Oxford Cambridge and RSA

GCE

Physics A

H556/02: Exploring physics

Advanced GCE

Mark Scheme for Autumn 2021

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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.

Annotations available in RM Assessor

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 numerical answers only, 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, formulæ 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 numerical answers only, 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

SECTION A

Question	Answer	Marks	Guidance
1	D	1	
2	A	1	
3	D	1	
4	C	1	
5	D	1	
6	C	1	
7	B	1	
8	A	1	
9	B	1	
10	B	1	
11	C	1	
12	D	1	
13	A	1	
14	B	1	
15	C	1	
	Total	15	

SECTION B

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

Question			Answer	Marks	Guidance
16	(a)	(i)	($v = f\lambda$) $340 = 20 \times 10^3 \times \lambda$	C1	
			wavelength = 1.7×10^{-2} (m)	A1	**Allow** 1 mark for 17 (m); 20 Hz used
		(ii)	Loudspeaker and signal generator	B1	**Allow** this mark for a labelled diagram
			Frequency increased until limit of hearing	B1	
			frequency determined using $f = 1/T$	B1	**Do not allow** t for time period
	(b)		Difference: (stationary waves) has nodes / antinodes	B1	Differences and/or similarities can be described in terms of net energy transfer, phase or amplitude variations
			Similarity: Oscillations are longitudinal	B1	
	(c)		Diagram showing angle within the block measured relative to the normal	B1	Allow i / θ / C as the angle to be measured. Must be clear which angle is being measured. Expect the normal as a line perpendicular to straight edge of block, and emergent ray. No labels expected for the rays or the normal.
			Increase the (incident) angle until the ray of light runs along the boundary / suffers total internal reflection (ORA) **or** angle measured using a protractor	B1	
			n determined using $n = 1/\sin C$	B1	Formula in this arrangement
			Total	10	

Question			Answer	Marks	Guidance
17	(a)		The minimum energy needed to remove an electron (from the surface of a metal)	B1	**Allow** work done for energy **Allow** photoelectron for electron
	(b)	(i)	energy of blue light / photon of blue light > 2.3 eV / work function or energy of red light / photon of red light < 2.3 eV / work function	B1	**Not** blue light has frequency > threshold frequency Or red light has frequency < threshold frequency
			Energy of photon is independent of intensity	B1	**Allow** intensity linked to rate of photons / rate of electrons emitted per second
			(energy of photon given by equation) $E = hf$ / $E=hc/\lambda$	B1	**Allow** E proportional f / E proportional *to* $1/\lambda$
			One photon interacts with one electron	B1	
		(ii)	(ϕ =) $2.3 \times 1.6 \times 10^{-19}$ **or** (E =) $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{320\times10^{-9}}$	C1	$\phi = 3.68 \times 10^{-19}$ (J); $E = 6.2156 \times 10^{-19}$ (J)
			(KE_{max} =) $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{320\times10^{-9}} - 2.3 \times 1.6 \times 10^{-19}$	C1	$KE_{max} = 2.5356 \times 10^{-19}$ (J)
			(v =) $\sqrt{\frac{2\times2.5356\times10^{-19}}{9.11\times10^{-31}}}$	C1	$v = 7.46 \times 10^{5}$ (m s^{-1})
			(wavelength =) $\frac{6.63\times10^{-34}}{9.11\times10^{-31}\times7.46\times10^{5}}$		
			wavelength = 9.8×10^{-10} (m)	A1	
			Total	**9**	

Question			Answer	Marks	Guidance
18	(a)	(i)	Arrow in anticlockwise direction	B1	**Allow** this mark for correct direction shown on diagram either on or off connecting wires
		(ii)	(E =) 4.5 – 2.4 **or** (R_T =) 0.80 + 0.50 + 1.2 4.5 – 2.4 = I × (0.80 + 0.50 + 1.2) I = 0.84 (A)	C1 C1 A1	E = 2.1 (V); R_T = 2.5 (Ω) Treat missing 1.2 resistance as TE **Allow** 2 marks for 2.8 (A); E = 6.9 V used
		(iii)	($I = Anev$) $0.84 = \pi \times (2.3 \times 10^{-4})^2 \times 4.2 \times 10^{28} \times 1.60 \times 10^{-19} \times v$ $v = 7.5 \times 10^{-4}$ (m s^{-1})	 C1 A1	 Possible ECF from **(ii)** **Note** answer is 2.5×10^{-3} (m s^{-1}) for I = 2.76 (A) **Allow** 1 mark for 1.9×10^{-4}; diameter used as radius
		(iv)	Sensible suggestion, e.g. use a water bath / fan / only switch on when taking readings Need to lower the temperature / reduce resistance of **R**	M1 A1	**Allow** keep the surroundings cold **Allow** to keep the temperature / resistance constant **OR allow** increase in temperature increases resistance

<table>
<tr>
<td></td>
<td>(b)*</td>
<td></td>
<td>Level 3 (5–6 marks)
E and r calculated correctly and table completed correctly and clear description of P and R

