi \times (1.5 \times 10^{11})^2$ power = $1400 \times (2.83 \times 10^{23})$ power = 3.96×10^{26} (W) / 4.0×10^{26} (W)	C1 C1 A0	
		(ii)2	number = $4.0 \times 10^{26}/3.7 \times 10^{-12}$ number = 1.1×10^{38} (s^{-1}) or 1.08×10^{38} (s^{-1})	C1 A1	**Allow**: 10^{38} (s^{-1}) because the question is about an estimate
			Total	**8**	

Question			Answers	Marks	Guidance
7	(a)		Any **two** from: 1. Electrons are accelerated through high voltage 2. (High speed) electron(s) hit metal 3. <u>kinetic</u> energy of electron(s) 'produces' X-ray (photons)	B1×2	**Allow**: X-rays are produced by (large) deceleration of electrons
	(b)	(i)	Packet /quantum of (electromagnetic) <u>energy</u>	B1	**Allow**: 'particle of (electromagnetic) <u>energy</u>'
		(ii)	$E = hc/\lambda$ <u>and</u> X-rays have shorter wavelength Or $E = hf$ <u>and</u> X-rays have higher frequency	B1	
	(c)		(KE of electron =) $1.6 \times 10^{-19} \times 120 \times 10^{3}$ $eV = \frac{hc}{\lambda}$ $1.6 \times 10^{-19} \times 120 \times 10^{3} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{\lambda}$ wavelength = 1.0×10^{-11} (m) or 1.04×10^{-11} (m)	C1 C1 A1	 **Allow**: 2 marks for $1.0(4) \times 10^{-n}$ (m) ($n \neq 11$ - powers of ten error) **Allow**: 1×10^{-11} (m)
	(d)		Compton (scattering) Incoming photon collides with an electron, the electron is ejected and the photon is scattered / has lower energy Or Pair production Incoming photon (disappears and) produces electron-positron pair	M1 A1 -------- M1 A1	**Must use ticks on Scoris to show where the marks are awarded** **Allow**: (Simple) scatter(ing) M1 The photon is absorbed and re-emitted without change in energy/wavelength/frequency A1
			Total	**9**	

Question			Answers	Marks	Guidance
8	(a)		No entry into body / no cutting/incision of patient / no surgery Lower risk of infection / less trauma	B1 B1	
	(b)		Radioactive substance that is ingested / injected (into patient) Technetium(-99m) / Iodine(-131) / fluorine(-18)	B1 B1	 **Not**: barium
	(c)		**Collimator** – gamma (ray photons) travel along the axis of lead tubes or allows parallel gamma (ray photons travel to the scintillator) Having thin / long / narrow (lead) tubes makes the image sharper / less blurred (**QWC mark**) **Scintillator** – gamma ray photon produces many/thousands of photons of (visible) light **Photomultiplier** - An electrical pulse is / electrons are produced from the light (photons) **Computer** – Signals (from photomultiplier tubes) are used to produce an image	B1 B1 B1 B1 B1	**Must use ticks on Scoris to show where the marks are awarded**
	(d)	(i)	$v = f\lambda$ $1500 = 2.0 \times 10^6 \times \lambda$ wavelength = 7.5×10^{-4} (m)	 C1 A1	
		(ii)	Ultrasound is reflected by (moving) blood (cells) The frequency / wavelength (of ultrasound) is changed (AW) The change of frequency is related to speed of blood / change of wavelength is related to speed of blood / 'Δfrequency $\propto$ speed of blood'	B1 B1 B1	**Must use ticks on Scoris to show where the marks are awarded** **Not**: Doppler effect mentioned
			Total	**14**	

Question			Answers	Marks	Guidance
9	(a)		Any <u>four</u> from: 1. (Sun / star formed from) dust cloud /nebula / (hydrogen) gas 2. <u>Gravitational</u> collapse (AW) 3. Temperature of (dust) cloud increases / KE (of cloud) increases / (cloud) heats up 4. Fusion occurs (when temperature is about 10^7 K) 5. Protons / hydrogen nuclei combine to make helium (nuclei) 6. Stable size star is produced when thermal / radiation pressure is equal to gravitational pressure Steps sequenced correctly – **QWC mark**	B1× 4 B1	**Must use ticks on Scoris to show where the marks are awarded**
	(b)		Any <u>two</u> from: 1. Very dense star 2. Hot star / high surface temperature / low luminosity 3. No fusion reactions take place / leaks away photons (from earlier fusion reactions) 4. Its collapse is prevented by Fermi pressure / mass less than 1.4 solar masses (AW)	B1×2	**Must use ticks on Scoris to show where the marks are awarded** **Not**: small in size, but <u>allow</u> 'smaller than main sequence star / Sun'
	(c)	(i)	Flat or universe will expand towards a (finite) limit or the rate of expansion will become/tend to zero	B1	
		(ii)	Hubble constant = 1/age $H_0 = 1/4.4\times10^{17} (= 2.273\times10^{-18}$ s^{-1}) density = $\dfrac{3H_0^2}{8\pi G}$ density = $\dfrac{3H_0^2}{8\pi G} = \dfrac{3\times(2.273\times10^{-18})^2}{8\pi\times6.67\times10^{-11}}$ density = 9.2×10^{-27} (kg m^{-3}) or 9.24×10^{-27} (kg m^{-3}) density is about 10^{-26} (kg m^{-3})	C1 C1 A1 A0	**Allow**: 2 marks for a bald 9.24×10^{-27} (kg m^{-3}) answer **Note**: This mark can only be scored if working is shown

Question			Answers	Marks	Guidance
		(iii)	number = $9.24 \times 10^{-27}/1.7 \times 10^{-27}$ number = 5.4 (Allow 5)	C1 A1	Possible ecf from **(c)(ii)** **Allow**: 2 marks for '$10^{-26}/1.7 \times 10^{-27}$ = 5.9 or 6'
	(d)		$\frac{1}{2}mv^2 = \frac{3}{2}kT$ / speed $\propto \sqrt{T}$ ratio = $\sqrt{\frac{10^8}{2.7}}$ ratio = 6.1×10^3 or 6.09×10^3	C1 A1	
			Total	**15**	

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RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE

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

Mark Scheme for June 2012

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Annotations

Annotation Available in Scoris	Meaning
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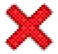	Incorrect response
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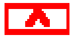
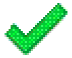
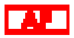
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error or ‘reading error’
	Error in number of significant figures
	Correct response
	Arithmetic error
	Wrong physics or equation

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( )	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

Subject-specific Marking Instructions

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:

Q2(d), Q6(b), Q7(d), Q8(a)(b), Q9(a)(b), Q10(c).

Note about significant figures:

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.

