OCR
Oxford Cambridge and RSA

GCE

Physics A

Unit **H556/02:** Exploring physics

Advanced GCE

Mark Scheme for June 2018

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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.

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

SECTION B

Question			Answer	Marks	Guidance
16	(a)		($R = \frac{V}{I} = \frac{W}{QI}$; $Q = It$) charge → A s **or** energy → kg m s^{-2} × m **or** kg m^2 s^{-2} (base units) kg m^2 A^{-2} s^{-3}	**C1** **A1**	**Allow** other correct methods **Allow** *Q* **or** *C* **or** coulomb for 'charge'; *E* **or** *W* **or** joule **or** J **or** work done for 'energy' **Allow** 1 mark for J s^{-1} A^{-2} **Allow** $\frac{\text{kg m}^2}{\text{A}^2\text{s}^3}$ **or** kg m^2 /(A^2 s^3) **Not** kg m^2 / A^2 / s^3 **or** kg m^2 / s^3 / A^2
	(b)	(i)	(R =) $\frac{6.0}{0.150}$ R = 40 Ω	**M1** **A0**	**Allow** any correct value of V (± 0.1 V) divided by the correct value of I (± 10 mA) from the straight line for **R**
		(ii)1	(V_L =) 1.4 (V) **or** (V_R =) 4.0 (V) **or** (R_T =) 6.0/0.1 (Ω) ($V_{terminal}$ =) 5.4 (V) **or** (V_r =) 0.6 (V) **or** (r =) 60 - 54 (Ω) r = 6.0 (Ω)	**C1** **C1** **A1**	**Allow** full credit for other correct methods Possible ECF from **(i)** **Allow** ± 0.1 V for the value of p.d. from the graph **Note** getting to this stage will also secure the first C1 mark **Allow** 1 SF answer here without any SF penalty
		(ii)2	$\rho = \frac{40 \times 2.4 \times 10^{-6}}{8.0 \times 10^{-3}}$ (Any subject) ρ = 0.012 (Ω m)	**C1** **A1**	**Allow** ECF **Allow** 1 mark for either 0.018 for using 60 Ω, 0.016(2) for using 54 Ω or for 0.0018 for 6.0 Ω
		(ii)3	$n = \frac{6.5 \times 10^{17}}{2.4 \times 10^{-6} \times 0.008}$ **or** n = 3.385 × 10^{25} (m^{-3}) $v = \frac{0.100}{2.4 \times 10^{-6} \times 3.385 \times 10^{25} \times 1.60 \times 10^{-19}}$ (Any subject) v = 7.7 × 10^{-3} (m s^{-1})	**C1** **C1** **A1**	 **Note** do not penalise again for the same POT error **Allow** 1 mark for 4(.0) × 10^5 (m s^{-1}); n = 6.5 × 10^{17} used
			Total	**11**	

Question			Answer	Marks	Guidance
17*			**Level 3 (5–6 marks)** Clear explanation, some description **and** both resistance values correct *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)** Some explanation, limited or no description **and** both resistance values correct **OR** Clear explanation, limited or no description **and** calculations mostly correct / one correct calculation **OR** Clear explanation, some description **and** no 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)** Some explanation **OR** Some description **OR** Some calculation *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:** **Explanation of trace** • The 'trace' is because of light reaching and not reaching LDR • Resistance of LDR varies with (intensity) of light • In light o resistance of LDR is low o p.d. across LDR is low o p.d across resistor (or *V*) is high o current in circuit is large • In darkness o resistance of LDR is high o p.d. across LDR is high o p.d across resistor (or *V*) is low o current in circuit is small • V_{max} = 4.0 V; V_{min} = 2.0 V • Potential divider equation quoted • Substitution into potential divider equation **Description of determining frequency** • Time between pulses is constant because of constant speed • Time between pulses = 0.4 (s) • $f = 1/T$ • frequency = 2.5 (Hz) **Calculations** • Resistance of LDR is 150 (Ω) in light • Resistance of LDR is 1500 (Ω) in darkness
			Total	**6**	

