GCE

Physics A

H556/02: Exploring physics

A Level

Mark Scheme for June 2022

OCR (Oxford Cambridge and RSA) is a leading UK awarding body, providing a wide range of qualifications to meet the needs of candidates of all ages and abilities. OCR qualifications include AS/A Levels, Diplomas, GCSEs, Cambridge Nationals, Cambridge Technicals, Functional Skills, Key Skills, Entry Level qualifications, NVQs and vocational qualifications in areas such as IT, business, languages, teaching/training, administration and secretarial skills.

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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.

RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are available in RM Assessor.

3. Log-in to RM Assessor and mark the **required number** of practice responses ("scripts") and the **required number** of standardisation responses.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the RM Assessor 50% and 100% deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader via the RM Assessor messaging system in the first instance.

5. **Crossed Out Responses**
   Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

   Multiple Choice Question Responses
   When a multiple-choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
   When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses
When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**)
Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth **two or more marks**)
If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response)
Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked. Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

6. On each blank page the icon BP must be inserted to confirm that the page has been checked. For additional objects (if present), a tick must be inserted on each page to confirm that it has been checked.
Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there.

7. Award No Response (NR) if:

- there is nothing written in the answer space

Award Zero '0' if:
- anything is written in the answer space and is not worthy of credit (this includes text and symbols).

Team Leaders must confirm the correct use of the NR button with their markers before live marking commences and should check this when reviewing scripts.

8. The RM Assessor **comments box** is used by the Principal Examiner or your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**

   If you have any questions or comments for your team leader, use the RM Assessor messaging system.

9. Assistant Examiners should send a brief report on the performance of candidates to the Principal Examiner by the end of the marking period. Please submit a short, bulleted report using Word.

10. **Level of response (LoR)**

    Read through the whole answer from start to finish, concentrating on features that make it a stronger or weaker answer using the indicative scientific content as guidance. The indicative scientific content indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance.

    Using a 'best-fit' approach based on the science content of the answer, first decide which set of level descriptors, Level 1 (L1), Level 2 (L2) or Level 3 (L3), **best** describes the overall quality of the answer using the guidelines described in the level descriptors in the mark scheme.

    Once the level is located, award the higher or lower mark.

    The higher mark should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met. **The lower mark** should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing.

    In summary:

    - the **science** content determines the **level**
    - the **communication statement** determines the **mark within a level**.

    Levels of response questions on this paper are **17b** and **20b**.

11. 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.

12. 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	B	1	
2	C	1	
3	C	1	
4	D	1	
5	A	1	
6	B	1	
7	A	1	
8	C	1	
9	A	1	
10	D	1	
11	A	1	
12	C	1	
13	D	1	
14	A	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)	(i)	π (rad)	B1	**Allow** 3.14 or 3.1 (rad) **Do not allow** answer in degrees
		(ii)	- 5.0 (cm)	B1	**Allow** 1 SF. **Must** see negative sign.
	(b)		540 (°)	B1	**Allow** 180° **Do not allow** answer in radians
			1.5 (λ)	B1	**Allow** 3/2
	(c)	(i)	Zero amplitude / displacement / oscillations / movement (at the nodes)	B1	**Allow** minimum or least for zero throughout **Ignore** references to pressure e.g. min/max pressure **Allow** correct answers in terms of pressure gradients **Penalise** incorrect answers in terms of antinodes **Ignore** correct answers in terms of antinodes
		(ii)	2λ = 25 (cm) / λ = 12.5 (cm)	C1	
			$v = 2720 \times 0.125$	C1	**Maximum** one POT error in this question
			v = 340 (m s^{-1})	A1	**Special case: one mark only** for bare 340 (m s^{-1}) with no working **Allow** 2 marks for 170 m s^{-1} if calculated from λ = 6.25 (cm)
		(iii)	$11f_0 = 2.72 (\times 10^3)$ **or** $11/4 \times 12.5 = \lambda_o/4$ **or** $\lambda_o = 1.375$ (m)	C1	**Allow** length of tube = 0.344 (m)
			f_0 = (340 / 1.375) = 247 (Hz)	A1	**Allow** 250 (Hz) **Allow** ecf on v from (c)(ii).
			Total	10	

