GCE A LEVEL MARKING SCHEME

SUMMER 2022

A LEVEL
PHYSICS – COMPONENT 3
A420U30-1

INTRODUCTION

This marking scheme was used by WJEC for the 2022 examination. It was finalised after detailed discussion at examiners' conferences by all the examiners involved in the assessment. The conference was held shortly after the paper was taken so that reference could be made to the full range of candidates' responses, with photocopied scripts forming the basis of discussion. The aim of the conference was to ensure that the marking scheme was interpreted and applied in the same way by all examiners.

It is hoped that this information will be of assistance to centres but it is recognised at the same time that, without the benefit of participation in the examiners' conference, teachers may have different views on certain matters of detail or interpretation.

WJEC regrets that it cannot enter into any discussion or correspondence about this marking scheme.

GCE A LEVEL PHYSICS

COMPONENT 3 – LIGHT, NUCLEI AND OPTIONS

SUMMER 2022 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

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	(a)	(i)	2 μ[m]	1			1		
		(ii)	0.70 - 0.85 [m] (1) Evidence of 3 (or 2) wavelengths divided by 3 (or 2) e.g. $\frac{2.41-0.07}{3}$ (1)		1 1		2	1	
		(iii)	Phase / lag increases / changes with distance (1) Numerical value **or** equation given e.g. 360° every wavelength (0.78 **ecf**) **or** $\varphi = \frac{x}{\lambda} \times 2\pi (\text{or } 360°)$ (1) Points separated by a wavelength (**ecf**) **or** $n\lambda$ in phase (1) Points separated by a half wavelength **or** $(n + \frac{1}{2})\lambda$ in anti-phase (1) Accept any 2 points in phase or anti-phase	4			4	1	
	(b)	(i)	Period = 2.24 - 2.30 m[s] (1) Evidence of 3 (or 2) periods divided by 3 (or 2) $\left(\frac{6.8}{3}\right)$ (1) Valid method $v = f\lambda$ and $f = \frac{1}{T}$ **OR** $v = \frac{\lambda}{T}$ (1) $v = 343$ [m s^{-1}] (**ecf**) (1)		4		4	3	
		(ii)	-2 ± 0.2 μ[m] or reasonably close to this (1) Explanation e.g. 7 ms + ¾ of a period **or** 6.4 ms + one period **or** equivalent **or** same as 6.45, 4.2, 1.9 etc. **or** since ε = 117° **or** since ε = 2.05 rad **or** ½ cycle after max at 7.6 ms (1)		2		2	1	
			Question 1 total	**5**	**8**	**0**	**13**	**6**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	(a)		Incident (or implied) and reflected waves (accept waves going left & right) (1) Interfere **or** constructive / destructive interference **or** superposition (1)	2			2		2
	(b)	(i)	4.9 cm is 3.5 internodal distances **or** 1.75 wavelengths (1) $\lambda = 2.8$ c[m] **ecf** on number of λ (this implies the 1st mark) (1) $f = \frac{c}{\lambda}$ =10.7 G[Hz] **ecf** on λ (1) 21.4 G[Hz] – award 2 marks $\lambda = 1.4$ c[m] only – 1 mark	1	1 1		3	2	3
		(ii)	Double the length / nodes **or** use ruler with increments / resolution halved (1) Absolute uncertainty remains the same **or** $\frac{0.1}{9.8}$ **or** absolute uncertainty decreased **or** $\frac{0.05}{4.9}$ (1) e.g. use vernier to decrease absolute uncertainty or to improve resolution – 1 mark (2nd) e.g. measure 9.8 cm to halve % uncertainty – 1 mark (1st) Accept for 2 marks: double the number of nodes (1) Hence double the distance (1)			2	2		2
	(c)		$\lambda = \frac{343}{12\,250} = 2.8$ c[m] (or same wavelength stated) (1) Valid comparison with (b)(i) (1)			2	2	1	2
			Question 2 total	**3**	**2**	**4**	**9**	**3**	**9**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	(a)		Maxima and minima detected. Accept constructive and destructive interference (1) Reference to central maximum (1) Diffraction happens at slits **or** overlap of beam from 2 slits **or** interference linked to the slits **or** 2 source interference (1) Maximum - constructive interference **or** minimum - destructive interference (1) Maximum due to whole wavelength path difference **or** minimum due to half wavelength path difference (1)	5			5		5
	(b)		Substitution into $\lambda = \frac{ay}{D}$ (1) $\lambda = 3.12$ c[m] (1) Power of ten slips gain half marks **Alternative:** Pythagoras used for path difference i.e. any difference between 2 square roots (1) Accept: 30.86 – 28.22 = 2.6 c[m] (1) **Alternative using diffraction grating equation:** Good attempt at using $n\lambda = d \sin\theta$ (1) expect an angle of 32° and d = 0.05 Correct answer (1) expect 0.02647 by this method	1	1		2	1	2
	(c)		[Charlie right because] not coherent sources **or** not same frequency / wavelength **or** don't have a constant phase difference Don't accept – not in phase / out of phase			1	1		1
			Question 3 total	**6**	**1**	**1**	**8**	**1**	**8**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
4	(a)	(i)		Linked to population inversion (1) So we need as many electrons in E2 **or** increase probability of stimulated emission (1) Accept for E2 to hold electrons	2			2		
		(ii)		Substitution into: $E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{632.8}$ [3.14×10^{-19}] (1) Correct conversion using 1.6×10^{-19} i.e. 1.96 [eV] **or** 2.95×10^{-18} [J] (1) E_2 = 20.38 [eV] **or** 32.6×10^{-19} [J] (1) **ecf**	1	1 1		3	2	
	(b)	(i)		Use of tan θ **or** Pythagoras e.g. tan $\theta = \frac{16.4}{20}$ (39.35) **or** $\sqrt{20^2 + 16.4^2}$ (25.86 cm) (1) Use of $\sin\theta$ e.g. sin ($\tan^{-1}\frac{16.4}{20}$) **or** $\frac{16.4}{25.9}$ (0.634) (1) Use of $n\lambda = d\sin\theta$ (could be to calculate λ, d or θ) (1) λ, d or θ calculated correctly with conclusion of OK (allow **ecf**) (1) (Expect 634 nm for λ, 9.98×10^{-7} m for d, 39.26 (0.687 rad) **and** 39.35 (0.692 rad) for θ Inaccurate alternative for a maximum of 2 marks. Substitution into double slit equation (1) i.e. $\frac{1\times10^{-6}\times0.164}{0.2}$ $(= 8.2 \times 10^{-7})$ Valid conclusion: 820 nm not the same as 632.8 nm or similar			4	4	3	4
		(ii)	I	Refraction **or** refractive index changes **or** reference to bending **or** Snell's Law **or** denser medium (1) towards normal **or** light is slower (in glass) (1) **Alternative:** Shorter wavelength (1) So smaller angle or $\sin\theta$ (1)	1	1		2		2

