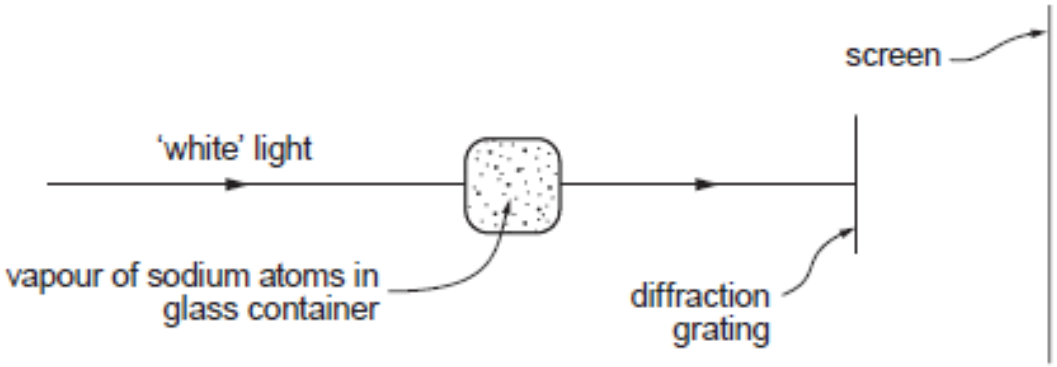
1.

6. *(a)* The diagram shows how the *absorption spectrum* of sodium atoms may be produced.



Describe the appearance of the absorption spectrum, comparing it with the *emission spectrum* of sodium atoms. [3]

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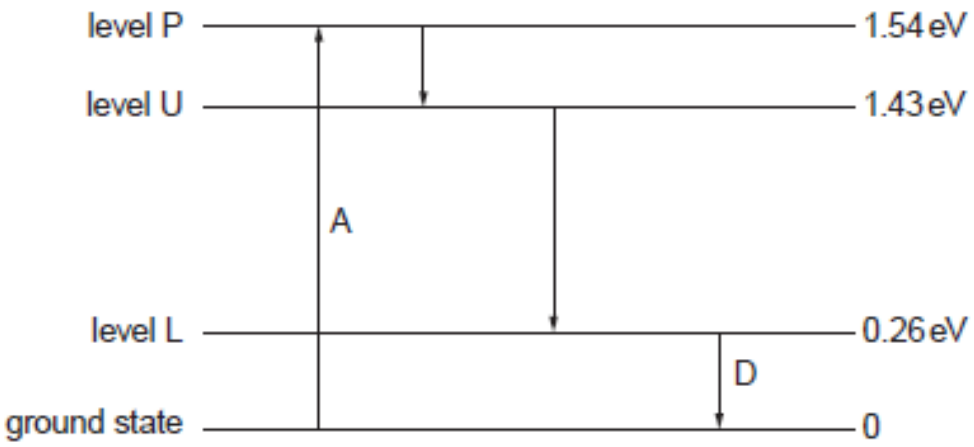
(b) A simplified energy level diagram for the amplifying medium of a 4 level laser is given.



(i) Referring to *populations*, explain the part played in the operation of the laser by:

I. transition A; [2]

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II. transition D. [2]

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(ii) Calculate the wavelength of the radiation emitted by stimulated emission from the laser, and name the region of the electromagnetic spectrum in which it lies. [4]

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(c) Most laser pointers produce polarised light. Discuss whether or not students attending a lecture in which a laser pointer is used should be given spectacles fitted with polarising filters (polaroids) to wear for safety during the lecture. [3]

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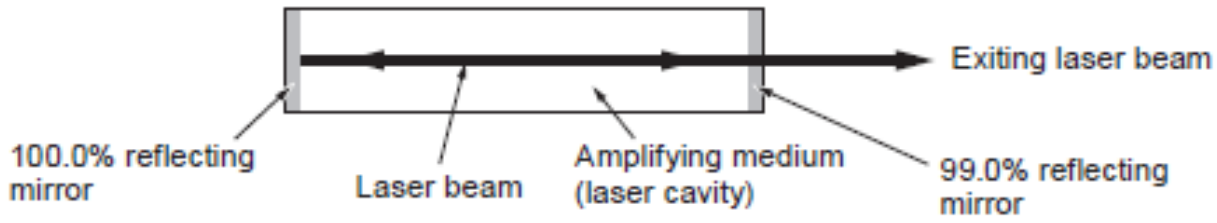
2. **4.** A laser has two mirrors either side of the amplifying medium as shown.



