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GCE A LEVEL MARKING SCHEME

AUTUMN 2021

A LEVEL
PHYSICS – COMPONENT 3
A420U30-1

INTRODUCTION

This marking scheme was used by WJEC for the 2021 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 COMPONENT 3 – LIGHT, NUCLEI AND OPTIONS

AUTUMN 2021 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)	Max intensity at 0, 180, 360 (2 mentioned) (1) Zero/very low at 90 (& 270) (1) Changes gradually between (1)	3			3		3
		(ii)	Minimum rather than zero (1) Because unpolarised cannot be blocked **OR** because unpolarised has random polarisation (1)		2		2		2
	(b)		Displacement is a vector implied or stated (1) 2 displacements at 90° cannot cancel (also implies 1st mark since direction is implied) (1) Fringes will not be seen **OR** only diffraction pattern seen (1)		3		3		3
	(c)	(i)	Substitution into diffraction grating equation i.e. $2 \times 633 \times 10^{-9} = d \sin 47°$ (1) $d = 1.73 \times 10^{-6}$ m (1) Answer = 578 lines / mm	1	1 1		3	2	3
		(ii)	Substitution into equation i.e. $3\lambda = 1.73 \times 10^{-6}$ **ecf** $\times \sin 47°$ **OR** $2\lambda_1 = 3\lambda_2$ (1) Answer = 422 n[m] (1)	1	1		2	1	2
			Question 1 total	**5**	**8**	**0**	**13**	**3**	**13**

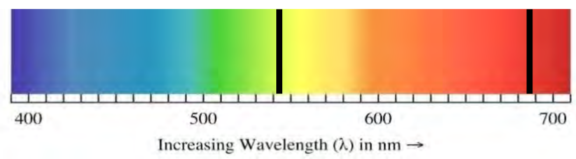
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*		Antinode at open end, node at closed (1) 3rd harmonic correct (1) 5th harmonic correct (1)	3			3	2	
	(b)	(i)	$L=\frac{\lambda}{4}$ or $4L=\lambda$ (1) v or $c = f\lambda$ incorporated (1)	1	1		2	1	2
		(ii)	16.3 (1) 312 or 313 (1)		2		2	2	2
		(iii)	$\frac{0.3}{15.3}$ is 2 % **OR** 1st principles method i.e. using 16.0 or 16.6 (1) 2 % × 312 seen or implied by ± 6.1 (1)		2		2	2	2
		(iv)	[All] values are outside tolerance or wtte (1) Values getting smaller **OR** all too small – pattern (1)			2	2		2
		(v)	Substitution into equation (1) Answer = 342 [m s^{-1}] (1)	1	1		2	2	2
		(vi)	**Any 2 ×(1) from:** - Values agree with 343 (some clear statement) - 343 lies in range for each measured value (implies first mark) - Calculating mean of 343			2	2		2
			Question 2 total	**5**	**6**	**4**	**15**	**9**	**12**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*		Substitution into Snell's law i.e. $1.00 \times \sin 21.1° = 1.58 \times \sin \theta$ (1) $\theta = 13.2°$ (1) $\phi = 90° - \theta$ **ecf** = 76.8° (1)	1	1 1		3	2	
	(b)		Snell's applied to critical angle **OR** 76.8° **(ecf)** (1) Critical angle = 78.8° **OR** refracted angle = 82.9° (accept simply sin comes out as less than 1) (1) Conclusion consistent with correct/incorrect calculation (1)			3	3	3	
	(c)	(i)	Substitution: $v = \frac{3 \text{ x } 10^8}{1.58}$ [$=1.90 \times 10^8$] (1) Valid distance divided by valid speed e.g. 18.43 μs, 18.78 μs, 0.345 μs (1) **ecf** on speed of light (11.67 μs etc.) Zig-zag distance = $\frac{3\,500}{\cos 11}$= 3 565.5 [m] (1) Final answer = 0.345 μ[s] (range depending on rounding) (1) (0.22 μ[s] if $3 \text{x} 10^8$ used for 3 marks) **beware all steps in one**, e.g. $\frac{1.58 \times 3.5 \times 10^3}{3.0 \times 10^8}\left[\frac{1-\cos 11°}{\cos 11°}\right]$s	1	1 1 1		4	3	
		(ii)	$f = \frac{1}{T}$ **OR** $\frac{1}{2T}$ (1) = 2.9 M[Hz] **OR** 1.45 M[Hz] (**ecf** e.g. 4.6 MHz for 3×10^8) (1) (accept anything in between)		2		2	2	
			Question 3 total	**2**	**7**	**3**	**12**	**10**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*	(i)	**Greg right + 1 reason award 1 mark only** **Greg right + 2 reasons award 2 marks** Reasons are: - both magnetic forces or same type - always equal and opposite - act on different objects Accept action & reaction			2	2		2
		(ii)	[F]LHR (& field to right)	1			1		1
	(b)	(i)	6.8 (1) 26.9 (1)		2		2	2	2
		(ii)	All 6 points plotted to within < ½ small square tolerance (**ecf** on table) (2) 5 points plotted to within < ½ small square tolerance (1) 4 or less points plotted to within < ½ small square tolerance (0) Straight line of best fit (1)		3		3	3	3
		(iii)	Straight line **ecf** (1) Through origin **ecf** (1) All points close to line **ecf** (1)			3	3	2	3
		(iv)	Gradient = 8.40 **OR** point on the line chosen with I > 3 A (1) Gradient is Bl **OR** substitution into equation (1) B = 0.168 [T] (1) 2 or 3 sf chosen (1)			4	4	3	4