Question			Answer	Marks	Guidance
18	(a)		$1.00 \times \sin 56.3 = 1.50 \times \sin r$ (Any subject) $r = 33.7°$ Correct working / reasoning leading to 90.0° (e.g. $\theta = 180 - (56.3 + 33.7)$, therefore $\theta = 90.0°$)	M1 A1 A1	**Allow** with or without the 1.00 **Allow** 34°
	(b)		Use a polaroid / polarising filter Rotation will change intensity	B1 B1	 **Allow** brightness / light
	(c)		distance = 6.0/cos 33.7 **or** 7.2 (cm) **OR** $v = 3.00 \times 10^8 / 1.50$ **or** 2.00×10^8 (m s^{-1}) $t = 7.2 \times 10^{-2} / 2.00 \times 10^8$ $t = 3.6 \times 10^{-10}$ (s)	 C1 A1	**Allow** 34° **Allow** 2×10^8
			Total	7	

Question			Answer	Marks	Guidance
19	(a)		Any **two** from: • Reflection • Diffraction • Interference / superposition	**B1 × 2**	**Allow** correct annotation of Fig. 19.1 for each effect
	(b)		Interference / superposition (of microwaves along **PQ**)	**B1**	
			Maximum (signal) / constructive (interference) when waves are in phase	**B1**	**Allow** constructive when phase difference is $n \times 360°$ (n is an integer) / 0° / 360°
			Minimum (signal) / destructive (interference) when waves are in anti-phase	**B1**	**Allow** destructive phase difference is $[2n + 1] \times 180°$ (n is an integer) / 180° **Not** 'out of phase' **Special case -** allow 1 mark from the last two B1 marks, for signal linked to path difference and wavelength
			Total	**5**	

Question			Answer	Marks	Guidance
20	(a)	(i)	A straight line with non-zero V_0 intercept	B1	**Ignore** spread of data points on either side of the line **Allow** Intercept > 0 and < 1.0 V
			gradient = 1.3×10^{-6}	B1	**Allow** $(1.10 \text{ to } 1.60) \times 10^{-6}$; no need to check calculation
		(ii)	gradient = $\frac{hc}{e}$ (Any subject)	C1	
			$h = \frac{1.3 \times 10^{-6} \times 1.60 \times 10^{-19}}{3.00 \times 10^{8}}$ (Any subject)	C1	Possible ECF from **(i)**
			$h = 6.9 \times 10^{-34}$ (J s)	A1	**Note** the answer must be given **2 SF** only
		(iii)	difference = $\frac{6.9 \times 10^{-34} - 6.6(3) \times 10^{-34}}{6.6(3) \times 10^{-34}} \times 100$ %		Possible ECF from **(ii)** **Ignore** sign **Not** division by value from **(ii)**
			difference = 4.1 %	B1	**Allow** 1 SF answer
		(iv)	Random (error) / data points are spread about line	B1	
			Systematic (error) / line does not pass through origin	B1	
			Take (many) repeat readings (of V_0) **and** average	B1	
			Conduct the experiment in a darkroom / use (black) tube over the LED to view when it is lit / use a (digital) voltmeter with no zero error	B1	**Allow** other sensible suggestion **Not** faulty voltmeter

Question			Answer	Marks	Guidance
	(b)				**Allow** *f* for frequency, λ for wavelength and ϕ for work function throughout **Allow** 'overcome' / 'met' / 'reached' when describing > or < **Allow** photon**s**
			Any **one** from: Energy of visible light photon < work function (of zinc) (frequency of) visible (light/photon) < threshold frequency	**B1**	**Not** f_0 for threshold frequency **Allow** equivalent statement with wavelength
			Any **one** from: Energy of UV photon > work function (of zinc) (frequency of) UV (radiation/photon) > threshold frequency	**B1**	**Allow** = instead of > or < throughout for UV **Allow** equivalent statement with wavelength
			Any **two** from: • Collapse of leaf linked to removal of electrons • One-to-one interaction of photon and (surface) electron • Photon energy is independent of intensity / Intensity linked to rate of photons (incident on the zinc plate)	**B1 × 2**	**Ignore** stem / plate / leaf / electroscope becoming positive
			Total	**14**	