Question			Answer	Marks	Guidance
1	(a)		(farad = 1) coulomb per (unit) volt	B1	**Allow**: C V^{-1}
	(b)	(i)	1/C	B1	**Allow**: 'inverse of *C*'
		(ii)	work (done) / energy	B1	
	(c)		**Diagram**: All 3 capacitors connected in **series** $\frac{1}{C} = \frac{1}{100} + \frac{1}{200} + \frac{1}{500}$ / $\frac{1}{C} = 1.7 \times 10^{-2}$ capacitance = 59 (μF)	B1 C1 A1	**Note**: Correct symbol must be used for capacitor and at least one of the capacitance values (without the unit) must be shown **Allow**: Answer to 1 sf **Note**: Answer to 3sf is 58.8 (μF) **Allow**: 1.7×10^{-2} (μF) scores 1 mark from the C1A1
	(d)	(i)	$Q = 0.040 \times 60$ charge = 2.4 (C)	C1 A1	**Allow**: 1 mark for 2.4×10^{n}, $n \neq 0$ (POT error)
		(ii)	energy = $\frac{1}{2} \times \frac{2.4^2}{0.10}$ energy = 29 (J)	C1 A1	Possible ecf from **(d)(i)** **Note**: Answer to 3 sf is 28.8 (J) Allow full credit for correct use of ½ *VQ* or ½ V^2C; the final p.d is 24 (V)
			Total	**10**	

Question			Answer	Marks	Guidance
2	(a)	(i)	Correct direction of force at **A** (and marked **F**)	B1	
		(ii)	The force is perpendicular to velocity / motion (hence no work done on the electron) or No (component of) acceleration / force in direction of velocity / motion (hence no work done on electron) or No distance moved in the direction of the force	B1	
	(b)		$F = \frac{mv^2}{r}$ force = $\frac{9.11\times10^{-31}\times(6.0\times10^7)^2}{0.24}$ force = 1.4 × 10^{-14} (N)	C1 A1	**Note**: Answer to 3sf is 1.37 × 10^{-14} (N) **Allow**: 1 mark for 1.4 × 10^n; n ≠ -14 (POT error)
	(c)		$F = BQv$ $1.37\times10^{-14} = B\times1.60\times10^{-19}\times6.0\times10^7$ B = 1.4 × 10^{-3} (T)	C1 A1	Possible ecf from **(b)** **Note**: Answer to 3 sf is 1.43 × 10^{-3} (T) for 1.37 × 10^{-14} (N) **Note**: Using 1.4 × 10^{-14} (N) gives 1.46 ×10^{-3} (T) **Note**: Using $B = mv/Qr$ gives 1.42 × 10^{-3} (T)
	(d)		Using $(E =)mc^2$ and $(E =)\frac{hc}{\lambda}$ **(QWC)** $2\times mc^2 = 2\times\frac{hc}{\lambda}$ or $mc^2 = \frac{hc}{\lambda}$ or $mc = \frac{h}{\lambda}$ Correct substitution (any subject) λ = 2.4 × 10^{-12} (m)	B1 C1 A1	Eg: $2\times9.11\times10^{-31}\times(3.0\times10^8)^2 = 2\times\frac{6.63\times10^{-34}\times3.0\times10^8}{\lambda}$ Answer to 3 sf is 2.43 × 10^{-12} (m) **Allow**: 1 mark for 1.21 × 10^{-12} (m) or 4.86 × 10^{-12} (m) for the C1A1 marks
			Total	**9**	

Question			Answer	Marks	Guidance
3	(a)	(i)	$f = \frac{1}{T} = \frac{1}{10 \times 10^{-3}}$ frequency = 100 (Hz)	B1	
		(ii)	$2.0 \times 10^{-2} = B \times 1.6 \times 10^{-3} \times 400$ $B = \frac{2.0 \times 10^{-2}}{1.6 \times 10^{-3} \times 400}$ $B = 3.1 \times 10^{-2}$ (T)	C1 C1 A1	**Allow**: 2 mark for 3.1×10^{n}; $n \neq -2$ (POT error) Answer to 3 sf is 3.13×10^{-2} (T) **Special case**: 12.5 scores 1 mark; number of turns omitted
		(iii)	(e.m.f. = -) rate of change of flux <u>linkage</u> <u>Tangent</u> drawn on Fig. 3.1 at 2.5 (ms) or 7.5 (ms) or 12.5 (ms) Values substituted to determine the gradient. The gradient must be 12.5 ± 1.0 (V)	B1 B1 B1	**Allow**: $E = (-)\frac{\Delta(N\phi)}{\Delta t}$ or (e.m.f. =) gradient **Alternative**: maximum e.m.f. = $2\pi f \times$ maximum flux linkage C1 maximum e.m.f. = $2\pi \times 100 \times 2 \times 10^{-2}$ C1 maximum e.m.f. = 12.6 (V) or 4π (V) A1
	(b)		$P = \frac{V^2}{R}$ $P = \frac{12^2}{150}$ power = 0.96 (W)	 C1 A1	Possible ecf from **(a)(iii)**
			Total	**9**	

Question			Answer	Marks	Guidance
4	(a)		Any <u>two</u> from: 1. There is a repulsive (electrical) force (between the gold nucleus and the alpha particle) 2. Momentum is conserved (because there are no external forces) / initial momentum of alpha particle = final momentum of gold nucleus (because there are no external forces) 3. KE of alpha particle transformed into (electrical) PE	B1×2	**Allow**: (The gold nucleus and alpha particle experience) forces in opposite directions
	(b)		Correct directions of field shown on lines from **A** and **B** Correct curved field lines from **A** and **B**	B1 B1	
	(c)		$F = \dfrac{Qq}{4\pi\varepsilon_0 r^2}$ $Q = 79e$ and $q = 2e$ force = $\dfrac{79 \times 2 \times (1.60 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12} \times (6.0 \times 10^{-14})^2}$ force = 10.1 (N)	C1 C1 C1 A0	 **All** values must be substituted for this mark
	(d)		Correctly shaped curve with F decreasing as r increases Value of F is between 2 to 3 (N) at $r = 12 \times 10^{-14}$ m	M1 A1	 **Note**: $F \propto 1/r^2$, hence F should be about 2.5 (N)
			Total	**9**	

Question			Answer	Marks	Guidance
5	(a)		no: of neutrons = 142	B1	
	(b)	(i)	(5.6 MeV =) 5.6 × $\underline{10^{6}}$ × $\underline{1.6 \times 10^{-19}}$ energy = 8.96 × 10^{-13} (J)	M1 A0	**Allow**: 5.6 × $\underline{1.6 \times 10^{-13}}$
		(ii)	$\frac{1}{2} \times 6.65 \times 10^{-27} \times v^{2} = 8.96 \times 10^{-13}$ $v = \sqrt{\frac{2 \times 8.96 \times 10^{-13}}{6.65 \times 10^{-27}}}$ speed = 1.6 × 10^{7} (m s^{-1})	C1 A1	Answer to 3 sf is 1.64 × 10^{7} (m s^{-1}) **Note**: The answer is 1.65 × 10^{7} (m s^{-1}) if 9 × 10^{-13} (J) is used
	(c)	(i)	activity = $\frac{62}{8.96 \times 10^{-13}}$ activity = 6.92 × 10^{13} (Bq)	C1 A0	**Allow**: activity = $\frac{62}{9 \times 10^{-13}}$ (= 6.89 × 10^{13} Bq) Possible ecf from **(b)(i)**
		(ii)	$\lambda = \frac{0.693}{T}$ $\lambda = \frac{0.693}{88 \times 3.16 \times 10^{7}}$ decay constant = 2.49 × 10^{-10} (s^{-1}) or 2.5 × 10^{-10} (s^{-1})	C1 A1	**Note**: ln2 = 0.693 **Allow**: 1 mark for using 88 years and getting an answer of 7.9 × 10^{-3}
		(iii)	**1** $A = \lambda N$ $N = \frac{6.92 \times 10^{13}}{2.49 \times 10^{-10}}$ number =2.78 × 10^{23} or 2.8 × 10^{23} **2** mass = $\frac{2.78 \times 10^{23}}{6.02 \times 10^{23}} \times 0.24$ mass = 0.11 (kg)	C1 A1 B1	Possible ecf from **(c)(ii)** **Note**: '7 × 10^{13}/2.5 × 10^{-10} = 2.8 × 10^{23}' Possible ecf for mass from incorrect value for number of nuclei
			Total	**10**	

