RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE

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

Mark Scheme for June 2011

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 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 electrical per 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 one from: More coils / turns on secondary Less coils / turns on primary Laminate the core	B1	**Not:** Increase frequency of alternating supply
	(d)	(i)	$\frac{n_s}{4200} = \frac{12}{230}$ (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 = $\frac{0.5\times 4.5^2 \times 150\times 10^{-6}}{0.5\times 1.5^2 \times 450\times 10^{-6}}$ 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 per (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 upward 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}) $a = \frac{EQ}{m}$ $a = \frac{6.8\times10^4 \times1.6\times10^{-19}}{9.11\times10^{-31}}$ 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 $a = \frac{EQ}{m}$ $a = \frac{6.8\times10^6 \times1.6\times10^{-19}}{9.11\times10^{-31}}$ 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)	$v^2 = (4.0 \times 10^7)^2 + (1.2 \times 10^7)^2$ velocity = 4.2 × 10^7 (m s^{-1}) Or $v^2 = (4.0 \times 10^7)^2 + (1 \times 10^7)^2$ velocity = 4.1 × 10^7 (m s^{-1})	C1 A1 C1 A1	Possible ecf from **(iv)**
		(vi)	KE = ½ mv^2 KE = 0.5 × 9.11 × 10^{-31} × (4.2 × 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)		$E = \frac{Q}{4\pi\varepsilon_0 r^2}$	C1	
			$\frac{(-)4.0\times10^{-9}}{4\pi\varepsilon_0\times(1.75\times10^{-2})^2}$ and $\frac{5.0\times10^{-9}}{4\pi\varepsilon_0\times(1.75\times10^{-2})^2}$	C1	Ignore signs
			$E_B = 1.17 \times 10^5$ (N C^{-1}) and $E_A = 1.47 \times 10^5$ (N C^{-1}) field strength = $(1.17 + 1.47) \times 10^5$ (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 $2.9(4) \times 10^4$ (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)		$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$	C1	
			force = $\frac{4.0\times10^{-9}\times5.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(3.5\times10^{-2})^2}$	C1	Ignore signs **Allow:** ε_0 in the equation
			force = 1.47×10^{-4} (N)	A0	
	(c)		(weight =) $4.5 \times 10^{-5} \times 9.81$ or (weight =) $4.4(1) \times 10^{-4}$ (N)	C1	**Allow:** weight = $4.5 \times10^{-5} \times g$
			$\tan\theta = \frac{1.5\times10^{-4}}{4.41\times10^{-4}}$	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 '$\tan\theta = \frac{1.5\times10^{-4}}{4.5\times10^{-5}}, \theta = 73^0$' 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 <u>core/magnets</u> is up(wards) (According to Newton's third law) the forces (on the rod and steel core/magnets) are equal <u>and</u> 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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