GCE

Physics A

H556/02: Exploring physics

Advanced GCE

Mark Scheme for June 2019

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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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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 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 answer.

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 answer. 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.

SIGNIFICANT FIGURES

If the data given in a question is to 2 sf, then allow an answer 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 Guidance.

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	C	1	
2	D	1	
3	B	1	
4	C	1	
5	A	1	
6	B	1	
7	C	1	
8	B	1	
9	D	1	
10	C	1	
11	B	1	
12	A	1	
13	A	1	
14	B	1	
15	B	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)		time	B1	**Allow** *t* but **not** *T* **Ignore** any correct unit given with the correct label **Not** a wrong unit with the correct label, e.g *t* / m (CON) **Not** just a unit of time, e.g. second
	(b)		(*v* = distance/time) $v = \frac{\lambda}{T}$ $f = \frac{1}{T}$ and $v = f\lambda$ **or** There are *f* wavelengths per unit time *v* = distance travelled per unit time and $v = f \times \lambda$	M1 A1 M1 A1	**Allow** '(distance travelled is) λ in one period / *T* **Not** *t* for *T* **Allow** '…in 1 s' instead of 'per unit time' **Allow** λ / 'waves'; **not** cycles / oscillations instead of wavelengths
	(c)	(i)	(speed in material =) $\frac{3.0 \times 10^8}{1.20}$ **or** 2.5×10^8 (m s^{-1}) (t_V =) $\frac{1.5 \times 10^{-6}}{3.0 \times 10^8}$ **or** 5.0×10^{-15} (s) (t_M =) $\frac{1.5 \times 10^{-6} \times 1.20}{3.0 \times 10^8}$ **or** 6.0×10^{-15} (s) $t = [6.0 - 5.0] \times 10^{-15} = 1.0 \times 10^{-15}$ (s)	C1 C1 C1 A0	**Allow other correct methods** **Note** omitting or incorrect use of 1.2 is XP **Allow** 1 SF answer 5×10^{-15} **Allow** 1 SF answer 6×10^{-15} **Note** this also scores the first C1 mark **Note** omitting or incorrect use of 1.2 is XP
		(ii)	(f =) $\frac{3.0 \times 10^8}{6.0 \times 10^{-7}}$ **or** 5.0×10^{14} (Hz) **or** (T =) $\frac{6.0 \times 10^{-7}}{3.0 \times 10^8}$ $T = 2.0 \times 10^{-15}$ (s)	C1 A1	**Allow** 1 SF of 2×10^{-15} **Allow** 1 mark for 2.4×10^{-15} (s); 2.5×10^8 m s^{-1} used

Question	Answer	Marks	Guidance
(iii)	ϕ = 180 °	B1	Possible ECF from **(i)** and **(ii)** **Note** answer must be ϕ = **(c)(i)** × 360°/**(c)(ii)** **Not** an answer in rad, e.g. π rad
(d)*	**Level 3 (5–6 marks)** Clear description **and** clear analysis *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 analysis **or** Some description **and** some analysis *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 analysis *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**	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description** • Method for creating wave / pulse, e.g. lifting and releasing tray, dropping a ball into the water, ripple-tank arrangement, etc. (Details not expected) • speed = distance ÷ time **or** $v = x \div t$ **or** $v = f\lambda$ • Measure distance travelled using a ruler • Use a stopwatch / timer/ video technique / strobe to measure time / frequency • Measure the depth of water using a ruler etc • Record / measure / determine *v* for different *d* • Repeat to find average *v* **Analysis** • Plotting a graph, e.g. *v* against $\sqrt{d}$ **or** v^2 against *d* **or** lg*v* against lg*d* etc. • Correct determination of *g* from straight-line graph **or** • Table with *v* and $\sqrt{d}$ **or** v^2 and *d* • Correct calculation of average value of *g* from the table
	Total	**15**	

Question			Answer	Marks	Guidance
17	(a)	(i)	'Inverted' graph	B1	**Ignore** amplitude
		(ii)	Nodes shown correctly	B1	Expect at least 2 nodes labelled **N** No mark if the labels **N** are omitted **Note** the nodes must be on the original graph and not that sketched in **(a)(i)**
	(b)		Correct relationship between length of tube and λ for at least **two** stationary waves	B1	**Allow** *L* for length of tube Example $L = \lambda/4$ at 60 Hz, $L = 3\lambda/4$ at 180 Hz $L = 5\lambda/4$ at 300 Hz **Allow** $\lambda/4$ linked to 60 (Hz) etc on diagram or in text
			speed / *v* is constant **or** $f\lambda$ = constant **or** $f \propto 1/\lambda$	B1	**Not** just *f* increases λ decreases
			Calculation comparing at least **two** stationary waves to show $f\lambda$ = constant **or** $f \propto 1/\lambda$	B1	**Note** - calculation can also score the previous B1 mark E.g *f* increases by a factor of 5 (from 60 Hz to 300 Hz) and λ decreases by the same factor (of 5)
			Total	**5**	

