Examiner only

1. *(a)* (i) State Ohm's law. [2]

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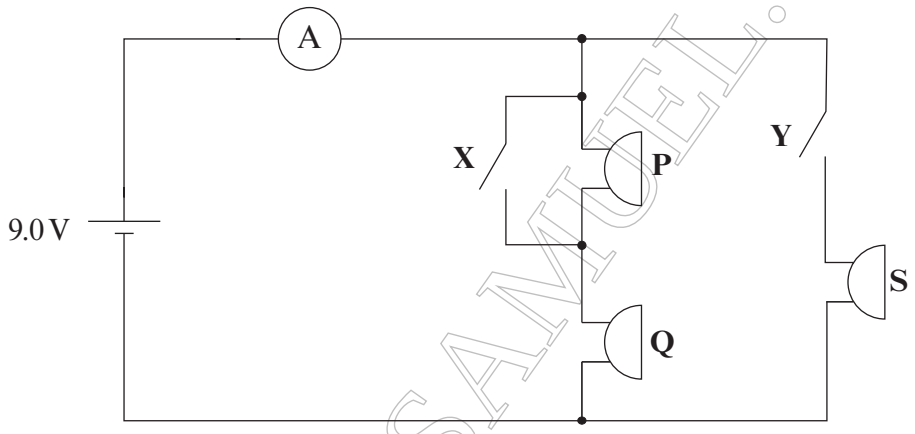
(ii) The unit of resistance is the ohm (Ω). One of the following is a correct alternative unit to the ohm. Circle the correct one. [1]

VA^{-1} AV^{-1} JC^{-1} Js^{-1}

(b)



In the above circuit, buzzers **P**, **Q** and **S** are controlled using switches **X** and **Y**. **The buzzers are identical and their resistances remain constant.**

(i) The table shows the possible combinations of open and closed switches. When a switch is closed, charge can flow through it. Complete the table. The first row has been done for you. [3]

Switch combination	**P**	**Q**	**S**
X open, **Y** open	On	On	Off
X closed, **Y** open			
X open, **Y** closed			
X closed, **Y** closed			

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(ii) With **X** open and **Y** open, the ammeter reads 0.18 A. Calculate the resistance of **each** of the buzzers. [3]

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(iii) Determine the reading on the ammeter when all three buzzers are on. [2]

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(iv) When all three buzzers are on, show that

power used by **S** = 4 × power used by **Q** [3]

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Examiner only

2. *(a)* What is a *superconductor*? [1]

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(b) A metal conductor is placed in liquid helium. It is noted that at a certain temperature, as the metal cools, its resistance changes suddenly, dropping rapidly to zero.

(i) What name is given to the temperature at which this sudden change occurs? [1]

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(ii) Sketch a graph of resistance against temperature for the above conductor, labelling any key features of your graph. [2]

(iii) What potential difference would be needed to maintain a current in the conductor when it has been immersed in the liquid helium for some time? [1]

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(c) Conducting electrons in a superconductor do not cause a heating effect. Explain why conducting electrons **do** produce a heating effect in wires at room temperature. [2]

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Examiner only

3. A car battery has an emf of 12.0 V. When the car is started the battery supplies a current of 120 A to the starter motor. The potential difference between the battery terminals [terminal pd] drops at this time to 8.4 V due to the internal resistance of the battery.

(a) Explain, **in terms of energy**,

(i) what is meant by 'an emf of 12.0 V', [2]

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(ii) why the terminal pd drops when the battery supplies a current. [1]

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(b) Calculate the internal resistance of the battery. [2]

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(c) The manufacturer warns against accidentally short-circuiting the battery. Calculate the current that would flow if the battery terminals were short-circuited with a spanner of negligible resistance. [1]

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(d) The battery will become 'flat' (i.e run out of energy) if it is continually run for a long period of time. It can then be fully recharged by a current of 3.0 A supplied for 16 hours.