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
			II	$\theta_2 = 23.03°$ (1) Use of $n_1 \sin\theta_1 = n_2 \sin\theta_2$ (1) $n_2 = 1.62$ (1) **Alternative:** $\theta_2 = 23.03°$ or calculating $\sin\theta = 0.391$ (1) Use of $n\lambda = d \sin\theta$ (gives $\lambda =$ 391 nm) (1) $n_2 = 1.62$ (1)	1	1 1		3	2	3
				Question 4 total	**5**	**5**	**4**	**14**	**7**	**9**

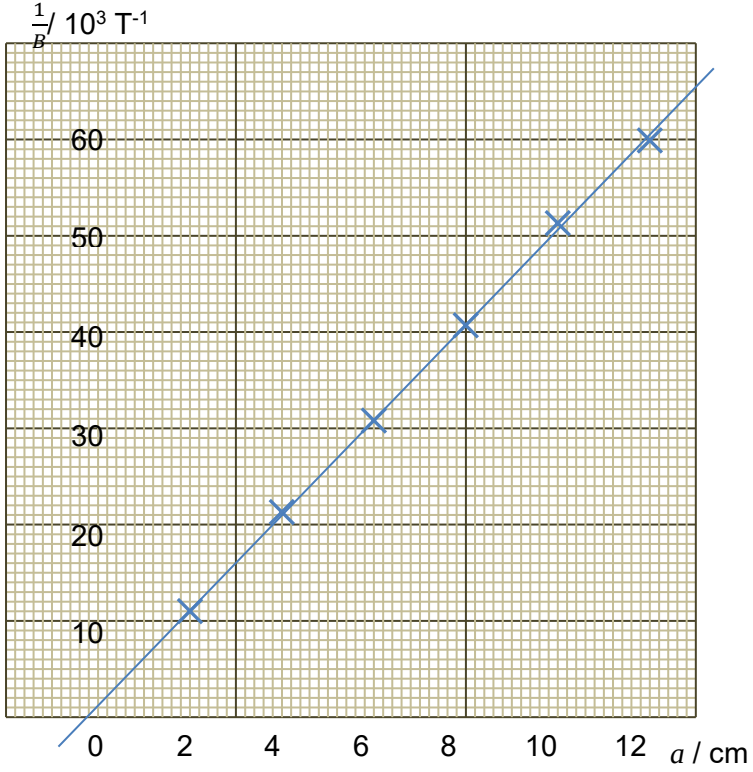
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	(a)		**(Action explanation)** Light has momentum (1) Provides forward force on rocket **or** transfers [forward] momentum to rocket **or** reference to cons. of momentum (1) **OR (reaction explanation)** Light changes momentum [on reflection] **or** reference to rate of change of momentum of photons (1) N3 law force [is forward on rocket] (1)	2			2		
	(b)	(i)	$E = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{403\times10^{-9}}$ [= 4.94 × 10^{-19} J] (1) Final substitution seen $\frac{1270}{4.94 \times 10^{-19}}$ **or** 2.57 × 10^{21} seen (1)	1	1		2	2	
		(ii)	$p = \frac{h}{\lambda}$ or $\frac{E}{c}$ used (1.645 × 10^{-27}) (1) Final substitution seen (2 × 1.645 × 10^{-27} × 2.57 × 10^{21}) **or** 8.47 μ seen (1)	1	1		2	1	
		(iii)	$p = N\Delta p$ **or** more likely $\frac{1}{2}mv^2 = 1\,270$ [J] (1) $KE = \frac{p^2}{2m}$ **or** $v = 296$ [m s^{-1}] (1) $KE = \frac{N^2\Delta p^2}{2m}$ **or** 296 × 0.029 = N × 8 × 10^{-6} (1) N = 1.01 × 10^{6} (or 1.07 × 10^{6} depending on 8 μN s or 8.47 μN s) (1) **Slight alternative:** $\frac{8 \times 10^{-6}}{0.029}$ = 2.76 × 10^{-4} (1) (this is change of velocity) $\frac{1}{2}mv^2 = 1\,270$ (1) $v = 296$ [m s^{-1}] (1) $\frac{296}{2.76 \times 10^{-4}}$ = 1.07 × 10^{6} (1)		4		4	4	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(iv)	Kinetic energy [of rocket] is [continually] increasing (1) Energy of light is constant / doesn't decrease **or** any reference to red shift (accept Doppler) (1) Any reference to conservation of energy (1) (don't accept conservation of kinetic energy			3	3		
