GCE A LEVEL MARKING SCHEME

SUMMER 2025

A LEVEL
PHYSICS – COMPONENT 3
A420U30-1

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About this marking scheme

The purpose of this marking scheme is to provide teachers, learners, and other interested parties, with an understanding of the assessment criteria used to assess this specific assessment.

This marking scheme reflects the criteria by which this assessment was marked in a live series and was finalised following detailed discussion at an examiners' conference. A team of qualified examiners were trained specifically in the application of this marking scheme. The aim of the conference was to ensure that the marking scheme was interpreted and applied in the same way by all examiners. It may not be possible, or appropriate, to capture every variation that a candidate may present in their responses within this marking scheme. However, during the training conference, examiners were guided in using their professional judgement to credit alternative valid responses as instructed by the document, and through reviewing exemplar responses.

Without the benefit of participation in the examiners' conference, teachers, learners and other users, may have different views on certain matters of detail or interpretation. Therefore, it is strongly recommended that this marking scheme is used alongside other guidance, such as published exemplar materials or Guidance for Teaching. This marking scheme is final and will not be changed, unless in the event that a clear error is identified, as it reflects the criteria used to assess candidate responses during the live series.

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GCE A LEVEL PHYSICS

COMPONENT 3 – LIGHT, NUCLEI AND OPTIONS

SUMMER 2025 MARK SCHEME

GENERAL INSTRUCTIONS

The mark scheme should be applied precisely and no departure made from it.

Recording of marks
Examiners must mark in red ink.
One tick must equate to one mark (except for the extended response questions).
Question totals should be written in the box at the end of the question.
Question totals should be entered onto the grid on the front cover and these should be added to give the script total for each candidate.

Marking rules
All work should be seen to have been marked.
Marking schemes will indicate when explicit working is deemed to be a necessary part of a correct answer.
Crossed out responses not replaced should be marked.
Credit will be given for correct and relevant alternative responses which are not recorded in the mark scheme.

Extended response question
A level of response mark scheme is used. Before applying the mark scheme please read through the whole answer from start to finish. Firstly, decide which level descriptor matches best with the candidate's response: remember that you should be considering the overall quality of the response. Then decide which mark to award within the level. Award the higher mark in the level if there is a good match with both the content statements and the communication statement.

Marking abbreviations
The following may be used in marking schemes or in the marking of scripts to indicate reasons for the marks awarded.

cao = correct answer only
ecf = error carried forward
bod = benefit of doubt

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SECTION A

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	(a)	(i)	Trans – oscillations (or wtte) at 90° to wave direction (1) Long – oscillations (or wtte) parallel to wave direction (1) em waves and sound or similar with both identified as the correct type of wave (1) (no ecf i.e. wrong way round gets zero marks) NOTE water wave default are the transverse surface waves (Seismic waves P-longitudinal, S-transverse, surface waves-transverse (Rayleigh & Love waves)	3			3		
		(ii)	Only transverse can be polarised ("only" can be implied) **OR** equivalent – only waves oscillating perpendicularly (1) There are two dimensions / different directions at 90° to wave direction **OR** Idea that <u>oscillations</u> can be confined in only one direction **OR** idea that one <u>oscillation</u> direction can be blocked (1) Longitudinal – oscillations in one direction only (wtte) (1) Must talk about <u>polarisation</u> directions - 1 mark penalty if not clear what "direction" means NOT "path" or "travel direction"	3			3		
	(b)	(i)	$\frac{19.2}{5}$ seen or reference to 5 wavelengths (1) Answer = 3.84 c[m] accept 3.8 (1) Allow 1 mark for 3.2 c[m] (dividing by 6) Allow 1 mark for 2.7 c[m] multiplied by sensible fraction e.g. $2.7 \times \frac{4}{3}$ = 3.6 c[m]		2		2	1	
		(ii)	Arrow at Q pointing outwards in the correct direction [by eye] Withdraw mark if clearly not perpendicular to the wavefront		1		1		
		(iii)	In phase or 0 ACCEPT {<u>same / equal</u>} phase etc. NOT 2π or 360° -these are neutral answers	1			1		