(i) Calculate how much charge flows through the battery in this time. [2]

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(ii) Estimate how long the starter motor could be operated on a fully-charged battery. [1]

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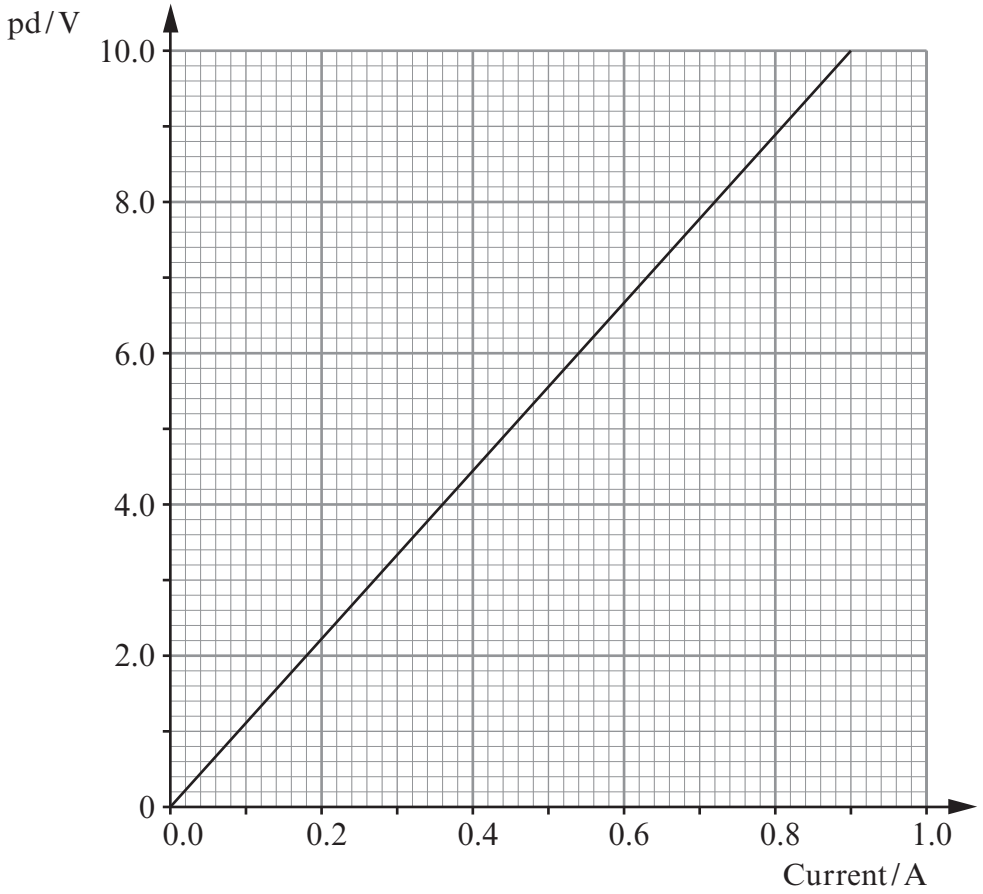
Examiner only

6. Experiments are carried out to determine the material from which a metal wire is made. Initially the resistivity of the metal is found. The wire's density is then determined and the results compared with known values of resistivity and density.

(a) As a first step to finding the resistivity, an experiment investigates the relationship between pd and current for the wire. The results are shown in the graph.