Question			Answer	Marks	Guidance
18	(a)		Sum of e.m.f(s) is equal to the sum of p.d.(s) (in a loop of a circuit)	B1	**Allow** total / Σ instead of 'sum' **Allow** voltage instead of p.d. **Not** ….sum of *IR* ….., unless I and *R* are defined Expect 'sum' at least once in the statement **Not** Σ*E* = Σ*V*, unless *V* and *E* are defined
			Energy is conserved	B1	
	(b)		$L \rightarrow$ [m] and $A \rightarrow$ [m^2] **or** $L/A \rightarrow$ [m^{-1}]	C1	
			kg m^3 s^{-3} A^{-2}	A1	**Allow** $\frac{\text{kg m}^3}{\text{s}^3\ \text{A}^2}$ **or** kg m^3/s^3 A^2
	(c)	(i)	Line of best fit drawn	B1	Expect the extrapolated line to have a *y*-intercept in the range 0.60 to 0.85 **and** at least one data point on each side of the line
			gradient = 2.8	B1	**Allow** gradient of line in the range 2.60 to 3.00
		(ii)	$E = I(r + R)$ **and** $R = \rho L/A$	C1	**Allow** $E = V + IR$ **and** $R = \rho L/A$
			$\frac{1}{I} = \frac{r}{E} + \frac{\rho}{AE}L$ (and comparison with $y = mx + c$ leads to gradient = $\frac{\rho}{AE}$)	A1	
		(iii)	(ρ = gradient × *AE*)		
			$\rho = 2.8 \times \pi \times (0.19 \times 10^{-3})^2 \times 1.5$	C1	Possible ECF from **(i)** **Note** not using $A = \pi r^2$ is wrong physics (XP)
			$\rho = 4.8 \times 10^{-7}$ (Ω m)	A1	**Allow** 1 mark for 1.9×10^{-6}, diameter used instead of radius
		(iv)	The graph / points just shift horizontally (AW)	B1	**Allow** shifted to the right or left / 'systematic error' / zero error / change in length stays the same / 'no change in vertical values'
			The gradient is unchanged (and ρ will be the same)	B1	
			Total	**12**	

Question			Answer	Marks	Guidance
19	(a)		current = 0.01 (A) p.d. = 0.01 × 50 (= 0.50 V)	M1 A1	
	(b)		(V_{75} =) **0.5 + 2.5** (V) **or** (R_{LED}) = **250** (Ω) **or** (R_p =) **60** (Ω) (I_{100} =) **0.05** (A) (E = 3.0 + 0.05 × 100) E = 8.0 (V)	C1 C1 A1	**Allow** other correct methods **Note** there is no ECF from **(a)** **Allow** 1 SF for the p.d. of 3 (V) There is no ECF here from wrong physics (XP) from the parallel network **Allow** 1 SF answer of 8
	(c)	(i)	(P =) 0.01 × 2.5 **or** 0.01^2 × 250 **or** $2.5^2/250$ **or** 0.025 (W) (E_{photon} =) $\frac{6.63\times10^{-34}\times3.0\times10^{8}}{4.7\times10^{-7}}$ **or** 4.23 × 10^{-19} (J) (number per second = $\frac{0.025}{4.23\times10^{-19}}$) number per second = 5.9 × 10^{16} (s^{-1})	C1 C1 A1	**Allow** 4.0 × 10^{-19} (J); which is 2.5 eV **Note** using 4.0 × 10^{-19} (J) gives 6.25 × 10^{16} (s^{-1})
		(ii)	(E_{photon} =) 2.64 (eV) **or** (ϕ =) 3.68 × 10^{-19} (J) **or** (f_0 =) 5.55 × 10^{14} (Hz) **or** (λ_0 =) 5.40 × 10^{-7} (m) Photoelectrons are emitted and 2.6(4) > 2.3 **or** 4.23 × 10^{-19} > 3.68 × 10^{-19} **or** 6.38 × 10^{14} (Hz) > 5.55 × 10^{14} (Hz) **or** 4.7 × 10^{-7} (m) < 5.40 × 10^{-7} (m)	M1 A1	Possible ECF from **(i)** **Allow** 2.6 (eV) **or** 3.7 × 10^{-19} (J) **Allow** 2.5 (eV) as the energy of the photon **Note** the conclusion must be consistent with **(i)** **Allow** $hf > \phi$ **Note** this can be implied by calculating the KE of the emitted electron
			Total	10	