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(iv)	Correct fraction of wavelength i.e. $\frac{2.70}{\text{(b)(i)}}$ (1) **ecf** on λ Multiplying the fraction by 2π (1) Answer = (+) 4.4 [rad] or (-)1.9 [rad] (1) (accept 1.4π or $\frac{45}{32}\pi$ OR $-\frac{19}{32}\pi$) Award full marks if they say ahead by 4.4 rad **OR** 1.9 rad behind Award 2 marks if they say 4.4 rad behind **OR** 1.9 rad ahead ALLOW 4.4 rad without + DON'T allow 1.9 rad without – NOTE – only 1 mark for $\frac{45}{64}\pi$		3		3	3	
	(c)	(i)	Applying 10.7 = $2\pi f$ (1) [f = 1.7 Hz] **OR** equivalent method e.g. $\frac{2\pi}{T}$ Applying $v = f\lambda$ **or** $\frac{\lambda}{T}$ (1) **ecf** only on λ Correct answer = 6.54 cm s^{-1} **UNIT MARK** (1)		3		3	2	

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	Applying max speed = ωA (1) Beware: not $\omega \times 8\,\text{cm}$ Correct answer = 2.3[5 cm s^{-1}] (1) NOTE: Mark for calculating T or f can be awarded wherever it is done but must appear as a mark for (c)(i). Otherwise no credit can be awarded for the wrong speed.		2		2	2	
		(iii)	Stating that KE is conserved **OR** reasonable explanation (1) ALLOW sensible discussion of dissipation / viscosity / energy loss ALLOW intensity halves, power / energy per unit length halves NOT – energy halves (although next 2 marks still available with this) Equation set up (implied by correct answer) e.g. ${A_1}^2 2\pi r_1 = {A_2}^2 2\pi r_2$ (a well set out equation like this implies 1st mark) (1) accept $A_2 = \frac{A_1}{\sqrt{2}}$ Final calculation and conclusion correct (1) e.g. $2.2^2 \times 8 = 38.7$ and $1.6^2 \times 16 = 41$ – about right **OR** amplitude = $\sqrt{\frac{2.2^2 \times 8}{16}}$ = 1.56 hence yes NOTE: BOD calculation arriving at $\frac{2.2}{\sqrt{2}}$: 2 marks Mention of inverse square law and amplitude halves – 1 mark NOT: calculations based on speed changing Allow 1 mark for Floella wrong because amplitude is constant			3	3	2	
			Question 1 total	**7**	**11**	**3**	**21**	**10**	**0**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	(a)	(i)	Path difference is zero (1) ACCEPT constructive interference **OR** in phase **OR** bright fringe For all wavelengths (needs idea that there is a range of wavelengths here) (1) ACCEPT white light not split into spectrum **Alternative:** When $n = 0$, then $\theta = 0$ (1) For all wavelengths (1)		2		2		
		(ii)	Angle depends on wavelength (1) ACCEPT "diffracted at different angles" linked to $n\lambda = d \sin\theta$ NOT: just "diffraction depends on wavelength" - needs more White light spread out (to its constituent wavelengths) i.e. the idea that the white light has spread out into its spectrum (1)		2		2		
	(b)	(i)	Sub into $n\lambda = d \sin\theta$ and rearrange (1) Value of d obtained (4.15×10^{-6}) (1) Correct answer = 241 (1) Allow 2 marks for POT slips, radian slip (-3×10^{-6} m $\rightarrow$ 332 mm^{-1})		3		3	2	
		(ii)	Suitable wavelengths chosen 380 – 450 nm **and** 650 – 750 nm (1) Some valid numerical use of $n\lambda = d \sin\theta$ e.g. 1×750 nm = $d \sin\theta$ e.g. talking of λ halving / doubling **OR** ratio found ($\frac{700}{400}$ = 1.75) etc (1) Yousef correct backed by suitable numbers (e.g. 11.1° and 9.7° **OR** ratio less than 2) (1) (allow **ecf** on their range)			3	3	2	