(i) Draw a circuit diagram to show how the above results could be obtained. The apparatus available includes a battery, a switch, a variable resistor, an ammeter and a voltmeter. [2]

Examiner only

(ii) The wire has length 3.2 m and **diameter** 0.20 mm. Use this information and the graph to calculate the resistivity of the material in the wire. [4]

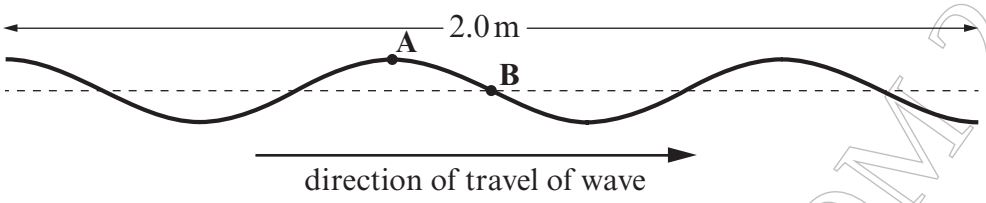
(iii) Using the information in the table, write down **two** possible materials for the wire. [1]

Material	Resistivity / Ω m	Density / kg m^{-3}
Iron	0.97×10^{-7}	7 850
Platinum	1.06×10^{-7}	21 400
Tin	1.12×10^{-7}	7 300
Nichrome	1.10×10^{-6}	8 400

(b) The mass of the wire is found to be 0.74 grammes. Explaining how you obtain your answer, determine the material from which the wire is made. [3]

Examiner only

1. *(a)* A water wave is travelling from left to right along a canal. The diagram shows the wave at one instant.



(i) (I) Show that the wavelength of the wave is 0.80 m. [1]

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(II) How do the *amplitudes* compare for water particles **A** and **B**? [1]

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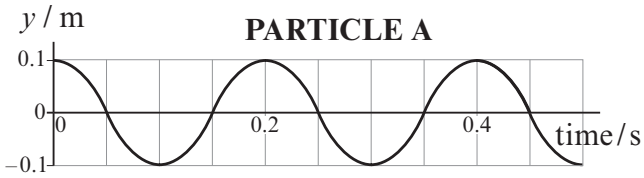
(ii) A graph of displacement, y (vertical component) against time is given alongside for water particle **A**.



(I) Calculate the *frequency*. [1]

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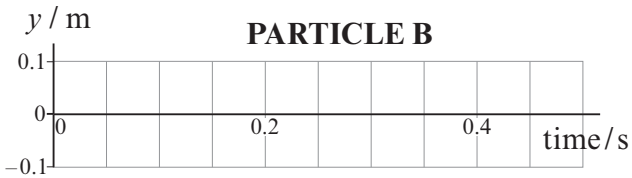

(II) Sketch the corresponding graph for particle **B** on the axes given. [2]

(iii) Calculate the *speed* of the wave. [1]

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Examiner only

(b) When the wave in the first diagram has travelled further, it reaches a length of the canal where the water is shallower. The wavelength in the shallow water is 0.60 m.

Calculate the speed of the wave in the shallow water, **giving your reasoning**. [2]

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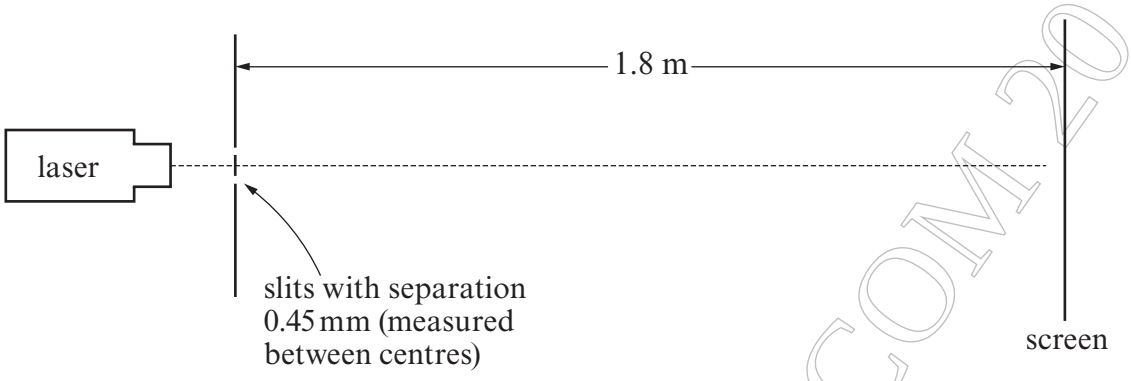
Examiner only

