OCR
Oxford Cambridge and RSA

GCE

Physics A

H556/02: Exploring physics

A Level

Mark Scheme for June 2023

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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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MARKING INSTRUCTIONS

PREPARATION FOR MARKING
RM ASSESSOR

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *RM Assessor 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 posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

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

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

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% (traditional 40% Batch 1 and 100% Batch 2) 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 by telephone or the RM Assessor messaging system, or by email.

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.

   Rubric Error Responses – Optional Questions
   Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. Enter a mark for each question answered into RM assessor, which will select the

highest mark from those awarded. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

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. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there, then add a tick to confirm that the work has been seen.

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 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 phone, the RM Assessor messaging system, or e-mail.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:
    a. **To determine the level** – start at the highest level and work down until you reach the level that matches the answer
    b. **To determine the mark within the level**, consider the following

Descriptor	Award mark
On the borderline of this level and the one below	At bottom of level
Just enough achievement on balance for this level	Above bottom and either below middle or at middle of level (depending on number of marks available)
Meets the criteria but with some slight inconsistency	Above middle and either below top of level or at middle of level (depending on number of marks available)
Consistently meets the criteria for this level	At top of level

11. **Annotations**

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.

Annotation		Meaning
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).

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

12. **Subject Specific Marking Instructions**

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.

SECTION A

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

SECTION B

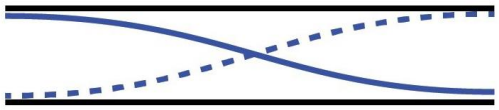
General rule: For substitution into an equation, allow any subject - unless stated otherwise in the guidance

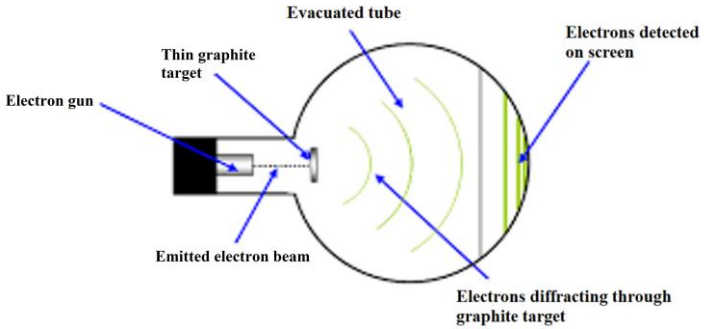
Question			Answer	Mark	Guidance
16	(a)		Interference given in A and D and/or B and C A and D diffraction **OR** A and D = destructive interference / destructive superposition **AND** B and C = constructive interference / constructive superposition	**B1** **B1**	**IGNORE** superposition alone
	(b)		The waves have a constant/same/fixed phase relationship	**B1**	Constant/same/fixed phase difference **IGNORE** in phase, frequency, wavelength, diffraction and other correct physics **REJECT** incorrect references to amplitude and other wave properties
	(c)		Waves arrive in phase / path difference of whole number of wavelengths Phase difference = 4π or 720^0 / with a path difference of 2λ	**C1** **A1**	Phase difference = 0 or path difference = $n\lambda$

Question			Answer	Mark	Guidance
	(d)		$\lambda = a\,x / D = 640\text{x}10^{-9} = 1.00\text{x}10^{-5}$ x x / 4 (= 0.256 (m))	**C1**	Correct substitution 0.256m assumes correct substitution
			B to C = 2x = 0.512 (m)	**C1**	Recognition that B-C is two fringe separation, and evaluation
			$\theta = \tan^{-1}(0.512 / 4) =$ **7.3** (^{o})	**A1**	Correct to at least 2 significant figures **ALLOW** $\theta = \sin^{-1}(0.512 / 4) =$ 7.4 (^{o}) Note: RAD mode in calculators (0.127) MAX 2 marks Note: No doubling of x with correct working leading 3.7° MAX 2 marks
			Alternative method: Use of $n\lambda = d \sin\theta$		
			substitution of λ and d with any integer value of n	**(C1)**	e.g. n x = $1.00\text{x}10^{-5}$ x sin θ where n is an integer
			recognition that n = 2	**(C1)**	
			$\theta = \sin^{-1}(2 \text{ x } 640 \text{ x } 10^{-9} / 1.00\text{x}10^{-5})$ = **7.4** (^{o})	**(A1)**	Correct to at least 2 significant figures Note: only allow use of incorrect value of n = 1, leading to 3.7° MAX 2 marks Note: RAD mode in calculators (0.128) MAX 2 marks