			Question 2 total	**0**	**7**	**3**	**10**	**4**	**0**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	(a)		Substitution into Snell's law i.e. 1.00 × sin 16.4 = 1.54 × sin θ (1) θ = 10.6° (1)	1	1		2	2	
	(b)		Light (attempting to pass) from dense to less dense **OR** $n_2 > n_3$ (1) Incident angle at A is 79.4° (1) Correct use of Snell's law giving critical angle = 78.7° **OR** no refracted angle because sin>1 (1) TIR because incident > critical angle **OR** because no refraction (1)	1 1	1 1		4	2	
	(c)		Substitution: $v = \frac{3\times10^8}{1.54}$ [=1.95 × 10^8] (1) Straight through time = 82.1 μ[s] **OR** zig-zag = 83.5 μ[s] **OR** difference in distance divided by speed (1) Zig-zag distance = $\frac{16\,000}{\cos 10.6 \text{ ecf}}$ = 16 276 [m] (1) Final answer = 83.5 – 82.1 = 1.4 μ[s] (range depending on rounding) (1) (0.92 μ[s] if 3 × 10^8 used for 3 marks) **beware all steps in one** e.g. $\frac{\frac{16000}{\cos 10.58}-16000}{\frac{3\times10^8}{1.54}}$ (1st 3 marks)	1	1 1 1		4	3	
			Question 3 total	**4**	**6**	**0**	**10**	**7**	**0**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	(a)		Vary / increase pd until current drops to zero (1) ACCEPT …until electrons cannot complete circuit or similar Record / find / measure V_{stop} **OR** get V_{stop} from voltmeter **OR** just reference to stopping voltage (1) NOT just any "voltage / pd" (unless it follows from 1st mark and is implied) Multiply by e (1) ACCEPT $eV_{(stop)}$ is / = [kinetic] energy Repeat for different wavelengths / filters / frequency / LEDs (1)	4			4		4
	(b)		Points taken from line e.g. (5.3, 0) and (10.3, 3.2) needs $\Delta f \geq 2.5 \times 10^{14}$ (1) Gradient method ok (1) Correct answer (expect 6.3 ± 0.2 × 10^{-34}) J s (1) **UNIT MARK** NOTE: $E_{k\,\max} = hf - \varphi$ $0 = h \times 5.4 \times 10^{14} - \varphi$ $3.1 \times 10^{-19} = h \times 10.2 \times 10^{14} - \varphi$ These 2 equations can be subtracted to get h (it's equivalent)		3		3	2	3
	(c)		Threshold frequency = 5.3 ± 0.1 × 10^{14} **OR** good attempt at intercept (1) Work function = 3.5 × 10^{-19} [J] (1) Conversion to eV (expect 2.2 eV) (1) Valid conclusion e.g. probably Cs or could be Cs or K etc Note: a few different answers may lead to a range (1)			4	4	2	4
			Question 4 total	**4**	**3**	**4**	**11**	**4**	**11**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	(a)	(i)	Number of disintegrations / decay per second / unit time ACCEPT rate of decay ACCEPT atoms decaying per second i.e. ignore "atoms" NOT counts per second	1			1		
		(ii)	<u>One</u> disintegration / decay per second (accept per unit time) NOT per second **OR** s^{-1}	1			1		
	(b)	(i)	28		1		1		1
		(ii)	604 (1) 63.8×10^{-3} (1)		2		2	2	2
		(iii)	Point plotted correctly within ½ square (1) Error bar correct (1) N.B. independent mark (both ± ½ square i.e. top of error bar between 0.056 and 0.057, bottom between 0.049 and 0.050)		2		2	2	2
	(c)	(i)	Taking square root e.g. $\sqrt{C} = \frac{\sqrt{k}}{d}$ (1) Putting in correct form i.e. $\frac{1}{\sqrt{C}} = \frac{d}{\sqrt{k}}$ **OR** identifying intercept = 0 **and** gradient = $\frac{1}{\sqrt{k}}$ (1) ACCEPT $d = \frac{\sqrt{k}}{\sqrt{C}}$ hence $\frac{1}{\sqrt{C}} \propto d$ **Alternative:** $C \propto \frac{1}{d^2}$ (1) $\frac{1}{\sqrt{C}} \propto d$ (1) ACCEPT: 1st mark by 1st method and 2nd mark via alternative if clear NOTE: $\sqrt{C} = \frac{k}{d}$ hence $\frac{1}{\sqrt{C}} = \frac{d}{k}$ loses 1 mark for poor algebra		2		2	2	2

