GCE A LEVEL MARKING SCHEME

SUMMER 2017

A LEVEL (NEW)
PHYSICS - COMPONENT 3
A420U30-1

INTRODUCTION

This marking scheme was used by WJEC for the 2017 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.

MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark (except for the extended response question).

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)*		• In 4-level E3 to E2 • In 3-level E2 to E1 • Pumping is upward in **both** diagrams All 3 correct award 2 marks 1 or 2 correct award 1 mark 0 correct award 0 marks	2			2		
	(b)		E2 is [initially] nearly empty or empties quickly or has a short half-life or lifetime [in 4 level] (1) E1 is [initially] occupied or ground state or full [in 3-level] (1) More pumping needed for 3 level or converse (1) At least 50% of electrons need pumping in 3 level or any pumping produces population inversion in 4 level (1)	1 1	1 1		4		
	(c)		Cannot pump a full energy level or pumping not as effective if level is fuller etc (1) Electrons need to go to next level down [E3 or E2 for population inversion] (1)		2		2		
			Question 1 total	**4**	**4**	**0**	**8**	**0**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	Charge: 6 = 7 -1 + 0 **or** 0 = 1 - 1 + 0 **or** $-\frac{1}{3} = \frac{2}{3} - 1 + 0$ (1) Baryon number: 14 = 14 + 0 + 0 **or** 1 = 1 + 0 + 0 **or** $\frac{1}{3} = \frac{1}{3} + 0 + 0$ **or** 42 = 42 + 0 + 0 (1) Lepton number: 0 = 0 + 1 – 1 **or** 6 = 6 + 1 – 1 (1)		3		3		
		(ii)	Change of quark flavour [from d to u] (1) Neutrino involved accept symbol (1) Accept long half-life		2		2		
	(b)	(i)	Use of the equation $T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ (1) $T_{\frac{1}{2}}$ = 1.81 × 10^{11} [s] (1) 5 730 [year] (1)	1	1 1		3	3	
		(ii)	Use of the equation $A = \lambda N$ (1) Method for obtaining N correct (6.02 × 10^{23} × 1 × 10^{-12}) (1) Answer = 2.30 Bq **unit mark** (1)	1	1 1		3	3	
		(iii)	0.34 × 10^{-12} = 1 × 10^{-12} $e^{-\lambda t}$ i.e. substitution or into $\frac{1}{2^n}$ (1) Taking logs correctly e.g. $\log A = \log A_0 - \lambda t$ (1) 2.82 × 10^{11} [s] or 8 900 [year] (1)	1	1 1		3	3	
	(c)		11, 5 for boron (1) Positron symbol correct e.g. e+ or beta + (1) Neutrino symbol correct (ν_e) but accept ν (1) Any fourth particle added lose 1 mark		1	1 1	3		

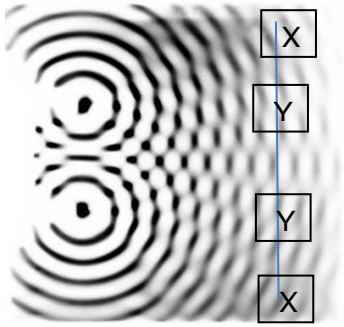
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(d)		**Any 3 × (1) from:** • cannot tell who is correct or words to that effect • further experiments or research must be carried out • experiments at higher (collision) energies (to find other particles) / bigger or better colliders • time/history will (probably) show who was correct • further theory / theoretical research • reference to the Higgs behaving as expected or not as expected • those who claim not should suggest an alternative • Higgs thought to be detected with 5σ [confidence] **Don't accept** any reference to charge or baryon number or lepton number conservation			3	3		
			Question 2 total	**3**	**12**	**5**	**20**	**9**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*		LHS – RHS (3.0155 – 3.01493 – 0.00055 i.e. standard knowledge of conservation of mass-energy (1) ×931 or equivalent (× c^2) (1) 0.0186 [MeV] (2.98 × 10^{-15} [J]) (1)	1	 1 1		 3	 2	
	(b)	(i)	Mass of p + 2n (3.0246u) - 3.0155 (1) Dividing by 3 **and** ×931 (or equivalent) (1) Answer = 2.82 [MeV / nucleon] (4.52 × 10^{-13} [J/nucleon]) (1)		 3		 3	 2	
		(ii)	Tritium decays to helium-3 **or** helium has a better proton/neutron ratio **or** proton has a smaller mass than neutron (1) And emits energy **or** products have lower mass **or** helium more stable (1) You would expect the products to have a greater BE/N **or** contrary to what you would expect (1)			 3	 3		
			Question 3 total	**1**	**5**	**3**	**9**	**4**	**0**

