GCE A LEVEL MARKING SCHEME

SUMMER 2023

A LEVEL
PHYSICS – UNIT 4
1420U40-1

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INTRODUCTION

This marking scheme was used by WJEC for the 2023 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.

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GCE A LEVEL PHYSICS

UNIT 4 – FIELDS AND OPTIONS

SUMMER 2023 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.

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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 dou

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SECTION A

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	(a)		(i) Correct answer only = 14 p[F] (1) (ii) Correct equation used i.e. $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ (1) Correct answer = 1.14 p[F] (1) (iii) Correct use of $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$ for 2 pF and 4 pF (1) Adding 8 (pF) (1) Final answer = 9.33 p[F] (1) (allow 1 mark for 3.43 pF **or** $\frac{24}{7}$) Deduct 1 mark max if answers expressed as fractions	1 1 1	1 1 1		6	5	
	(b)		Area of 0.42 × 0.42 seen [0.1764] (1) Rearrangement i.e. $d = \frac{\varepsilon_0 A}{C}$ (1) Separation = 5.78 × 10^{-7} [m] **OR** C = 15.6 [nF] ish (coming from using d = 1 mm) (1) Unrealistic - too thin **OR** capacitance too small - not achievable (1) **ecf**			4	4	3	
	(c)		Increases	1			1		
			Question 1 total	**4**	**3**	**4**	**11**	**8**	**0**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	(a)		Correct expression for centripetal force used (accept acceleration if equated to gravitational field strength) (1) accept with ω^2 Equating to gravitational expression i.e. $\frac{mv^2}{r} = \frac{GMm}{r^2}$ **or** $\frac{v^2}{r} = \frac{Gm}{r^2}$ (1) Enough algebra shown. Minimum is this: $\frac{mv^2}{r} = \frac{GMm}{r^2}$ $v^2 = \frac{GM}{r}$ (1) **Alternative 1:** $m\omega^2 r$ **or** $\omega^2 r$ quoted (1) $m\omega^2 r = \frac{GMm}{r^2}$ **and** $v = \omega r$ **or** acceleration equivalent (1) Minimum algebra leading to answer (1) **Alternative 2:** Using M_1 or M_2 negligible in $T = 2\pi\sqrt{\frac{d^3}{G(M_1+M_2)}}$ (1) e.g. $2\pi\sqrt{\frac{d^3}{G(M_1+M_2)}} \approx 2\pi\sqrt{\frac{d^3}{GM}}$ Quoting $v = \omega r$ and $\omega = \frac{2\pi}{T}$ (1) or equivalent All algebra ok leading to the answer (1)	3			3	2	
	(b)		Measured velocities are too large (1) Accept velocity increasing on graph Link to the equation e.g. velocity increases with mass (1) Dark matter accounts for increased mass **or** the mass must be bigger (1)	3			3		

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(c)		Rearrangement for M i.e. $M = \frac{v^2 r}{G}$ (1) Conversion of distance i.e. 20 000 × 9.46 × 10^{15} = (1.892 ×10^{20}) (1) Answer = 7.09 × 10^{39} k[g] (1)		3		3	3	
	(d)		Speed estimated as 110 - 130 [km s^{-1}] (1) Use of the Doppler equation **ecf** (1) Answer = 7.7 × 10^{-5} to 9.1 × 10^{-5} [m] (1)	1	1 1		3	2	
	(e)		Use of Hubble equation $v = H_0 d$ (1) Answer = 5.0 × 10^{22} to 5.9 × 10^{22} [m] (**ecf** on v) (1)	1	1		2	2	
			Question 2 total	**8**	**6**	**0**	**14**	**9**	**0**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	(a)	(i)	Use of Newton's gravitational force equation (1) Answer = 1.266×10^{20} [N] or final substitution seen i.e. $\frac{6.67\times10^{-11}\times(6.2\times10^{25})^2}{(4.5\times10^{10})^2}$ (1)	1	1		2	2	
		(ii)	Each planet experiences two [equal and attractive] forces [from each of the other two] (1) N.B. same forces can be implied Resultant must be along centre lines (from symmetry) (1) $\times$ cos 30° seen (1) $2 \times 1.3 \times 10^{20} \times$ cos 30° (seen) **OR** 2.25 OR 2.19 (seen) (1)		4		4	2	
	(b)	(i)	30° angle seen or explained (1) $\cos 30° = \frac{2.25\times10^{10}}{d}$ or equivalent seen (1)		2		2	2	
		(ii)	Mass is [far] greater (1) can be implied if substituted Factor of 10^5 **or** calculation 2.5×10^{25} N so Rhodri is correct (1) No penalty for incorrect distance as long as force is much bigger			2	2	1	
	(c)	(i)	Potential equation used i.e. $[-]\frac{GM}{r}$ (1) Potential due to star = [-]1.05×10^{10} (1) Other potentials negligible (either stated or full calculation) (1)	1	1 1		3	2	

