

GCE

Physics A

H556/02: Exploring physics

Advanced GCE

Mark Scheme for November 2020

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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.

- 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 answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.
- A** marks These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to 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.
- 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 answers.

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
	Incorrect response
AE	Arithmetic error
BOD	Benefit of doubt given
BP	Blank page
CON	Contradiction
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
POT	Power of 10 error
SEEN	Seen
SF	Error in number of significant figures
TE	Transcription error
XP	Wrong physics or equation
^	Omission

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	C	1	
3	A	1	
4	B	1	
5	C	1	
6	C	1	
7	D	1	
8	B	1	
9	C	1	
10	B	1	
11	B	1	
12	A	1	
13	A	1	
14	D	1	
15	D	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)		(special coupling) gel is used that has the same / 'matching' (acoustic) impedance as skin / body	B1	Allow Z Allow gel and impedance is the same / matching for two materials / mediums
			Reduced / less / zero <u>reflection</u> (at the skin)	B1	Allow more transmission
	(b)		(Pulses of) ultrasound sent into the eye	B1	Allow ultrasound reflected by any part of the eye Allow 'sound' / wave (since ultrasound is in the question) Ignore transducer placed close / next to eye
			Reflections from <u>front</u> and <u>back</u> of lens (and pulses displayed on oscilloscope)	B1	
			(Thickness of lens) determined from speed (of ultrasound) and time (difference)	B1	Allow thickness = $\frac{ct}{2}$ with c = speed (of ultrasound) and t = time (difference) Allow this mark even when the reflections are from incorrect boundaries
			Total	5	

Question			Answer	Marks	Guidance
17	(a)		$(E =) 1.8 \times 1.6 \times 10^{-19}$ or 2.88×10^{-19} (J) $1.8 \times 1.6 \times 10^{-19} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{\lambda}$ $\lambda = 6.9 \times 10^{-7}$ (m)	C1 C1 A1	
	(b)		$(V_R =) 2.7$ (V) or (current =) 0.018 (A) (ratio = $\frac{0.018 \times 1.8}{0.018 \times 2.7}$) ratio = 0.67	C1 A1	Note the mark can be scored on circuit diagram Note values of powers are: 0.0324 W and 0.0486 W Allow 2/3; Not 0.66 (rounding error)
	(c)	(i)	In darkness LDR has more resistance / p.d. across LDR is large or In light LDR has less resistance / p.d. across LDR is small Clear idea that when the LED is on, this will force the p.d. across LED / LDR to decrease, forcing the LED to switch off (ORA) (The cycle of LED switching on and off is repeated)	B1 B1	Note the explanation must be in terms of p.d. / potential divider. Ignore current
		(ii)	A sensible suggestion, e.g. Point the LED away from the LDR / increase distance (between LED and LDR) / insert a card between (LED and LDR)	B1	
			Total	8	

Question	Answer	Marks	Guidance
18*	Level 3 (5–6 marks) Clear description and clear analysis of data <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description and some analysis of data OR Clear description OR Clear analysis of data <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description and limited analysis OR Some description OR Some analysis of data <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	B1×6	Indicative scientific points may include: Description • Circuit showing supply, ammeter, voltmeter and resistance wire /coil • Measure I (in coil) with ammeter • Measure V (across coil) with voltmeter • Power (for coil) calculated: $P = VI$ • Resistance of thermistor either calculated using $R = V/I$ or measured with ohmmeter • Change P / change V / use variable power supply / use variable resistor (to change I) • Keep the number of turns of coil constant throughout / no draughts / wait until the resistance stabilises Analysis • $\lg P = \lg k + n \lg R$ (or natural logs $\ln$) • Plot a graph of $\lg P$ against $\lg R$ • If expression is correct, then a straight line with non-zero intercept • gradient = n • intercept = $\lg k$ • $k = 10^{\text{intercept}}$ (or $k = e^{\text{intercept}}$ for natural logs)
	Total	6	

