Oxford Cambridge and RSA

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.

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	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	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)	C1	
			$1.8 \times 1.6 \times 10^{-19} = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{\lambda}$	C1	
			$\lambda = 6.9 \times 10^{-7}$ (m)	A1	
	(b)		(V_R =) 2.7 (V) **or** (current =) 0.018 (A)	C1	**Note** the mark can be scored on circuit diagram
			(ratio = $\frac{0.018 \times 1.8}{0.018 \times 2.7}$)		**Note** values of powers are: 0.0324 W and 0.0486 W
			ratio = 0.67	A1	**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	B1	
			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	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 *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** some analysis of data **OR** Clear description **OR** Clear analysis of data *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 **and** limited analysis **OR** Some description **OR** Some analysis of data *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** • 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)		$h \rightarrow$ J s / $h \rightarrow$ N m s / J $\rightarrow$ kg m^2 s^{-2}	C1	
			base unit = kg m^2 s^{-1}	A1	
	(b)	(i)	$Vq = ½\ mv^2$ **and** $\lambda = \frac{h}{mv}$	M1	**Allow** *p* for *mv* **Allow** *e* for *q* in **(b)(i)** – this is to be treated as a 'slip'
			Clear algebra leading to $\lambda^2 = \frac{h^2}{2mq} \times \frac{1}{V}$	A1	
		(ii)1	(% uncertainty in λ^2 =) 10%	C1	
			(% uncertainty in λ =) 5%	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})	C1	**Ignore** POT for this mark; **Allow** $\pm$ 0.20 ($\times$ 10^{-22})
			$\frac{h^2}{2mq} =$ gradient	C1	
			$\frac{(6.63\times10^{-34})^2}{2\times m\times 3.2\times 10^{-19}}$ = gradient	C1	Possible ECF for incorrect value of gradient
			m = 6.9 $\times$ 10^{-27} (kg) (hence about 10^{-26} kg)	A1	**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} kg scores 3 marks for *q* = 1.6 $\times$ 10^{-19} 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 = $n \times 360(°)$ for bright (fringes) / constructive (interference) phase difference = $(n + ½) \times 360(°)$ for dark (fringes) / destructive (interference)	B1 B1	**Allow** zero **or** $n \times 2\pi$(rad) **or** even number of π (rad) **or** even number of 180(°) **Allow** 180(°) **or** $(n + ½) \times 2\pi$(rad) **or** odd number of π (rad) **or** odd number of 180(°) **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	
			There are 6 electrons, 6 protons and 8 neutrons	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
			Composition of proton → u u d	B1	**Allow** '2 up and 1 down'
			Composition of neutron → u d d	B1	**Allow** '2 down and 1 up'
	(b)	(i)	(decay constant =) $\frac{\ln 2}{5700}$	C1	
			decay constant = $1.2(2) \times 10^{-4}$ (y^{-1})	A0	
		(ii)	$0.78 = e^{-\lambda t}$	C1	**Note** $1 = 0.78e^{-\lambda t}$ is **XP**; answer is negative (- 2100 y)
			$\ln 0.78 = (-)\ 1.2 \times 10^{-4} \times t$	C1	There is no ECF from **(b)(i)**
			age = 2100 (y)	A1	**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 *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** 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 *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** Limited analysis for $r \propto A^{1/3}$ **OR** Limited calculation of mean density *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** • 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 $r \propto A^{1/3}$** • $r \approx 3.6 (\times 10^{-15}$ m) for Al-27 / $r \approx 5.5 (\times 10^{-15}$ m) for Mo-96 / $r \approx 7.0 (\times 10^{-15}$ m) for Hg-200 • $r/A^{1/3}$ = 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 = 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** $\rho \approx Am_n \div$ diameter^3 • $m_n \approx 1.7 \times 10^{-27}$ (kg); $\rho = 2.3 \times$ **10^{17}** (kg m^{-3}) 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** ($E \div N$) = constant
			Total	**7**	

Question			Answer	Marks	Guidance
23	(a)	(i)	(force =) $\frac{(1.6\times10^{-19})^2}{4\pi\epsilon_0\times(1.0\times10^{-15})^2}$	C1	**Special case:** $F = \frac{Qq}{4\pi\epsilon_0 r^2}$ = $\frac{2\times1.6\times10^{-19}}{4\pi\epsilon_0\times(1.0\times10^{-15})^2}$ 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
			(F =) 230 (N)	C1	**Note** force to 4 SF is 230.2 N
			$F^2 = 230^2 + 230^2 - 2\times230\times230\times\cos120°$ **or** $F = 2\times230\cos30°$	C1	**Allow** sine rule / scale drawing **Allow** this mark for $230\cos30°$ **or** 200 (N)
			F = 400 (N)	A1	**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)	B1	**Ignore** gravitational force
			The strong (nuclear) force is attractive	B1	**Allow** pulls / holds (the protons) / binds (the protons) for 'attractive'
	(b)	(i)	$12\,000 = \frac{Q}{4\pi\varepsilon_0 r}$	C1	**Allow** $E = (V/d =)\ 6.316\times10^4$ **C1** and
			$12\,000 = \frac{Q}{4\pi\varepsilon_0\times0.19}$	C1	$E = 6.316\times10^4 = \frac{Q}{4\pi\varepsilon_0\times0.19^2}$ **C1**
			$Q = 2.5(4)\times10^{-7}$ (C)	A0	
		(ii)1	$t = 78\times3600$	C1	
			$(I =) \frac{2.5\times10^{-7}}{78\times3600}$	C1	There is no ECF from **(b)(i)**
			$I = 8.9\times10^{-13}$ (A)	A0	**Note** 2.54×10^{-7} gives an answer 9.0×10^{-13} A
		(ii)2	$(R =) \frac{6000}{9.0\times10^{-13}}$ **or** 6.7×10^{15} (Ω) **or** $V = IR$ and $R = \frac{\rho L}{A}$	C1	There is no ECF from **(b)(ii)1** **Take** 12000 V as **TE** for this C1 mark, then ECF
			$\frac{6000}{9.0\times10^{-13}} = \frac{\rho\times0.38}{1.1\times10^{-4}}$	C1	
			$\rho = 1.9\times10^{12}$ (Ω m)	A1	**Note** 8.9×10^{-13} (A) gives an answer 2.0×10^{12} (Ω m)
			Total	14	

Question			Answer	Marks	Guidance
24	(a)		Emits gamma (photons / radiation / waves / rays)	B1	
			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	**Not** injected into a patient / non-invasive **Allow** for half-life is a few hours
	(b)				**Ignore** any other components named / described
			Collimator: Allows gamma (photons) parallel to the axis of the tubes to pass through	B1	**Allow** photon / waves / rays **Allow** idea of tubes allowing the gamma (photons) to travel in the same direction
			Scintillator: gamma (photons) produces (many) light (photons)	B1	**Allow** crystal (or named crystal) for scintillator **Allow** high-energy photons produce (many) low-energy photons
			Photomultiplier (tubes): light (photons) produces electrons / current / electrical pulse / p.d. / signal	B1	
			Total	5	

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

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