Question			Answer	Marks	Guidance
6	(a)		The neutrons interact with other uranium (nuclei) / the neutrons cause further (fission) reactions	B1	**Not**: neutrons interact with uranium <u>atoms</u> / <u>molecules</u> / <u>particles</u>
	(b)		**Fuel rod**: Contain the <u>uranium</u> (nuclei) / fissile material **Control rods**: Absorb (some of the) neutrons *Controlled chain reaction*: The control rods are inserted into the reactor so as to allow (on average) one neutron from previous reaction to cause subsequent fission (AW) **Moderator**: Slows down the (fast-moving) neutrons / lowers the KE of (fast moving) neutrons / makes the (fast moving) neutrons into thermal neutrons Slow moving neutrons have a greater chance of causing fission / of being absorbed (by U-235) / sustaining chain reaction	B1 B1 B1 B1 B1	**Show annotation on Scoris** **Not** 'contains fuel' **QWC mark** **Allow**: Fast moving neutrons are captured (easily) by uranium-238 (nuclei leaving insufficient number of nuclei for fission / chain reaction) for the last B1 mark
	(c)	(i)	power = $3.0 \times 10^9/0.22$ power = 1.36×10^{10} (W) or 1.4×10^{10} (W)	B1	
		(ii)	energy = $1.36 \times 10^{10} \times 8.64 \times 10^4$ energy = 1.18×10^{15} (J) or 1.2×10^{15} (J)	B1	Possible ecf from **(c)(i)**
		(iii)	(number of reactions per day) = $\dfrac{1.18\times10^{15}}{3.2\times10^{-11}}$ mass = $\dfrac{1.18\times10^{15}}{3.2\times10^{-11}}\times3.9\times10^{-25}$ mass = 14.4 (kg) or 14 (kg)	C1 A1	Possible ecf from **(c)(ii)** **Note**: Using 1.2×10^{15} (J) gives an answer of 14.6 (kg); allow 15 (kg)
	(d)		Nuclear waste is (radio)active for a long time (AW) Causes ionisation	B1 B1	**Allow**: '*Nuclear waste can have long* half *life'*
			Total	**12**	

Question			Answer	Marks	Guidance
7	(a)		Any <u>two</u> from: (X-rays) are EM waves Travel at speed of light / 3×10^8 <u>m s^{-1}</u> (in a vacuum) Travel in a vacuum / empty space Transverse waves Can cause ionisation Have wavelength of about 10^{-10} <u>m</u> (X-rays are high energy) photons (AW)	B1×2	**Allow**: reference to diffraction / interference / refraction / reflection / polarisation for 1 mark
	(b)		(X-ray) <u>photon</u> interacts with an (orbital) <u>electron</u> The (scattered) photon has a longer wavelength / lower frequency / lower energy **AND** The electron is ejected (from the atom at high speed)	B1 B1	 **Allow**: 'X-rays' instead of 'photons' for the second B1 mark
	(c)	(i)	Initial / original / incident <u>intensity</u>	B1	**Allow**: Initial / original / incident <u>power</u> <u>per</u> (unit) <u>area</u>
		(ii)	$0.5 = e^{-(3.3x)}$ $\ln(0.5) = -3.3x$ $x = \ln(0.5)/(-3.3)$ $x = 0.21$ (cm)	C1 C1 A1	 **Allow**: $\ln(2) = 3.3x$ **Allow**: 2 marks for 2.1×10^n; $n \neq -1$ (POT error)
	(d)		A contrast material has large attenuation coefficient / large atomic number / large Z (and hence easily absorbs X-rays) Idea of revealing tissue	B1 B1	
			Total	**10**	

Question			Answer	Marks	Guidance
8	(a)		Any <u>seven</u> from: 1. Protons / nuclei have spin / behave like (tiny) magnets 2. Protons / nuclei precess about the magnetic field (provided by the strong electromagnet) 3. Transmitting coils provide (pulses of) radio waves of frequency equal to the Larmor frequency 4. The protons / nuclei absorb energy / radio waves / resonate and flip into a higher energy state 5. When protons / nuclei flip back to a lower energy state they emit (photons of) radio waves 6. The relaxation time (of the protons/nuclei) depends on the (surrounding) tissues 7. The radio waves are picked up by the receiving coils 8. The gradient coils alter the magnetic flux density (through the body) 9. The Larmor frequency (of the protons / nuclei) varies through the body 10. The computer (processes all the signals from the receiving coils and) generates the image(s)	B1 × 7	**Show annotation on Scoris** **Not**: Atoms / particles for nuclei /protons. **Allow**: The protons / nuclei absorb energy / radio waves / resonate and get excited **Allow**: When protons / nuclei relax they emit (photons of) radio waves
	(b)		Ay <u>two</u> from: 1. PET scan: uses radioactive substance / uses positron-emitting substance / uses F(-18) / mention of gamma rays / mention of gamma photons 2. PET scan reveal the 'function' of the brain (AW) 3. MRI scan show variation in tissues (in the brain) (AW)	B1×2	**Allow**: MRI scan: no radioactive substance is required / mention of radio waves **Allow**: PET scans are used to diagnose dyslexia / Alzheimer (disease)
			Total	**9**	

Question			Answer	Marks	Guidance
9	(a)		Any four from: 1. (Fusion is the) joining / fusing together of ('lighter') nuclei / protons (to make 'heavier' nuclei) 2. Mass decreases in the reaction and this is transformed into energy OR the products have greater binding energy 3. High temperatures / ~10^7 K needed for fusion 4. High pressure / density (required in the core) 5. The protons / nuclei repel (each other because of their positive charge) 6. The strong (nuclear) force comes into play when the protons / nuclei are close to each other	B1×4	**Not**: Atoms / particles for nuclei /protons.
	(b)		(When hydrogen / helium runs out) the outer layers of the star expands / a (super) red giant is formed The core (of the star) collapses (rapidly) / a supernova is formed (Depending on the initial mass of the star the remnant is either a) neutron star or a black hole	B1 B1 B1	
			Total	**7**	

Question			Answer	Marks	Guidance
10	(a)		$F = \dfrac{GMm}{r^2}$ force = $\dfrac{6.67\times10^{-11}\times(10^{41})^2}{(4\times10^{22})^2}$ force = 4.2×10^{26} (N)	C1 C1 A1	**Allow**: 4×10^{26} (N) or 10^{26} since this is an estimation **Allow**: 2 marks for 4.2×10^{n}; $n \neq 26$ (POT error)
	(b)		Allow any <u>one</u> from: • The galaxies are receding / moving away from each other (because of the big bang) • Other galaxies may be pulling them in opposite direction • The acceleration is too small to collapse (other than over a very long period of time)	B1	
	(c)		Any <u>six</u> from: 1. (At the start it was) very hot / extremely dense / singularity 2. All forces were unified 3. Expansion led to cooling 4. Quarks / leptons (soup) 5. More matter than antimatter 6. Quarks combine to form hadrons / protons / neutrons 7. Imbalance of neutrons and protons / (primordial) helium produced 8. Atoms formed 9. Idea of gravitational force responsible for formation of stars / galaxies 10. Temperature becomes 2.7 K / 3 K or (the universe is saturated with cosmic) microwave background radiation	B1×6	**Show annotation on Scoris**
	(d)	(i)	Dark lines / bands against a background of <u>continuous</u> <u>spectrum</u>	M1 A1	