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	Straight line (1) Through all error bars **ecf** on their 1 point (1) NOT close to points Small intercept / doesn't pass through origin (1) accept nearly through the origin Exact distance to source / detector difficult to measure (1) (this is a slightly subtle point, distance probably measured to the mica window and to the front of the radioisotope holder so real distance is probably a bit longer as the graph shows. If they understand that it's something to do with this distance, award the mark). NOT – absorption in air (would give curve and a different intercept)			4	4		4
	(d)		Assumption/reasoning – all gamma entering window give count (also accept e.g. only 1% of gamma entering window give a count (1) NOTE: a clear method implies this mark ACCEPT: explanation of radiation propagating uniformly in 3D Obtaining valid data point e.g. 5 cm and 11 087 (1) NOTE: must be corrected count Idea of ratio of areas i.e. $\frac{1.27}{4\pi d^2}$ (1) (depends on point used) Correct answer (expect 46 kBq × efficiency) and sensible conclusion (1) NOTE: answers similar to 2.8 MBq lose 1 mark for forgetting to divide by 60 NOTE: without 4π, last 2 marks are unavailable ** Beware large range of correct values available** Note: k is the activity measured at 1 m and is of no use by itself **Alternative via gradient:** Gradient measured as 0.21 m^{-1} (1) Statement k is the count rate at 1 m **OR** other explanation e.g. derivation of gradient (1) Activity = $\frac{1}{\text{gradient}^2} \times \frac{4\pi}{1.27 \times 10^{-4}}$ **OR** grad= $\sqrt{\frac{A \times 1.27 \times 10^{-4}}{4\pi}}$ (1) Answer = 38 kBq and wrong (1)			4	4	2	4
			Question 5 total	**2**	**7**	**8**	**17**	**8**	**15**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	(a)		Induced emf is equal / proportional to the (1) rate of change / cutting of flux / flux linkage (1) Induced emf / current / B-field [tends to] opposes the change (to which it is due) (1) ACCEPT: emf / current opposes the motion to which it is due ACCEPT: emf opposes the [direction] change in flux NOT: rate of change of flux linkage opposes the change	3			3		
	(b)	(i)	Position 1 - No cutting flux **OR** no change in flux **OR** max flux (1) Position 2 - Max cutting **OR** max [rate of] change (1) Position 3 - Direction of cutting opposite **OR** flux changing in opposite direction (implied if increasing and decreasing flux mentioned) (1) Position 4 - Cutting flux but not at max rate **OR** changing flux not at max rate (1) N.B. rate must appear somewhere for last mark **Mathematical alternative:** Flux = $NBA\cos\theta$ (1) EMF = $(-)\frac{\mathrm{d}}{\mathrm{dt}}(NBA\cos\omega t)$ (1) (implies 1st mark) EMF = $\omega NBA\sin\omega t$ (1) All 4 positions explained using equation (1) NOTE: the last 2 marks are available if not starting from Faraday's		4		4		
		(ii)	{Max pd / amplitude} is doubled (1) Frequency of pd doubled / period halved (1) NOT: wavelength halved **Alternative:** x-axis squashed by factor 2 **OR** stretched by ½ (1) y-axis stretched by factor 2 (1)		2		2		
			Question 6 total	**3**	**6**	**0**	**9**	**0**	**0**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)		**Indicative content:** **3 level:** E1-E3 is pumping E3 short lifetime Drop from E3-E2 is spontaneous E2 metastable E1 ground state Population inversion between E2 and E1 Description of stimulated emission Stimulated emission more likely than absorption More than half the electrons must be pumped **OR** 3 level is inefficient **OR** difficult to achieve population inversion **Cavity** Intensity increases each pass **OR** chain reaction idea Due to stimulated emission No light lost left mirror Some light leaves right mirror for output Photons traverse many times Other more specific details creditworthy: Pumping photons will have energy E3-E1 **OR** pumping using accelerated electrons Spontaneous emission negligible because of high intensity Intensity increases exponentially Cavity eventually reaches equilibrium Because output photons $s^{-1} \leq$ pumped electrons s^{-1} Short lifetime ~ns, metastable ~ms	6			6		