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(v)	Forces are horizontal **OR** equal & opposite **OR** wires might not be vertical (1) Conclusion consistent with argument (1)			2	2		2
		(vi)	Field not uniform **OR** weaker away from centre **OR** Earth's magnetic field mentioned **OR** wire not quite 90° (1) Value might be a little low **OR** mean value measured **OR** Earth's field small / depends on orientation **OR** forces [very] slightly too low (1)			2	2		2
			Question 4 total	**1**	**5**	**13**	**19**	**10**	**19**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*		**Indicative content:** **Appearance:** A1 emission - coloured lines A2 absorption - black lines on continuous A3 sharp lines **Production** P1 emission - excited or hot gas P2 absorption - continuous spectrum passing through gas P3 diffraction grating/prism/spectrometer for observing **Atomic processes** AP1 [sharp/definite] energy levels AP2 absorption - electrons go up AP3 electrons later drop but emission in all directions AP4 emission - electrons go down AP4 photon energy equal to energy gap **5-6 marks** Comprehensive description of the appearance, production and atomic processes. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Comprehensive description of 2 out of 3 of appearance, production and atomic processes OR limited description of all 3 areas. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.*	6			6		

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
			1-2 marks Comprehensive description of 1 out 3 of appearance, production and atomic processes OR limited description of 2 areas. *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)		2 energy differences worked out e.g. 4.1, 2.29, 1.81 (1) Multiply by 1.6×10^{-19} i.e. conversion to J (1) One correct wavelength e.g. 303 nm, 543 nm, 687 nm (1)  Correct lines in diagram (1) [At 541-545 nm and 685-689 nm]		4		4	3	
			Question 5 total	**6**	**4**	**0**	**10**	**3**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*		Emission of electrons (1) From [metal] surface (1) When light / UV / em radiation incident (1)	3			3		
	(b)	(i)	$E = hf$ used (1) Division by photon energy (1) Area multiplied by intensity (1) Correct answer = 5.53×10^{16} [s^{-1}] (1)	1	 1 1 1		4	2	
		(ii)	Multiplication by $\frac{0.54}{100}$ and 1.6×10^{-19} (1) Correct answer = 48 μ[A] **ecf** on (i) (1)		2		2	2	
	(c)		Change polarity of supply (1) Increase V until current drops to zero (1) KE is V in eV OR multiply V by e (1)	3			3		3
			Question 6 total	**7**	**5**	**0**	**12**	**4**	**3**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*		BN: 3 + 1 = 4(+ 0 + 0) (1) LN: 0 (+ 0) = (0) -1 + 1 **OR** accept 2 + 1 = 3 -1 + 1 (if electrons are included) (1) Q: 2 + 1 = 2 + 1 (+ 0) **OR** accept 0 = - 1 + 1(+0) (if electrons are included) (1)		3		3		
	(b)		Change of quark flavour	1			1		
	(c)		LHS - RHS = 0.033[089] $\times 10^{-27}$ (1) Correct answer = 2.978 $\times 10^{-12}$ [J] or 18.6 MeV (1)		2		2	2	
	(d)		Strong force reaction (1) Reason given e.g. rearrangements of quarks (1)			2	2		
			Question 7 total	**1**	**5**	**2**	**8**	**2**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*		Induced emf is equal to or proportional to (1) The rate of change of flux [linkage] (1) Induced emf [tends to] opposes the change (1)	3			3		
	(b)	(i)	Emf induced linked to flux change (1) Heating linked to [induced] current (1)		2		2		
		(ii)	emf = $A \times \frac{dB}{dt}$ (1) = 1.03 [V] (1) Current = 11.9 [A] (1)		3		3	3	
	(c)		**Any 2 × (1) relevant points made:** • Not enough information • Not ionising [radiation] • Higher/different photon energy • Intensity too low OR far below Sun intensity • More research required • Intensity drops off with distance • Microwaves can be focused Conclusion linked to at least one point (1)			3	3		
			Question 8 total	**3**	**5**	**3**	**11**	**3**	**0**