Question			Answer	Marks	Guidance
		(ii)	$\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$ speed = $\frac{86.6}{393.4} \times 3.0 \times 10^8$ (Any subject) speed = 6.6×10^7 (m s^{-1}) or 66000 (km s^{-1}) $v = H_0 d$ $66000 = 50 \times d$ distance = 1300 (Mpc)	C1 C1 A1	**Allow**: 1 mark for $\frac{86.6}{480.0} \times 3.0 \times 10^8 = 5.41 \times 10^7$ (m s^{-1}) **Allow**: 2 marks for 1.3×10^n; $n \neq 3$ (POT error) **Note**: Answer is 1080 (Mpc) if 5.4×10^7 (m s^{-1}) is used; this value will score 2 marks
			Total	**15**	

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PART OF THE CAMBRIDGE ASSESSMENT GROUP

RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE

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

Mark Scheme for January 2013

Annotations

The following annotations are available on the marking scheme:

/	=	alternative and acceptable answers for the same marking point
(1)	=	separates marking points
allow	=	answers that can be accepted
not	=	answers which are not worthy of credit
reject	=	answers which are not worthy of credit
ignore	=	statements which are irrelevant
( )	=	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

The following annotations are available in SCORIS.

Annotation	**Meaning**
✓	correct response
✗	incorrect response
AE	arithmetic error
BOD	benefit of the doubt (where professional judgement has been used)
NBOD	benefit of the doubt **<u>not</u>** given
ECF	error carried forward
^	information omitted
CON	contradiction (in cases where candidates contradict themselves in the same response)

Annotation	**Meaning**
	rounding error
	error in the number of significant figures
	error in the power of 10 in a calculation
	wrong physics or equation
	not answered question
	follow through

Highlighting is also available to highlight any particular points on the script.

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:
Q5(e), 6(d), 7(a), 8(a) and Q9(a)

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)	Any <u>two</u> from: Correct direction of movement of electrons Electrons deposited on **Y** / removed from **X** An equal number of electrons removed and deposited on plates (AW)	B1 × 2	
		(ii)1	$Q = 40 \times 10^{-6} \times 100$ (= 4.0×10^{-3} C) $4.0 \times 10^{-3} = 1.6 \times C$ $C = 2.5 \times 10^{-3}$ (F)	C1 C1 A1	**Allow**: 2 marks for 2.5×10^{n} (F), where $n \neq -3$ (POT error)
		(ii)2	Graph starts at <u>origin</u> and has positive gradient A straight line graph that passes between 1-2 V at 100 s	M1 A1	
	(b)	(i)	$CR = 4.7 \times 10^{-6} \times 220$ (= 1.03×10^{-3} s) $4.00 = 6.00e^{-\frac{t}{1.03\times10^{-3}}}$ $t = -\ln(4.00/6.00) \times 1.03 \times 10^{-3}$ time = 4.2×10^{-4} (s)	C1 C1 A1	**Note**: Answer to 3 sf is 4.19×10^{-4} (s) **Allow**: 2 marks for $t = -lg(4.00/6.00) \times 1.03 \times 10^{-3} = 1.8 \times 10^{-4}$ s
		(ii)	speed = $\dfrac{0.100}{4.2 \times 10^{-4}}$ speed = 240 (m s^{-1})	B1	Possible ecf from **(b)(i)**
			Total	**11**	

Question			Answer	Marks	Guidance
2	(a)		force per unit (positive) charge	B1	**Allow**: $E = \dfrac{F}{Q}$, where F = force on (a positive) charge Q
	(b)	(i)	The direction is different (AW)	B1	
		(ii)	$E \propto 1/r^2$ or distance is doubled $\therefore$ E decreases by a factor of 4 electric field strength = 2.0×10^5 (N C^{-1})	C1 A1	**Not**: $E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$ on its own **Allow** 1 sf answer
	(c)	(i)	$F = \dfrac{Qq}{4\pi\varepsilon_0 r^2}$ $F_E = \dfrac{1.6\times10^{-19}\times1.6\times10^{-19}}{4\pi\varepsilon_0\times(5.0\times10^{-11})^2}$ $F_E = 9.2 \times 10^{-8}$ (N)	C1 C1 A1	**Allow**: 1 mark if $Q = q = 1$ giving an answer of 3.6×10^{30} (N)
		(ii)	$F_G = \dfrac{6.67\times10^{-11}\times1.67\times10^{-27}\times9.11\times10^{-31}}{(5.0\times10^{-11})^2}$ $F_G = 4.06 \times 10^{-47}$ (N) ratio = $9.2 \times 10^{-8}/4.06 \times 10^{-47}$ ratio = 2.3×10^{39}	C1 A1	**Note**: Deduct 1 mark if mass of two electrons or two protons is used, then ecf Possible ecf from **(c)(i)**
		(iii)1	wavelength = 2.0×10^{-10} (m) $\lambda = h/mv$ $p = \dfrac{6.63\times10^{-34}}{2.0\times10^{-10}}$ $p = 3.3 \times 10^{-24}$ (kg m s^{-1})	C1 C1 A1	Possible ecf for incorrect wavelength **Note**: Answer to 3 sf is 3.32×10^{-24} (kg m s^{-1}) **Allow**: 1 sf answer

Question			Answer	Marks	Guidance
		(iii)2			Possible ecf from **(iii)1**
			$v = \dfrac{3.32\times10^{-24}}{9.11\times10^{-31}}$ (= 3.64×10^{6} m s^{-1})	C1	**Note**: Deduct 1 mark if mass of proton is used, then ecf
			$E_k = ½ \times 9.11 \times 10^{-31} \times (3.64 \times 10^{6})^2$	C1	
			$E_k = 6.0 \times 10^{-18}$ (J)	A1	**Note**: Answer to 3 sf is 6.05×10^{-18} (J) **Allow**: 1 sf answer
			or		
			$E_k = ½\, p^2/m$	C1	**Note**: Deduct 1 mark if mass of proton is used, then ecf
			$E_k = ½ \times (3.32 \times 10^{-24})^2/9.11 \times 10^{-31}$	C1	
			$E_k = 6.0 \times 10^{-18}$ (J)	A1	
			Total	**15**	

Question			Answer	Marks	Guidance
3	(a)		(Fleming's) left-hand rule	B1	
	(b)		The force is at right angles to the velocity (hence no work is done on the ions) / no (component of) force in the direction of motion / no (component of) acceleration in the direction of motion (AW)	B1	**Allow**: 'force is right angles to the motion'
	(c)	(i)	$F = \frac{mv^2}{r}$ force = $\frac{1.2 \times 10^{-26} \times (4.0 \times 10^5)^2}{0.15}$ force = 1.3×10^{-14} (N)	 C1 A1	 **Note**: Answer to 3 sf is 1.28×10^{-14} (N)
		(ii)	$F = BQv$ $1.28 \times 10^{-14} = B \times 1.6 \times 10^{-19} \times 4.0 \times 10^5$ $B = 0.20$ (T)	C1 A1	Possible ecf from **(c)(i)** **Allow**: 1 sf answer of 0.2 (T)
		(iii)	number per second = $\frac{4.8 \times 10^{-9}}{1.6 \times 10^{-19}}$ number per second = 3.0×10^{10} (s^{-1})	C1 A1	 **Allow**: 1 sf answer of 3×10^{10} (s^{-1})
	(d)		(height is smaller) hence less abundance (than lithium-7) position suggests that the ions are less massive / lighter fewer neutrons (than lithium-7)	B1 B1	**Allow**: fewer / less (than lithium-7)
			Total	**10**	