Question			Answer	Marks	Guidance
19	(a)		$h \rightarrow \text{J s} \quad / \quad h \rightarrow \text{N m s} \quad / \quad \text{J} \rightarrow \text{kg m}^2 \text{s}^{-2}$ base unit = $\text{kg m}^2 \text{s}^{-1}$	C1 A1	
	(b)	(i)	$Vq = \frac{1}{2} mv^2$ and $\lambda = \frac{h}{mv}$ Clear algebra leading to $\lambda^2 = \frac{h^2}{2mq} \times \frac{1}{V}$	M1 A1	Allow p for mv Allow e for q in (b)(i) – this is to be treated as a ‘slip’
		(ii)1	(% uncertainty in λ^2 =) 10% (% uncertainty in λ =) 5%	C1 A1	Note 10 (%) on answer line will score the C1 mark
		(ii)2	Straight line of best fit passes through all error bars	B1	
		(ii)3	gradient = $1.0 (\times 10^{-22})$ $\frac{h^2}{2mq} = \text{gradient}$ $\frac{(6.63 \times 10^{-34})^2}{2 \times m \times 3.2 \times 10^{-19}} = \text{gradient}$ $m = 6.9 \times 10^{-27} \text{ (kg)}$ (hence about 10^{-26} kg)	C1 C1 C1 A1	Ignore POT for this mark; Allow $\pm 0.20 (\times 10^{-22})$ Possible ECF for incorrect value of gradient Note check for AE (condone rounding error here) and answer must be about 10^{-26} (kg) for any incorrect gradient value for this A1 mark Special case: $1.37 \times 10^{-26} \text{ kg}$ scores 3 marks for $q = 1.6 \times 10^{-19} \text{ C}$ because answer is about 10^{-26} kg
			Total	11	

Question			Answer	Marks	Guidance
20	(a)	(i)	sensible diameter, e.g. 7 (mm) (power = $4.8 \times 10^{-7} \times \pi \times (0.0035)^2$) power = 1.8×10^{-11} (W)	C1 A1	Allow 2 – 16 (mm) Not πd^2 ; this is XP Note check for AE (condone rounding error here) Possible ECF for diameter outside the range 2 – 16 (mm) Allow 1 SF answer here
		(ii)	$(I \propto A^2$; intensity doubles) $A = \sqrt{2} \times 7.8$ (or equivalent) $A = 11$ (nm)	C1 A1	Allow the C1 mark for $4.8 (\times 10^{-7}) = k \times [7.8 \times (10^{-9})]^2$
	(b)		(When two or more waves meet at a point) the resultant displacement is (equal to) the sum of the (individual) displacements (of the waves)	B1	Allow sum / total / net for resultant Ignore vector sum
	(c)	(i)	phase difference = $n \times 360(^{\circ})$ for bright (fringes) / constructive (interference) phase difference = $(n + \frac{1}{2}) \times 360(^{\circ})$ for dark (fringes) / destructive (interference)	B1 B1	Allow zero or $n \times 2\pi(\text{rad})$ or even number of π (rad) or even number of $180(^{\circ})$ Allow $180(^{\circ})$ or $(n + \frac{1}{2}) \times 2\pi(\text{rad})$ or odd number of π (rad) or odd number of $180(^{\circ})$ Special case: 1 mark for ‘completely in phase for bright fringes/constructive (interference) and in anti-phase / completely out of phase for dark fringes /destructive (interference)’
		(ii)	$\lambda = \frac{3.0 \times 10^8}{4.75 \times 10^{14}}$ or $\lambda = 6.316 \times 10^{-7}$ (m) $x = \frac{6.316 \times 10^{-7} \times 8.2}{0.20 \times 10^{-3}}$ or $x = 0.0259$ (m) $t = 0.14$ (s)	C1 C1 A1	Note the answer must be given to 2 SF for this mark Special case: allow 1 mark for 8.6×10^{-11} s on the answer line; incorrect physics using $0.18 = 4.75 \times 10^{14} \lambda$
			Total	10	