2. The apparatus shown is set up to produce a clear display on the screen of Young's fringes.



(a) The bright fringes result from constructive interference. Explain, in terms of *phase* and *path difference*, why there are bright fringes. You may add to the diagram above, or draw your own diagram(s) to assist your explanation. [2]

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Examiner only

(b) (i) The centres of the bright fringes are measured to be 2.4 mm apart. Calculate the wavelength of the light from the laser. [2]

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(ii) To obtain an accurate value of wavelength, it is better to use a diffraction grating than a double slit. Give **two** reasons for this. [2]

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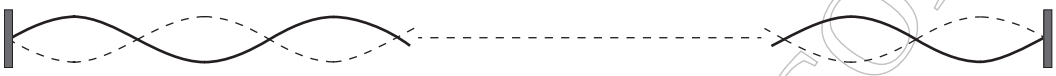
Examiner only

3. The cavity of a laser has reflecting ends a distance L apart. Assuming there is a node at each end, the possible wavelengths of stationary waves are given by the equation

$$\lambda = \frac{2L}{n} \quad \text{in which } n \text{ is a whole number.}$$

(a) Label relevant lengths on the diagram, and hence show how this equation arises. [The stationary wave is shown as if it were a stationary wave on a stretched string.] [2]



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(b) For a particular semiconductor laser, L = 0.2050 mm.

(i) Using the equation above, show that a stationary wave of wavelength 820.0 nm can exist in the cavity, but that a stationary wave of wavelength 821.0 nm cannot. [2]

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(ii) Find the next wavelength above 820.0 nm of stationary wave that could exist in the cavity. [2]

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(c) A stationary wave is equivalent to a superposition of progressive waves of equal amplitude travelling in opposite directions. Why is this condition not exactly met in a laser emitting a beam of light? [2]

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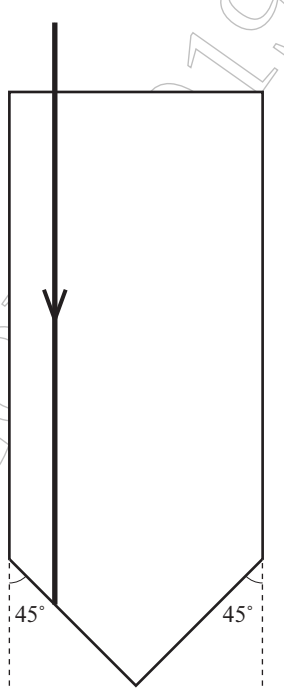
Examiner only

4. *(a)* A rod made of clear plastic of refractive index 1.55 is shaped as shown. The surrounding air has refractive index 1.00.



(i) Calculate the critical angle for light approaching a boundary between the plastic and the air. [2]

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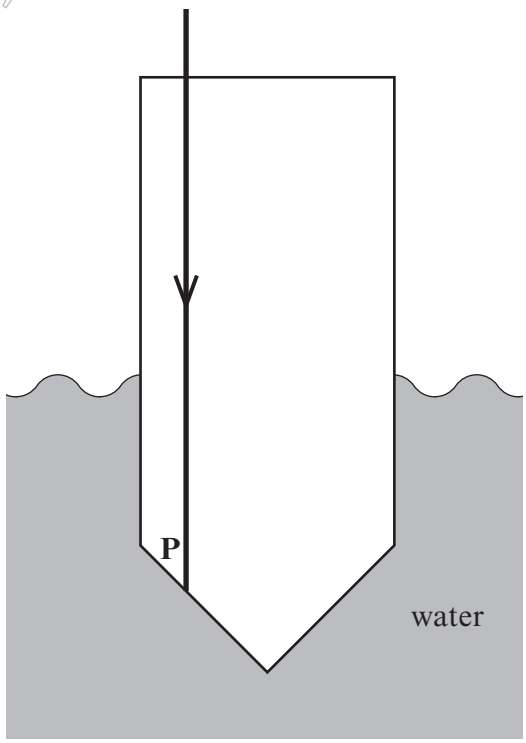
(ii) Hence complete the path of the beam in the diagram, showing its emergence into the air. [2]

(b) The bottom of the rod now dips into water, of refractive index 1.33.



