GCE

Physics A

H556/03: Unified physics

Advanced GCE

Mark Scheme for November 2020

Oxford Cambridge and RSA Examinations

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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.

Here are the subject specific instructions for this question paper.

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.

SIGNIFICANT FIGURES

If the data given in a question is to 2 SF, then allow an answer to 2 or <u>more</u> significant figures.
If an answer is given to fewer than 2 SF, then penalise once only in the <u>entire</u> paper.
Any exception to this rule will be mentioned in the Additional Guidance.

Annotations

Annotation		Meaning
✓	Correct response	Used to indicate the point at which a mark has been awarded (**one tick per mark awarded**).
✗	Incorrect response	Used to indicate an incorrect answer or a point where a mark is lost.
AE	Arithmetic error	Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
BOD	Benefit of doubt given	Used to indicate a mark awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done.
BP	Blank page	Use BP on additional page(s) to show that there is no additional work provided by the candidates.
CON	Contradiction	No mark can be awarded if the candidate contradicts himself or herself in the same response.
ECF	Error carried forward	Used in <u>numerical answers only</u>, unless specified otherwise in the mark scheme. Answers to later sections of numerical questions may be awarded up to full credit provided they are consistent with earlier incorrect answers. Within a question, ECF can be given for AE, TE and POT errors but not for XP.
L1	Level 1	L1 is used to show 2 marks awarded and L1^ is used to show 1 mark awarded.
L2	Level 2	L2 is used to show 4 marks awarded and L2^ is used to show 3 marks awarded.
L3	Level 3	L3 is used to show 6 marks awarded and L3^ is used to show 5 marks awarded.
POT	Power of 10 error	This is usually linked to conversion of SI prefixes. Do not allow the mark where the error occurs. Then follow through the working/calculation giving ECF for subsequent marks if there are no further errors.
SEEN	Seen	To indicate working/text has been seen by the examiner.
SF	Error in number of significant figures	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. **Penalised only once in the paper.**
TE	Transcription error	This error is when there is incorrect transcription of the correct data from the question, graphical read-off, formulae booklet or a previous answer. Do not allow the relevant mark and then follow through the working giving ECF for subsequent marks.
XP	Wrong physics or equation	Used in <u>numerical answers only</u>, unless otherwise specified in the mark scheme. Use of an incorrect equation is wrong physics even if it happens to lead to the correct answer.
^	Omission	Used to indicate where more is needed for a mark to be awarded (what is written is not wrong but not enough).

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

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

General rule: For substitution into an equation, allow any subject – unless stated otherwise in the guidance

Question			Answer	Marks	Guidance
1	(a)	(i)	$F = QE = QV/d$ **or** $E = 5(.0) \times 10^4$ (Vm^{-1})	C1	
			$F = 9.0 \times 10^{-9} \times 4000/ 8.0 \times 10^{-2}$ ($= 4.5 \times 10^{-4}$ N)	A1	$F = 5.0 \times 10^4 \times 9.0 \times 10^{-9}$
		(ii)		B1 x 2	All correct, 2 marks; 2 correct, 1 mark 1 mark maximum if more than 3 arrows are drawn **Ignore** position of arrows
			weight; arrow vertically downwards		**Allow** W **or** 0.030(N) (**not** gravity or g)
			tension; arrow upwards in direction of string		**Allow** T
			electric (force); arrow horizontally to the <u>right</u> (not along dotted line)		**Allow** F **or** E or 4.5×10^{-4}(N) or electrostatic **Ignore** repulsion or attraction **Not** electric field / electric field strength / electromagnetic
		(iii)	$W x = F l$		**Allow** any valid alternative approach e.g. M1 deflection angle $\theta = 1^o$ M1 $x = 120\sin\theta$
			$0.03\,x$	M1	1 mark for each side of the equation
			$= 4.5 \times 10^{-4} \times 120$ **or** $= 4.5 \times 10^{-4} \times 1.2$	M1	
			$x = 1.8$ cm **or** $x = 0.018$ m	A0	

	(b)		Electric force/field (strength) increases Ball deflected further from vertical / moves to the right / touches negative plate Ball acquires the charge of the (negative) plate when it touches (Oscillates because) constantly repelled from (oppositely) charged plate	**B1** **B1** **B1** **B1**	Must be clear which force is increasing Must have the idea of a repeating cycle
	(c)		$I = Qf$ **or** $Q = It$ $f = 3.2 \times 10^{-8}/9.0 \times 10^{-9} = 3.6$ (Hz)	**C1** **A1**	
			Total	**12**	