Question			Answer	Marks	Guidance
20	(a)		$F = BQv$ **and** $F = mv^2/r$ **or** $B = mv/Qr$ (Any subject) $(B =) \frac{1.4\times10^{-25}\times4.8\times10^{4}}{1.6\times10^{-19}\times0.18}$ B = 0.23 (T)	**C1** **C1** **A1**	**Allow** *e*
	(b)	**(i)**	Electron **and** (electron) antineutrino	**B1**	**Allow** beta-minus (particle) / β^- ; $\bar{\upsilon}_{(e)}$ **Allow** anti electron neutrino
		(ii)	λ = ln2/49 **or** λ = 0.0141 (billion y^{-1}) $0.95 = e^{-0.0141t}$ **or** $0.95 = e^{-4.48\times10^{-19}t}$ (age = - ln(0.95)/0.0141) age = 3.6 (billion years)	**C1** **C1** **A1**	**Allow** $\frac{\ln2}{49\times10^{9}\times3.16\times10^{7}}$ **or** 4.48×10^{-19} (s^{-1}) **Allow** both C1 marks for ln(0.95) = ln(0.5) × *t*/49 **Allow** 0.05/0.0141 ≈ *t* (this gives 3.5.. for the final mark) **Note** age in seconds is 1.15×10^{17} (s); this will score 2 marks
			Total	**7**	

Question			Answer	Marks	Guidance
21	(a)	(i)	Too many *N* / neutrons	B1	**Allow** 'neutron-rich' **or** (for stability) neutron changes to proton **or** (for stability) charge increases / *Z* changes to 8 **Allow** too few protons / 'proton-poor'
		(ii)	Too few *N* / neutrons	B1	**Allow** 'neutron-poor' **or** (for stability) proton changes to neutron **or** (for stability) charge decreases / *Z* changes to 6 **Allow** too many protons / 'proton-rich'
	(b)	(i)	More neutron**s** produced (from each fission reaction) Go on to produce further (fission) reactions / splitting (of nuclei) / energy	B1 B1	
		(ii)	Control rod(s) used These absorb the neutrons (without fission)	B1 B1	**Allow** boron / cadmium / indium / silver **Not** moderator **Not** neutrons slowed down and/or stopped
		(iii)			**Note** the 3.0% can be done at any stage, allow other correct methods
			(Δm =) $0.190 \times 1.66 \times 10^{-27}$ **or** 3.15×10^{-28} (kg)	C1	**Allow** the use of $1.6\mathbf{7} \times 10^{-27}$
			(ΔE =) $0.190 \times 1.66 \times 10^{-27} \times (3.0 \times 10^{8})^2$ **or** 2.84×10^{-11} (J)	C1	**Allow** ECF from 1.66×10^{-27} omitted
			$\frac{1.00}{0.235} \times 6.02 \times 10^{23}$ **or** 2.56×10^{24} (energy = $0.03 \times 2.56 \times 10^{24} \times 2.84 \times 10^{-11}$)	C1	**Note** 7.69×10^{22} will score this C1 mark; 3.0% included
			energy = 2.2×10^{12} (J)	A1	**Allow** 3 marks for 7.3×10^{13} (J); 3.0% omitted **Allow** 3 marks for 1.3×10^{39} (J); 1.66×10^{-27} omitted
			Total	10	