Question			Answer	Marks	Guidance
21	(a)		Electrons and quarks identified as fundamental particles	B1	Allow e for electron, p for proton, and n for neutron throughout Allow 6 electrons, 20 u and 22 d Do not award this mark if electron has quark-composition Allow '2 up and 1 down' Allow '2 down and 1 up'
			There are 6 electrons, 6 protons and 8 neutrons	B1	
			Composition of proton $\rightarrow$ u u d	B1	
			Composition of neutron $\rightarrow$ u d d	B1	
	(b)	(i)	(decay constant =) $\frac{\ln 2}{5700}$ decay constant = $1.2(2) \times 10^{-4} \text{ (y}^{-1}\text{)}$	C1 A0	
		(ii)	$0.78 = e^{-\lambda t}$ $\ln 0.78 = (-) 1.2 \times 10^{-4} \times t$ age = 2100 (y)	C1 C1 A1	Note $1 = 0.78e^{-\lambda t}$ is XP ; answer is negative (- 2100 y) There is no ECF from (b)(i) Note 1.22×10^{-4} gives an answer of 2040 y or 2000 y
		(iii)	The ratio (of carbon-14 to carbon-12) has remained constant	B1	

	(c)*	Level 3 (5–6 marks) Some description and clear analysis for $r \propto A^{1/3}$ and correct calculation of mean density <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description and some analysis for $r \propto A^{1/3}$ or some calculation of mean density OR Some description and clear analysis for $r \propto A^{1/3}$ OR Some description and correct calculation of mean density OR Clear analysis for $r \propto A^{1/3}$ and correct calculation of mean density <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Some description OR Limited analysis for $r \propto A^{1/3}$ OR Limited calculation of mean density <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	B1×6	Indicative scientific points may include: Description • The density is independent of A • The density is constant for most of d • Nucleus with bigger A is larger (d / volume / mass) Analysis for $r \propto A^{1/3}$ • $r \approx 3.6 (\times 10^{-15} \text{ m})$ for Al-27 / $r \approx 5.5 (\times 10^{-15} \text{ m})$ for Mo-96 / $r \approx 7.0 (\times 10^{-15} \text{ m})$ for Hg-200 • $r/A^{1/3} = \text{constant}$ (or equivalent) • Evidence for $r \propto A^{1/3}$ with at least 2 nuclei (Note: $3.6 (\times 10^{-15})/27^{1/3} \approx 5.5 (\times 10^{-15})/96^{1/3} \approx 7.0 (\times 10^{-15})/200^{1/3} \approx 1.2 (\times 10^{-15})$) or • $r^3/A = \text{constant}$ (or equivalent) • Evidence for $r^3 \propto A$ with at least 2 nuclei (Note: $3.6^3 (\times 10^{-45})/27 \approx 5.5^3 (\times 10^{-45})/96 \approx 7.0^3 (\times 10^{-45})/200 \approx 1.7 (\times 10^{-45})$) Calculation for density • $\rho = M/V$ • $\rho = Am_n \div \frac{4}{3} \pi r^3$ or $\rho \approx Am_n \div \text{diameter}^3$ • $m_n \approx 1.7 \times 10^{-27} \text{ (kg)}$; $\rho = 2.3 \times 10^{17} \text{ (kg m}^{-3}\text{)}$ for at least one of the nuclei given in the figure or table
		Total	15	

Question			Answer	Marks	Guidance
22	(a)		Magnetic <u>field</u> (around current-carrying wire) (Fleming's) left-hand rule mentioned (Magnetic) field into page, (current is up the page) and force is to the left / towards X	B1 B1 B1	Not magnetic force Allow 'field into page and wires attract' Note the field direction and force direction can be shown on the figure
	(b)	(i)	(induced) e.m.f. is (directly) proportional / equal to the rate of change of (magnetic) flux linkage	B1	Not current Allow 'rate of cutting' for 'rate of change'
		(ii)	Connect the primary (coil) to an alternating voltage / current Oscilloscope connected across secondary coil / to measure E A graph of E against N will be a straight line through the origin.	B1 B1 B1	Allow AC (can be on the figure) Not changing / variable for alternating Allow voltmeter (can be on the figure) Allow p.d. / voltage for e.m.f. / E throughout Ignore any component (e.g. lamp or resistor) connected across the secondary coil Allow $(E \div N) = \text{constant}$
			Total	7	

