COMPONENT 3 – LIGHT, NUCLEI AND OPTIONS

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 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)*	(i)	v = 2.0 [m s^{-1}] e.g. via $v = \frac{0.1}{0.05}$ **or** $\frac{0.2}{0.1}$ **or** (with **ecf**) $f\lambda = 5 \times 0.4$ (1) f = 5.0 [Hz] e.g. via $\frac{1}{T} = \frac{1}{0.20}$, **or** (with **ecf**) $\frac{v}{\lambda} = \frac{2.0}{0.4}$ (1) λ = 0.40 [m] No justification needed **ecf** if via $\lambda = \frac{v}{f} = \frac{2.0}{5.0}$ (1)		1 1 1		3	3	
		(ii)	F **and** J		1		1		
		(iii)	Oscillations **or** displacements [of cars] and direction of travel of wave **or** energy [clarity needed for this mark] (1) are perpendicular [award mark even if directions not quite clear] (1)	1 1			2		
		(iv)	Cars shown in a line, so they can roll back and forth longitudinally. Springs shown joining cars head to tail		1		1		
	(b)	(i)	$S_2Q = \sqrt{(600^2 + 135^2)}$ **or** 615 [mm] **or** by implication (1) $S_2Q - S_1Q$ = 15 [mm] (1) For Q, $n\lambda$ = 15 [mm] **and** n = 2 **or** n = 0 for P (1) λ = 7.5 [mm] (1)	1	1 1 1		4	4	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1		(ii)	Correct use of $\lambda = \frac{(135\text{x}33.75))}{600}$ (1) λ = 7.6 mm **UNIT mark** [no credit for 7.5 mm without working] (1)	1	1		2	2	
	(c)	(i)	Diagram with recognisably parallel rays leaving two adjacent slits, perpendicular dropped and θ marked (1) $n\lambda$ and d marked on diagram or associated clearly with relevant sides of triangle (1) **Either** $n\lambda$ stated to be path difference [for light from adjacent slits] **or** θ stated also to be angle between light and normal (1)	1 1 1			3		
		(ii)	Any correct and relevant first order calculation (1) Any correct and relevant second order calculation (1) Conclusion argued correctly from first or second order (1) Conclusion argued correctly and involving ± 1^{o} (1)			1 1 1 1	4	2	
			Question 1 total	**7**	**9**	**4**	**20**	**11**	**0**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)		Numerical data ($E_{k\,max}$, ϕ, h) correctly inserted into **correct** Einstein's eq. **or** the eq. transposed thus: $f = \frac{(E_{k\,max} + \phi)}{h}$ **or** by implication (1) f = 7.1 × 10^{14} [Hz] (1)		1 1		2	2	
		(ii)	I	Calculation showing that 5.9 × 10^{14} Hz is above threshold **or** statement that this is assumed to be so (1) **More** photons [per second] eject more electrons [per second] (1)		1 1		2	1	
			II	$E_{k\,max}$ unaffected because extra (5.9 × 10^{14} Hz) photons are less energetic **or** equivalent **or** photons don't co-operate **or** equivalent (1)		1		1		
	(b)	(i)		Use of $\Delta E = hf$ **and** $\lambda = \frac{c}{f}$, **or** $\Delta E = \frac{hc}{\lambda}$ (1) λ = 700 n[m] **or** 695 n[m] (1)	1	1		2	2	
		(ii)		Gained by [or raises energy of] electron [**or** ion; accept atom]	1			1		
		(iii)		Any **two** of: phase, direction of travel, polarisation [direction]	1			1		
		(iv)		More electrons [**or** ions; accept atoms] in U than L	1			1		
		(v)		Population inversion needed for stimulated emission to be more probable, **or** frequent, than [**or** predominant over] absorption (1) This ensures light amplification **or** photon number increase **or** without population inversion no amplification **or** equivalent **or** by implication (1)		1 1		2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
2	*(c)*	(i)		Max gradient = 1.08 [± 0.03] $\times$ 10^{-6} [V m] (1) Min gradient = 0.93 [± 0.03] $\times$ 10^{-6} [V m] (1)		1 1		2	2	2
		(ii)		Use of h = gradient **or** equivalent **or** by implication (1) h = 5.4 $\times$ 10^{-34} J s **UNIT mark ecf** Accept 3 sig figs (1) Uncertainty 0.8 $\times$ 10^{-34} [J s] **ecf** including repeat of error in going from gradient to h. Accept 3 sig figs if h given to 3 sig figs. (1)		1	1 1	3	3	3