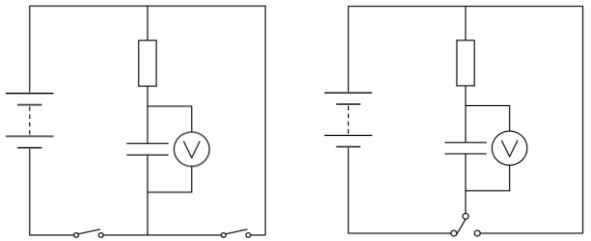
Question			Answer	Mark	Guidance
17	(a)		Longitudinal waves With a frequency greater than 20 kHz	B1 B1	 **ALLOW** 20 kHz and above
	(b*)	(i)	**Level 3 (5–6 marks)** Clear explanation of transducer **and** clear explanation of gel *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Clear explanation of transducer **OR** clear explanation of gel **or** Some explanation of transducer **and** some explanation of gel *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 explanation of transducer or gel *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*	6 x B1	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Transducer** • High frequency alternating PD applied to the faces of the piezoelectric crystal. • Causes the piezoelectric crystal to stretch and compress / oscillate / resonate at high frequency. • Ultrasound waves sent in pulses • Between pulses, reflected ultrasound incident on the piezoelectric crystal causes the crystal to change shape / oscillate / resonate • An alternating PD is induced **Gel** • Acoustic impedance of air is different to body • Acoustic impedance of gel is similar to body • This allows greater transmission of the ultrasound waves into / out of the patient's body • There is less reflection of the ultrasound waves at the body boundary • Reference to $\frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$

Question			Answer	Mark	Guidance
	(c)	(i)	There is no change in (acoustic) impedance	B1	**ALLOW** there is no change in the density (of the medium) **ALLOW** there is no boundary / there is nothing to reflect from **NOT JUST** there is nothing there **IGNORE** undefined symbols
		(ii)	Acoustic impedance of C is different from B Change in acoustic impedance at B is greater (than at C) (relative to their surrounding medium/A)	C1 A1	**IGNORE** explanations in terms of density Second point gains both marks **ALLOW** soft tissue/skin/belly for C **ALLOW** skull/bone/head for B
	(d)		$v = \Delta f\, c / 2 f \cos\theta$ $= \frac{(10.0000 \times 10^6 - 9.9987 \times 10^6) \times 1600}{2 \times 10.0000 \times 10^6 \times \cos 50}$ **0.16** (ms^{-1})	C1 A1	IGNORE cancelling powers of 10 Correct to at least 2 significant figures

Question			Answer	Mark	Guidance
18	(a)			B1	Both parts needed – either dotted or solid. Correct curvature needed by eye. Middle node by eye. **IGNORE** lines outside of tube
	(b)		Frequency f_0 = 340 / 0.600 = **567** (Hz)	A1	Correct to at least 2 significant figures No ecf from 18(a)
	(c)		Next wavelength for standing wave is λ = 0.300m Frequency = 340 / 0.300 = **1.13 x 10^3** (Hz)	C1 A1	Ecf from (b) if wavelength used is 0.600m Correct to at least 2 significant figures **Special case:** If wavelength drawn in (a) is 0.300m and f_0 in (b) = 1130 Hz, then allow ecf (C1) for next λ = 0.200m and (A1) frequency as 1700 Hz for full credit.

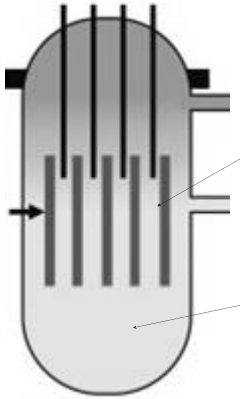
Question			Answer	Mark	Guidance
19	(a)		Any four from: In an evacuated tube (Electrons released by) thermionic emission / (low voltage supply causes) emission of electrons from cathode/filament/electron gun Electrons accelerated towards anode / electrons accelerated through (high) pd / electric field Diffracted through a graphite (target) / graphite is thin Electrons detected on a (phosphor) screen / electrons produce visible light on impact with screen	4xB1	**ALLOW** marking points as labels on the diagram or as the answer lines. 
	(b)		(Provides evidence of) wave nature of electrons Light circles caused by constructive interference / waves arriving in phase Dark circles caused by destructive interference / waves arriving in antiphase	B1 B1 B1	 **ALLOW** out of phase by 180 / π **NOT** just out of phase
	(c)	(i)	Work done = 1.60×10^{-19} x 5×10^{3} = **8.0×10^{-16}** (J)	A1	**ALLOW** correct answer to 1 significant figure