Question			Answer	Marks	Guidance
4	(a)	(i)	momentum / mass-energy / charge / proton number / baryon number / nucleon number	B1	**Not**: 'energy' on its own
		(ii)	Some basic labelling of neutron(s), Xe and Sr Correct extension of diagram showing at least one of the neutrons interacting with <u>U-235</u> nucleus and producing neutron(s) and 'fragments'	B1 B1	
	(b)	(i)	initial $m = 6.686 \times 10^{-27}$ (kg) or final $m = 6.681 \times 10^{-27}$ (kg) or $\Delta m = 0.005 \times 10^{-27}$ (kg) $\Delta E = 0.005 \times 10^{-27} \times (3.0 \times 10^8)^2$ energy = 4.5×10^{-13} (J)	C1 C1 A1	
		(ii)	kinetic (energy)	B1	**Not**: heat / sound **Allow**: (gamma) photons / EM radiation
		(iii)	KE = $\frac{3}{2}kT$ KE = $\frac{3}{2} \times 1.38 \times 10^{-23} \times 10^9$ KE = 2.1×10^{-14} (J)	C1 A1	**Allow**: 1 sf answer or 10^{-14} (J) because the temperature is given as 10^9 K
		(iv)	Some nuclei will have KE greater than the mean KE (and hence cause fusion) (AW)	B1	
			Total	**10**	

Question			Answer	Marks	Guidance
5	(a)		$\lambda = \dfrac{0.693}{6.6\times10^{3}}$ or $\lambda = \dfrac{\ln 2}{6.6\times10^{3}}$	C1	
			decay constant = 1.1×10^{-4} (s^{-1})	A1	**Note**: Answer to 3sf is 1.05×10^{-4} (s^{-1})
	(b)		$A = \lambda N$ $N = \dfrac{250\times10^{6}}{1.05\times10^{-4}}$	C1	Possible ecf from **(a)**
			number = 2.38×10^{12} or 2.4×10^{12}	A0	**Allow** full credit for bald 2.4×10^{12}
	(c)		mass of F-18 = $\dfrac{2.38\times10^{12}}{6.02\times10^{23}}\times0.018$ (= 7.116×10^{-14} kg)	C1	Possible ecf from **(b)**
			mass of FDG= $7.116\times10^{-14}/0.099$	C1	
			mass of FDG = 7.2×10^{-13} (kg)	A1	**Allow** full credit for using 2×10^{12}; answer is 6.04×10^{-13} (kg)
	(d)		$A = 250\times e^{-(1.05\times10^{-4}\times20\times60)}$	C1	
			activity = 220 (MBq)	A1	Possible ecf from **(a)** **Allow**: 1 mark for 249 (MBq); factor of 60 omitted
	(e)		(FDG/positron-emitting substance is injected into the patient) Any <u>three</u> from: 1. Annihilation of electron and positron 2. Positron-electron annihilation produces <u>two</u> gamma photons 3. The gamma photons travels in opposite directions 4. The patient is surrounded by (a ring of) gamma detectors 5. A 3-D image is created (using the detector-signals with the aid of computer software)	B1 × 3	**Allow**: rays / waves instead of photons in 2 and 3
			QWC: The arrival times / delay times of the photons (at diametrically opposite detectors) are used to pinpoint areas of increased activity (AW)	B1	
			Total	**12**	

Question			Answer	Marks	Guidance
6	(a)		(Fast-moving) electrons hit a metal / an anode The kinetic energy of the electrons is transferred into X-rays / photons / EM waves	B1 B1	**Allow**: (X-rays are produced by large) deceleration of electrons
	(b)		An X-ray photon interacts an electron (within the atom) The electron is ejected and the energy / frequency of the (scattered) photon is reduced	B1 B1	**Allow**: The electron is ejected and the wavelength of the (scattered) photon is increased
	(c)	(i)	$I = I_0 e^{-\mu x}$ $I = 3.0 \times 10^9 \times e^{-(6.5 \times 1.7)}$ intensity = 4.8×10^4 (W m^{-2})	C1 C1 A0	
		(ii)	power of beam = $4.8 \times 10^4 \times 5.0 \times 10^{-6}$ (= 0.24 W) power absorbed by tumour = 0.24/10 = 0.024 (W) time = 200/0.024 time = 8.3×10^3 (s)	C1 C1 A1	Possible ecf from **(c)(i)** **Allow**: 2 marks for 8.3×10^2 (s) if 10% is omitted **Note**: Using 5×10^4 (W m^{-2}) gives an answer of 8000 (s)
	(d)		X-ray beam passes through the patient at different angles / X-ray tube rotates around the patient A <u>thin</u> fan-shaped beam is used (AW) Images of 'slices' through the patient (in one plane are produced with the help of computer software) X-ray tube / detectors are moved along (the patient for the next slice through the patient) Advantage: 3D image / better contrast between different (soft) tissues	B1 B1 B1 B1 B1	
			Total	**14**	

Question			Answer	Marks	Guidance
7	(a)		Any <u>six</u> from: 1. Protons / nuclei have spin or they behave like (tiny) magnets 2. Protons precess around the magnetic field (provided by the strong electromagnet) 3. The frequency of precession is known as the *Larmor frequency* 4. (Transmitting) coils provide (pulses of) radio waves (of frequency equal to the Larmor frequency) 5. The protons absorb energy (from the radio waves) / resonate and enter into a high energy state (AW) 6. When protons return back to their low energy state and they emit (photons of) radio waves 7. The *relaxation time* is the (average) time taken for the protons to return back to their normal / low energy state 8. The relaxation time depends on the tissues (A computer processes all the signals from the receiving coils and with the help of computer software generates a 3D image)	B1 × 6	**Not**: Atoms / particles **Note**: Must have reference to radio (waves) in 4 and 6 **Allow** 'excited' for 'high-energy state' **Allow**: Relaxing protons emit radio waves
	(b)		Disadvantage: Patient with metallic objects cannot be scanned / patient has to remain still (for a long time) / confined space / difficult for patient suffering from claustrophobia / or another suitable suggestion Advantage: Non-ionising /non invasive / better contrast (between soft tissues) / or another suitable suggestion	B1 B1	**Not** '3 D image' because it is given in **(a)**
			Total	**8**	

Question			Answer	Marks	Guidance
8	(a)		Any <u>three</u> from: 1. (Interstellar dust and gas) cloud is drawn together by gravitational force / gravity 2. Loss in (gravitational) PE / KE increases / temperature increases 3. Fusion (of protons / hydrogen nuclei) takes place 4. Energy is released in fusion reactions 5. A stable star is formed when gravitational pressure is equal to internal / gas / radiation pressure QWC: The steps in the process are correctly sequenced	B1 × 3 B1	**Allow**: 'gravitational collapse'
	(b)	(i)	Any <u>two</u> from: • (extremely) dense / (very) hot / low luminosity • no fusion reactions occur • it is a remnant of a low-mass star • correct reference to Fermi pressure / electron degeneracy / Chandrasekhar's limit	B1 × 2	
		(ii)	Red giant identified (It is cooler but has) large <u>surface</u> area (and therefore radiates large amounts of energy)	B1 B1	
			Total	**8**	