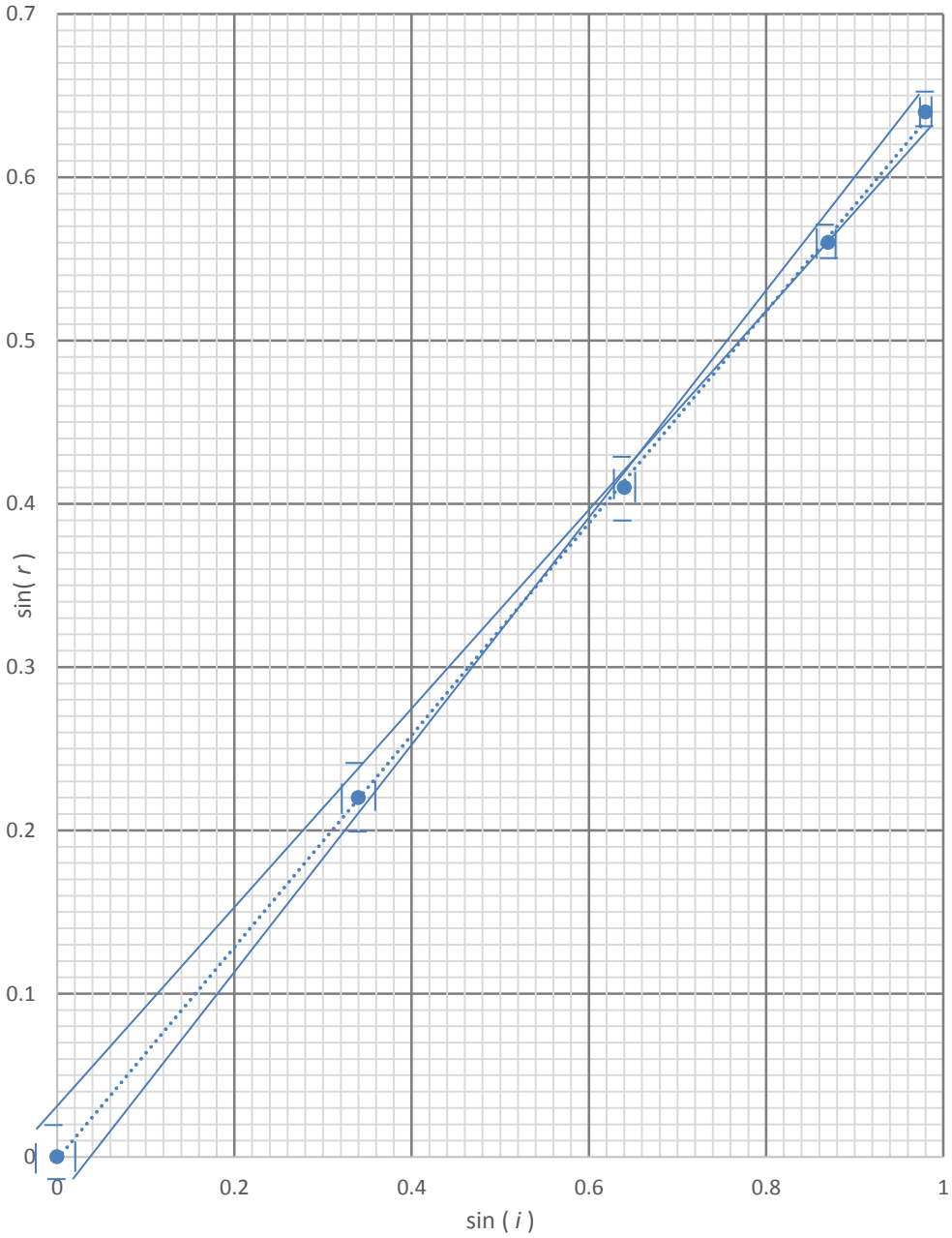
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*		Method for obtaining N e.g. $\frac{4\,000}{0.25 \times 10^{-3}}$ (1) Use of πd or $2\pi r$ (1) 1 508 m or $16\,000 \times \pi \times 0.03$ seen or equivalent (1)	1	1 1		3	3	
	(b)		$R = \frac{\rho l}{A}$ used and $I = \frac{V}{R}$ used (1) 0.25 mm used as diameter for area or (0.125 mm as radius) (1) 24.6 mA seen or $\frac{12}{488}$ or $\frac{12}{486}$ seen or equivalent evidence (1)	1	1 1		3	3	
	(c)		$n = \frac{N}{\text{length}}$ (1) Answer = 1.23×10^{-4} [T] (1) Award 1 mark only for answer of 3.35×10^{-7} [T]	1	1		2	2	
	(d)		$B = \mu_0 nI$ used to calculate I **ecf** (1) Correct conclusion stated and consistent with calculation (1) Wires would melt / damaged / burnt / become hot / use superconductor / use cooling (1)			3	3	1	
			Question 4 total	**3**	**5**	**3**	**11**	**9**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*	(i)	Emf is induced due to rate of change of flux (or cutting) **or** reference to [Fleming's] RH rule (1) **don't accept** RH grip rule Current can flow **or** circuit is complete (1)	1	1		2		
		(ii)	Vertical component is perpendicular to the area swept **or** other components are not cut **Accept** flux due to horizontal field is zero or motion is in plane / parallel to horizontal field **Don't accept** current in the field		1		1		
	(b)		Induced emf = $\frac{\mathrm{d}}{\mathrm{d}t}(BA)$ with or without N (accept $\frac{BA}{t}$) (1) $\frac{\mathrm{d}}{\mathrm{d}t}(A)=\frac{l\mathrm{d}x}{\mathrm{d}t}$ accept $\frac{A}{t}=\frac{lx}{t}$ or $\frac{A}{t}=lv$ (1) $I=\frac{V}{R}$ and reasonable algebra (1)	1	1 1		3	3	
	(c)	(i)	Good method employed e.g. calculating 3× ratio $\frac{v}{I}$, calculating B 3 times, or I is proportional to v etc. (1) Correct calculations e.g. 0.5, 0.5, 0.55, 0.53 / I is roughly $2v$ (1) B, ℓ and R are constants or equivalent e.g. $\frac{Bl}{R}$ is constant (1) Ok within uncertainties (1)			4	4	3	4
		(ii)	80 m s^{-1} and 150 μA used **accept** mean points if 80 m s^{-1} and 150 μA used for uncertainty (1) Rearrangement $B=\frac{RI}{lv}$ (1) Answer = 57.6 μ[T] (1) 1% and 7% used (1.25% and 6.7% ok) **ecf** accept first principles (1) Percentages added (8%) **ecf** (1) B = (58 ± 5) μT **ecf** accept (57.6 ± 4.6) μT unit mark and with consistent sig figs allow a max of 2 sig figs for the uncertainty (1)		1 1 1	1 1 1	6	6	6
			Question 5 total	**2**	**7**	**7**	**16**	**12**	**10**