Question			Answer	Marks	Guidance
17	(a)		eV or J $\rightarrow$ [kg m^2 s^{-2}] in base units by any method base units = kg m^2 s^{-1}	C1 A1	**Allow** kg (m s^{-1})^2 **Allow** base units in any order
	*(b)		**Level 3 (5–6 marks)** Clear description of method **and** 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 of method **and** analysis of data **or** Clear description **or** Clear 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	**Indicative scientific points may include:** **Description** • Circuit with LED connected to a variable supply (and series /current limiting resistor) / or use of variable resistor • p.d. across LED increased until LED emits light • Voltmeter (across LED) used to measure V • Use a range of LEDs • λ determined using diffraction grating / spectrometer / double-slit / use $n\lambda = d\sin\theta$ / $\lambda = ax/D$ **OR** λ determined from manufacturer's data / known wavelength • Darkroom used / tube placed over LED used to establish switching of LED / switch-on identified from finite ammeter reading **Analysis of data** • Plot of V against λ^{-1} / eV against λ^{-1} / eV against c/λ • Line of best-fit drawn through the points • Straight line (through origin) • Correct gradient for described graph hc/e or hc or h • Correct arrangement for determination of h h = (gradient $\times$ e) / c or h = gradient / c (allow numerical values for e *and/or* c)
			Total	8	

Question			Answer	Marks	Guidance
18	(a)		e.m.f → (chemical) to electrical and p.d. → from electrical (to thermal / heat) **or** e.m.f → charges/electrons gain energy and p.d. → charges/electrons lose energy	B1	**Allow** e.m.f. is work done on charges and pd is work by charges **Allow** battery for e.m.f and resistor for p.d. **Allow** less p.d. (than e.m.f.) due to energy transferred in internal resistance (must be clear that it is internal or cell resistance and not any other circuit resistance). **AW**
	(b)		length (of wire)	B1	
	(c)	(i)	$E = V + Ir$ / $E = IR + Ir$ / $E = I(R + r)$ Clear manipulation leading to $\frac{1}{I} = \frac{R}{E} + \frac{r}{E}$	M1 A1	**Allow** ε for E throughout **Expect** at least one line of intermediate correct algebra leading to correct expression, explicitly shown.
		(ii)1	$I^{-1} = 0.8$ (A^{-1}) / $I = 1.25$ (A) P ($= 1.25^2 \times 3.0$) = 4.7 (W)	C1 A1	**Allow** $I = 1.3$ (A). **Expect** at least 2sf. **No ecf** from graph misread. **Allow** 5.1 (W) from use of 1.3 (A)
		(ii)2	(Intercept =) 0.20 (A^{-1}) $r = (0.20 \times 5.0) = 1.0$ (Ω)	M1 A1	Value of 0.2 anywhere in calculation implies correct reading of intercept. **Allow** ± 0.02. **Allow** current = 5 (A) implies intercept correctly read **Do not allow** substitutions into $E = IR + Ir$ other than using the intercept. **Allow** 1 SF answer **Alternative** r = (E / I = 5 / 5) = 1.0 (Ω)
			Total	8	