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)
Table completed correctly and some description of P and R / some attempt at E and r
OR
E and r calculated correctly
OR
Some attempt at calculating E and r and some description of P and R

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 calculation of E and r
OR
Table completed correctly
OR
Limited description of relationship between P and R

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</td>
<td>B1×6</td>
<td>Indicative scientific points may include:

Calculating E and r
• $E = Ir + V$
• gradient = (-) r
• y-intercept = E
• Line extrapolated to y-axis
• E = 1.2 (V)
• r = 0.8(0 Ω)

Table and description
• Table completed (ignore SF) – see below
• R increases as V increases (or I decreases)
• P increases and decreases
• Maximum power is when internal resistance is equal to R (0.8 Ω)

<table>
<tr><th>V / V</th><th>I / A</th><th>R / Ω</th><th>P / W</th></tr>
<tr><td>0.20</td><td>1.25</td><td>0.16</td><td>0.25</td></tr>
<tr><td>0.40</td><td>1.00</td><td>0.40</td><td>0.40</td></tr>
<tr><td>0.60</td><td>0.75</td><td>0.80</td><td>0.45</td></tr>
<tr><td>0.80</td><td>0.50</td><td>1.60</td><td>0.40</td></tr>
<tr><td>1.00</td><td>0.25</td><td>4.00</td><td>0.25</td></tr>
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<td>Total</td>
<td>14</td>
<td></td>
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</table>

Question			Answer	Marks	Guidance
19	(a)		Direction of field shown as clockwise	B1	Expect at least one field line with an arrow
			Three field lines shown as concentric circles and distance between adjacent field lines increasing as distance from wire increases	B1	**Allow** more than three lines, but distance between adjacent field lines increasing distance from wire must increase for all
	(b)		(force =) $2.2 \times 10^{-3} \times 9.81$	C1	
			$2.2 \times 10^{-3} \times 9.81 = B \times 5.0 \times 0.060$ (= 0.072 T)	C1	
			(absolute uncertainty =) $\frac{0.2}{6.0} + \frac{0.1}{5.0}$ ($\times 0.072 =$ 0.0038 T)	C1	**Allow** calculation of percentage uncertainty = 5.3% **Allow** calculation of max B (=0.0759 T) and min B (=0.0683 T)
			$B = 0.072 \pm 0.004$	A1	**Note** *B* must be given to 2 SF and the uncertainty given to 1 SF. **Special case**: allow follow through from incorrect B calculation.
			Total	**6**	

Question			Answer	Marks	Guidance
20	(a)		(CR =) $2000 \times 10^{-6} \times 120 \times 10^{3}$	C1	CR = 240 (s)
			$1.00 = 1.48 \times [1 - e^{-t/240}]$ **or** $0.48 = 1.48e^{-t/240}$	C1	
			(t =) $- 240 \times \ln(0.48/1.48)$	C1	
			t = 270 (s)	A1	Special case: 94 (s) for use of discharging equation. Max 2 marks
	(b)		Line of best fit drawn through the data points	B1	
			Gradient = 38	C1	Allow ± 2. Not calculated through use of a single point.
			(Ckln2 = gradient)		
			$1.2 \times 10^{-3} \times k \times \ln 2 = 38$	C1	Possible ECF from incorrect gradient
			$k = 4.6 \times 10^{4}$ (Ω m^{-1})	A1	**Note**: gradient of 40 gives 4.8×10^{4} and gradient of 36 gives 4.3×10^{4}
			Total	8	

Question			Answer	Marks	Guidance
21	(a)		Electron removed / ejected (from atom) Photon (scattered with) increased wavelength / lower frequency / lower energy	B1 B1	 Needs a comparative statement
	(b)		(intensity $I = I_0e^{-\mu x}$) $= 4.6 \times 10^3 \times e^{-0.85 \times 2.1}$ Either: (power =) $4.6 \times 10^3 \times e^{-0.85 \times 2.1} \times 3.4 \times 10^{-4}$ Or (energy per unit area =) $4.6 \times 10^3 \times e^{-0.85 \times 2.1} \times 30$ energy $= 4.6 \times 10^3 \times e^{-0.85 \times 2.1} \times 3.4 \times 10^{-4} \times 30$ energy = 7.9 (J)	C1 C1 C1 A1	intensity = 772 (W m^{-2}) power = 0.262 (W) energy per unit area = 23160 J m^{-2} energy at surface = 47 (J) 2 marks
	(c)		CAT (CT) scan Any one from • A CAT scan will give 3D image • A CAT scan gives better contrast	M1 A1	 Insufficient: more detail / clearer image
			Total	**8**	

Question			Answer	Marks	Guidance
22			The positrons / beta-plus particles annihilate electrons (within the patient)	B1	
			Two gamma-photons are produced	B1	**Allow** 'two gamma rays' instead of 'two gamma-photons' **Allow** gamma symbol
			these (photons / rays) travel in opposite directions	B1	
			The difference in the arrival times at the detectors is used to locate the point of annihilation / nuclei	B1	**Allow** delay time
			Total	4	