OPTION A – ALTERNATING CURRENTS

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	*(a)*	(i)	Angle 0 and 180° gives max (1) Angle 90° and 270° gives zero/min (1)	2			2		
		(ii)	Angle 90° and 270° gives max (1) Because max flux cutting/rate of change (1)	2			2		
		(iii)	Obtaining ω (100π or 314) (1) Conversion and substitution into equation (1) Correct answer = 1.72 [V]		3		3	3	
	(b)	(i)	Correct substitution shown **OR** 10 026 [Hz] seen	1			1	1	
		(ii)	X_L and X_C cancel **AND** $\frac{4.5}{85}$		1		1		
		(iii)	Substitution into both reactance equations (1) Correct impedance obtained (1) $I = \frac{4.5}{270}$ or similar seen (1)	1	1 1		3	2	
		(iv)	Peak at approx 10 000 Hz and 50 mA (1) 16.7 mA at 16 kHz plotted (1) General shape including current = 0 when f = 0 (1)		3		3	1	

<table>
<tr><th colspan="3" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td></td><td>(c)</td><td></td><td>Resonance frequency unchanged (1)
Peak current greater OR 0.106 A (1)
which is the same as $\frac{4.5}{42.5}$ (1)
Sharper curve or greater Q factor (as expected) (1)
Extra detail e.g. current at 16 kHz similar OR a value calculated and confirmed and Caitlin correct (1)</td><td></td><td></td><td>5</td><td>5</td><td>3</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Question 9 total</td><td>6</td><td>9</td><td>5</td><td>20</td><td>10</td><td>0</td></tr>
</table>

OPTION B – MEDICAL PHYSICS

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
10	*(a)*	(i)	$E = 1.6 \times 10^{-19} \times 45\,000$ (1) $= 7.2 \times 10^{-15}$ [J] (1)	1	1		2	2	
		(ii)	Rearrangement: $\lambda_{\text{min}} = \frac{hc}{E}$ (1) $\lambda_{\text{min}} = 2.76 \times 10^{-11}$ [m] (1)		2		2	2	
		(iii)	Power = $0.12 \times 45\,000 = 5\,400$ [W] (1) X-rays power = $0.005 \times 5\,400 = 27$ [W] (1)		2		2	2	
	(b)		$Z_1 = 442$ **and** $Z_2 = 1.71 \times 10^6$ (1) $f = 1$ or 0.999 (1)		2		2	2	
	(c)	(i)	Hydrogen nuclei / protons precess about magnetic field (1) Radio waves emitted/absorbed when alignment flips [to opposite] (1) [Accept quantum explanation]	2			2		
		(ii)	$f = 42.6 \times 10^6 \times 1.4 = 59.6 \times 10^6$ (1) $\lambda = \frac{3 \text{ x } 10^8}{59.6 \text{ x } 10^6 \textbf{ecf}}$= 5.0[3 m] (1)		2		2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(d)		Positrons annihilate electrons (1) Produce two gamma rays (1) in opposite directions **or** time delay of detection gives location (1)	3			3		
	(e)		**Any 5 × (1) from:** - Ultrasound can measure the speed of blood flow (Doppler) - Ultrasound effective and not harmful - CT / X-ray ionising - CT / X-ray effective with contrast medium - Radioactive tracers not effective (although PET recently shown to be promising) **OR** CT / X-ray usually ineffective (without contrast medium) - MRI can be used but expensive /cannot be used for patients with metal in their bodies / pacemakers			5	5		
			Question 10 total	**6**	**9**	**5**	**20**	**10**	**0**

