OCR
RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE **G485**

Fields, Particles and Frontiers of Physics

Mark Scheme for June 2010

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by Examiners. It does not indicate the details of the discussions which took place at an Examiners' meeting before marking commenced.

All Examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the Report on the Examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

Any enquiries about publications should be addressed to:

OCR Publications
PO Box 5050
Annesley
NOTTINGHAM
NG15 0DL

Telephone: 0870 770 6622
Facsimile: 01223 552610
E-mail: publications@ocr.org.uk

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)	$E = \frac{1}{2} CV^2 = 0.5 \times 4.5 \times \mu \times (6.3)^2$ $= 8.9(3) \times 10^{-5}$ (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)	$\rho_c = 3H_0^2 / 8\pi G$ $= [3 \times (2.1 \times 10^{-18})^2] / (8 \times \pi \times 6.67 \times 10^{-11})$ = 7.9×10^{-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 if galaxies have always been moving apart then at some stage they must have been closer together / or started from a point evidence in red shift either optical / microwave further away the galaxy the faster the speed of recession the existence of a (2.7 K) <u>microwave</u> background radiation there is more helium in the universe than expected **MAX 4**	**(B1)** **(B1)** **(B1)** **(B1)** **(B1)** **(B1)** **B4**	Allow stars for galaxies allow from a singularity allow statement that red shift is observed or that blue light becomes red or gamma from big bang has become microwave
			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 = <u>(16 x10^{-3}) / 2 x 10^5</u> = 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	B1	Allow protons instead of nuclei in the context of hydrogen nuclei or a single proton instead of nuclei
			Need for a strong magnetic field	B1	There are 5 essential marks **(in bold)**
			the frequency of precession is known as Lamor frequency (1)		and a maximum of THREE extra marks (1)
			Application of RF pulses	B1	Maximum of **8 marks**
			produces resonance / flip energy states (1)		Do not allow 'atoms' for nuclei but penalise once only
			RF pulse turned off nuclei relax / flip back (and emit RF signal)	B1	**Please annotate scripts as follows:**
			RF detected (by coil receiver) and processed (1)		**Essential marks: ✓(ticks) on left hand side of candidate's work**
			Use of non-uniform field / gradient field (1)		**Extra marks: ✓(ticks) on right hand side of candidate's work**
			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 **MAX B8**	

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 for initial period 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]**	

OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

OCR Customer Contact Centre

14 – 19 Qualifications (General)
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk

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Head office
Telephone: 01223 552552
Facsimile: 01223 552553