Question			Answer	Marks	Guidance
21	(a)	(i)	The gradient is maximum / maximum rate of change of B / maximum rate of change of flux (linkage)	B1	**Allow** slope instead of gradient
		(ii)	Tangent drawn to curve at $B = 0$	C1	
			gradient = 12.5	C1	**Allow** 11.70 to 13.30; no need to check calculation **Allow** fraction if calculated value is within the range
			(maximum e.m.f. = $12.5 \times 14 \times 10^{-4} \times 85$)		
			maximum e.m.f. = 1.5 (V)	A1	**Allow** ECF from the gradient value if value is outside the range **Alternative:** $E = BAN\omega$ **C1** $E = 40 \times 10^{-3} \times 14 \times 10^{-4} \times 85 \times 2\pi \times 50$ **C1** maximum e.m.f. = 1.5 (V) **A1**
	(b)		Sinusoidal curve with the same peak e.m.f.	B1	**Note** curve must show at least half a period **Allow** $\pm$ 1 small square for e.m.f. **Ignore** phase
			Sinusoidal curve with half period	B1	**Note** graph must show at least half a period **Allow** $\pm$ 1 small square for t
			Total	6	

Question			Answer	Marks	Guidance
22	(a)		$(V = V_0e^{-t/CR})$ $\ln(V/V_0) = -t/CR$ **or** $\ln V = \ln V_0 - t/CR$ $\ln V = \ln V_0 - t/CR$ **and** $y = mx + c$ / gradient $= -1/CR$	**B1** **B1**	 **Note** the minus sign is necessary
	(b)*		**Level 3 (5–6 marks)** Clear description **and** correct value of C *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 **and** some correct working **OR** Some description **and** correct value for C *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)** Some description **OR** Some working *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** • $C = \varepsilon A/d$ • A = area (of overlap) and d = separation. • Use ruler to measure the side / radius / diameter (and hence the area A) • Ensure total overlap of plates. • Measure the thickness / d of paper using micrometer / (vernier) caliper. • Take several readings of thickness and determine an average value for d **Calculation of capacitance** • gradient ≈ 85 • $C \approx 1.2 \times 10^{-8}$ (F)
			Total	**8**	

Question			Answer	Marks	Guidance
23	(a)	(i)	(N at 15°/N at 150° =) $10^{5.1} \div 10^{1.5}$ **or** $10^{3.6}$ (≈ 4000)	**B1**	
		(ii)	Most of the (alpha) particles went through without (much) deflection, hence the atom is mostly empty / space / vacuum Some of the (alpha) particles were scattered (through large angles / greater than 90°), hence there must be a <u>nucleus</u> (at the centre of the atom). Any <u>one</u> from: • The nucleus is very small compared with the atom • Positive charge at the centre / nucleus is positive • Most of the mass (of the atom) is at centre / dense nucleus	**B1** **B1** **B1**	**Allow** Many / Majority / Lots of the alpha particles ….. **Allow** Few(er) / Small(er) number of the alpha particles …
	(b)	(i)	Kinetic energy (of proton) changes to potential (energy) **or** Potential energy increases as the kinetic energy (of the proton) decreases **or** Potential energy increases as work is done against the field / against repulsion / positive charge	**B1**	**Allow** 'it' / PE for (electric) potential energy **Allow** KE / E_k
		(ii)	energy = $0.52 \times 10^6 \times 1.60 \times 10^{-19}$ **or** $8.3(2) \times 10^{-14}$ (J) $\frac{1.60 \times 10^{-19} \times 27 \times 1.60 \times 10^{-19}}{4\pi\varepsilon_0 R} = 8.32 \times 10^{-14}$ $R = 7.5 \times 10^{-14}$ (m)	**C1** **C1** **A1**	**Allow** 2 mark for 1.6×10^{-13} (m); $Z = 59$ used **Allow** 2 mark for 8.9×10^{-14} (m); $Z = 32$ used **Allow** 1 mark for 2.8×10^{-15} (m); $Z = 1$ used **Allow** 1 mark for 1.2×10^{-32} (m); energy = 5.2×10^5 used
			Total	**8**	