Question		Marking details	Marks available					
			AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*	d and θ labelled (1) $d\sin\theta$ is the path difference stated **and** shown (1) Equals $n\lambda$ for in phase / constructive / bright (1)	3			3	1	
	(b)	$d = \frac{1}{\text{number}}$ used or implied (1) Values substituted into $n\lambda = d\sin\theta$ **ecf** on d (1) At least one correct angle 7.6° or 15.4° (no **ecf** here) (1) Correct answer (accept 7.8° or 7.7° even if $\frac{\theta}{2}$) (1) Accept answers in radians i.e. 0.133 and 0.269 Difference = 0.136 [rad]	1 1	1 1		4	4	
	(c)	Realisation of small angles approximation **ecf** or $d\sin 3.9$ **ecf** = λ(1) 125 lines per mm (1) **accept** 127 or 128		2		2	2	
		Question 6 total	**5**	**4**	**0**	**9**	**7**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*		Coherent sources or inphase and superposition (1) There is a path difference or waves from sources travel different distances (1) Constructive interference **and** destructive interference happens (1) Condition for constructive or destructive stated: $n \times 360$ or $n\lambda$ or $(n{+}½) \times 360$ or $(n + ½)\lambda$ (1)	4			4		
	(b)	(i) & (ii)	 (i) 1 mark (ii) 1 mark		2		2		2
	(c)	(i)	Distance of 2 or more wavelengths used (1) 0.50 – 0.70 [cm] (1)		2		2		2
		(ii)	Measuring $a = 2.9 \pm 0.2,\ \Delta y = 1.0 - 1.3,\ D = 5.2 \pm 0.1$ (note that $\frac{\Delta y}{D} \approx \frac{1}{6}$ or 0.23) (1) Making a calculation using 3 of the 4 e.g. $\lambda = \frac{2.9 \times 1.2}{5.2}$ = 0.67 [cm] (1) Evaluative comment in line with figures e.g. correct order of magnitude but not a very good approximation (1)			3	3	1	3
			Question 7 total	**4**	**4**	**3**	**11**	**1**	**7**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*		Bending toward the normal in the glass (not along normal) (1) Light comes out approximately parallel to original (by eye) (1)	2			2		2
	(b)	(i)	See graph on next page Most y error bars correct (1) Most x error bars correct (1) All error bars correct (1) Drawing maximum and minimum lines (1)		4		4	4	4
		(ii)	Method for calculating gradient (accept inverse if used correctly) (1) At least 2 gradients correct (0.695, 0.648, 0.606) (1) Refractive index = $\frac{1}{\text{gradient}}$ used or implied (1) n = 1.6 ± 0.1 or 1.56 ± 0.12 needs to be with consistent sig figs allow a max of 2 sig figs for the uncertainty (1) **accept** 0.08 - 0.12 for the uncertainty			4	4	4	4
			Question 8 total	**2**	**4**	**4**	**10**	**8**	**10**