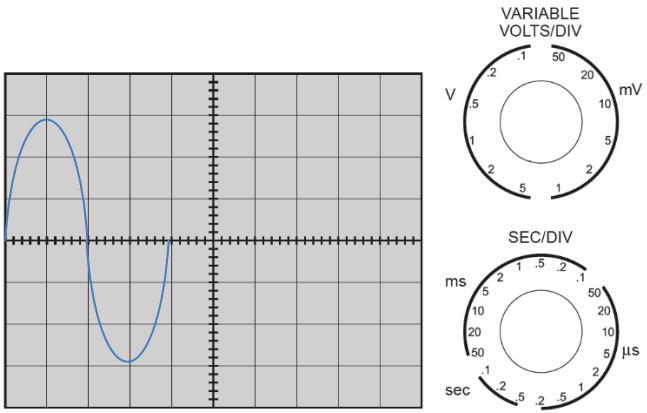
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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
			5-6 marks Comprehensive description of the levels and cavity *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Limited description of both levels and cavity or comprehensive description of one of the two. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Limited description of either levels or cavity. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*						
	(b)		Smaller, only require 3 V, cheaper, mass produced, easier to achieve population inversion etc (1) Any laser use other than fusion e.g. surveying, scanning, LIDAR, gun sights, CD, DVD, Blu ray, pinpoint objects in space, laser cutters, spirit level etc (1)	2			2		
			Question 7 total	**8**	**0**	**0**	**8**	**0**	**0**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	(a)		Q: -1 = 0 + Q(X) i.e. Q(X) = -1 (1) BN: 1 = 1 + BN(X) i.e. BN(X) = 0 (1) LN: 0 = 0 + LN(X) i.e. LN(X) = 0 (1) X = π^- **OR** negative pion (1) (not $\bar{u}d$) no ecf If reasoning unclear subtract 1 mark only e.g. charge = -1, BN = 0, LN = 0 gets 2 marks e.g. charge = -1, BN = 0, LN = 0 hence π^- gets 3 marks if no reasoning i.e. just π^- OR negative pion: 1 mark (1)		4		4		
	(b)		Q = $-\frac{1}{3}-\frac{1}{3}-\frac{1}{3}$ (negative values) ALLOW bod for charge of d = $-\frac{1}{3}$ hence ddd only combination	1			1		
	(c)		udd for n seen (1) ddd = udd + $\bar{u}d$ (**ecf**) **and** correct comment e.g. OK (**ecf**) (1) ALLOW ddd→dd+d **OR** 3 = 2 +1 0→u + $\bar{u}$ **OR** 0 = 1-1 (these lines imply both marks)	1	1		2		
	(d)		Difference in mass = 1.323 – 1.009 – 0.150 [= 0.164 u] (1) × 931 (1) × 1.6 × 10^{-13} (1) **OR** × 1.66 × 10^{-27} (1) × c^2 (24 pJ) (1) Application of KE equation e.g. ½ 0.15 × 1.66 × 10^{-27} v^2 = (2.44 × 10^{-11}) (1) Answer ~4 × 10^8 m s^{-1}, hence Yes (1) **ecf** only on slips Note: first 3 marks are available even if conservation of momentum applied and candidate gets stuck. For candidates who get stuck and can't get last 2 marks, award 1 mark for applying conservation of momentum **Beware alternative:** Difference in mass = 1.323 – 1.009 – 0.150 [= 0.164 u] (1) is greater than **OR** significant in comparison with… (1) the rest mass (1) so must use relativity – full marks!!!! (2)			5	5	3	
	(e)		Further experiments (to confirm / contradict) (1) Alternative theory (1)			2	2		
			Question 8 total	**2**	**5**	**7**	**14**	**3**	**0**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	(a)	(i)	Increase the cross-sectional area of the coil (1) Increase the number of turns (1) Accept add iron core		2		2		
		(ii)	$V = \omega BAN$	1			1	1	
		(iii)	Calculate peak emf $4.2 \times \sqrt{2} = 5.9$ [V] (1) Calculate period $T = \frac{1}{50}$ = 0.02 [s] (1) Number of divisions on y-axis $\frac{5.9}{2}$ = approx. 3 divisions (**ecf**) (1) Number of divisions on x-axis $\frac{0.02}{5 \times 10^{-3}}$ = 4 (**ecf**) (1) Correct shape (**ecf**) (1) e.g.  		5		5	4	

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(b)		At higher frequency, X_L is larger (1) V across inductor will be larger (1) so V_{out} will be smaller and Sophie is correct (1) **Alternative:** At higher frequency, X_L is larger (1) So total impedance is greater (1) So current through resistor is less, so pd is less and Sophie is correct (1)	1		1 1	3		
	(c)	(i)	0	1			1		
		(ii)	Resonance stated or implied (1) Use of: $\omega_L = \frac{1}{\omega_C}$ **or** $f_0 = \frac{1}{2\pi\sqrt{LC}}$ (1) Substitution (1) L = 24 m[H] (1)	1		1 1 1	4	3	
		(iii)	Use of $Q = \frac{\omega_0 L}{R}$ (ecf for L) **or** $\frac{1}{\omega_0 CR}$ (1) Substitution (1) Q = 40 (1)	1	1 1		3	2	
		(iv)	Resonance curve is sharper	1			1		
			Question 9 total	**6**	**9**	**5**	**20**	**10**	**0**

