Marking Scheme

#1

Question		Marking details	Marks available					
			AO1	AO2	AO3	Total	Maths	Prac
	(a)	Electron drops giving 2 photons (1) (Stimulated by) incoming photon of correct energy / wavelength (1)	2			2		
	(b)	Short lifetime (1) Above ground level **OR** level above is metastable / long T (1)	2			2		
	(c)	1 % lost each round trip (due to transmission) (1) Equilibrium requires 1 % gain or WTTE (1) Which is 0.5 % each length & Victoria is correct (or similar) (1) **Award a maximum of 2 marks -** David is correct because large amplification (1) must counteract other losses (1)			3	3		
		Question total	4	0	3	7	0	0

#2

Question		Marking details	Marks available					
			AO1	AO2	AO3	Total	Maths	Prac
	(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 total	4	4	0	8	0	0

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	(a)	(i)	<u>Stimulated emission</u> 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. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **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. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **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. *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 3 total	10	0	0	10	0	0

#4

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	More electrons in higher energy level [E_2] compared to lower energy level [E_1]	1			1		
		(ii)	Population inversion ensures stimulated emission [rather than spontaneous emission] (1) Produces 2 photons for 1 incoming photon (1)	2			2		
	(b)		Conversion of eV to J correct (1) Wavelength = 1.00×10^{-5} m (1) Wavelength lies in the infra-red (1)	1 1	1		3	2	
	(c)		Converting 2 290 km² to 2.29×10^9 m² (1) Force on the crater (= pressure × area **ecf**) = 1.38×10^{12} [N] (1) Momentum of each molecule calculated = 4×10^{-23} [N s] (1) Momentum change per collision = 8.03×10^{-23} [N s] **or** realisation that momentum change = initial − (-final) (1) Number of molecules = 1.71×10^{34} (1)		5		5	5	
			Question total	5	6	0	11	7	0

#5

	Question		Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
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 *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** 5 to 8 points from either E1 to E7 and S0 to S5 *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.*	6			6		
			1-2 marks 1 to 4 points from either E1 to E7 and S0 to S5 *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)	(i)	Substituting for wavelength into $E = \frac{hc}{\lambda}$ (1) Energy of photon = 3.14 × 10⁻¹⁹J unit mark(1)	1	1		2	2	
		(ii)	Number of photons per second = $\frac{1\times10^{-3}}{3.14\times10^{-19}}$ = 3.18 × 10¹⁵ s⁻¹ (ecf on value of energy of photon) (1) Number of incident photons per second = 3.18 × 10¹⁵ × 500 (1) Answer = 1.6 × 10¹⁸ (1) ecf power 10		3		3	3	
			Question 5 total	7	4	0	11	5	0

#6

Question			Marking details	AO1	AO2	AO3	Total	Maths	Prac
						Marks available			
4	(a)		{Multiple passes of beam / reflection / keeps most of the light} for more amplification / stimulated emission or increased 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 × 10³⁴) (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 × 10³⁴ × 6.31 × 10⁻²⁸ [N] seen or implied (1) 2 × due to reflection stated (1) [→1.33 × 10⁷ N] [Using the 'show that' figures → 1.2 × 10⁷ N]		2		2	1	
		(iv)	$E = \frac{stress}{strain}$ 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