Question			Answer	Marks	Guidance
2	(a)		(initial charge) $Q = EC_0$ **or** (Q conserved so final) $Q = V(C + C_0)$ (as capacitors are in parallel)	M1	At least one correct expression for Q for first mark
			<u>so</u> $EC_0 = V(C + C_0)$ (and hence $V = C_0E / (C + C_0)$)	A1	The two correct expressions equated for the second mark
	(b)	(i)	$1/V = 1/E + C/EC_0$ (and compare to $y = c + mx$)	B1	Mark is for rearrangement into linear equation
		(ii)	$1/EC_0 = 51 = 1/(9.1\ C_0)$ giving $C_0 = 1/(51 \times 9.1)$ F		$C_0 = 2.1547 \times 10^{-3}$ F
			$C_0 = 2.2$ (mF)	B1	Answer must be correct, rounded correctly and given in mF
				B1	Candidate's answer must be given to 2 SF
		(iii)	(at least) one correct worst fit line drawn	B1	Top and bottom points chosen must be from opposite extremes of uncertainty limits, accurate to within half a small square
			gradient calculated correctly using a large triangle	B1	$\Delta x \geq 1.5 \times 10^{-3}$; **expect** 59±1 or 44±1 (**or** 0.059 **or** 0.044); **allow ECF** from poorly drawn line; readings must be accurate to within half a small square
			uncertainty = $C_0 - 1/$(wfl gradient x 9.1)	B1	**ECF** from **b(ii)**; **expect** uncertainty of up to 0.4(mF)
			uncertainty given is to the same number of decimal places as C_0	B1	**ECF** from **b(ii)** **If** no value for C_0 given in b(ii), **allow** any answer given to 1dp
	(c)		Only effect is to slow the charging and/or discharging (of capacitor(s)) <u>and so</u> the final charges are unchanged / the values for V are unchanged / the graph is unchanged / the gradient is unchanged / there is no effect on the experiment (results)	B1	**Allow** and so the experiment takes longer
			Total	**10**	

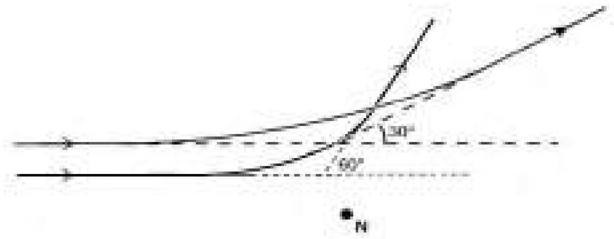
Question			Answer	Marks	Guidance
3	(a)	(i)	L (= $4\pi r^2\sigma T^4$) = $4 \times \pi \times (7.0 \times 10^8)^2 \times 5.67 \times 10^{-8} \times 5800^4$	M1	Mark is for substitution of values **Allow** σ for 5.67×10^{-8}
			$L = 3.95 \times 10^{26}$ (W)	A0	
		(ii)	By ratios: $25 = 1.7^2 \times (T/5800)^4$	C1	**or** $T^4 = 25L/4\pi\sigma(1.7r)^2$ $= \dfrac{25 \text{ x } 3.95 \text{ x} 10^{26}}{4\pi \text{ x } 5.67 \text{x } 10^{-8} \text{ x } (1.7 \text{ x } 7 \text{ x } 10^8)^2}$ **ECF** for L in **a(i)** but only if $L = 4 \times 10^{26}$ to 1s.f. **ECF** for incorrect σ in **a(i)**
			$T^4 = 9.8 \times 10^{15}$	C1	**Allow** 9.9×10^{15} (using $L = 4 \times 10^{26}$)
			T = 9950 (K)	A1	**Allow** 10,000 K
	(b)		**see next page**	B1 x 6	
			Total	10	