			Question 5 total	**4**	**6**	**3**	**13**	**7**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	(a)		Method 1 i.e. mass of LHS - RHS (gives 0.01889 u) (1) $\times 931$ **or** $\times c^2$ and $\times 1.66 \times 10^{-27}$ (1) 17.6 MeV **or** 2.81×10^{-12} J (1) **unit mark**	1	1 1		3	3	
	(b)		Helium[-4] has large BE/N (1) Hydrogen[-2 and 3] have low BE/N (1) Accept: Helium has [much] higher BE/N than hydrogen for 2 marks		2		2		
	(c)		**Any 3 × (1) for valid points:** Solar energy is cheapest electricity Solar is renewable Solar needs much area / low energy output Solar is proven to work Solar is locally available / good for remote areas Fusion - could solve future energy problems Fusion - could last millions of years Fusion - so far is waste of money Fusion - research for the sake of research is good Fusion - not weather dependent or solar is weather dependent / day-night etc. Fusion could release a lot of energy			3	3		
			Question 6 total	**1**	**4**	**3**	**8**	**3**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)	(i)	$^{3}_{2}\mathrm{He}$ (1) β^- **or** e^- or e **or** $^{0}_{-1}\beta$ **or** $^{0}_{-1}\mathrm{e}$ (1) NOT $^{1}_{0}\beta$ **or** $^{1}_{0}\mathrm{e}$ $\bar{\nu}_e$ **or** $\bar{\nu}$ (1)	1 1	1		3		
		(ii)	Use of $pV = nRT$ **or** $pV = NkT$ (1) $n = 1.60$ mol **or** $N = 9.6 \times 10^{23}$ (1) Final substitution seen $1.60 \times 2 \times 6.02 \times 10^{23}$ **or** 1.93×10^{24}	1	1 1		3	3	
		(iii)	Use of $\lambda = \dfrac{\ln 2}{T_{\frac{1}{2}}}$ ($0.056\,\text{year}^{-1}$ **or** $1.78 \times 10^{-9}\,\text{s}^{-1}$) (1) Answer = 3.44×10^{15} Bq **or** $1.08 \times 10^{23}\,\text{year}^{-1}$ **unit mark** (1)	1	1		2	2	
		(iv)	Substitution into equation e.g. $0.1 = e^{-\lambda t}$ **or** $0.1 = \frac{1}{2^n}$ **ecf** on λ (1) Taking logs of equation e.g. $\ln 0.1 = -\lambda t$ **or** $\ln 0.1 = -n\ln 2$(1) Answer = 40.9 [year] **or** 1.29×10^{9} [s] (1)	1	1 1		3	3	
	(b)		**Indicative content:** **Standard conservation laws:** BN 0 = 0 + 0 and 0 = 0 + 0 Q 1(e) = 1(e) + 0 And 0 = 0 + 0 LN 0 = -1 + 1 And 0 = 0 + 0 Mention of conservation of energy Greater mass on LHS goes to KE of particles / photon energy Mention of conservation of momentum		6		6		