Question			Answer	Mark	Guidance
		(ii)	$W = ½\ mv^2 = 8 \times 10^{-16} = ½ \times 9.11 \times 10^{-31} \times v^2$ $= 4.2 \times 10^7\ ms^{-1}$ $\lambda = h/mv = 6.63 \times 10^{-34} / 9.11 \times 10^{-31} \times 4.2 \times 10^7$ = **1.7 x10^{-11}** (m) OR Momentum of electrons = $\sqrt{2 \times m_e \times W}$ $= \sqrt{2 \times 9.11 \times 10^{-31} \times 8 \times 10^{-16}}$ = (3.82 x10^{-23} kgms^{-1}) 6.63 x 10^{-34} / 3.82 x10^{-23} = **1.74 x10^{-11}** (m)	**C1** **A1** **(C1)** **(A1)**	Substitution leading to velocity Ecf from (c)(i) **ALLOW** correct answer to 1 significant figure Ecf from (c)(i) **ALLOW** correct answer to 1 significant figure
		(iii)	(For diffraction to occur) the gap needs to be approximately the same size as the wavelength so spacing should be 1.74 x 10^{-11} m	**B1**	Reason <u>and</u> value required. **ALLOW** suggested value spacing as (c)(ii) same power of ten

Question			Answer	Mark	Guidance
20	(a)		Circuit showing (6V) supply in series with a capacitor and resistor, with a voltmeter in parallel with the capacitor. Switch/switches allowing discharging of the capacitor through the resistor.	B1 B1	No labels required. **ALLOW** any suitable symbol for d.c. supply **ALLOW** this mark if resistor and capacitor in parallel if switch will allow the discharge Examples of correct circuit for both marks e.g. 
	(b)		Charge = $1.0 \times 10^{-6} \times 6.0 =$ **6.0×10^{-6}** (C)	A1	**ALLOW** correct answer to 1 significant figure
	(c)		(CR =) $1 \times 10^{-6} \times 10 \times 10^{3}$ CR / Time constant / τ = 0.010 (s) Time constant / τ is time taken to fall to 1/e (37%) of initial value The time it takes to record the variation of pd / the capacitor to discharge is far less than (human) reaction time OR	C1 A1 B1 B1	**ALLOW** POT error for capacitance if same as in (b) **ALLOW** 1sf **ALLOW** t for τ **NOT** fallen by 37%

Question			Answer	Mark	Guidance
			$V = V_0 e^{-(\frac{t}{CR})}$ to give $0.6 = 6.0e^{-(\frac{t}{1.0\times10^{-6}\times10\times10^{3}})}$	(C1)	Substitution into exponential decay equation to fall to a value of V less than $0.9V_0$ (<5.4V). **ALLOW** calculation in log form e.g $\ln 0.6 = \ln 6.0 - t/0.01$
			t = 0.023 (s)	(A1)	
			0.6 is the voltage when it has fallen to 10% of the initial voltage	(B1)	Justification/explanation for using a given voltage
			The time it takes to record the variation of pd / for the capacitor to discharge is far less than human reaction time	(B1)	
			OR		
			$V = V_0 e^{-(\frac{t}{CR})}$ to give $V = 6.0e^{-(\frac{0.02}{1.0\times10^{-6}\times10\times10^{3}})}$	(C1)	Substitution into exponential decay equation with a time less than 0.1s (t < 0.1s). **ALLOW** calculation in log form $\ln V = \ln 6.0 - 0.02/0.01$
			V = 0.81 V	(A1)	
			0.02 s is a very short amount of time	(B1)	Justification/explanation for using a given time
			The time it takes to record the variation of pd / for the capacitor to discharge is far less than human reaction time	(B1)	
	(d)		Use an oscilloscope / data logger with a voltmeter probe	B1	**ALLOW** connect a voltmeter to a datalogger
	(e)	(i)	$V = V_0 e^{-(\frac{t}{CR})}$ to give $4.12 = 6.0\, e^{-(\frac{t}{1.0\times10^{-6}\times10\times10^{3}})}$	C1	**ALLOW** in terms of logs eg $\ln 4.12 = \ln 6.0 - \frac{t}{0.01}$
			= 3.76 x 10^{-3} (s)	A1	Correct to at least 2 significant figures **IGNORE** minus sign in final answer