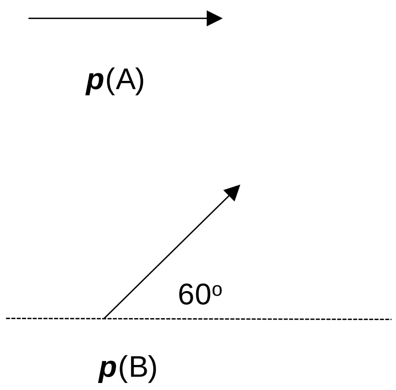
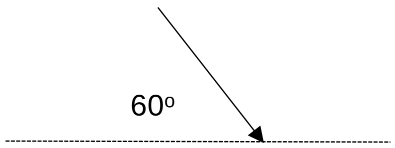
Question			Answer	Marks	Guidance
3	(b)	*	**Level 3 (5 - 6 marks)** Clear expansion of three statements *There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear, relevant and substantiated.* **Level 2 (3 – 4 marks)** Clear expansion of two statements **or** Limited attempt at all three *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1 – 2 marks)** Limited attempt at one or two statements *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	B1 x 6	**Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc.** **Indicative scientific points may include:** **statement 1** • fusion reactions are occurring • which change H into He • and mass is lost which releases energy • energy released = $c^2\Delta m$ • Δm per second = luminosity / c^2 **statement 2** • average k.e. of each proton is $\frac{3}{2}kT$ • high T means protons are travelling at high speed • so fast enough to overcome repulsive forces • and get close enough to fuse • p.e. = $e^2/4\pi\varepsilon_0 r$ so T must be high enough for $\frac{3}{2}kT > e^2/4\pi\varepsilon_0 r$ • r is approximately 3fm **statement 3** • k.e. $\propto T$ so average energy at 10^7 K is only one thousandth of the average energy at 10^{10} K when protons might fuse • but M-B distribution applies so at the high energy end there will be a few p with enough energy • quantum tunnelling across potential barrier is possible • small probability of many favourable collisions to boost energy of p • 4 p must fuse to produce He; it is complicated process making probability of fusion much less • number of p in Sun is so huge that, even with such a small probability, 4 x 10^9 kg of p still interact s^{-1} • a larger probability means lifetime of the Sun would be shorter

Question			Answer	Marks	Guidance
4	(a)		There is no contact force between the astronaut and the (floor of the) space station (so no method of measuring / experiencing weight)	B1	**Allow** astronaut and the space station have same acceleration (towards Earth) / floor is falling (beneath astronaut)
	(b)	(i)	$M = 5.97 \times 10^{24}$(kg) **or** ISS orbital radius $R = 6.78 \times 10^{6}$(m) **or** $g \propto 1/r^2$	C1	
			(gr^2= constant so) $g \times (6.78 \times 10^6)^2 = 9.81 \times (6.37 \times 10^6)^2$	C1	**or** $g\ (= GM/R^2) = 6.67 \times 10^{-11} \times 5.97 \times 10^{24} / (6.78 \times 10^6)^2$
			$g = 8.66$ (N kg^{-1})	A1	**Allow** rounding of final answer to 2 SF i.e. 8.7 (N kg^{-1})
		(ii)	$2\pi r / T = v$ **or** $T = 2 \times 3.14 \times 6.78 \times 10^6 / 7.7 \times 10^3$	M1	**ECF** incorrect value of R from **b(i)**
			$T = 5.5 \times 10^3$ s (= 92 min)	A1	
	(c)		$\frac{1}{2}Mc^2\ (\frac{1}{2}N_A mc^2) = \frac{3}{2}RT$	C1	**or** $\frac{1}{2}mc^2 = \frac{3}{2}kT$ **or** $c^2 = 3kT/m$
			$c^2 = 3 \times 8.31 \times 293 / 2.9 \times 10^{-2} = 2.52 \times 10^5$	C1	**or** $c^2 = 3 \times 1.38 \times 10^{-23} \times 6.02 \times 10^{23} \times 293/2.9 \times 10^{-2} = 2.52 \times 10^5$
			$\sqrt{c^2} = 500$ (m s^{-1})	A1	**not** $(7.7 \times 10^3 / 15) = 510$ (m s^{-1})
			$(= 7.7 \times 10^3 / 15)$	A0	
	(d)		power reaching cells ($= IA$) $= 1.4 \times 10^3 \times 2500 = 3.5 \times 10^6$ W	C1	
			power absorbed $= 0.07 \times 3.5 \times 10^6 = 2.45 \times 10^5$ W	C1	mark given for multiplication by 0.07 at any stage of calculation
			cells in Sun for (92 - 35 =) 57 minutes	C1	(90 – 35 =) 55 minutes using T = 90 minutes **ECF** value of T from **b(ii)**
			average power $= 57/92 \times 2.45 \times 10^5 = 1.5 \times 10^5$ (W)	A1	$55/90 \times 2.45 \times 10^5 = 1.5 \times 10^5$ (W) using T = 90 minutes
			Total	**13**	

Question			Answer	Marks	Guidance
5	(a)		$c = f\lambda$ **or** $f = 3.0 \times 10^8 / 0.60$	C1	**Allow** $v = f\lambda$
			$f = 5.0 \times 10^8$ (Hz)	A1	**Allow** 5×10^8
	(b)		$a_{max} = -\omega^2 A$ or $a_{max} = -(2\pi f)^2 A$	C1	**Allow** without the minus sign
			$\omega = 2 \times \pi \times 5.0 \times 10^8 = 3.1(4) \times 10^9$ (rad s^{-1}) or $10^9\pi$	C1	**ECF** from **(a)**
			a_{max} $(= \pi^2 \times 10^{18} \times 4.0 \times 10^{-6}) = 3.9 \times 10^{13}$ (m s^{-2})	A1	**Not** $4.0 \times 10^{12}\pi^2$
	(c)		the current (induced in the aerial) is alternating (5×10^8 times per second) (so the meter would register zero) / AW **or** the diode (half-)rectifies the current / changes the current (from a.c.) to d.c. / AW	B1	**Allow** 'a diode only lets current pass through in one direction' AW
	(d)		**see next page**	**B1 x 6**	
			Total	**12**	