		(iii)		**Any 3 x (1) from:** • Points lie on straight line [as required] • [But] too few data points to form a valid conclusion • Accepted value of h outside range of uncertainty • Need to check if graph goes through [true] origin			3	3		3
				Question 2 total	**4**	**11**	**5**	**20**	**10**	**8**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*		1.540 sin 77° = n_{clad} sin 90° or equivalent (e.g = n_{clad}) **or** by implication (1) n_{clad} = 1.500 (1)		1 1		2	2	
	(b)	(i)	$v = \frac{c}{1.540}$ **or** 1.92×10^8 [m s^{-1}] (1) t = 1.80 μ[s] **ecf** on wrong n (1.75 μs) or n omitted (1.17 μs) **or** multiplying c by n (0.76 μs) (1)	1	1		2	2	
		(ii)	AC = AB sin 77° (1) Zigzag distance = $\frac{350}{\sin 77^o}$ [= 359 m], or Zigzag time = 1.80×10^{-6} (**ecf**) sin 77° = [1.85 μs] (1) Extra time = 47 n[s] (1)		1 1 1		3	3	
	(c)		A lower n means that θ increases (or equivalent) (1) Therefore there is less lag time by different routes (1) Therefore there will be a greater frequency (1)			1 1 1	3		
			Question 3 total	**1**	**6**	**3**	**10**	**7**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*	(i)	Place Hall probe varying distances from the wire (1) Hall probe placed perpendicularly to the field (1)	1 1			2		2
		(ii)	Method for calculating gradient (1) Answer =[-]1.05 [± 0.05] (1)	1	1		2	1	2
		(iii)	No mark for just stating Yes or No Straight line (1) Small scatter of points/low random error etc. (1) Gradient close to -1 and Yes stated (1)			1 1 1	3		3
		(iv)	40% is incorporated into the constants i.e. μ_0, 2π, I (1) So the intercept will be greater (1) The gradient will be the same (1)			1 1 1	3		3
	(b)		I_1 – B field into paper at P (1) I_2 – B field out of paper at P (1) Directions determined using the right hand grip rule / corkscrew rule (1) Overall direction is out due to the stronger current being I_2 (1)	1	1 1 1		4		
			Question 4 total	**4**	**4**	**6**	**14**	**1**	**10**

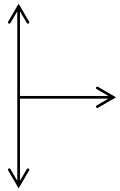
Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*		Valid complete statement - 2 marks e.g. Induced emf is proportional to (or equal to) the rate of change (or cutting) of flux (linkage) e.g. Accept induced emf = change of flux / time Nearly complete statement - 1 mark e.g. emf = rate of flux cutting (missing induced) e.g. $\varepsilon = -\frac{d\phi}{dt}$ (terms not defined) e.g. Induced emf is proportional to change of flux (missing rate of)	2			2		
	(b)		$\varepsilon = -\frac{d\phi}{dt}$ **or** $\frac{\phi}{t}$ **or** $\frac{BA}{t}$ **or** $\frac{BAN}{t}$ (1) $A = \pi r^2$ used (1) $I = \frac{V}{R}$ used (1) Answer = 1 991 [A] (1)	1 1	1 1		4	3	
			Question 5 total	**4**	**2**	**0**	**6**	**3**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
6	*(a)*		No mark for agreeing or disagreeing Society should realise that the paper is not radioactive **or** society doesn't know if paper is radioactive **or** society thinks paper is radioactive (1) Radioactivity needs to be linked to health issues e.g. society should realise the paper is harmless **or** society doesn't know whether **or** not the paper might cause cancer **or** people think the radioactive paper is harmful / carcinogenic etc (1)			2	2		
	(b)		${}^{90}_{39}\mathrm{Y}$ **and** ${}^{0}_{-1}\beta$	1			1		
	(c)		$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$ clearly selected (1) $\frac{\ln 2}{28.8\text{x}365\text{x}24\text{x}3600}$ = 7.63 $\times 10^{-10}$ [s^{-1}] (1)	1	1		2	2	
	(d)		Correct equation used i.e. some understanding of $A = A_0 e^{-\lambda t}$ **or** $A = \frac{A_0}{2^x}$ (1) Answer = 110 G[Bq] **ecf** on λ (1)	1	1		2	2	
	(e)		Use of $\frac{1}{2}mv^2 = E_k$ (1) *v* calculated correctly = 4.4 $\times$ 10^8 [m s^{-1}] (1) Greater than speed of light and relativistic speed (1)	1	1 1		3	2	
			Question 6 total	**4**	**4**	**2**	**10**	**6**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	*(a)*	(i)	Attempt at LHS – RHS (1) Attempt at mass-energy conversion $\times$ 931 **or** $E=mc^2$ used (1) Answer = 7.26 MeV (1.16×10^{-12} J) (1)	1	1 1		3	2	