Question				Marking details		Marks available				
					AO1	AO2	AO3	Total	Maths	Prac
9				**Multimode points** 1 – Multiple paths/angles (of propagation) or in diagram 2 – Paths of varying lengths take different times / longer zigzag or in diagram 3 – (Individual) pulses spread out / blurring / smearing / dispersion 4 – Pulses can overlap / not in the same sequence 5 – (Leads to) data loss / pulses unreadable **Monomode points** 1 – Only one path or in diagram 2 – No or minimal dispersion 3 – Cores are very thin or a few wavelengths thick or multimode thicker i.e. by implication 4 – Advantage is greater bandwidth/pulse frequency/greater distance [without data loss] **5-6 marks** 7-9 points made *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** 4-6 points made *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** 1-3 points made *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.*	6			6		
				Question 9 total	**6**	**0**	**0**	**6**	**0**	**0**

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
10	*(a)*	(i)	Converting peak to rms (1) Answer = 3.9 [A] (1)	1	1		2	1	
		(ii)	Use of $P = I^2 R$ (1) Answer = 64 [Ω] (1)	1	1		2	1	
	(b)		Use of $X_C = \frac{1}{\omega C}$ to explain frequency variation (1) Realisation that X_C is large at low freq or low at high freq (1) Hence 68 Ω at high freq (1) Infinite/high at zero freq/low freq (1) Helen is wrong on both counts (1)			5	5	2	
	(c)	(i)	All pd across R at resonance or reactances of capacitor and inductor cancel (accept $Z = R$ at resonance) (1) $I = \frac{12}{18}$ or 667 m[A] or 0.67[A] etc. (1)	2			2	1	
		(ii)	Use of valid equation e.g. $\omega^2 = \frac{1}{LC}$ (1) $f = \sqrt{\frac{1}{4\pi^2 \times 0.0052 \times 13.5 \times 10^{-6}}}$ or 600.7 [Hz] (1)	1	1		2	1	
		(iii)	X_L or X_C calculated correctly (29.4 or 13.1) (1) Calculation of $Z = \sqrt{(X_L - X_C)^2 + R^2}$ (= 24.3 Ω) (1) Use of $I = \frac{V}{Z}$ (1) Answer = 0.494 [A] (1)	1	1 1 1		4	1	
		(iv)	X_L decreases by 1.5 or X_C increases by 1.5 (accept 2.25) (1) X_L and X_C swap values from part (iii) (1) $\sqrt{(X_L - X_C)^2 + R^2}$ or $(X_L - X_C)^2$ is unaffected (1)		3		3	3	
			Question 10 total	**6**	**9**	**5**	**20**	**10**	**0**