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Option B - **Medical Physics**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
10	(a)	(i)	I	Rearrangement to: $V = \frac{hc}{e\lambda}$ (1) V = 49.7 k[V] (1)		2		2	2	
			II	Whole spectrum drawn below the original **and** λ_{min} to the right (1) Line spectrum missing / in a different place (1)	2			2		
		(ii)	I	$I = \frac{I_0}{2}$ so $\frac{I_0}{2} = I_0 e^{-\mu x}$ (1) $\frac{1}{2} = e^{-\mu x}$ and convincing & logs (1)		2		2	2	
			II	$\mu = \frac{\ln 2}{1.4}$ so μ = 0.495 (1) $\ln\left(\frac{100}{65}\right)$ = 0.495x (1) **ecf** x = 0.87 (cm) (1)		3		3	3	
	(b)			X-ray not sensitive enough / 2 dimensional (1) MRI can penetrate the skull / would be able to diagnose a bleed / high resolution to detect the bleed (1) Ultrasound B scan wouldn't penetrate the skull / gives moving images / doesn't detect depth (1) Radioactive tracers cannot detect bleeds / absorbed by organs/might detect blood congregation (1) CT scans give 3D images / suitable for diagnosing a bleed / are quick and available in all hospitals (1)			5	5		

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Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(c)	(i)		Gamma rays pass through a collimator (1) Cause scintillations / light flashes on a crystal (1) accept light / visible photons Collected by a series of photomultiplier tubes (1)	3			3		
		(ii)		KE of positron in J = $1.6 \times 10^{-19} \times 2.2 \times 10^{6} = 3.52 \times 10^{-13}$ [J] (1) Energy equivalent of 2 masses = $2 \times 9.11 \times 10^{-31} \times c^2 = [1.64 \times 10^{-13}]$ (1) E in J of each gamma ray = $\frac{5.2 \times 10^{-13}}{2} = 2.6 \times 10^{-13}$ [J] (1) Answer of 1.76×10^{-13} award 2 marks	1	1 1		3	3	
				Question 10 total	**6**	**9**	**5**	**20**	**10**	**0**

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Option C - **The Physics of Sports**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
11	(a)	(i)	Centre of {gravity / mass} is acting through centre of body and feet (1) No net moment **OR** large moment required / no resultant force – accept reduce chance of toppling (1)	1	1		2		
		(ii)	Relative speed of ball before collision = (1) 0.830 × relative speed after collision (1) N.B. Relative needs to be included at least once in the definition	2			2		
		(iii)	Using torque $\tau = I\alpha$ (1) Angular acceleration = $\frac{280-0}{0.26\times10^{-3}}$ = 10.8×10^5 [rad s^{-2}] (1) Torque = $\frac{2}{5} \times 0.046 \times 0.0215^2 \times 10.8 \times 10^5$= 9.2 [N m] (1) Award 2 marks for 36.6 [N m] (using diameter instead of radius) or power of 10 slips	1	1 1		3	2	
		(iv)	Applying principle of conservation of angular momentum i.e. angular momentum of initial {swing / club} = angular momentum of the ball + final angular momentum of {swing / club} **OR** angular momentum before = angular momentum after (1) External forces act e.g. person swinging club, air resistance, hitting the tee – so cannot be applied Accept – can be applied over very short time of collision (1) Award 1 mark for (Yes) there is no air resistance / external forces acting			2	2		
	(b)	(i)	Vertical component of speed = 40sin28° = 18.8 [m s^{-1}] **and** horizontal component of speed = 40cos28° = 35.3 [m s^{-1}] (1) Time to travel 68 m = 1.9[3 s] (1) Using and substituting values into: $x = ut + ½at^2$ to determine height gained (1) Height gained at 68 m = 18.0 + 1.7 = 19.7[m] – so the ball will clear the tree (1)		4		4	4	