(a) Explain the purpose of the 99.0% reflecting mirror and the 100.0% reflecting mirror. [2]

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(b) Explain the purpose of a population inversion in the laser cavity. [3]

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(c) (i) The light intensity inside a powerful laser is 2.0×10^{15} W and its wavelength is 1.05 µm. Show that this corresponds to approximately 1×10^{34} photons per second. [2]

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(ii) Show that the momentum of a 1.05 μm photon is approximately 6×10^{-28} kg m s^{-1}. [1]

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(iii) Show that the force exerted on a 100.0% reflecting mirror by a beam of power 2.0×10^{15} W is approximately 1×10^{7} N. [2]

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(iv) Calculate the strain produced in a laser structure if the power of the beam between the mirrors is 2.0×10^{15} W. You may assume that the structure of the laser cavity has a cross-sectional area of 43 cm^2 and is made of a material with Young modulus 2.8×10^{11} Pa. [3]

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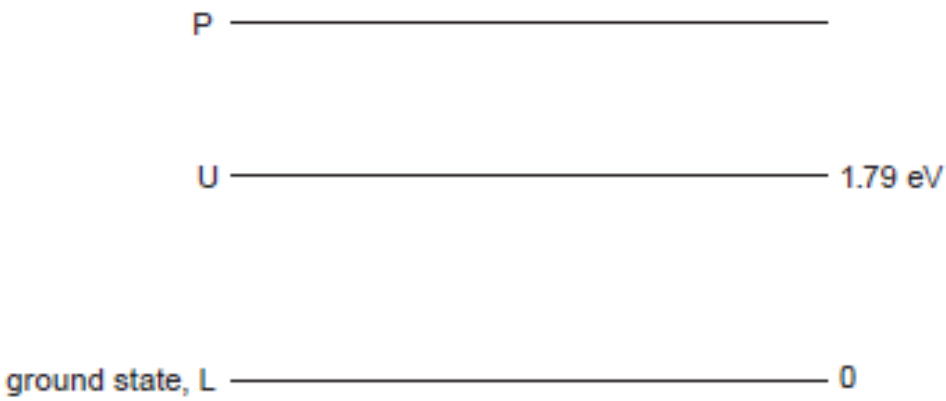
3. 3. A simplified energy level diagram for a 3-level laser system is given.



(a) (i) Calculate the wavelength of light emitted by stimulated emission. [3]

(ii) Assuming that some photons of this wavelength are already present in the laser cavity, explain why a population inversion is needed for light amplification to take place. [2]

(b) The laser produces a light beam of power 6.0 mW.

(i) Show that the number of photons emitted per second is approximately 2×10^{16} s^{-1}. [2]

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(ii) Calculate the momentum of the light leaving the laser per second. [2]

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(iii) Calculate the force exerted by the light beam on a perfectly reflecting surface, if it strikes the surface normally. [1]

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4.

3. *(a)* (i) Explain why a population inversion is not usually possible with a 2-level energy system pumped using light. [2]

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(ii) State an advantage of semiconductor lasers and an example of their use. [2]

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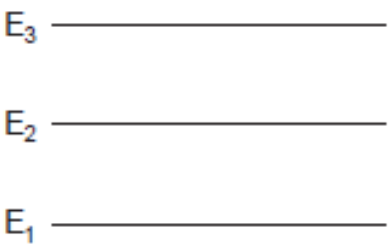
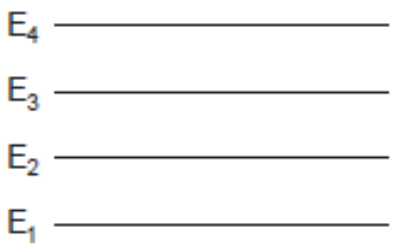
(b) Explain how 3-level and 4-level laser systems work and the advantages of a 4-level system. Refer to the diagrams in your answer. [6 QER]

3-level system



4-level system



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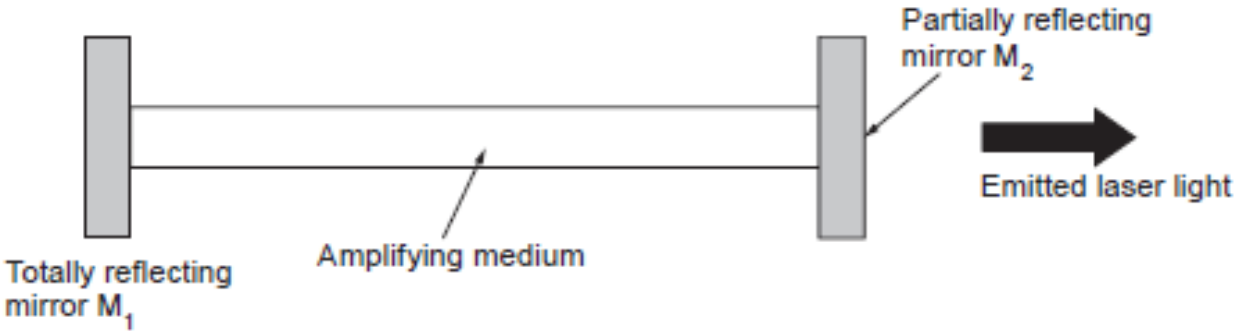
5.

5. *(a)* Explain how a 3 level laser operates, explaining also why a 2 level laser is not possible. [6 QER]

(b) The simplified diagram shows the cavity of a laser.



(i) The wavelength of light from the laser is 633 nm. Calculate the energy of a photon of light emitted by the laser. [2]

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(ii) The power output of the laser is 1.0 mW. Mirror M_2 transmits 1 in 500 photons. Determine the number of photons per second incident on mirror M_2. [3]

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