Question			Answer	Marks	Guidance
19	(a)		$(hf = \phi + KE_{max}) = 6.63 \times 10^{-34} \times 6.3 \times 10^{14} = \phi + 4.8 \times 10^{-20}$ $\phi = 3.6969 \times 10^{-19}$ (J) $\phi = 2.3$ (eV)	C1 C1 A1	**OR** (in eV) $hf = 6.63 \times 10^{-34} \times 6.3 \times 10^{14} / 1.6 \times 10^{-19}$ $\phi = 2.6 - 0.30$ (eV) $\phi = 2.3$ (eV)
	(b)	(i)	$a = \frac{VQ}{dm}$ OR $a = \frac{EQ}{m}$ OR $KE = ½ mv^2$ and $v^2 = u^2 + 2as$ OR $KE = F \times d$ and $F = m \times a$ $a = \frac{0.30 \times 1.6 \times 10^{-19}}{6.0 \times 10^{-3} \times 9.11 \times 10^{-31}}$ / $a = \frac{50 \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}$ / (Use of $KE = ½ mv^2$) $= 4.8 \times 10^{-20} = ½ \times 9.11 \times 10^{-31} \times v^2$ and (use of $v^2 = u^2 + 2as$ =) $v^2 = (1.05 \times 10^{11}) = 2 \times a \times 6 \times 10^{-3}$ ($\pm 0^2$) / (Use of $KE = F \times d$) $= 4.8 \times 10^{-20} = F \times 6 \times 10^{-3}$ and (use of $F = m \times a$) $F = (8.0 \times 10^{-18}) = 9.11 \times 10^{-31} \times a$ $a = 8.78 \ldots \times 10^{12}$ (m s^{-2})	C1 M1 A1	**Allow** u and v interchangeably throughout **Allow** calculation of E = $(0.30 / 6 \times 10^{-3}) = 50$ (V m^{-1}) or $v = 3.2 \times 10^5$ (m s^{-1}) or $v^2 = 1.05 \times 10^{11}$ (m s^{-1})^2 or $F = 8.0 \times 10^{-18}$ (N) for C1 mark Substitution mark – in any arrangement. Expect full substitutions including numerical value of m_e if appropriate Method 1: direct calculation of a Method 2: using $KE = ½ mv^2$ and $v^2 = u^2 + 2as$ Method 3: using $KE = F \times d$ and $F = m \times a$ **Note** must be more than 2 SF (not paper SF penalty) **Ignore** negative sign
		(ii)	(Use of $KE = ½ mv^2$) $= 4.8 \times 10^{-20} = ½ \times m \times v^2$ OR ($u^2 = v^2 - 2as$) $= 0^2 - [2 \times (-) 8.8 \times 10^{12} \times s]$ Full substitution leading to $v = 3.2\ldots \times 10^5$ (m s^{-1})	C1 A1	**Allow** u and v interchangeably Numerical value of m_e must be used if using KE method **Note** must be more than 1 SF (not paper SF penalty) **Note** 3.25 is acceptable for A1, but not 3.3

Question			Answer	Marks	Guidance
		(iii)	$t = \frac{3.2 \times 10^5}{8.8 \times 10^{12}}$	C1	**Allow** correct full substitution into any suvat equation **Allow** 3×10^5 for v **Ignore** signs of substituted values
			$t = 3.6 \times 10^{-8}$ (s)	A1	**Expect** values between 3.4×10^{-8} and 3.8×10^{-8} (s) **No ecf** from (b)(i) or (b)(ii)
		(iv)	Any line with negative slope starting from 0, 4.8×10^{-20}	M1	½ square tolerance. **ALLOW** a curve with negative gradient. **ALLOW** a region of zero gradient, but not whole line
			A straight line finishing at 6.0,0	A1	½ square tolerance on axis intercepted
	(c)		Energy of photon increases	B1	**Do not allow** increased <u>kinetic</u> energy of photons
			(max) kinetic energy / speed (of electrons) increases / (some) electrons (now) reach **C and** there is a current or reading (on ammeter)	B1	**Do not allow** explanation in terms of increased number of **emitted** electrons (per second) **Allow** photoelectrons for electrons
			Total	**14**	