Question			Answer	Marks	Guidance
23	(a)	(i)	$(\text{force}) = \frac{(1.6 \times 10^{-19})^2}{4\pi\epsilon_0 \times (1.0 \times 10^{-15})^2}$ $(F =) 230 \text{ (N)}$ $F^2 = 230^2 + 230^2 - 2 \times 230 \times 230 \times \cos 120^\circ$ or $F = 2 \times 230 \cos 30^\circ$ $F = 400 \text{ (N)}$	C1 C1 A1	Special case: $F = \frac{Qq}{4\pi\epsilon_0 r^2} = \frac{2 \times 1.6 \times 10^{-19}}{4\pi\epsilon_0 \times (1.0 \times 10^{-15})^2}$ loses this C1 mark, then ECF for the rest of the marks Not the first two C1 marks for incorrect charge, then allow ECF for the final C1A1 marks Note force to 4 SF is 230.2 N Allow sine rule / scale drawing Allow this mark for 230cos30° or 200 (N) Allow ± 10 (N) if scale drawing used
		(ii)	F / arrow vertical up the page	B1	Allow correct arrow direction anywhere on the figure
		(iii)	Strong (nuclear) force (acts on the protons) The strong (nuclear) force is attractive	B1 B1	Ignore gravitational force Allow pulls / holds (the protons) / binds (the protons) for 'attractive'
	(b)	(i)	$12\,000 = \frac{Q}{4\pi\epsilon_0 r}$ $12\,000 = \frac{Q}{4\pi\epsilon_0 \times 0.19}$ $Q = 2.5(4) \times 10^{-7} \text{ (C)}$	C1 C1 A0	Allow $E = (V/d) = 6.316 \times 10^4$ C1 and $E = 6.316 \times 10^4 = \frac{Q}{4\pi\epsilon_0 \times 0.19^2}$ C1
		(ii)1	$t = 78 \times 3600$ $(I =) \frac{2.5 \times 10^{-7}}{78 \times 3600}$ $I = 8.9 \times 10^{-13} \text{ (A)}$	C1 C1 A0	There is no ECF from (b)(i) Note 2.54×10^{-7} gives an answer $9.0 \times 10^{-13} \text{ A}$
		(ii)2	$(R =) \frac{6000}{9.0 \times 10^{-13}}$ or $6.7 \times 10^{15} \text{ (}\Omega\text{)}$ or $V = IR$ and $R = \frac{\rho L}{A}$ $\frac{6000}{9.0 \times 10^{-13}} = \frac{\rho \times 0.38}{1.1 \times 10^{-4}}$ $\rho = 1.9 \times 10^{12} \text{ (}\Omega \text{ m)}$	C1 C1 A1	There is no ECF from (b)(ii)1 Take 12000 V as TE for this C1 mark, then ECF Note $8.9 \times 10^{-13} \text{ (A)}$ gives an answer $2.0 \times 10^{12} \text{ (}\Omega \text{ m)}$
			Total	14	

Question			Answer	Marks	Guidance
24	(a)		Emits gamma (photons / radiation / waves / rays) Any one from: (Diagnosing the) function of organ Detecting tumour Small half-life (Gamma rays) can be detected outside body / passes through patient / least ionising Position of tracer located	B1 B1	Not injected into a patient / non-invasive Allow for half-life is a few hours
	(b)		Collimator: Allows gamma (photons) parallel to the axis of the tubes to pass through Scintillator: gamma (photons) produces (many) light (photons) Photomultiplier (tubes): light (photons) produces electrons / current / electrical pulse / p.d. / signal	B1 B1 B1	Ignore any other components named / described Allow photon / waves / rays Allow idea of tubes allowing the gamma (photons) to travel in the same direction Allow crystal (or named crystal) for scintillator Allow high-energy photons produce (many) low-energy photons
			Total	5	

Question			Answer	Marks	Guidance
25	(a)		All except pair production / PP	B1	Allow PE, S and C
	(b)		$(\text{energy} =) 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$ $(\text{energy} =) 2 \times 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2 / 1.60 \times 10^{-19}$ $\lg 1.0(2) \times 10^6 = 6$ (as on graph) OR $(\text{energy} =) 1.0 \times 10^6$ (eV) or $\lg 1.0 \times 10^6 = 6$ (from graph) $(\text{energy} =) 1.6 \times 10^{-13}$ J and evidence of mc^2 $2 \times 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2 \approx 1.6 \times 10^{-13}$	B1 B1 B1 B1 B1 B1	Note this is 8.2×10^{-14} (J) Note this is $1.0(2) \times 10^6$ eV Note this can be shown in a variety of ways
			Total	4	

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