OPTION C – THE PHYSICS OF SPORTS

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
11	*(a)*	(i)	Centre of gravity is acting through centre of body and between feet (1) Player A – more stable – feet wider apart (wtte) (1)	2			2		
		(ii)	Speeds after and before mentioned (1) Ratio = 0.8 with correct orientation or equiv. (1)	2			2		
		(iii)	Using equation $e = \sqrt{\frac{h}{H}}$ (1) $e_{\text{wood}} = 0.70$ **and** $e_{\text{mesh}} = 0.63$ **or** ratios $\frac{h}{H}$ calculated (1) **OR** Wood greatest - higher rebound (1) From smaller height (1)	1	1		2	1	
	(b)	(i)	[Type] of spin will cause a lift force on the ball (1) [Other] forces acting on the ball = weight and air resistance (1) Ball will change height or spin too small to have an effect (1)			3	3		

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	Definition of angular acceleration = change in angular velocity/time used (1) Angular acceleration = 24.3 [rad s^{-2}] (1) Moment of inertia = 3.6×10^{-3} [kg m^2] (1) Torque = 0.09 [N m] (1) **Alternative**: Definition of torque = $\frac{\text{change of angular momentum}}{\text{time}}$ used (1) Moment of inertia = 3.6×10^{-3} [kg m^2] (1) Final angular momentum = 0.0263 [N m s] (1) Torque = 0.088 [N m] (1)	1	1 1 1		4	3	
		(iii)	Re-arranging $\omega = \sqrt{\frac{2 \text{ x Rotational KE}}{I}}$ (1) Angular velocity $= \sqrt{\frac{2 \text{ x } 4.4}{3.6 \text{ x } 10^{-3} \textbf{ ecf}}}$ =49.4 [rad s^{-1}] (1) Number of revolutions s^{-1} = 7.9 (1)		3		3	3	
	(c)	(i)	Horizontal component of speed = 8.0 cos30° (1) Time to reach goal = 0.69 [s] (1)		2		2	1	
		(ii)	Vertical height = 1.8 + $ut - \frac{1}{2}gt^2$ (or without 1.8) (1) Vertical height = 2.25 [m] (or gains 0.43 m) –will not reach height (1)			2	2	2	
			Question 11 total	**6**	**9**	**5**	**20**	**10**	**0**

OPTION D – ENERGY AND THE ENVIRONMENT

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
12	*(a)*		Intensity peak would be in the infra-red/at longer wavelength (1) Intensity would be less (1) Certain wavelength bands missing/reduced (due to absorption by atmosphere) (1)	1	1 1		3		
	(b)	(i)	Any object [wholly or partially] immersed in a fluid experiences an upwards force equal to (1) the weight of the fluid displaced by the object (1)	2			2		
		(ii)	Use of $\rho = \frac{M}{V}$ to find mass of saltwater displaced (and mass of block of ice) = 0.102 [kg] (1) Volume of block of ice = 110.9 [cm^3] (1) Volume of ice above surface = 110.9 – 100 = 10.9 [cm^3] (1)	1	1 1		3	2	
		(iii)	Mass of displaced water remains 0.102 [kg] (1) Volume of displaced water = $\frac{0.102}{<1020}$ = >100 [cm^3] hence, Harry is correct (1)			2	2		
	(c)	(i)	Use of $P = \frac{1}{2}\rho A v^3$ to find initial KE s^{-1} = ½ × 1.2 × π × 82^2 × 14^3 [= 34.8 × 10^6 [W]] (1) Final KE s^{-1} = (34.8 – 16) × 10^6 = 18.8 10^6 [W] (1) Manipulation to give v = 11.4 [m s^{-1}] (1)	1	1 1		3	3	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
		(ii)	$\frac{210 \times 10^6}{24}$ = 8.75 M[W] (1) $\frac{8.75}{16} \times 100 = 54.7$ [%] (1) For 2nd marking point accept $\frac{8.75}{34.8\ (\text{ecf})} \times 100 = 25.1$ [%]		2		2	2	
	(d)	(i)	Rate of heat transfer (accept power) per unit area per unit temperature difference. (or equation and terms defined)	1			1		
		(ii)	Extrapolate graph line to obtain 5 °C (1) Gradient = UA = 4.8 (1) U = [$\frac{4.8}{(4 \times 5)}$ =] 0.24 [W m^{-2} K^{-1}] (1) Alternatively, second marking point awarded for use of $P = UA\Delta\theta$ with 5 °C and point from graph line			3	3	3	
		(iii)	Bob did not consider skin of air [on inner and outer surface/between layers] that reduces heat flow		1		1		
			Question 12 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	3	13
2	5	6	4	15	9	12
3	2	7	3	12	10	0
4	1	5	13	19	10	19
5	6	4	0	10	3	0
6	7	5	0	12	4	3
7	1	5	2	8	2	0
8	3	5	3	11	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**	**54**	**47**