Question			Answer	Marks	Guidance
20	(a)		Mark **first two named** forces only Strong (nuclear force) Any one from: short-range / range of about 3 fm / attractive between 0.5 fm to about 3 fm / repulsive below 0.5 fm Gravitational (force) Any one from: long (infinite) range / attractive / negligible / follows inverse square law	 **M1** **A1** **M1** **A1**	**Ignore** any comments on the weak nuclear force **Penalise** any clearly incorrect statements. Implication that strong is always attractive will lose A mark **Allow** 'gravity' **Penalise** any clearly incorrect statements
	(b)		**Level 3 (5–6 marks)** Clear description including at least one correct comment on quarks **and** analysis of 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 of density **or** clear description **or** clear analysis of 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)** 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**	**Indicative scientific points may include:** **Description (max L2 if either alpha or beta not described)** • $^{14}_{6}\mathrm{C} \rightarrow {}^{0}_{-1}\mathrm{e} + {}^{14}_{7}\mathrm{X}$ (ignore identification of X) • Before: 6 protons and 8 neutrons • After: 7 protons and 7 neutrons • Neutron → u d d and/or Proton → u u d • Neutron changes into proton (+ electron + antineutrino) • Down quark changes into an up quark (+ electron + antineutrino) • $^{235}_{92}\mathrm{U} \rightarrow {}^{4}_{2}\alpha + {}^{231}_{90}\mathrm{Y}$ (ignore identification of Y) • Before: 92 protons and 143 neutrons • After: 90 protons and 141 neutrons • 2 neutrons and 2 protons removed (by alpha particle) • Has 6 fewer u quarks and 6 fewer d quarks **Density (max L2 if analysis done without use of data)** • masses: 14.0(u) and 235.0(u) • ratios: masses = 16.8; radii = 2.55; volumes = 16.6 • volume ~ 2.9^3 and 7.4^3 (ignore $4/3\pi$ and 10^{-15}) • densities calculated (about 2.3×10^{17} kgm^{-3}) • density shown to be (roughly the) same
			Total	**10**	

Question			Answer	Marks	Guidance
21	(a)		When switch is opened, there is (rate of) change in (magnetic) flux (linkage) which induces an emf / current	B1	Not just a statement of Faraday's law
			as the (magnetic) flux links to **B** which causes the lamp to light	B1	**Allow** flux is cut by **B**
			(Lamp off) at start / end there is constant flux / no change in (magnetic) flux (linkage for coil **B**)	B1	
	(b)	(i)	Oscilloscope / CRO	B1	**Allow** a.c. voltmeter **Ignore** datalogger / multimeter
		(ii)1	*f*	B1	**Not** any other symbol. **Only** mark quantity letters – ignore any words, but allow frequency.
		(ii)2	θ or $\sin\theta$	B1	**Allow** θ or $\sin\theta$ with any or all of K, I_0, *A, N.* **Only** mark quantity letters – ignore any words.
		(iii)	$f = \frac{0.62}{5000 \times 4.0 \times 10^{-3} \times 8.0 \times 7.8 \times 10^{-5}}$ / f = 49.67…. (Hz)	C1	
			$\frac{0.2}{8.0}$ / $\frac{0.1}{7.8}$ / $\frac{0.03}{0.62}$	C1	Any individual raw uncertainty Max value = 54.11 (Hz) **and** min value = 45.54 (Hz) for *f* **Allow 8.6%** as evidence of this calculation
			abs uncertainty = $(\frac{0.2}{8.0} + \frac{0.1}{7.8} + \frac{0.03}{0.62}) \times 49.67$ … / 4.28… (Hz)	C1	For min / max method: difference / 2 = 4.29 (Hz) **Allow** ecf on abs uncertainty from incorrect *f*
			$f = 50 \pm 4$ (Hz)	A1	Any ecf on *f* must be given to 2sf and uncertainty sf consistent. **Not** the paper SF penalty
			Total	**10**	