Question			Answer	Marks	Guidance
9	(a)		The night sky should be bright / have uniform brightness (but it is not) The line of sight ends on (the surface of a star) or 'number of stars $\propto r^2$ and intensity $\propto 1/r^2$' Any <u>two</u> assumptions about the Universe: Infinite / uniformly distributed matter or stars throughout / static / infinite age	B1 B1 B1	
	(b)		(recessional) speed of <u>galaxy</u> $\propto$ its distance (from the Earth) The universe is finite / it is expanding / it has a beginning / visible light is red-shifted (because of expansion of space) (AW)	B1 B1	**Allow**: $v = H_0 x$, v = (recessional) speed of galaxy, x = distance and H_0 is Hubble constant / a constant
	(c)	(i)	$v = H_0 x$ $3.4\times10^7 = H_0 \times 1.4\times10^{25}$ $H_0 = 2.4 \times 10^{-18}$ unit: s^{-1}	C1 A1 B1	**Note**: This is an independent mark **Note**: Allow full credit for an Hubble constant of 75 with unit km s^{-1} Mpc^{-1}
		(ii)1	age = $\dfrac{1}{2.4\times10^{-18}}$ age = 4.17×10^{17} (s) age = 1.3×10^{10} (years)	C1 A1	Possible ecf from **(i)**
		(ii)2	distance = $4.17 \times 10^{17} \times 3.0 \times 10^8$ (= 1.25×10^{26} m) distance = $\dfrac{4.17\times10^{17}\times3.0\times10^8}{3.1\times10^{16}}$ distance = 4.0×10^9 (pc)	C1 A1	Possible ecf from **(ii)1**
			Total	**12**	

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RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE

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

Mark Scheme for June 2013

Oxford Cambridge and RSA Examinations

Annotations

The following annotations are available on SCORIS.

Annotation	Meaning
✓	correct response
×	incorrect response
AE	arithmetic error
BOD	benefit of the doubt (where professional judgement has been used)
NBOD	benefit of the doubt **not** given
ECF	error carried forward
^	information omitted
CON	contradiction (in cases where candidates contradict themselves in the same response)
RE	rounding error
SF	error in the number of significant figures
POT	error in the power of 10 in a calculation
?	wrong physics or equation
NAQ	not answered question
FT	follow through

The following annotations are available on the marking scheme:

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	separates marking points
allow	answers that can be accepted
not	answers which are not worthy of credit
reject	answers which are not worthy of credit
ignore	statements which are irrelevant
( )	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

Subject-specific Marking Instructions
One tick per mark. All questions must have appropriate annotation.

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)		Series branch: Using $(100^{-1} + 300^{-1})^{-1}$ and C = 75 (μF) capacitance = 500 + 75 capacitance = 575 (μF)	C1 A1	 Possible ecf, if capacitance of series branch is incorrect
	(b)	(i)	**Time constant method:** 37% of 6.0 V is 2.2 V. The time taken to reach 2.2 V is equal to the time constant time constant = 60 (s) / CR = 60 (s) $500 \times 10^{-6} \times R = 60$ $R = \frac{60}{500 \times 10^{-6}}$ resistance = 1.2×10^5 (Ω) **Substitution method:** Correct values for p.ds and t substituted into $V = V_0 e^{-\frac{t}{CR}}$ Correct values substituted into $\ln(V/V_0) = -\frac{t}{CR}$ resistance = 1.2×10^5 (Ω)	 C1 C1 A1 C1 C1 A1	**Note**: Allow full credit for other correct methods **Allow**: time constant in the range 58 s to 62 s Deduct 1 mark for misreading graph followed by ecf **Note**: If C value from **(a)** is used, then deduct 1 mark followed by ecf **Eg**: $2.2 = 6.0e^{-\frac{60}{CR}}$ - values read to ± 1 small square **Eg:** $\ln(2.2/6.0) = -\frac{60}{500 \times 10^{-6} \times R}$ **Note**: If C value from **(a)** is used, then deduct 1 mark followed by ecf. Using 575 (μF) gives 1.04×10^5 (Ω)
		(ii)	Correct p.ds from graph: 6 (V) and 3.6 (V) $\frac{1}{2} \times 500 \times 10^{-6} \times 6.0^2$ or $\frac{1}{2} \times 500 \times 10^{-6} \times 3.6^2$ energy is 9.00×10^{-3} (J) and 3.24×10^{-3} (J) energy lost = 5.76×10^{-3} (J) or 5.8×10^{-3} (J)	C1 C1 A1	**Allow** V value to be in the range 3.5 V to 3.7 at 30s **Note**: Do not penalise 10^n error from **(b)(ii)** again here **Allow** 1 mark for: $\frac{1}{2} \times 500 \times 10^{-6} \times (6.0 - 3.6)^2 = 1.44 \times 10^{-3}$ (J) **Note**: Do not penalise use of 575 μF again. This gives a value of 6.62×10^{-3} (J)
			Total	**8**	

Question			Answer	Marks	Guidance
2	(a)		number = $\frac{2.8\times10^{-9}}{1.6\times10^{-19}}$ number = 1.75×10^{10} or 1.8×10^{10}	B1	Ignore a negative sign
	(b)		$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$ $F = \frac{2.8\times10^{-9}\times2.8\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(2.0\times10^{-2})^2}$ force = 1.76×10^{-4} (N) or 1.8×10^{-4} (N)	C1 A1	**Note**: No credit for using charge equal to *e*
	(c)	(i)	Tension <u>and</u> weight	B1	**Allow**: force provided by the <u>string</u> / force in the <u>string</u> instead of tension **Not**: 'gravity' for weight **Allow**: force due to gravity **Allow**: gravitational (force)
		(ii)	(weight =) $6.5 \times 10^{-5} \times g$ $\tan\theta = 1.76 \times 10^{-4}/6.38 \times 10^{-4}$ $\theta = 15°$ Or Scale drawing of triangle of force θ in the range 13° to 18° θ in the range 14° to 16°	C1 C1 A1 C1 A1 A1	Deduct 1 mark for the use of 10 (m s^{-2}) followed by ecf **Note** that getting to this stage scores both C1 marks Possible ecf from **(b)** **Note**: No marks if mass is used instead of the weight
			Total	**7**	

Question			Answer	Marks	Guidance
3	(a)		Arrow to the left	B1	
	(b)	(i)	1500 (eV)	B1	**Note**: 2.4×10^{-16} (J) on the answer line scores zero
		(ii)	(KE =) $1500 \times 1.6 \times 10^{-19}$ (= 2.4×10^{-16} J) $2.4 \times 10^{-16} = \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$ (Allow any subject) $v = 2.3 \times 10^7$ (m s^{-1})	C1 C1 A1	Possible ecf from **(b)(i)** **Allow**: 2 marks for 5.3×10^{14} (answer not square-rooted) **Note**: $v = \sqrt{\frac{2 \times 1500}{9.11 \times 10^{-31}}} = 5.74 \times 10^{16}$ (m s^{-1}) does not score
	(c)	(i)	$F_{(E)} = Eq$ and $F_{(M)} = Bqv$ $Eq = Bqv$ (This mark is for equating the two equations) (Hence) $v = \frac{E}{B}$	 M1 A1	 **Allow** an equivalent approach **Allow** any subject
		(ii)	Force due to magnetic field > force due to electric field Electrons drift 'downwards'	B1 B1	**Allow**: magnetic force > electric force or $F_M > F_E$ or $Bqv > Eq$ or magnetic force is bigger <u>and</u> electric force is the same **Note**: This mark can be scored on Fig. 3.2
			Total	**9**	