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
			Forces 1st decay is weak force Due to neutrino And change of quark flavour 2nd decay is electromagnetic Due to photons Annihilation of quarks Expect far shorter lifetime for 2nd decay. **5-6 marks** Comprehensive description of the conservation laws and forces. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Comprehensive description of either the conservation laws or forces **or** limited description of both areas. *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 the conservation laws or forces. *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.*						
			Question 7 total	**5**	**12**	**0**	**17**	**8**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	(a)		Substitution (1) Answer = 9.75 [A] (1)	1	1		2	1	1
	(b)	(i)	Line should (more or less) go through all points but below penultimate point and above last point  		1		1	1	1

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	Intercept measured or implied to be the distance (1) Expect 1-6 mm into phone from x-intercept (**ecf** on line) (1)			2	2	1	2
	(c)		Method for obtaining gradient (1) Correct gradient i.e. expect 4.92 ($\times 10^5$) (implies 1st mark) (1) Identifying gradient $=\frac{2\pi}{\mu_0 I}$ (1) Current = 10.2 [A] **ecf** on gradient (1) **OR for a max of 3 marks** Allow mark for obtaining 2nd value of current (9.07 A, 9.4 A, 9.75 A, 9.84 A, 9.75 A) (1) Allow mark for obtaining mean value of at least 3 currents (1) Correct current (e.g. 9.64 A) (1)			4	4	4	4
	(d)		Good because: All points close to line (1) Straight line (1) Don't accept positive gradient Correct agreement with (10.5 ± 0.5) A **(ecf)** (1) (bad agreement if mean method, good agreement if graph method) Not so good because: Should pass through origin (but reason given and already marked) (1) (any sensible discussion of missing the origin should be ok)			4	4		4
			Question 8 total	**1**	**2**	**10**	**13**	**7**	**13**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	(a)		Current flows (1) Opposes [relative] motion (1) Accept reference to Lenz's law Damping / energy loss due to electrical heating or equivalent e.g. energy loss due to resistance (1)		3		3		
	(b)		$V = IR$ = 0.15 × 0.18 = 0.027 (1) This is the rate of change of flux [by Faraday] (1)		2		2	1	
			Question 9 total	**0**	**5**	**0**	**5**	**1**	**0**

Option A – Alternating Currents

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
10	(a)	(i)		Inductor - reactance proportional (accept increase) to frequency (1) Resistor no frequency dependence or constant (1)	2			2		
		(ii)	I	Reactance = 14.7 k[Ω] (1) Pd = $\frac{14.7}{\sqrt{12^2+14.7^2}} \times 8.2$ **or** current = $\frac{8.2}{\sqrt{12^2+14.7^2}}$ (0.432 mA) (1) Correct answer = 6.35 [V] (1)		3		3	3	
			II	pd increases **OR** takes a greater share of the supply pd		1		1		
		(iii)	I	Answer = 14.7 k[Ω]		1		1	1	
			II	Reactance decreases with frequency (or inversely proportional) (1) As reactance decreases, takes a smaller share of the pd (1) OR current increases so pd increases across resistor	1	1		2		
		(iv)		Reactances will cancel **or** pd across L and C cancel **OR** calculating the frequency (1) Resistor is a little less than reactances **OR** calculated (1)	1	1		2		
		(v)		Resonance current calculated (0.68 mA) (1) 50 kHz, 0.68 mA **ecf** plotted correctly (1) Current = 0 when f = 0 (1) General shape (1)	1 1	1 1		4	2	