Question			Answer	Marks	Guidance
22	(a)	(i)1	0.5 (C_0)	B1	**Allow** ½
		(i)2	2 (V_0)	B1	**Ignore working** No ecf
		(i)3	2 (E_0)	B1	**Ignore working** No ecf
		(ii)	Work done against attractive forces	B1	**Allow** WD for work done
	(b)	(i)	Evidence of use of $V = V_0 e^{-t/CR}$ leading to ln (½) = $-T/CR$ or ln2 = T/CR	M1	**Must** see exponential decay as starting point (allow Q for V) **Allow** t for T **Allow** x for V and x_0 for V_0
			$T = C\ln2 \times R$ compared with $y = mx$ with gradient = Cln2	A1	**Not** T/R = gradient
		(ii)1	Best-fit line drawn correctly	B1	**Note** line must pass through all (vertical part of) error-bars. If more than one line drawn, all lines must pass through all error-bars (1/2 square tolerance).
			gradient = 5.4 ($\times 10^{-9}$)	B1	**Allow** ± 0.2 ($\times 10^{-9}$) **Ignore** POT
			C = (gradient / ln2) = 7.8×10^{-9} (F)	B1	**Ecf** from incorrect gradient, but penalise POT error here
		(ii)2	$7.8 \times 10^{-9} = \frac{\varepsilon \times 3.1 \times 10^{-2}}{8.0 \times 10^{-5}}$	C1	Possible ECF from **(b)(ii)1**
			$\varepsilon = 2.0 \times 10^{-11}$ (F m^{-1})	A1	**Allow** 1 mark if final answer is relative permittivity correctly calculated (ε divided by 8.85 x$\times 10^{-12}$)
			Total	**11**	

Question			Answer	Marks	Guidance
23	(a)		Allows only those gamma rays / waves / photons travelling along axis (of the collimator) to get through (and reach scintillator)	B1	**Allow** less fuzzy / clear image **Allow** all the gamma rays / waves / photons are parallel / in the same direction (to each other) **Allow** absorbs those gamma rays / waves / photons not parallel (to the axis of collimator) **Allow** so the photons are travelling perpendicular to the scintillator **Do not allow** the gamma rays are travelling vertically, unless it is clear the collimator is also vertical
	(b)		Turn gamma (photons) into (many photons of) light	B1	**Ignore** reference to rays / waves **Ignore** reference to flash
	(c)		number of electrons = $\frac{0.32 \times 10^{-6} \times 1.2 \times 10^{-9}}{e}$ number of electrons = 2400	C1 A1	**Ignore** any POT error for C1 mark
	(d)		Any sensible diagnostic suggestion, e.g. detection of cancer / scans of (named) organ / scans of tissue / bone scans / observing functionality of (named) organ	B1	**Not** medical treatment e.g. radiotherapy **Not** body scan **Ignore** PET scanner **Do not allow** CAT scan
			Total	5	

Question			Answer	Marks	Guidance
24	(a)		Photon scattered with less energy / X-ray of lower frequency / X-ray of longer wavelength Electron removed (from the atom)	B1 B1	**Allow** X-ray for photon and vice versa **Ignore** wave **Not** electron scattered or electron removed from surface
	(b)	(i)	Identification from graph of two intensities and corresponding separation between them (x). Correct substitution into $I = I_0 e^{-\mu x}$ and fully correct calculation leading to $\mu = 0.84$ (cm^{-1})	C1 A1	**Note** check value of intensities to $\pm$ ½ small square. x missing implies $x = 1$. Graph misread lose all marks. May be seen from substitution into $I = I_0 e^{-\mu x}$. No POT error at this point **Note** I_0 and I must be in correct position in equation, so that ($I < I_0$). If I and I_0 are reversed, μ will be negative. **Penalise** this mark for negative answer, or working that would lead to negative answer. **Penalise** POT error here. **Allow** small range of values around 0.84 for variations in graph readings.
		(ii)	$I = 1.3 \times 10^3$ / 1300 ($E = I \times A \times t$) = $2.6 = 1300 \times 1.0 \times 10^{-4} \times t$ $t = 20$ (s)	B1 C1 A1	**Allow** a value in the range $1.25 - 1.35 \times 10^3$. **Allow** ecf from incorrect reading of I at 1.0cm from (b)(i) **Allow** use of value of I from B1 except use of 3000 **POT** error allowed on area if area clearly included in the calculation, or if A included in equation **Note**: use of $I = 1.6 \times 10^3$ leading to $t = 16$ (s) with A included scores 2 marks
		(iii)	A curve starting at $x = 1.0$cm with initially larger negative gradient at $x = 1.0$ cm Exponential curve	M1 A1	**Must not** have a positive gradient for more than half a square vertically Curve must not touch x-axis or be horizontal for more than 3 small squares
			Total	9	

Need to get in touch?

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