Question			Answer	Marks	Guidance
4	(a)		magnetic flux = magnetic flux density × area <u>normal</u> to the field	B1	**Allow**: $\phi = BA$, with terms defined; B = magnetic flux density or magnetic field strength and A = area <u>normal</u> to the field **Note**: If angle is used in the definition then it must be defined correctly
	(b)	(i)	$R = \dfrac{1.7\times10^{-8}\times130}{\pi\times(4.6\times10^{-4})^2}$ (Any subject) R = 3.3(2) (Ω) current = $\dfrac{24}{3.32}$ current = 7.2 (A)	C1 C1 A1	**Allow**: Possible ecf if value for R is incorrect after attempted use of the equation $R = \dfrac{\rho L}{\pi r^2}$.
		(ii)	e.m.f. = rate of change of magnetic flux linkage (initial ϕ =) 0.090 × 1.3 × 10^{-3} or 1.17 × 10^{-4} 150 = $\dfrac{1100\times0.090\times1.3\times10^{-3}}{t}$ (Any subject) time = 8.6 × 10^{-4} (s)	 C1 C1 A1	 **Allow**: (initial $N\phi$ =) 0.090 × 1.3 × 10^{-3} × 1100 or 0.129 **Allow**: 2 marks for 7.8 × 10^{-7} (s) if 1100 turns omitted
			Total	**7**	

Question			Answer	Marks	Guidance
5	(a)	(i)	Any number in the range: 10^4 to 10^5	B1	
		(ii)1	$10^{-14} = \frac{h}{mv}$ momentum = $\frac{6.63 \times 10^{-34}}{10^{-14}}$ momentum = 6.6×10^{-20} (kg m s^{-1})	C1 A1	**Allow** 1 sf answer of 7×10^{-20} (kg m s^{-1})
		(ii)2	The mass of the electron is greater (than its rest mass / 9.11×10^{-31} kg)	B1	**Allow**: Dividing (momentum) by 9.11×10^{-31} (kg) would give a speed of 7.3×10^{10} (m s^{-1}) which is greater than the speed of light / *c* (this is not possible) (AW)
	(b)	(i)	Different number of <u>neutrons</u>	B1	**Not**: different number of nucleons / different mass number / different A
		(ii)	u u d	B1	
		(iii)	u $\rightarrow$ d + positron + neutrino	M1 A1	**Allow**: u u d $\rightarrow$ u d d **Allow**: symbols for positron (e^+ / β^+ / ${}^{0}_{+1}e$) and neutrino (υ) **Allow** full marks for an answer in words **Allow** 1 mark for p $\rightarrow$ n + e^+ + υ
		(iv)	Any <u>two</u> from: charge or proton number / momentum / mass-energy / nucleon number / lepton number / strangeness / baryon number / spin	B1	**Not**: <u>mass</u> on its own or <u>energy</u> on its own, but **allow** mass <u>and</u> energy
		(v)	β^+ when there are fewer neutrons / β^+ for lighter nuclei or β^- when there are more neutrons / β^- for heavier nuclei	B1	**Allow**: Alternative correct answers in terms of ratio of protons to neutrons
			Total	**10**	

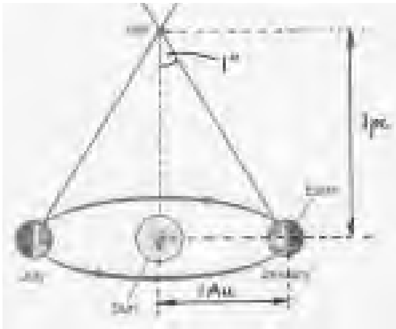
Question			Answer	Marks	Guidance
6	(a)		Impossible to predict when a <u>nucleus</u> will decay or impossible to predict which <u>nucleus</u> will decay	B1	
	(b)		$N = N_0 e^{-\lambda t}$ (λ =) 0.693/7.1 $\times 10^8$ $\lambda = 9.76 \times 10^{-10}$ y^{-1} $0.011 = e^{-(9.76\times10^{-10}\times t)}$ (age =) $\dfrac{\ln(0.011)}{-9.76\times10^{-10}}$ age = 4.6 $\times 10^9$ (y)	C1 C1 A1	**Alternatives:** $N = N_0 e^{-\lambda t}$ (λ =) 0.693/[7.1 $\times 10^8 \times 3.16 \times 10^7$] C1 $\lambda = 3.089 \times 10^{-17}$ s^{-1} $0.011 = e^{-(3.089\times10^{-17}\times t)}$ C1 (age =) $\dfrac{\ln(0.011)}{-3.089\times10^{-17}}$ age = 1.46... $\times 10^{17}$ (s) age = 4.6 $\times 10^9$ (y) A1 Or $0.011 = \dfrac{1}{2^n}$ C1 $n = -\dfrac{\ln(0.011)}{\ln 2}$ or n = 6.5 C1 age = 6.5 $\times$ 7.1 $\times 10^8$ (y) age = 4.6 $\times 10^9$ (y) A1
	(c)	(i)	number in the range 50 to 70	B1	
		(ii)	Correct reference to binding energy. Eg: The BE per nucleon will decrease for fusion (which is impossible unless external energy is supplied) (AW)	B1	

Question			Answer	Marks	Guidance
		(iii)	(mass of nucleons =) $4 \times 1.673 \times 10^{-27} + 4 \times 1.675 \times 10^{-27}$ (Δm =) $[4\times1.673 \times 10^{-27} + 4\times1.675 \times 10^{-27}] - 1.329 \times 10^{-26}$ (mass defect =) 1.020×10^{-28} (kg) BE = mass defect $\times$ c^2 (BE =) $1.020 \times 10^{-28} \times (3.0 \times 10^8)^2$ (= 9.180×10^{-12} J) (BE per nucleon) = $9.180 \times 10^{-12}/8$ BE per nucleon =1.148×10^{-12} (J)	C1 C1 C1 A1	**Allow**, due to misinterpretation of Data, Formulae and Relationship Booklet, the following (though incorrect): (nucleon mass =) $8 \times 1.661 \times 10^{-27}$ (kg) C1 (Δm =) $[8 \times 1.661 \times 10^{-27}] - 1.329 \times 10^{-26}$ (kg) C1 (BE =) (-) $2.0 \times 10^{-30} \times (3.0 \times 10^8)^2$ (= 1.8×10^{-13} J) C1 (BE per nucleon =) $1.8 \times 10^{-13}/8$ BE per nucleon = 2.25×10^{-14} (J) A1 **Allow** 2 sf or 3 sf answer
			Total	**10**	

Question			Answer	Marks	Guidance
7	(a)		Any <u>two</u> from: • Can travel in a vacuum • Travel at the speed of light / c / 3×10^8 <u>m s^{-1}</u> in <u>vacuum</u> • No charge / no (rest) mass • (Highly) ionising	B1 × 2	**Not**: EM radiation / wave because not *particulate* nature **Not**: Short wavelength or high frequency **Not**: High energy photons **Not**: reflect / refract / diffract
	(b)		$\frac{hc}{\lambda}$ <u>and</u> $E = mc^2$	C1	**Allow**: $\frac{hc}{\lambda}$ and 1.02 <u>MeV</u> or 0.51 <u>MeV</u> for this first C1 mark
			$\frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{\lambda} = 2 \times 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$	C1	**Allow**: Correct use of mass = 0.00055 u
			wavelength = 1.2×10^{-12} (m)	A1	**Allow**: 2 marks for 2.4×10^{-12} (m) for omitting factor of 2 **Note**: Using the de Broglie equation with $v = c$, also gives an answer of 2.4×10^{-12} (m); this scores zero – see below: $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 3.0 \times 10^8} = 2.4 \times 10^{-12}$ m scores zero
	(c)		Barium / iodine	B1	
			(Contrast medium absorbs X-rays because it) has large attenuation coefficient / has large absorption coefficient / has large Z values	B1	**Not**: X-rays are (easily) absorbed by the contrast material
			Ideal for imaging the <u>outline</u> (of soft tissues)	B1	**Allow**: If there is a hole then the barium shows this up by flowing out / Barium is used to find blockage with explanation
			Total	**8**	

