

Marking Scheme

1.	Question				Marking details	Marks available					
						AO1	AO2	AO3	Total	Maths	Prac
6.	(a)				Dark lines [or equivalent] (1) Bright background [accept rainbow background or equivalent] (1) Dark lines in same positions [or for same wavelengths] as [some of the] bright lines in emission spectrum (1)	3			3		
	(b)	(i)	I		Electron given energy or pumped' (1) [Electron having fallen from P to U] increases population of U or brings about population inversion (1)	2			2		
			II		Electron falls quickly or spontaneously [from L to level G] (1) So depopulating level L or making pop inversion easier to establish (1)	2			2		
		(ii)			Photon energy = $(1.43 - 0.26)$ [eV] [= 1.17 eV] or by impl (1) Conversion to J even if incorrect energy gap [= 1.87×10^{-19} J or by implication] (1) Correct use of $\lambda = \frac{hc}{E}$ or $\lambda = \frac{c}{f}$ and $f = \frac{E}{h}$ ecf on E (1) 1 060 n[m] no ecf and infra-red (1)		4		4	3	
	(c)				A maximum of (3) marks by addition from... - Laser pointer (arguably) too low-powered to be dangerous - Lecturer should be trusted not to shine lasers at students (or strongly reflecting surfaces) or lasers not viewed directly - Might stop sight of bright spot even when pointer used correctly - Any good physics involving polarisation - Will make field of view dimmer so note-taking difficult or opening pupils of eyes, making laser beam <i>more</i> dangerous - Any other valid point - Conclusion argued using more than one of the above			3	3		
					Question 6 total	7	4	3	14	3	0

2.	Question				Marking details	Marks available					
						AO1	AO2	AO3	Total	Maths	Prac
4	(a)				(Multiple passes of beam / reflection / keeps most of the light) for <u>more</u> amplification / stimulated emission or <u>increased</u> collimation (1) Some light (1%) transmitted by 99% mirror (1)	2			2		
	(b)				Increase of stimulated emission (1) Compared with absorption (1) [Exponential] increase in intensity or amplification or more power] (1) NB Stimulated emission > absorption → 2 marks	3			3		
	(c)	(i)			Energy of photon = 1.89×10^{-19} [J] seen or implied (1) $\frac{2 \times 10^{15}}{1.89 \times 10^{-19}}$ seen or implied (1.056×10^{34}) (1) [no e.c.f.]		2		2	2	
		(ii)			$p = \frac{6.63 \times 10^{-34}}{1.05 \times 10^{-6}}$ [kg m s ⁻¹] seen or implied [= 6.314×10^{-28} N s]		1		1	1	
		(iii)			$1.06 \times 10^{34} \times 6.31 \times 10^{-28}$ [N] seen or implied (1) 2 × due to reflection stated (1) [→ 1.33×10^7 N] [Using the 'show that' figures → 1.2×10^7 N]		2		2	1	
		(iv)			$E = \frac{\text{stress}}{\text{strain}}$ used (1) [or by implication] Stress = $\frac{F}{A}$ used (1) [or by implication] Answer = 0.0083 or 0.011 (or 0.0105) seen (depends on (iii) but check) (1) [0.83% ✓]	1 1	1		3	3	
					Question 4 total	7	6	0	13	7	0

3.