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	PE of system / planet = [-]1 $\times$ 10^{10} $\times$ 6.2 $\times$ 10^{25} = (6.2 $\times$ 10^{35} J) (1) **Alternative for the 1st mark:** Obtaining escape velocity: 140 000 [m s^{-1}] **and** velocity of 7 $\times$ 10^{35} [J] i.e. 150 000 [m s^{-1}] **Another alternative for the 1st mark:** $\frac{7 \times 10^{35}}{6.2 \times 10^{25}}$ = 1.13 $\times$ 10^{10} [J kg^{-1}] However, conservation of momentum / other energy transfers must be considered (1) minimum required is {elastic / inelastic} collision Conclusion consistent with their argument but must be based on a value of PE **or** potential **or** escape velocity (1)			3	3	1	
	(d)		Star is at centre of mass **or** resultant force will be zero (1) Hence, no wobble / orbit etc. **or** stationary (1) No Doppler shift and not detectable so Delyth is correct (1)			3	3		
			Question 3 total	**2**	**9**	**8**	**19**	**10**	**0**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	(a)	(i)	Force down on magnet or the balance (due to positive) (1) N3 **or** equal and opposite mentioned (1)		2		2		2
		(ii)	Right side is N (on diagram or stated) (1) [F] LHR (1)	1	1		2		2
		(iii)	Forces are horizontal **OR** forces are equal and opposite Accept forces are outwards and inwards NOT wire not perpendicular to field		1		1		1
	(b)	(i)	12.0 [$\times 10^{-3}$ N] (1) 3.65 [g] (1) 2 points plotted correctly within half square (2) **ecf** on 12.0 [$\times 10^{-3}$ N] 1 point plotted correctly within half square (1) 0 points plotted correctly within half square (0)		4		4	4	4
		(ii)	Ignored the last 2 points (1) Since [partly] outside uniform field (1) **Award the first 2 marks for:** Has only used the points in the uniform field Line good [with same number above and below] (1)			3	3		3

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(iii)	Conversion of cm (1) Correct method for gradient (1) Gradient = 0.583 (1) Gradient equated to BI (1) Field = 0.115 T **unit mark** (accept 0.11 to 0.12 to 2sf or 3sf) (1) Note 1.1 T to 1.2 T obtains 4 marks **Alternative:** Obtaining point on line – don't award for point more than ½ square from line, don't award if point has a length for XY less than 3 cm (1) Converting cm to m (1) Rearranging equation i.e. $B = \frac{F}{Il}$ (1) Substituting (1) Field = 0.115 T **unit mark** (accept 0.11 to 0.12 to 2sf or 3sf) (1) Note 1.1 T to 1.2 T obtains 4 marks			5	5	5	5
			Question 4 total	**1**	**8**	**8**	**17**	**9**	**17**

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	(a)		Flux in heated object varies (1) Faraday's law referred to or implied (1) Current flows, [providing heating] (1) High frequency increases rate of change of flux (1)	1	1 1 1		4		
	(b)		**Indicative content:** **Diagram** Diagram of Hall probe / chip / wafer B-field shown Current flow shown perpendicular Force direction shown correctly Voltmeter correctly connected Slice orientated / adjusted in field **Explanation and measuring B** Electrons / charge carriers experience force Given by FLHR They move to one side Setting up Hall voltage or field Equilibrium is reached between magnetic and electric forces Hall voltage is proportional to B **OR** equation quoted Can be calibrated to give B directly **OR** hence B calculated **5-6 marks** Comprehensive diagram and explanation and measuring B. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.*	6			6		6

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
			3-4 marks Comprehensive diagram **or** explanation and measuring B **or** limited attempt at both. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Limited attempt at either the diagram **or** explanation and measuring B. *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 5 total	**7**	**3**	**0**	**10**	**0**	**6**