		(ii)	Scientists have gathered evidence for carbon being essential to life (1) Scientists have discovered that this is the process in stars that produces carbon (1)			2	2		
	(b)		Method for converting BE/nucleon to BE (1) Mass equivalent = 0.5857 u (1) Understanding of mass and atomic numbers i.e. 28 protons & 34 neutrons stated or implied (1) Mass of 28p & 34n = 62.49828 (1) Answer = 61.913 [u] (1) Light nuclei increase A, heavy nuclei decrease A (1)	1 1	1 1 1	 1	5 2	3	
			Question 7 total	**3**	**5**	**2**	**10**	**5**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
8	*(a)*	(i)	d has charge ⅓ that of e^- d feels strong force; e^- doesn't d cannot be isolated; e^- can **or** equivalent	1 1 1			3		
		(ii)	$3 \times (-\frac{1}{3}e) = -e$. Accept $3 \times (-\frac{1}{3}) = -1$ **or** $3 \times (\frac{1}{3}) = 1$ if negative charge implied in some other way, e.g. total same as electron		1		1		
	(b)		No neutrino nor gamma emission (accept either) No change in quark flavour [and no gamma]		1 1		2		
	(c)	(i)	x is an electron and y is a[n electron] neutrino (1) Charge conservation used to identify charge of x as negative (1) Lepton number conservation used to identify y as antilepton (1)			1 1 1	3		
		(ii)	Weak as neutrino involved or quark flavour change		1		1		
			Question 8 total	**3**	**4**	**3**	**10**	**0**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9	*(a)*	(i)	Flux (linkage) is $BAN\sin\omega t$ **or** flux (linkage) varies sinusoidally (1) Induced emf is $\omega BAN\cos\omega t$ **or** rate of change of flux also sinusoidal (1) Accept flux cutting argument e.g rate of flux cutting depends on direction (of motion of long side) and this depends on $\cos\omega t$	1	1		2		
		(ii)	Area = 8×10^{-4} [m^2] (1) Peak pd = ωBAN (1) Answer = 31.5 [mV] (1)	1	1 1		3	3	
	(b)		Taking valid readings e.g. 4 cycles in 10 cm and peak V ~ 3.4 cm (1) Multiplying by one correct factor i.e. 0.02 or 50×10^{-6} (1) Answers i.e. 68 ± 4 [mV] and 125 ± 5 [μs] (1)		1	1 1	3	3	
	(c)	(i)	At resonance $Z=R$ **or** all pd across R **or** equivalent (1) $I=\frac{30}{67}$ (1)	1	1		2	1	
		(ii)	$V = IX_L$ and $X_L = \omega L$ (1) Answer = 99 [V] (1) **ecf** on I	1	1		2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
9		(iii)	Answer = 99 [V] **ecf**		1		1		
		(iv)	Answer = $\frac{99}{30}$ = 3.3 **ecf**		1		1		
		(v)	Decrease R **or** increase L and decrease C (1) Because this increases Q ditto for alternative (1) Because ω depends only on L and C **or** $f = \frac{1}{2\pi\sqrt{LC}}$ (1)			1 1 1	3	1	
	(d)		Basic shape ok (1) Vectors labelled (1) V_L bigger than V_C (1) 	1 1	 1		3	1	
			Question 9 total	**6**	**9**	**5**	**20**	**11**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
10	*(a)*	(i)	Continuous background spectrum (1) At least one line spectrum **and** minimum wavelength not at (0,0) (1)	1 1			2		
		(ii)	Rearrangement of $V = \frac{hc}{e\lambda}$ (1) V = 82 500 [V] (1) The energy of the electron is transferred into the energy of the photon (1)	1	1 1		3	2	
	(b)		CT X-ray machine rotates [about the body] **and** produces a 3D image (1) Justification: High radiation [ionizing] dose (1)	1		1	2		
	(c)		At centre B = 1.25 [T] (1) Use of f = 42.6 × 10^6 × 1.25 = 53.22 [MHz] (1) $\lambda = \frac{c}{f}$ = 5.64 [m] (1)	1	1 1		3	3	
	(d)	(i)	Alternating voltage applied (1) To piezoelectric crystal (1)		1 1		2		
		(ii)	Z_1 = 442 and Z_2 = 1 700 × 10^3 (1) f approximately = 1 (1) [Almost] all ultrasound reflected (1) Gel should have a similar impedance (1)		1 1	1 1	4	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
10	*(e)*	(i)	Use of $I = I_0 \exp(-\mu x)$ (1) I = 0.208 [mW cm^{-2}] **and** 0.169 [mW cm^{-2}] (1)	1	1		2	2	
		(ii)	0.208 $\times$ 0.08 = 0.017 and 0.169 $\times$ 0.12 = 0.020 (1) The tissue 9.8 cm below the skin receives a higher effective dose hence more likely to develop cancer (1)			1 1	2	2	