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
11	*(a)*		Electrons accelerated through a pd (in a vacuum) (1) Collide with target (or anode) / decelerated by target (or nucleus) (1)	2			2		
	(b)	(i)	$\frac{I}{I_0}=\frac{1}{2}$ or $I=I_0e^{-\mu x}$ (1) $2=\frac{e^{\mu x}}{\frac{1}{2}}=e^{-\mu x}$ or $\frac{1}{2}=e^{-\mu x}$ (1) $\ln 2=\mu x$ (1) If negative sign lost for no reason deduct 1 mark	1	1 1		3	3	
		(ii)	$\mu=\frac{\ln 2}{1.5}$ so μ = 0.46(2) or 46.2 (1) $\ln(\frac{100}{40})$ = 0.46 x **ecf** (1) x = 2 (.0) cm **with units** (1) **Alternative:** 0.5 = $e^{-\mu x\ 1.5}$ and 0.4 = $e^{-\mu x}$ (1) $\mu=\frac{\ln 0.5}{1.5}$ and $\mu=\frac{\ln 0.4}{x}$ (1) $x=1.5\text{x}\frac{\ln 0.4}{\ln 0.5}$ x = 2(.0) cm **with units** (1) Answer of 1.1 award 2 marks If orders of magnitude incorrect award 1 mark maximum $\ln 0.4=-\mu x$ (1)		3		3	3	
		(iii)	X-rays absorbed by skull / bone (1) MRI / PET (1) High quality images of *soft tissue* (1) or opposite statement i.e. X-rays poor soft tissue contrast	1		1 1	3		
	(c)		Alternating voltage or current applied (1) Crystal vibrates / resonates (1) don't accept just expands and contracts	2			2		

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(d)	(i)	1.71×10^6 1.34×10^6 7.78×10^6 Any 1 correct (1) All three correct (2)		2		2	2	
		(ii)	Must select bone as by far the largest (1) Bone and fat as difference biggest (1) Value calculated as 0.5 (1)		1	1 1	3	1	
	(e)		1.5 T **with units** (1) Patients with any metal in their bodies / pacemakers (1) (accept claustrophobic/young children need general anaesthetic)		1	1	2	1	
			Question 11 total	**6**	**9**	**5**	**20**	**10**	**0**