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(b)			V_{peak} = 20 mV $\times \sqrt{2}$ = 28 mV **OR** state > 20 mV (1) Dividing by VOLTS/DIV = 5.7 squares **OR** 4 $\times$ 5 mV = 20 mV **OR** 4 $\times$ 5 mV $\neq$ 28 mV (1) Substitution for period = $\frac{1}{0.2 \times 10^6}$ [= 5 $\times$ 10^{-6} s] (1) Multiplying by 1 μs by 5 squares **OR** 10 squares (1) Conclusion - period drawn correctly but not enough room for peak pd **OR** candidate correct except forgot to $\times \sqrt{2}$ (1)			5	5	4	
				Question 10 total	**6**	**9**	**5**	**20**	**10**	**0**

Option B – Medical Physics

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
11	(a)	(i)	$eV = \frac{hc}{\lambda}$ rearranged to $V = \frac{hc}{e\lambda}$ (1) Answer V = 50 (or 49.7 etc.) k[V] (1)		2		2	2	
		(ii)	Whole spectrum drawn below the original (1) Line spectrum missing / in a different place (1)	2			2	1	
		(iii)	$I = \frac{I_0}{2}$ leading to setting up $\frac{I_0}{2} = I_0 e^{-\mu x_{\frac{1}{2}}}$ (1) $\frac{1}{2} = e^{-\mu x}$ 2 = $e^{\mu x}$ i.e. just enough algebra to be convincing (1)		2		2	2	
		(iv)	$\mu = \frac{\ln 2}{1.4}$ so μ = 0.495 or 0.5 (1) $\ln\left(\frac{100}{65}\right)$ = 0.43x **ecf** (1) x = 0.87 cm (1) **unit mark**		3		3	3	
	(b)	(i)	**Any 2 × (1) from:** - alignment mark i.e. normally with B-field but flipped is opposite. - radio absorbed - causes nuclei/protons to flip - radio emitted - when nuclei/protons flip back	2			2		
		(ii)	$f = \frac{3 \times 10^8}{5.9}$ = 5.08 × 10^7 [Hz] (1) $B = \frac{5.08 \times 10^7}{42.6 \times 10^6}$ = 1.2 [T] (1)		2		2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(c)		**Any 2 × (1) from:** - Isotope of / [chemically] the same as the element it replaces - Suitable half-life **or** stable daughter nuclide - Only γ emitter	2			2		
	(d)		X-ray not sensitive enough to soft tissue / absorption by skull / 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 (4×reflection at bone-soft tissue interface (1) Radioactive tracers cannot detect bleeds / absorbed by organs (PET scans can be used to diagnose bleeds) (1) CT scans give 3D images / suitable for diagnosing a bleed /are quick and available in all hospitals (1)			5	5		
			Question 11 total	**6**	**9**	**5**	**20**	**10**	**0**

Option C – The Physics of Sports

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
12	(a)			Low centre of gravity (1) Wide base **or** feet wide apart (1)	1	1		2		
	(b)			Coefficient of restitution is the ratio of final speed to initial speed accept more energy recovered when CoR is greater (1) So for greater speed; higher coefficient of restitution – so hockey stick C (1)			2	2		
	(c)	(i)		Moment of inertia = 8.29×10^{-5} [kg m^2] (1) Definition of angular acceleration = $\frac{\text{change in angular velocity}}{\text{time}}$ **OR** torque = $\frac{\text{change in } L}{t}$ (1) Application of torque $= I\alpha$ (1) Torque = 30.8 [N m] **ecf** on moment of inertia and angular acceleration (1)	1	1 1 1		4	3	
		(ii)		Rotational kinetic energy $= \frac{1}{2} I\omega^2$ (1) Rotational KE = 0.257 [J] (**ecf** on I and ω) (1) Linear KE = 144 [J] (1)	1	1 1		3	2	
		(iii)		Use $F = \frac{mv-mu}{t}$ (1) F = - 2163 [N] – negative sign required or implied (1) Force exerted by ball on the goalkeeper is 2163 [N] – so is large – protection is advisable (1)			3	3	1	