Question			Answer	Mark	Guidance
		(ii)	Change in energy = ½ CV_1^2 - ½ CV_2^2	C1	
			= (½ x $1x10^{-6}$ x 6^2) – (½ x $1x10^{-6}$ x 4.12^2) = $9.5 x10^{-6}$ (J)	C1	**ALLOW** POT error from (e)(i)
			rate = $9.5 x10^{-6}$ / $3.76 x 10^{-3}$		Ecf from (e)(i)
			= **$2.53 x 10^{-3}$** (Js^{-1})	A1	Correct to at least 2 significant figures

Question			Answer	Mark	Guidance
21	(a)	(i)	 (Nuclear) fuel rods **(i)**	B1	**ALLOW** any correctly named fuel e.g. uranium (oxide) for **(i)**
		(ii)	Moderator **(ii)**	B1	**ALLOW** any correctly named moderator e.g. (heavy) water for **(ii)** **ALLOW** coolant for **(ii)** **ALLOW** any correctly named coolant (e.g. CO_2) for **(ii)**
	(b)*		**Level 3 (5–6 marks)** Clear description **and** full correct calculation. *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** full correct calculation. **or** Some description **and** some calculation *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.*	6 x B1	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description** • Absorption of neutron by U-235 • U-235 nuclei become unstable U236 nuclei • U-236 undergoes fission • Resulting in smaller nuclei daughter products and additional fast neutrons • Moderator slows neutrons so that they can be absorbed by U-235 nuclei • Process repeats to form a chain reaction • Rate of chain reaction controlled by raising or lowering control rods • Which absorb excess neutrons

Question			Answer	Mark	Guidance
			Level 1 (1–2 marks) Limited description **or** Limited 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.*		• To allow one neutron per fission to cause further fission **Calculation** Use of ${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{92}_{36}Kr + {}^{141}_{56}Ba + 3{}^{1}_{0}n$ Mass of U236 = 235.04395 + 1.00867 = 236.05262u Total mass of fission products = 140.91440 + 91.92617 + (3 x 1.00867) = 235.86658u Difference = 0.18604 u Mass defect =$0.18604 \times 1.661 \times 10^{-27}$ $= 3.0901244 \times 10^{-28}$ kg Energy equivalence per fission event = $3.0901244 \times 10^{-28} \times (3 \times 10^{8})^{2} = 2.78111 \times 10^{-11}$J Alternative: Energy equivalence per fission in MeV = 174 MeV
	(c)		Marks may be awarded for the following considerations only: technology, reaction, fuel, waste, safety. Technology: • Fission: technology already established / Fusion: technology not yet established	**4 x B1**	ALLOW 1 mark for basic comparison within each consideration if no other marks are awarded.

Question			Answer	Mark	Guidance
			Reaction: • Fission: chain reaction self-sustaining once initiated • Fusion: very high temperatures/pressures /amounts of energy required to initiate and continue reaction / challenges with storage and containment of plasma Fuel: • Fission: finite amount of uranium / needs to be enriched • Fusion: (unlimited) fuel available from (sea) water Waste: • Fission: Produces highly / high level / long half-life / long storage time radioactive waste • Fusion: Produces (effectively) no radioactive waste (products) / only radioactive material in contained in the reactor Safety: • Fission: Possibility of serious accident / leakage of radioactive material / “meltdown” AND/OR Fusion: very unlikely to produce serious accident (due to near instant shut down of reaction) / no leakage of radioactive material		**ALLOW** hydrogen is easier to source (than uranium) for 1 mark **ALLOW** Fission produces radioactive waste and fusion does not for 1 mark. **IGNORE** nuclear for radioactive