Question			Answer	Marks	Guidance
5	(d)	*	**Level 3 (5 - 6 marks)** Response shows clear distinction between investigations; clear and correct reasoning is given for the situations which give maximum/minimum readings in <u>both</u> cases, including correct numerical values *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3 – 4 marks)** Response refers to both investigations; some reasoning is given for the situations which give maximum/minimum readings in <u>both</u> investigations, including some numerical values *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1 – 2 marks)** Limited reasons are given for the situations which give maximum/minimum readings in <u>either</u> investigation *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	B1 x 6	**Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc.** **Indicative scientific points may include:** **explanation 1** • receiver aerial vertical – electrons are driven (maximum distance) up and down along the length of the aerial because the oscillations (of the electric field) are vertical, causing maximum (a.c.) current • receiver aerial horizontal – electrons are driven (minimum distance) across the aerial because the oscillations (of the electric field) are only in the vertical plane (no oscillation along the aerial to cause current), so zero / minimum current • rotation of receiver aerial by ± 90^o (or 90^o and 270^o) from vertical leads to zero current **explanation 2** • reflected wave superposes with incident wave at receiver aerial • coherent waves as from same source • constructive interference/waves in phase gives max current • reflected wave has travelled nλ further, n = 0,1, etc • so max current when plate is at λ/2, 2λ/2, etc from receiver aerial, i.e. 30, 60 cm • destructive interference/waves 180^o (π rad) out of phase gives zero current • reflected wave has travelled (2n +1)λ/2 further, n = 0,1, etc • so zero current when plate is at λ/4, 3λ/4, etc from receiver aerial, i.e. 15, 45 cm • reflected signal will be weaker the further it has to travel so no longer complete cancellation (ammeter reads close to zero) **Note:** Give full credit to candidates who take the 180^o (π rad) phase change on reflection into account, which gives max current at 15, 45 cm etc and zero current at 30, 60 cm etc.

Question			Answer	Marks	Guidance
6	(a)			B1 B1	Path is initially horizontal **and** further up the page than original Path <u>ends</u> at 30^0 to horizontal (angle must be labelled) in the direction shown
	(b)		Q = 79e and q = 2e $F = (1/4\pi\varepsilon_0)Qq/r^2$ $= 79 \times 2 \times (1.6 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (6.8 \times 10^{-14})^2]$ = 7.9 (N)	C1 C1 C1 A1	**Apply ECF** for wrong charge(s), e.g. Q and/or q = e, or Q = 79 and/or q = 2, etc
6	(c)		(k.e. =) $E = 5.0 \times 10^6 \times 1.6 \times 10^{-19}$ $v = \sqrt{(2E/m)}$ **or** $= \sqrt{(2 \times 8.0 \times 10^{-13} / 6.6 \times 10^{-27})} = 1.6 \times 10^7$ (ms^{-1}) p (= mv) = $6.6 \times 10^{-27} \times 1.6 \times 10^7$ giving $p = 1.1 \times 10^{-19}$ (kg m s^{-1})	C1 C1 A1	$E = 8(.0) \times 10^{-13}$ J **or** ($E = p^2/2m$ so) $p = \sqrt{(2mE)}$ **Note:** A value of $v = 1.6 \times 10^7$ (ms^{-1}) automatically scores both C1 marks even if the calculation for E is not shown **or** p (= $\sqrt{(2mE)}$ = $\sqrt{(2 \times 6.6 \times 10^{-27} \times 8.0 \times 10^{-13})}$) giving $p = 1.0 \times 10^{-19}$ (kg m s^{-1}) Full substitution of values must be shown and answer (if calculated) must be correct

Question			Answer	Marks	Guidance
6	(d)	(i)	Example (not to scale): 	B1 B1	horizontal arrow (judge by eye), in the direction shown arrow drawn at an angle of 60º to the horizontal (angle must be shown), in the direction shown
		(ii)	Example (not to scale):  (Can apply principle of) conservation of momentum (since no external forces are acting)	B1 B1	arrow drawn at an angle of 60º to the horizontal (angle must be shown), in the direction shown
			Total	**13**	

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