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
		(iv)	I	Using Bernoulli equation $p = p_o - \frac{1}{2}\rho v^2$ (1) Realising difference in pressure = $\frac{1}{2}\rho(v_1^2 - v_2^2)$ (1) [= 53.8 Pa] (Lift) Force = 53.8 × area = 0.215 [N] (accept 0.430 N) (1) Comparing with weight of 1.6 N allow **ecf** (1)	1 1	 1 1		4	2	
			II	Recall drag force equation **or** can be implied from $F \propto v^2$ (1) Force will <u>reduce</u> by a factor/fraction of $\frac{1}{4}$ **or** 0.25 of the initial force (1)	1	1		2	1	
				Question 12 total	**6**	**9**	**5**	**20**	**10**	**0**

Option D - Energy and the Environment

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
13	(a)	(i)		Power per unit area (perpendicular to radiation direction) / $\frac{P}{4\pi R^2}$ at a distance R from a source UNIT: W m^{-2} or equivalent	1			1		
		(ii)		Use of $\lambda_{\max} = \frac{W}{T}$ and $P = \sigma A T^4$ (1) Convincing algebra e.g. sub into $I = \frac{P}{A}$ with cancelling of 4π (1)	1	1		2	1	
		(iii)		Correct substitution e.g. $\frac{(6.96\times10^8)^2\sigma W^4}{(150\times10^9)^2\,(500\times10^{-9})^4}$ (allow power slips) (1) 1 380 (1)	1	1		2	1	
	(b)	(i)		Use of $\mathrm{PE} = mgh$ (1) $P = \frac{\rho V g h}{t} = 1\times10^3\times40\times9.81\times390$ = 153 M[W] (1)	1	1		2	1	
		(ii)		**Any 3 ×(1) from:** • Electricity generation process produces no greenhouse gases / CO_2 • Electricity used for pumping from thermal power stations producing greenhouse gases / CO_2 **or** from wind turbines not producing greenhouse gases / CO_2 • Not continuously in operation so greenhouse gases / CO_2 impact minimal • Greenhouse gases / CO_2 emissions during construction • Greenhouse gases / methane addition from decaying matter at bottom of reservoir		3		3		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(c)	(i)		The time that the fuel is able to maintain its internal energy **or** time the fuel is maintained at a temperature above the critical ignition temperature	1			1		
		(ii)	I	k and/or e used in conversion (1) $\frac{1.38\times10^{-23}\times1.1\times10^{8}}{1.6\times10^{-19}}$ **or** 9.5 seen accept $\frac{3}{2}\times\frac{1.38\times10^{-23}\times1.1\times10^{8}}{1.6\times10^{-19}}$ **or** 14 seen (1)	1	1		2	1	
			II	Manipulation to give $\tau_E = \frac{\text{triple product}}{nT}$ i.e. $\frac{8.0\times10^{22}}{2.0\times10^{21}\times9.5}$ (1) 4.2 or 4.0 or 2.8 [s] (1)		2		2	2	
	(d)			$\frac{\Delta Q}{\Delta t}$ same through both layers (can be implied) (1) $0.1(20-\theta) = 0.5(\theta-5)$ or equivalent (1) θ = 7.5 [°C] so Tom is correct (1) $\frac{\Delta Q}{\Delta tA} = \frac{0.1\times(20-7.5\ \mathbf{ecf})}{0.1}$ or $\frac{0.5\times(7.5\mathbf{ecf}-5\ )}{0.1}$ or $\frac{0.083\times(20-5)}{0.1}$ or $\frac{15}{\frac{0.1}{0.1}+\frac{0.1}{0.2}}$(1) $\frac{\Delta Q}{\Delta tA} = 12.5$ [W m^{-2}] so Tom is incorrect (1)			5	5	4	
				Question 13 total	**6**	**9**	**5**	**20**	**10**	**0**

A LEVEL COMPONENT 3: LIGHT, NUCLEI AND OPTIONS

SUMMARY OF ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	5	8	0	13	6	0
2	3	2	4	9	3	9
3	6	1	1	8	1	8
4	5	5	4	14	7	9
5	4	6	3	13	7	0
6	1	4	3	8	3	0
7	5	12	0	17	8	0
8	1	2	10	13	7	13
9	0	5	0	5	1	0
10	6	9	5	20	10	0
11	6	9	5	20	10	0
12	6	9	5	20	10	0
13	6	9	5	20	10	0
TOTAL	**36**	**54**	**30**	**120**	**53**	**39**