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
12	*(a)*	(i)	Using 44cos7° as horizontal component of velocity (1) Range calculated correctly = 17.9 [m] (1) Conclusion – ball in play (1)			3	3	2	
		(ii)	Use of $F = \frac{mv-mu}{t}$ (1) $F = \frac{0.056 \times 44}{0.006}$ = 411 [N] (1)	1	1		2	1	
	(b)	(i)	Relative velocity <u>after</u> a collision = (1) <u>0.74</u> × relative velocity <u>before</u> a collision (1) **Alternative:** The ratio of the rebound speed (1) to the impact speed is 0.74 (1)	2			2		
		(ii)	Use of $e = \sqrt{\frac{h}{H}}$ or e used with speed/velocity (1) Height after first bounce = 1.07 [m] (1) Height after second bounce = 0.58 [m] **ecf** on height of first bounce (1)	1	1 1		3	2	
	(c)	(i)	Drag opposing motion and weight shown (1) Lift (Magnus force) shown at 90° to motion (up + left) (1) Lift keeps ball in air longer/gives greater height (1) Lift or drag vary/decrease during flight as speed/spin changes (1)	1	1	1 1	4		
		(ii)	Angular velocity = 367 rad s^{-1} (1) Moment of inertia = 4.6×10^{-5} kg m^2 (1) Total KE = linear + rotational (1) Total KE = 10.60 [J] **ecf** on rotational KE (1)	1	1 1 1		4	3	
		(iii)	$A = 3.8 \times 10^{-3}$ m^2 or $\pi \times (3.5 \times 10^{-2})^2$ (1) F = 0.33 [N] (1)		2		2	2	
			Question 12 total	**6**	**9**	**5**	**20**	**10**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
13	*(a)*	(i)		Use of Wien' law or correct substitution [$\lambda = \frac{0.0029}{288}$] (1) λ = 10.1 μ[m] and confirmation statement (1)			2	2	1	
		(ii)		**Any 3 ×(1) from:** • All gases absorb in IR region (or between 1 μm at 20 μm) • Methane absorbs strongly at 3 μm and 8 μm / has two peaks • CO_2 - Isolated peaks at 2 / 2.5 / 4 and 15 μm • CO_2 - Complete 'blockout' between 5 and 8 μm • H_2O - Numerous peaks between 1 and 10 μm **General comparison with no numerical data award max of 1 mark**			3	3		
		(iii)		**Any 2 ×(1) from:** CO_2 – Burning fossil fuels or deforestation (answer must imply increase as consequence of human activity e.g. more cars etc) CH_4 – Increased agriculture or melting permafrost H_2O – Melting ice caps (or global warming – more evaporation)	2			2		
	(b)	(i)		Correct attempt (without efficiency) at $mg\Delta h$ = 120 × 10^6 (1) Correct use of efficiency e.g. $m = \frac{120 \times 10^6}{0.85 \times 9.81 \times 420}$ (1) m = 3.4 × 10^4 [kg s^{-1}] (1)	1	1 1		3	3	
		(ii)		$t = \frac{E}{P}$ i.e. $\frac{240 \times 10^9}{365 \times 120 \times 10^6}$ or t = 2 000 hrs /yr seen (1) t = 5.5 hrs per day (1)	1	1		2	1	
		(iii)		Limited by amount of water available in upper lake / time taken to pump water up	1			1		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(c)	(i)		$\frac{Q}{t}$ = 1.6 × (16.12 – 4) × 8 + 154 (1) $\frac{Q}{t}$ = 309.14 [W] (1)		2		2	2	
		(ii)	I	$154 = \frac{(0.8 \text{ x } 4 \text{ x } \Delta\theta)}{6 \text{ x } 10^{-3}}$ (1) $\Delta\theta$ = 0.29 [°C] seen (1)		2		2	2	
			II	Inside air/glass boundary temp calculated to be = 16.15 °C **or** outside glass/air boundary temp to be 15.85 °C **or** $\Delta\theta$ for air = 3.85 °C (1) Correct use of thermal conduction equation to show thickness of air = 2.6 [mm] e.g. $154 = \frac{(4 \text{ x } 0.026 \text{ x } (20 - 16.5))}{x}$ (1) **Alternative:** $\Delta\theta$ across total air layers = (20 – 8 – 0.3) °C [= 7.7 °C] (1) Correct use of thermal conduction equation e.g. $154 = \frac{(4 \text{ x } 0.026 \text{ x } 7.7)}{2x}$ (1)		2		2	1	
			III	Rate of heat loss would increase due to removal of insulating (air) layer(s) (or $\Delta\theta$ for glass greater without air layers / greater temperature gradient). Accept appropriate calculation.	1			1		
				Question 13 total	**6**	**9**	**5**	**20**	**10**	**0**

A LEVEL COMPONENT 3: LIGHT, NUCLEI AND OPTIONS
SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

	Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
Section A	1	4	4	0	8	0	0
	2	3	12	5	20	9	0
	3	1	5	3	9	4	0
	4	3	5	3	11	9	0
	5	2	7	7	16	12	10
	6	5	4	0	9	7	0
	7	4	4	3	11	1	7
	8	2	4	4	10	8	10
	9	6	0	0	6	0	0
	TOTAL	**30**	**45**	**25**	**100**	**50**	**27**
Section B	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	**6**	**9**	**5**	**20**	**10**	**0**
	Overall TOTAL	**36**	**54**	**30**	**120**	**60**	**27**