Question			Answer	Marks	Guidance
24	(a)	(i)	alpha-particle / $^{4}_{2}\mathrm{He}$ / $^{4}_{2}\alpha$	B1	
		(ii)	nucleon number for Bi = 209	B1	
			antineutrino / $^{(o)}_{(0)}\bar{\upsilon}_{(e)}$	B1	**Note**: Do not allow incorrect subscript and superscript
	(b)	(i)	Aluminium (sheet placed between source and detector) The count (rate) reduces **or** Magnetic / electric field used Electrons identified from correct deflection / motion in field	M1 A1 M1 A1	 **Allow** count (rate) drop to background / zero **Allow** 2 marks for 'the range in air is a few m'
		(ii)	(λ =) ln2/3.3 (h^{-1}) **or** (λ =) 0.21 (h^{-1}) (A_0 =) $12 \times 10^3/e^{-(0.21 \times 7.0)}$ **or** (A_0 =) 5.219×10^4 (Bq) (N_0 =) $5.219 \times 10^4/5.835 \times 10^{-5}$ number of nuclei = 8.9×10^8 **Or** (λ =) ln2/[3.3 × 3600] (s^{-1}) **or** (λ =) 5.835×10^{-5} (s^{-1}) (N =) $1.2 \times 10^4/5.835 \times 10^{-5}$ **or** 2.057×10^8 (N_0 =) $2.057 \times 10^8/e^{-(0.21 \times 7.0)}$ number of nuclei = 8.9×10^8	C1 C1 C1 A1 C1 C1 C1 A1	**Allow** credit for alternative methods **Note** this is the same as $12 \times 10^3 \div (0.5)^{7.0/3.3}$ **Note** 9.0×10^8 can score full marks if numbers are rounded Possible ECF for incorrect conversion of time Note this is the same as $2.057 \times 10^8 \div (0.5)^{7.0/3.3}$
			Total	**9**	

Question			Answer	Marks	Guidance
25	(a)	(i)	Proton is repelled (by nucleus) (High-speed) proton can get close to (oxygen) nucleus	B1 B1	 **Allow** 'proton can experience the strong (nuclear) force' **Not** 'collide / hit nucleus'
		(ii)	E = [0.25 - (2.24 - 2.20)] × 10^{-11} (J) **or** 0.21 × 10^{-11} (J) $\lambda = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{0.21 \times 10^{-11}}$ (Any subject) λ = 9.5 × 10^{-14} (m)	C1 C1 A1	 **Allow** 2 marks for 6.9 × 10^{-14}; E = 0.29 × 10^{-11} used **Allow** 1 mark for a value correctly calculated based on any other incorrect value for E (e.g. 8(.0) × 10^{-14} for E = 0.25 × 10^{-11} and 5(.0) × 10^{-13} for E = 0.04 × 10^{-11})
		(iii)	Used in PET (scans) Any **one** from: Used to diagnose function of organ / brain / body Detection of cancer / tumour Non-invasive / no surgery / no infection 3D (image)	M1 A1	
	(b)		X-ray (tube) moves around the patient A thin (fan-shaped X-ray) beam is used (Images / scans of) cross-sections through the patient are taken Any **one** from: • A three-dimensional image is produced • (Soft) tissues can be identified	B1 B1 B1 B1	**Allow** 'X-rays passed through different angles.' **Allow** 'slice(s)' **Allow** 'good contrast image'
			Total	11	

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