			Question 10 total	**6**	**9**	**5**	**20**	**11**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
11	*(a)*		Both feet <u>apart and in line</u> (1) Centre of gravity acts between both feet (1)	 1	1		 2		
	(b)		$(T \times 28.5) = (20 \times 9.5) + (560 \times 21)$ i.e. principle of moments applied correctly (1) T = 419 [N] (1)	1	 1		 2	 2	
	(c)		Correct selection of equations to determine the time of flight and range (1) Correct method to determine the time of flight and range (1) No.6 iron x = 186 [m] (1) No.7 iron x = 151 [m] (1) Choose No.7 iron – need conclusion (**no ecf**) (1)	1 1		 1 1 1	 5	 3	
	(d)	(i)	Forces clearly identified as lift, drag and weight (1) Backspin provides more lift or equivalent e.g. air pressure reduced behind the ball (1) Description of ball landing e.g. ball spins back or stops suddenly <u>so ball will not travel far on landing</u> (or roll forward)(1) Well argued conclusion (1)		1 1	 1 1	 4		
		(ii)	$\omega = 2\pi 50 = 314$ [rad s^{-1}] (1) Correct use of density formula (1) $I = \frac{2}{5} \times 0.046 \times (0.0214)^2$ i.e. correct substitution (1) Rotational KE = 0.4 [J] (1)	1	1 1 1		 4	 4	
		(iii)	Angular acceleration α = 628 000 [rad s^{-2}] (1) Using correct equation to determine, torque, $\tau = I\alpha$ (1) Torque τ = 529 [Nm] (1)	1	1 1		 3	 2	
			Question 11 total	**6**	**9**	**5**	**20**	**11**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
12	*(a)*	(i)	Object totally or partially immersed in a fluid (accept liquid or gas) is buoyed (accept lifted, upward force, upthrust) by a force equal to the weight of the displaced fluid	1			1		
		(ii)	Volume of whole iceberg replaces submerged volume - negligible effect on sea level (1) Water from ice sheet flows to sea - greater effect on sea level (1)		1	1	2		
	(b)	(i)	$340 \times 2.6 \times 10^{14}$ (1) $= 8.84 \times 10^{16}$ [W] (1)	1	1		2	2	
		(ii)	8.84×10^{16} [W]	1			1		
		(iii)	Correct substitution into $I = \frac{P}{4\pi r^2}$ [1] e.g. $r^2 = \frac{8.84\text{x}10^{16}}{170\text{x}\pi\text{x}4}$ $r = 6.4 \times 10^6$ [m] [**ecf** on P] (1)	1	1		2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
12	*(c)*	(i)	**Any 2 x (2) from:** Easily controllable (accept: no chain reaction) (1) Because can switch off protons/hydrogen (1) **Or** No radioactive by-products **or** products are alpha particles (1) Any good relevant detail e.g. no storage costs for thousands of years **or** alpha particles easily contained etc. (1) **Or** Fuel cheaper than fuel for fission (1) Detail e.g. per MJ output, H from the sea, no isotope enrichment needed, selling the He would help pay for the fuel (1) **Or** Fuel supplies would last longer than for fission (1) Detail: sensible remarks about U and H (1)	2		2	4		
		(ii)	30 000 000 $\times$ 300 keV (in whatever units) (1) Conversion so that answer and reaction energy in the same units (i.e. 9 million MeV or equivalent e.g. 2.74×10^{-12} and 1.44×10^{-6}J) (1) Comment implying far less energy out than in (1)		1 1	1	3	2	
		(iii)	$7 \times 1.66 \times 10^{-27}$ seen (1) Answer $[\frac{10^{16}}{7u}] = 8.6 \times 10^{41}$ (1)		1 1		2	2	

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
12		(iv)	Answer (iii) $\times$ 17.1 MeV (or its J equivalent 2.74×10^{-12}) (1) Tolerate slips in powers of 10; answer mark will be lost. Previous answer / 5×10^{20} (regardless of mixed units) (1) Answer = 4.7×10^{9} and comment that claim is valid (1)		1 1	1	3	3	
			Question 12 total	**6**	**9**	**5**	**20**	**11**	**0**

COMPONENT 3: LIGHT, NUCLEI AND OPTIONS

SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	TOTAL MARK	MATHS	PRAC
1	7	9	4	20	11	0
2	4	11	5	20	10	8
3	1	6	3	10	7	0
4	4	4	6	14	1	10
5	4	2	0	6	3	0
6	4	4	2	10	6	0
7	3	5	2	10	5	0
8	3	4	3	10	0	0
SECTION A TOTAL	**30**	**45**	**25**	**100**	**43**	**18**
9 (option A)	6	9	5	20	11	0
10 (option B)	6	9	5	20	11	0
11 (option C)	6	9	5	20	11	0
12 (option D)	6	9	5	20	11	0
OVERALL TOTAL	**36**	**54**	**30**	**120**	**55**	**18**