Question			Answer	Marks	Guidance
8	(a)		Rate of decay / disintegration of <u>nuclei</u> or Number of γ (photons) emitted per unit time	B1	The question has 500 Bq. Hence a**llow** the following: Number of <u>nuclei</u> decaying per second / number of γ (photons) emitted per second **Not**: Rate of decay of atoms / molecules / particles
	(b)		(rate of energy =) $500 \times 10^{6} \times 2.2 \times 10^{-14}$ rate of energy emission = 1.1×10^{-5} (J s^{-1})	C1 A1	
	(c)		**Collimator / lead tubes** <u>and</u> ...... gamma (ray photons) travel along the axis of lead tubes (AW)	B1	**Not** 'it collimates' **Allow**: parallel rays / uni-directional rays travel along the lead tubes (AW)
			Scintillator / Sodium Iodide (crystal) <u>and</u> .... gamma ray / gamma photon produces (many) <u>photon**s**</u> of (visible) light	B1	
			Photomultiplier (tubes) / photocathode and dynodes <u>and</u> ...... (electrical) pulse / signal / electron<u>s</u> produced by photon(s) of visible light	B1	
			Computer <u>and</u> .... signals / pulses /electrons (from photomultiplier tubes) are used to generate an image	B1	**Not** 'information / data' in place of signals
			QWC: Quality of image improved by narrower / thinner / longer collimators OR longer scanning time	B1	
			Total	**8**	

Question			Answer	Marks	Guidance
9	(a)		Longitudinal (wave) Frequency (sound) $\geq$ 20 kHz	B1 B1	**Allow**: high frequency (sound) that cannot be heard **Allow** any value of frequency $\geq$ 20 kHz **Not**: It is non-ionising
	(b)		Emission: (Piezoelectric film / crystal connected to an) alternating e.m.f / p.d / current making it vibrate / contract and expand / resonate (and hence emits ultrasound) (AW) Reception: (Ultrasound makes the piezoelectric film / crystal) vibrate / contract and expand / resonate and this produces (alternating) e.m.f. / p.d / current (AW)	B1 B1	**Note**: The alternating p.d. can be implied by the term *frequency* **Not** varying p.d.
	(c)		Without the gel, the ultrasound would be reflected (at the skin /air interface) or The gel allows (maximum) transmission of ultrasound (into the body) Gel and skin has similar acoustic impedance / Z (values) or There is a large difference between the Z (values) of air and skin	B1 B1	**Allow**: Gel is used for impedance matching
	(d)		Transducer placed at an angle to the artery / arm Ultrasound (pulses) are reflected by (moving) blood (cells) The frequency / wavelength (of ultrasound) is changed Change in frequency is related to the speed (of blood) or change in wavelength is related to the speed	B1 B1 B1 B1	**Allow**: The wavelength / frequency is Doppler shifted (AW) **Allow**: $\frac{\Delta f}{f} = \frac{2v\cos\theta}{c}$ where c is the speed of ultrasound and v is the speed of blood; no need to define the angle
			Total	**10**	

Question			Answer	Marks	Guidance
10	(a)		(distance =) $3.0 \times 10^8 \times 3.16 \times 10^7$ distance = 9.48×10^{15} (m) $\approx 9.5 \times 10^{15}$ (m)	B1	**Allow**: (distance =) $3.0 \times 10^8 \times 365(\frac{1}{4}) \times 24 \times 3600$ **Allow** 1 mark for bald 9.48×10^{15} (m)
	(b)		Correct labelling of 1 pc, 1 AU and 1"  	B1	**Allow**: 'hypotenuse' labelled as 1 pc
	(c)	(i)	(distance =) $9.5 \times 10^{15} \times 2.1 \times 10^7$ (m) or 2.0×10^{23} (m) (distance in pc =) $2.0 \times 10^{23}/3.1 \times 10^{16}$ distance = 6.4×10^6 (pc)	C1 A1	Possible ecf from **(a)**
		(ii)	(time =) $10^{44}/4 \times 10^{26}$ (s) or 2.5×10^{17} (s) (time =) $2.5 \times 10^{17}/3.16 \times 10^7$ time = 7.9×10^9 years	C1 A1	 **Allow**: 1 sf answer of 8×10^9 years
	(d)		Any <u>one</u> from: • Very dense / infinite density / very small / singularity Any <u>one</u> from: • (Very strong gravitational field therefore) light cannot escape from it / curves space / slows down time / emits Hawking radiation	 B1 B1	
			Total	**8**	

Question			Answer	Marks	Guidance
11	(a)	(i)	H_0 = 1/age $H_0 = 1/(13.7 \times 10^9 \times 3.16 \times 10^7)$ (H_0 =) 2.31×10^{-18} (s^{-1}) (H_0 =) $\dfrac{2.31\times10^{-18}\times3.09\times10^{16}\times10^6}{10^3}$ Hubble constant = 71.4 (km s^{-1} Mpc^{-1})	 C1 C1 A1	**Allow:** 2 sf answer **Special case**: Using $H_0 = 1/13.7 \times 10^9 = 7.30 \times 10^{-11}$ (y^{-1}) gives an answer of 2.26×10^9 (km s^{-1} Mpc^{-1}) – allow 1 mark
		(ii)	$v = H_0$ d (v =) 71.4 × 50 or 3.57×10^3 (km s^{-1}) or 3.57×10^6 (m s^{-1}) $\dfrac{\Delta\lambda}{\lambda} = \dfrac{3.57\times10^6}{3.0\times10^8} (= 1.19\times10^{-2})$ $\Delta\lambda = 656 \times 1.19 \times 10^{-2}$ or $\Delta\lambda$ = 7.80 (nm) wavelength = 656 + 7.80 wavelength = 664 (nm)	 C1 C1 C1 A1	Possible ecf from **(a)** **Allow**: 2sf answer
	(b)		Big bang: Creation of the universe (from which space/time evolved) (AW) Any <u>three</u> from: 1. (At the start) the universe was hot / infinitely dense 2. Expansion of the universe led to cooling 3. The (current) temperature of universe is 2.7 K / 3 K 4. (The universe as a black body) is associated with microwaves at this temperature (AW) or The (wavelength of the) gamma radiation stretched to microwaves (by the expansion). QWC: (Cosmological principle is supported because) MBR is isotropic	B1 B1 × 3 B1	 **Not**: The universe now has microwaves. (The microwaves must be linked with current temperature) **Allow**: Microwaves have the same intensity in all directions

Question			Answer	Marks	Guidance
	(c)		(For an open / flat universe) Further expansion will lead to cooling / temperature lower than 3K / temperature tend to absolute zero (AW) The wavelength (of the EM radiation) gets longer / frequency (of the EM radiation) gets smaller / energy of photons decreases / microwaves become radio waves	 B1 B1	 **Alternative**: Temperature (will eventually) increases if closed universe B1 The wavelength (of EM radiation) get smaller B1
	(d)		Graph starting from origin and having a shape consistent with either open or accelerated universe	B1	**Not** a straight line
			Total	**15**	

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