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	Rotational kinetic energy $= \frac{1}{2}I\omega^2$ = 0.16 [J] **ecf for *I*** (rotational KE = 0.6 J if diameter used for moment of inertia in part (a)(iii)) (1) Using v = 35.3 [m s^{-1}] and linear KE = $\frac{1}{2}mv^2$ (1) Linear KE = 28.7 J and comment e.g. much greater than rotational (1)			3	3	3	
	(c)		**Any 2 of these 6 options** i.e. (i) factor change and (ii) description to a maximum of 2 examples in the list below Decrease COR (of club-ball) (1) by changing material of ball (1) Increase drag coefficient / air resistance (1) By changing dimple design or by implication (1) Increase size / area / radius / diameter (1) Greater drag (1) Decrease lift / make lift non-optimal (1) By changing material / dimples / make the ball smoother (1) Increase mass / weight (1) Decrease initial speed (1) Decrease the mass / weight of the ball (1) so that air resistance has a greater decelerating effect (slows it down more) (1) Any additional comments treat as neutral Don't accept non-specific factors e.g. heavier / softer / lighter Density of the ball given in the context of the drag force equation	2	2		4		
			Question 11 total	**6**	**9**	**5**	**20**	**10**	**0**

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Option D - **Energy and the Environment**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
12	(a)		An energy resource that can be replenished in a relatively short space of time e.g. human lifetime OR equivalent OR an energy resource that can be used for a long period of time	1			1		
	(b)	(i)	Mass difference calculated correctly (0.02871 [u]) (1) $\frac{0.02871}{4.03022} \times 100 = 0.71\%$ (1) **Alternative:** $\frac{4.00151}{4.03022} \times 100 = 99.29\%$ (1) $100 - 99.29\% = 0.71\%$ (1)		2		2	2	
		(ii)	[Radiated solar] {energy per second per m^2 / power per m^2 / accept intensity} [crossing a plane perpendicular to the line joining the Earth to the Sun], just outside the Earth's atmosphere (1) A = 2.8×10^{17} [km^2] **OR** 2.8×10^{23} [m^2] or can be implied (1) $I = \frac{P}{A} = \frac{3.83\times10^{26}}{4\pi\times(1.5\times10^{11})^2} = 1.36$ [$kW\ m^{-2}$] (1)	1	1 1		3	2	
		(iii)	0.2×342 (1) = 68.4 $\frac{70 \times 10^9}{68.4}$ = 1.02×10^9 [m^2] (1) **Alternative:** $\frac{70\times10^9}{342} = 2.05 \times 10^8$[$m^2$] (1) $\div 0.2$ **OR** equivalent = 1.02×10^9 [m^2] (1)		2		2	2	
	(c)	(i)	Use of $P = \frac{1}{2}\rho A v^3$ (1) To find final power 0.636 M[W] (1) Initial power calculated 2.636 M[W] and used to find initial speed 6.6 [$m\,s^{-1}$] (1) **ecf** on final power	1	1 1		3	2	

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	Assumption – water speed equal to wind speed **OR** water speed much smaller than wind speed (1) Use of $P = \frac{1}{2}\rho A v^3$ to calculate ratio **or** equivalent e.g. $P \propto \rho A$ (1) Conclusion consistent with reasoning e.g. much lower power (1) Expect that the claim is incorrect (if the speeds are taken as the same, a factor of ~30 expected rather than 100)		1	1 1	3	2	
	(d)	(i)	Chemical to electrical	1			1		
		(ii)	Allows [only positive] H ions through it to the cathode Accept [negative] electrons must travel along external circuit producing power	1			1		
		(iii)	Water	1			1		
		(iv)	Hydrogen cells do not release CO_2 directly (1) Consideration of how hydrogen fuel is obtained i.e. electrolysis of water **or** the manufacturing process of the cell **or** even the transportation of the cells (1) Details on how electrical energy is produced **or** the type of fuel used in transportation e.g. gas fired power contributes to CO_2 emissions whereas PV cells do not (1)			3	3		
			Question 12 total	**6**	**9**	**5**	**20**	**10**	**0**

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A LEVEL COMPONENT 3: LIGHT, NUCLEI AND OPTIONS

SUMMARY OF ASSESSMENT OBJECTIVES

QUESTION	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	7	11	3	21	10	0
2	0	7	3	10	4	0
3	4	6	0	10	7	0
4	4	3	4	11	4	11
5	2	7	8	17	8	15
6	3	6	0	9	0	0
7	8	0	0	8	0	0
8	2	5	7	14	3	0
9	6	9	5	20	10	0
10	6	9	5	20	10	0
11	6	9	5	20	10	0
12	6	9	5	20	10	0
TOTAL	**36**	**54**	**30**	**120**	**46**	**26**

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