Question			Answer	Marks	Guidance
22	(a)	(i)	Qd = constant	C1	**Allow** straight-line graph of Q against $1/d$ passes through the origin **Allow** as d increases by a given factor (e.g. doubles) then Q decreases by the same factor (e.g. halves)
			At least **two** pairs of values substituted to show that Qd = constant	A1	**Allow** numbers that show when d doubles then Q halves **Ignore** prefixes and POT errors
		(ii)	$Q = VC$ **and** $C = \frac{\varepsilon_0 A}{d}$	C1	**Allow** ε
			Hence $Q = \frac{V\varepsilon_0 A}{d}$ (and $Q \propto \frac{1}{d}$)	A1	**Note** Q, or Q/V must be the subject here **Allow** $Q \propto C$ and $C \propto \frac{1}{d}$
	(b)	(i)	1.8×10^{-14} (N)	B1	**Ignore** sign
		(ii)	(F_E =) $3 \times 1.8 \times 10^{-14}$ (N) **or** (F_E =) 5.4×10^{-14} (N) **or** (mass =) $\frac{1.8 \times 10^{-14}}{g}$	C1	**Note** this mark is for either electric force on the oil drop **or** the calculating the mass of the oil drop
			(resultant force = 3.6×10^{-14} N)		**Allow** for ECF from **(b)(i)**
			(a =) $\frac{3.6 \times 10^{-14}}{(1.8 \times 10^{-14}/g)}$	C1	
			a = 20 (m s^{-2})	A1	**Allow** g = 9.8, but not g = 10 **Note** answer to 3SF is 19.6 **Allow** 2 marks for $a = 2g$ **Note** a bald answer of 20 will score 3 marks, if however, we see evidence for g = 10, then maximum score will be 2 mark

Question	Answer	Marks	Guidance
(c)*	**Level 3 (5–6 marks)** Clear description **and** at least two from control of variables *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 description **and** at least one from control of variables *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)** Any description but no control of variables **or** Limited mention of control of variable(s) *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**	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description** • $E = V/d$ • Voltmeter used to measure p.d. • Ruler used to measure separation *d* plates • Plastic rod held in a stand • Safety: Do not touch the terminals of high-voltage supply / (positive) plate • Vary *d* or *V* to change *E* • θ determined for each value of *E* • Experiment repeated for several values of *E* • Sensible techniques used to determine θ, e.g. use a protractor • Plot $\tan\theta$ against *E* **or** $\tan\theta$ against $1/d$ graph • Straight line through origin (expected) **Control of variables** • Charge *q* kept constant (ignore method) • Method for keeping *q* constant (e.g. same *V* for the (positive) plate, use separate constant voltage supply, etc) • Use the same foil / keep *W* the same • Keep *d* or *V* constant • Foil in between plates (where the field is uniform) • Draught-free room • Do the experiment quickly to avoid leakage of charge
	Total	**14**	

Question			Answer	Marks	Guidance
23	(a)				**Ignore** polarity of high voltage supply throughout
			(Evacuated tube with) cathode / heater / filament **and** target / metal / anode	**B1**	**Note** the first two B1 marks can be scored on a labelled diagram
			High voltage (supply) connected between cathode and anode	**B1**	**Allow** a specific value in the range 10 kV to 1 MV **Note** expecting 'high' or qualified by values in range above
			(Accelerated) electrons hit the target / metal / anode and their KE is transformed into X-ray (photons)	**B1**	
	(b)		Any **two** from:		**Ignore** if interaction between photons and electrons is not one-to-one
			Photoelectric (effect) Photon (is absorbed and an) electron removed (from the atom)	**M1** **A1**	 **Not** X-ray wave etc; must refer to photon
			Compton (scattering / effect) Photon scattered / deflection with longer wavelength / low frequency / low energy and electron removed (from the atom)	**M1** **A1**	 **Not** reflected **Not** X-ray wave etc; must refer to photon
			Pair production Photon (absorbed) and produce electron-positron (pair)	**M1** **A1**	 **Not** X-ray wave etc; must refer to photon
			Total	**7**	

Question			Answer	Marks	Guidance
24	(a)		Piezoelectric (effect) mentioned	B1	**Allow** 'applied p.d. changes the shape of a crystal / film'
			An alternating p.d. applied to the film / crystal produces vibrations / resonance (and this in turn produces ultrasound)	B1	**Allow** alternating current / a.c. **Allow** expand and contract for vibrations (AW) **Allow** a named film / crystal
	(b)		density (of tissue) **or** speed (of ultrasound in tissue) **or** acoustic impedance mentioned	B1	**Not** ρ **or** c **or** Z
			Same Z, no reflection / different Z gives reflection	B1	**Allow** same Z, total transmission / different Z gives some transmission
			$I_r/I_0 = [Z_1 - Z_2]^2/[Z_1 + Z_2]^2$ **and** intensity mentioned	B1	**Allow** fraction of intensity reflected = $(Z_1 - Z_2)^2/(Z_1 + Z_2)^2$
			Total	5	

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