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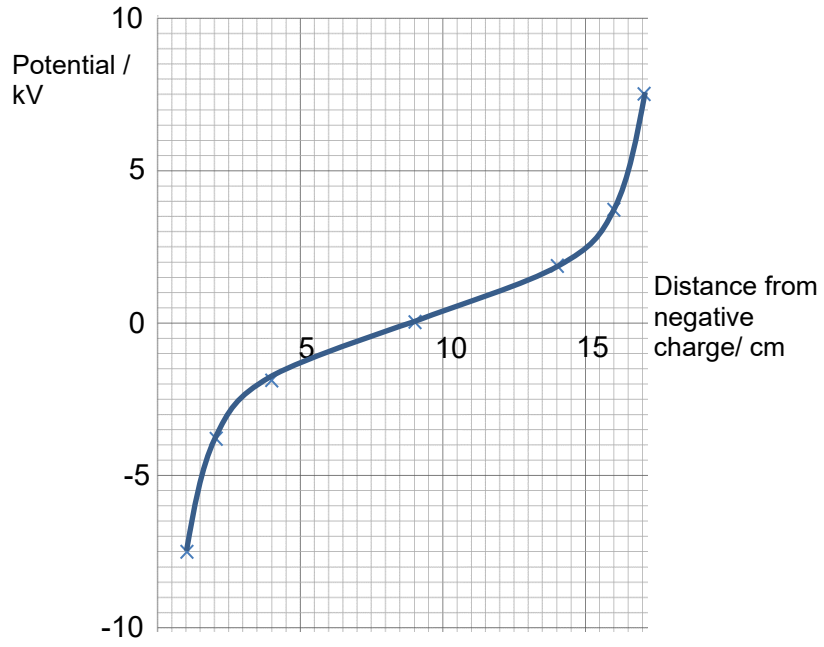
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	(a)	(i)	Use of potential equation i.e. $V = k\frac{q}{r}$ (1) -8100 [V] **OR** 426-506 [V] seen or implied (1) Both added / subtracted to give correct answer i.e. 7600 [V] (1)	1	1 1		3	2	
		(ii)	 General shape (1) +7500 @ 16 - 18 cm (1) 0 @ 8 - 10 cm (1) N.B. Ignore fields inside charges should be 0		3		3	2	

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(b)		Use of field equation i.e. $E = k\frac{q}{r^2}$ (1) 810 000 **and** negligible **OR** 2 800 **OR** 2 500 seen (1) Both fields to left at this point **OR** lines into -ve and out of +ve (1)	1	1 1		3	2	
			Question 6 total	**2**	**7**	**0**	**9**	**6**	**0**

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SECTION B

Option A – Alternating Currents

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)	(i)	Choosing correct equation (ωBAN) (1) Correct answer = 421 [V] (1)	1	1		2	1	
		(ii)	Choosing correct equation ($BAN\cos\omega t$) (1) Answer = 0 **or** close to 0 (1) Award 1 mark for answer of 1.34	1	1		2	1	
		(iii)	421 [V] **ecf** from (i)		1		1	1	
		(iv)	Period is 20 ms so 5 ms quarter cycle (1) ωt is 90° or equivalent (1) Expect max emf and zero flux (1) **Alternative:** ωt is 90° or equivalent (1) cos 90° = 0 and sin 90° = 1 (1) Expect max emf and zero flux (1)			3	3		
	(b)	(i)	Choosing correct equation i.e. $\frac{1}{2\pi}\sqrt{\frac{1}{LC}}$ (1) Answer = 103 k[Hz] (1)	1	1		2	1	