Question			Answer	Marks	Guidance
23	(a)		Control rods: absorb the <u>neutrons</u> (without further fission) Moderator: Slow down the <u>neutrons</u> / decrease KE of <u>neutrons</u>	**B1** **B1**	**Not** collide for absorb
	(b)*		**Level 3 (5–6 marks)** Clear description and clear calculations of energy per kg *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)** Clear description **OR** Clear calculations of energy per kg **OR** Some description **and** some calculations *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 description **OR** Limited calculations *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	**B1×6**	**Indicative scientific points may include:** **Description** • Energy is produced in both reactions • More energy produced (per reaction) in fission • The (total) binding energy of 'products' is greater • In fusion, nuclei repel (each other) • Fusion requires high temperatures / high KE • Fission reactions are triggered by (slow-)neutrons • Chain reaction possible in fission **Calculations** • 1 kg of uranium has 4.26 mols / 2.56×10^{24} nuclei • 1 kg of deuterium has 500 mol / 3.01×10^{26} nuclei / 1.50×10^{26} 'reactions' • 200 MeV = 3.2×10^{-11} J • 4 MeV = 6.4×10^{-13} J • Uranium: ~ 10^{14} (J kg^{-1}) (actual value 8.2×10^{13}) • Deuterium: ~ 10^{14} (J kg^{-1}) (actual value 9.6×10^{13}) • The energy per kg is roughly the same
			Total	**8**	

Question			Answer	Marks	Guidance
24	(a)	(i)	$(E =) \frac{4000}{0.080}$	C1	$E = 5.0 \times 10^4$ (V m^{-1})
			$(F =) \frac{4000}{0.080} \times 1.6 \times 10^{-19}$	C1	$F = 8.0 \times 10^{-15}$ (N)
			$(a =) \frac{8.0\times10^{-15}}{9.11\times10^{-31}}$ **or** 8.78×10^{15}	C1	**Allow** this mark if the working is shown. If only value is given, then the answer must be 3SF or more
			$a = 8.8 \times 10^{15}$	A0	
		(ii)	$(t =) \frac{0.12}{6.0\times10^{7}}$	M1	
			$(t = 2.0 \times 10^{-9}$ s)	A0	
		(iii)	$(x =) \frac{1}{2} \times 8.78 \times 10^{15} \times (2.0 \times 10^{-9})^2$	C1	**Allow** $a = 8.8 \times 10^{15}$
			$x = 1.8 \times 10^{-2}$ (m)	A1	
	(b)		Downward curved path	B1	**Ignore** any line outside of the plates
			Same *x*	B1	**Expect** same x by eye
	(c)		Apply a magnetic field at right angles to electric field	B1	**Note** this mark is for the idea that *E* and *B* are <u>perpendicular</u> even if direction of *B* is incorrect **Allow** 'apply horizontal magnetic field'
			electric force = magnetic force	B1	**Allow** $Eq = Bqv$
			No resultant vertical force, so only beta-particles with a specific speed will travel horizontally	B1	**Allow** $v = E/B$ in this arrangement
			Total	11	

Question			Answer	Marks	Guidance
25	(a)	(i)	Material **X** because of the shorter half-life	**B1**	Must be comparative **Allow** explanation in terms of decay constant
		(ii)	(Alpha particles are stopped by the glass but) the beta-particles are not (AW)	**B1**	**Allow** symbols
	(b)	(i)	1	**B1**	
		(ii)	Either: mass of nucleus $14.000 \times 1.66 \times 10^{-27}$ $(= 2.324 \times 10^{-26}$ kg)	**C1**	$\Delta m = 1.9262 \times 10^{-28}$ kg **Ignore** sign throughout
			Or: mass of nucleons $= 8 \times 1.675 \times 10^{-27} + 6 \times 1.673 \times 10^{-27}$ $(= 2.3438 \times 10^{-26}$ kg)		
			$(\Delta m =) 2.3438 \times 10^{-26} - 2.324 \times 10^{-26} = (1.98 \times 10^{-28}$ kg)	**C1**	$\Delta E = 1.782 \times 10^{-11}$ J
			$(\Delta E =) 1.98 \times 10^{-28} \times (3.00 \times 10^{8})^2$	**C1**	**Allow** for any mass difference $\times (3.00 \times 10^{8})^2$
			(BE per nucleon =) $1.782 \times 10^{-11}/14$		
			binding energy per nucleon $= 1.27 \times 10^{-12}$ (J per nucleon)	**A1**	**Note** A mark for correct answer to 3sf only
			Total	**7**	

OCR (Oxford Cambridge and RSA Examinations)
The Triangle Building
Shaftesbury Road
Cambridge
CB2 8EA

OCR Customer Contact Centre

Education and Learning
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk

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