Question			Answer	Mark	Guidance
22	(a)		$^{18}_{9}F \rightarrow {}^{18}_{8}O + {}^{0}_{1}\beta^{+}$ $(+\nu)$	C1 A1	Correct fluorine isotope Correct equation **ALLOW** numbers written to right of symbol **ALLOW** e / e^+ / $\overline{e}$ / β for positron symbol with correct numbers **IGNORE** gamma in products **ALLOW** $^{0}_{0}\upsilon$ for neutrino **ALLOW** ν_e for neutrino
	(b)		$E = mc^2 = 9.11 \times 10^{-31} \times (3.00 \times 10^8)^2$ $= 8.2 \times 10^{-14}$ (J)	C1	Working leading to evaluation of E **ALLOW** factor of 2 leading to 1.6×10^{-13} (J) **NOT** use of $\lambda = h/mv$ where v is 3×10^8 alone **XP** **ALLOW** use of $\lambda = hc/mc^2$ or $\lambda = h/mc$ **ALLOW** Use of electron mass = 0.511 MeV giving 8.2×10^{-14} (J)
			$E = hc / \lambda = 8.2 \times 10^{-14} = 6.63 \times 10^{-34} \times 3 \times 10^8 / \lambda$	C1	
			$\lambda = 3.00 \times 10^8 \div 1.2367 \times 10^{20} =$ **2.4×10^{-12}** (m)	A1	Correct to at least 2 significant figures Answer of 4.9×10^{-12} or 1.2×10^{-12} allow 2/3 due to incorrect accounting for factor of 2
	(c)		X-rays formed when <u>electrons</u> (in an atom) de-excite	B1	**ALLOW** X-rays may be produced by acceleration / deceleration of (fast moving) electrons / X-rays are produced when (fast moving) electrons are incident on a metal target / X-rays may be produced when electrons lose kinetic energy

Question			Answer	Mark	Guidance
			Gamma rays come from the decay of nuclei (in unstable isotopes)	B1	**ALLOW** gamma rays come from (the decay of) radioactive nuclei / gamma rays come from the nucleus of unstable atoms / gamma rays come from the de-excitation of nuclei / gamma rays come from annihilation of particle-antiparticle (pairs) / **IGNORE** gamma from fission
	(d)		The half-life is short	B1	**ALLOW** activity is high **IGNORE** it decays quickly
			Advantage: Exposure of the patient to ionising radiation is kept as low as possible.	B1	
			Disadvantage: (Radiographers have a) short time to scan/diagnose the patient	B1	**ALLOW** F18 has to be manufactured on site before use / high activity means exposure is high during handling **IGNORE** short time to treat the patient

Question			Answer	Mark	Guidance
23	(a)	(i)	4.804 3.839	A1	**ALLOW** 2dp for either or both values 4.80 and 3.84
		(ii)	Both points plotted correctly	A1	**ALLOW** plotting of their 23(a)(i) values as long as the values lie within the grid range Plotting to within ½ small square
		(iii)	Appropriate line of best fit	B1	Straight line with negative gradient Allow best fit line from their plotted points Expect even distribution of points across the whole line for their plotted points
	(b)	(i)	$\ln I_x = \ln I_0 - \mu x$ $\ln I_x = -\mu x + \ln I_0$ compare with $y = mx + c$	C1 A1	**ALLOW** log equation in any format **ALLOW** an indication that y = mx + c has been used, with the ln equation in the correct order. Negative sign for required μ.
		(ii)	Correct determination of their y intercept Correct $e^{intercept}$ of their y intercept value	C1 A1	Their intercept recorded to nearest ½ small grid square **ALLOW** values to more than 1 dp Answer to 2 sf
		(iii)	Evidence of use of graph to determine gradient	B1	Change in x value greater than half of their line AND points correctly read from the line (not the tabulated values unless they lie on the line).

Question			Answer	Mark	Guidance
			Correct answer for their gradient, and given as positive for μ	**B1**	½ square tolerance on readings of points Ignore sign on gradient. Correct to at least 2 significant figures **NOT** if graph shows positive gradient
	(c)	**(i)**	(100 / 5100) x 5 (= 0.098) (V) OR (8000 / 13000) x 5 (= 3.077) (V) **0.098 to 3.077** OR **2.98** (V)	**C1** **A1**	**ALLOW** rounding of either or both of these values to 2sf **ALLOW** final answer of range of 0.1 to 3 OR 3 (1sf answer) if more than 1sf seen previously
		(ii)	Any two from: Increase the input voltage Decrease (the resistance of) R_1 / (fixed) resistor Extend range of thickness of jelly used	**2 x B1**	**ALLOW** emf for input voltage but not just potential difference **IGNORE** current **NOT** decrease the resistance alone **NOT** just make jelly thinner/thicker. Must be clear that values below 1mm or above 5mm are to be used.
		(iii)	As the light intensity increases the resistance of the LDR/ R_2 decreases the PD measured (across R_2) decreases OR	**B1**	**ALLOW** reverse argument Must be clear that the resistance is that of the LDR **ALLOW** output voltage/voltmeter reading for PD across R_2

Question			Answer	Mark	Guidance
			As the light intensity increases the total resistance of the circuit decreases the current increases		

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