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	Both reactances cancel **or** total impedance is R **or** equivalent (1) $I = \frac{V}{Z} = \frac{V}{R}$ (or equivalent) (1)	1	1		2		
		(iii)	Any correct reactance (X_C = 10 105, X_L = 10 556) (1) Impedance correctly obtained 485 [Ω] (1) Substitution into $I = \frac{V}{Z}$ **ecf** on Z (1) Correct answer = 5.15 m[A] **ecf** on Z (1)	1	1 1 1		4	4	
		(iv)	Large decrease in current or $\frac{\Delta I}{\Delta f}$ (1) For small increase in frequency or is large (1)	1	1		2	2	
		(v)	Realising ω also changes **OR** using / deriving $\frac{1}{R}\sqrt{\frac{L}{C}}$ (1) Correctly linking valid equation to obtain yes **OR** simply yes e.g.in $\frac{\omega L}{R}$ ω decreases so yes (1)			2	2		
			Question 7 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
8	(a)	(i)	Heater to produce / boil off [free] electrons / thermionic emission (1) accept heater gives energy to electrons Avoid collisions [on way to target] (1)	2			2		
		(ii)	$\frac{100 \times 10^{-3}}{1.6 \times 10^{-19}}$ (1) = 6.25×10^{17} or 6.3×10^{17} with no units (1) accept electrons per second		2		2	2	
		(iii)	Application of conservation of energy: ½ $mv^2 = eV$ (1) Rearrangement: $v^2 = \frac{2eV}{m}$ (1) v = 8.3 or 8.4 $\times 10^7$ [m s^{-1}] (1)		1 1 1		3	3	
		(iv)	Use of $eV = \frac{hc}{\lambda_{min}}$ (1) Rearrangement: $\lambda_{min} = \frac{hc}{20000e}$ (1) λ_{min} = 6.2×10^{-11} [m] (1)	1	1 1		3	3	
	(b)	(i)	Alternating voltage used (1) accept alternating current used Causes piezoelectric crystal to vibrate (1) Ultrasound reflected **and** Doppler shift detected (1)	3			3		

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	$v = \frac{\Delta f c}{2 f_0 \cos 37}$ (1) Rearrangement and substitution v = 0.11[3] [m s^{-1}] (1)		2		2	2	
	(c)		**Any 5 × (1) from:** • MRI and ultrasound and CT – good images [only] (1) • X-ray – poor image / soft tissue contrast (1) • Radioactive tracer best **or** gives more information (1) • Tracer goes to hyperactive [parts of] thyroid (1) • Imaged using gamma camera (1) • Any further detail e.g. Initial diagnosis using blood (check levels of thyroid hormones) Iodine gives added contrast (for CT scan) Tracer can locate problem areas Tracer can be used to "kill" overactive thyroid / thyroid cancer			5	5		
			Question 8 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
9	(a)		Substitution into principle of moments i.e. $F\cos 8 \times 0.07 = (12.9 \times 0.19) + (74 \times 0.39)$ (1) F = 451 [N] (1) If $F\sin 7 \times 0.07$ **or** $F \times 0.07$ used correctly – award 1 mark	1	1		2	1	
	(b)		Recall $Ft = mv - mu$ or equivalent (1) Initial momentum = 907 N s and impulse = +/- 968 N s (1) Final velocity = - 0.52 [m s^{-1}] (need sign) (1) **Alternative:** Recall $F = ma$ (1) Acceleration = 47 m s^{-2} and use of $v = u + at$ (1) Final velocity = - 0.52 [m s^{-1}] (need sign) (1)	1	1 1		3	2	
	(c)	(i)	Recall drag force $F = \frac{1}{2}\rho v^2 A C_D$ (1) Density and drag coefficient are constant and increasing velocity increases the magnitude of F (1) accept density can be variable with altitude [Effective / cross-sectional / surface] area of A is less than B so drag [force] is reduced (1)	1	1 1		3		
		(ii)	Rotational kinetic energy $= \frac{1}{2}I\omega^2$ (1) ω is the number of revolutions $\times 2\pi$ (or ω is proportional to revs per second) so will not double (1)			2	2		