Question			Marking details	Marks available				Maths	Prac
				AO1	AO2	AO3	Total		
3	(a)	(i)	$1.79 \text{ eV} = 2.86 \times 10^{-19} \text{ J}$ or by implication (1) Use of $hf = E_U - E_L$ and $\lambda = \frac{c}{f}$, or $\lambda = \frac{hc}{E_U - E_L}$ or equiv (1) $\lambda = 694 [\pm 1] \text{ nm} / 6.9 \times 10^{-7} [\text{m}]$ (1)	1	1		3	2	
		(ii)	So a photon is more likely to cause stimulated emission than to be absorbed / more stimulated emission than absorption (or so more photons cause SE than are absorbed) (1) So number of photons increases [rather than decreases] / light builds up / 1 photon $\rightarrow$ 2 photons (1)	2			2		
	(b)	(i)	photons per second = $\frac{6.0 \times 10^{-3} [\text{W}]}{2.86 \times 10^{-19} [\text{J}]}$ ecf even if slips (eg by 10^6) (1) $2.09 \times 10^{16} [\text{s}^{-1}]$ (1)	1	1		2	1	
		(ii)	photon momentum = $\frac{6.63 \times 10^{-34} [\text{J s}]}{693 \times 10^{-9} [\text{m}]} [= 9.55 \times 10^{-28} \text{ N s}]$ or by implication ecf on λ (1) or beam momentum per second = $\frac{0.006 [\text{W}]}{c}$ or by implication beam momentum per second = $2.0 \times 10^{-11} [\text{N}]$ (1) [$1.91 \times 10^{-11} \text{ N}$ if 2×10^{16} used]	1	1		2	2	
		(iii)	$4.0 \times 10^{-11} \text{ N}$ ((unit)) ecf from (ii), i.e. $2 \times$ answer to (ii) But not if answer to (ii) was 0.		1		1	1	
			Question 3 total	5	5	0	10	6	0

Question			Marking details	Marks available					
				A01	A02	A03	Total	Maths	Prac
3	(a)	(i)	Stimulated emission also happens [1] Decreasing the upper population (accept 50 % population is greatest possible or equal probability of absorption / dropping) [1]	2			2		
		(ii)	Greater efficiency or requires less energy / small pumping voltage / larger population inversions / less pumping / cheaper and mass produced [1] Don't accept lower current CD / DVD / Blu ray / pointers / laser fusion / anything sensible [1]	2			2		
	(b)		3-level system Pumping E1-E3 E3-E2 quick E2 metastable E2-E1 laser output E1-E2 population inversion 4-level system Pumping E1-E4 E4-E3 quick E3 metastable E3-E2 laser output E2-E3 population inversion E2-E1 quick Advantages / Disadvantages E1 ground so usually full in 3-level More than 50% pumping required in 3-level E2 normally empty in 4-level Minimum pumping required in 4-level	6			6		
			5-6 marks Comprehensive description of how a 3-level works, how a 4-level works and its advantages. <i>There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.</i> 3-4 marks Comprehensive description of 2 from: how a 3-level works, how a 4-level works and its advantages or limited description of all 3. <i>There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.</i> 1-2 marks Comprehensive description of 1 from: how a 3-level works, how a 4-level works and its advantages or limited description of 2. <i>There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.</i> 0 marks <i>No attempt made or no response worthy of credit.</i>						
			Question 3 total	10	0	0	10	0	0

Question			Marking details	Marks available				Maths	Prac
				AO1	AO2	AO3	Total		
5	(a)		3-level energy system E1 – Clearly labelled diagram of 3-level energy system E2 – Population inversion mentioned E3 – More electrons in higher energy levels than lower E4 – Pumping used to achieve more electrons in higher energy level / state E5 – One state is metastable or long lived 2-level energy system E6 – Population inversion not possible in 2-level system E7 - Reference to absorption (either 2 or 3 level) Stimulated Emission S0 – Incident photon causes an electron to drop S2 – Photon emitted when electron drops S3 – Stimulated emission mentioned S4 – There are 2 photons instead of 1 photon (coherent) S5 – Incident photon of correct energy or frequency or wavelength 5-6 marks 9 to 12 points from either E1 to E7 and S0 to S5 <i>There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.</i> 3-4 marks 5 to 8 points from either E1 to E7 and S0 to S5 <i>There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.</i>	6			6		
			1-2 marks 1 to 4 points from either E1 to E7 and S0 to S5 <i>There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.</i> 0 marks No attempt made or no response worthy of credit.						
	(b)	(i)	Substituting for wavelength into $E = \frac{hc}{\lambda}$ (1) Energy of photon = 3.14×10^{-19} J unit mark(1)	1	1		2	2	
		(ii)	Number of photons per second = $\frac{1 \times 10^{-3}}{3.14 \times 10^{-19}} = 3.18 \times 10^{15} \text{ s}^{-1}$ (ecf on value of energy of photon) (1) Number of incident photons per second = $3.18 \times 10^{15} \times 500$ (1) Answer = 1.6×10^{18} (1) ecf power 10		3		3	3	
			Question 5 total	7	4	0	11	5	0