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(iii)	Using equation for coefficient of restitution $e = \sqrt{\frac{h}{H}}$ (1) Coefficient of restitution = 0.39 (1) The same value for both surfaces (1) If no square root taken award a max of 2 marks			3	3	2	
		(iv)	Recall $T = I\alpha$; (1) Torque = 6.2 [N m] (1) **Alternative:** Recall: torque = $\frac{\text{change in angular momentum}}{\text{time}}$ (1) Torque = 6.2 [N m] (1)	1	1		2		
		(v)	Either of the vertical components calculated correctly $12\sin 32^\circ = 6.4$ [m s^{-1}] or $12\cos 32^\circ = 10.2$ [m s^{-1}] (1) Substitute values into $v^2 = u^2 + 2ax$ **or** $x = ut + \frac{1}{2}at^2$ (1) Time to reach height = 0.65 [s] **or** height $x = \frac{6.4^2}{2 \times 9.81}$ **or** $t = \frac{6.2}{10\cos 32}$ [= 0.61 s] (1) [from level of the thrower] Maximum height reached by the ball = 2.1 [m] [from level of the thrower] **or** height reached = 2.05 [m] (1) Overall, height = $\frac{2.1}{2.05}$ + 2.0 [= 4.1 m] so jumper will catch the ball (1)	1 1	1 1 1		5	5	
			Question 9 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
10	(a)	(i)	Use of $\lambda_{\max} = \frac{W}{T}$ (1) $\lambda_{\max} = \frac{2.9\times10^{-3}}{288} = 1 \times 10^{-5}$ [m] (1)	1	1		2	1	
		(ii)	Gases allow shorter λ solar radiation to pass [where it is absorbed by Earth] (1) Gases absorb [some of the] longer λ / infra-red / 10 μm radiation [emitted by Earth] (1) Gases emit radiation {in all directions / back to Earth} (1)	3			3		
	(b)	(i)	$\text{mass}_{\text{ice}} = 920 \times 3.0 \times 10^{11} = 2.76 \times 10^{14}$ **and** $V_{\text{water}} = \frac{2.76\times10^{14}}{1000} = 2.76 \times 10^{11}$ (1) $2.76 \times 10^{11} \times 20 = 5.52 \times 10^{12}$ [m^3] (1) **Alternatively for 1st marking point:** $V_{\text{water}} = \frac{3.0\times10^{11}}{\frac{1000}{920}} = 2.76 \times 10^{11}$		2		2	2	
		(ii)	Darker areas will absorb more radiation / heat [than lighter areas] (1) Resulting in an increased temperature and rate of ice melting (1)		2		2		
	(c)	(i)	Hydroelectric relatively constant whereas PV increasing (1) No new hydroelectric sites available or commercially viable / advances in efficiency of PV cells / availability of [domestic] PV cells (1)			2	2		

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	Use of $P_{\max} = IV$ [at / close to 'knee'] (1) $P_{\max}$ = 130 ± 5 [W] (1) $P_{\text{in}} = IA = 600 \times 1.2 = 720$ [W] (1) $\frac{130\ \mathbf{ecf}}{720} = 0.18$ or 18 [%] (1)	1	1 1 1		4	3	
	(d)	(i)	Use of $\frac{\Delta Q}{\Delta t} = KA\frac{\Delta\theta}{\Delta x}$ (1) Answer seen 4900 (1)	1	1		2	1	
		(ii)	Attempt at calculating $\Delta\theta_{\text{for 1 layer}}$ (1) $\Delta\theta_{\text{carpet}} = \frac{1225\ \mathbf{ecf} \times 10 \times 10^{-3}}{0.045 \times 60} = 4.5$ and $\Delta\theta_{\text{underlay}} = 5.8$ and $\Delta\theta_{\text{concrete}} = 3.5$ (1) Add to give 13.8≈14 so claim is reasonable (1) Also accept use of $\frac{5\,000}{4}$ = 1250 W **Alternative:** Attempt at calculating $\frac{\Delta x}{KA}$ for 1 layer (1) $R_{\text{T(carpet)}} = \frac{\Delta x}{KA} = \frac{10 \times 10^{-3}}{0.045 \times 60} = 0.0037$ and $R_{\text{T(underlay)}} = 0.0048$ and $R_{\text{T(concrete)}} = 0.0029$ (1) Add to give 0.0114 and $\frac{\Delta Q}{\Delta t} = \frac{\Delta\theta}{\frac{\Delta x}{KA}} = 1228 \approx 1225$ so claim is reasonable (1)			3	3	3	

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Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
			Alternative: Attempt at using R values (1) $R_{\text{concrete}} = \frac{0.12}{0.7}$ = 0.17 $R_{\text{underlay}} = \frac{0.01}{0.035}$ = 0.29 $R_{\text{carpet}} = \frac{0.01}{0.045}$ = 0.22 Total R value = 0.68 [K m^2 W^{-1}] (1) So $R_{\text{T}} = \frac{\Delta T}{\frac{\phi}{A}} \rightarrow \phi = \frac{\Delta TA}{R_{\text{T}}}$ $\phi = \frac{14 \text{ x } 60}{0.68}$ = 1235 [W] so claim is reasonable (1)						
			Question 10 total	**6**	**9**	**5**	**20**	**10**	**0**

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GCE A LEVEL UNIT 4 – FIELDS AND OPTIONS

SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	4	3	4	11	8	0
2	8	6	0	14	9	0
3	2	9	8	19	10	0
4	1	8	8	17	9	17
5	7	3	0	10	0	6
6	2	7	0	9	6	0
7	6	9	5	20	10	0
8	6	9	5	20	10	0
9	6	9	5	20	10	0
10	6	9	5	20	10	0
TOTAL	**30**	**45**	**25**	**100**	**52**	**23**

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