(i) Calculate the angle of refraction of the beam into the water at **P**. [2]

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(ii) Sketch the refracted beam on the diagram. [1]

(iii) Suggest how this plastic rod might be used as part of a device to give a warning when the water level in a tank falls below a certain height. [1]

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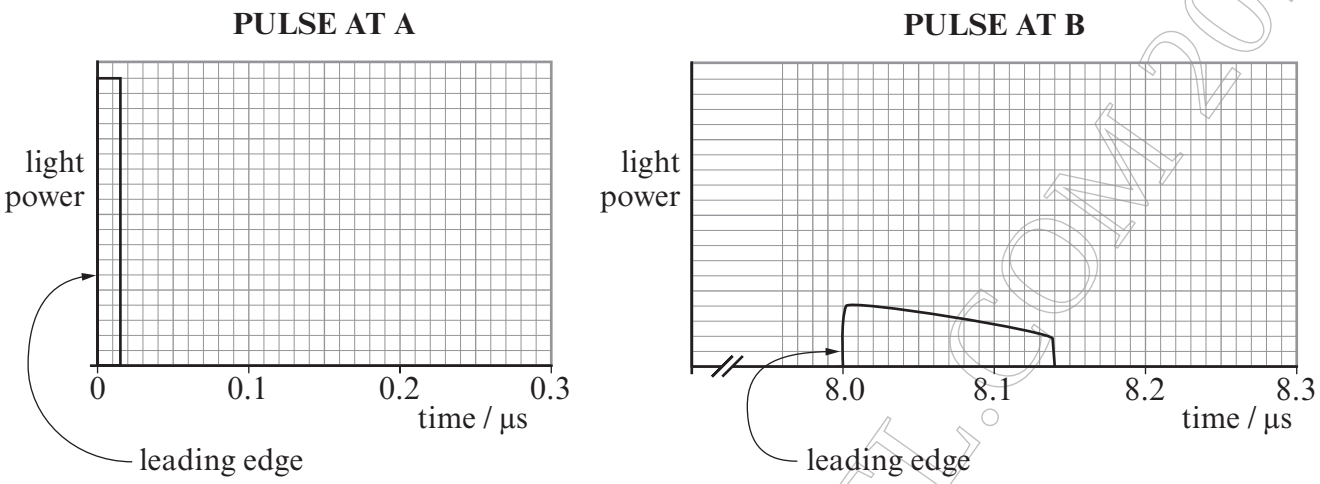
Examiner only

5. *(a)* Pulses of monochromatic light are sent from **A** to **B** through a multimode optical fibre. The graphs show the pulse at **A** and when it arrives at **B**.



(i) By considering the leading edge (the start) of the pulse, calculate the distance from **A** to **B** along the axis of the fibre. The refractive index of the fibre's core is 1.50. [3]

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(ii) Explain why the pulse is spread out over time when it arrives at **B**. A sketched diagram may help your explanation. [2]

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Examiner only

(b) Suppose a second pulse is sent from **A** to **B**.

(i) State the minimum time interval t_{min}, between the leading edges of the first and second pulses at **A**, for them to arrive at **B** without overlapping. [1]

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(ii) Show the second pulse on both graphs opposite, if the time interval between pulses at **A** is t_{min}. [2]

Examiner only

6. *(a)* State, **in terms of energy**, the meaning of each term in Einstein's photoelectric equation

$$E_{k\max} = hf - \phi.$$

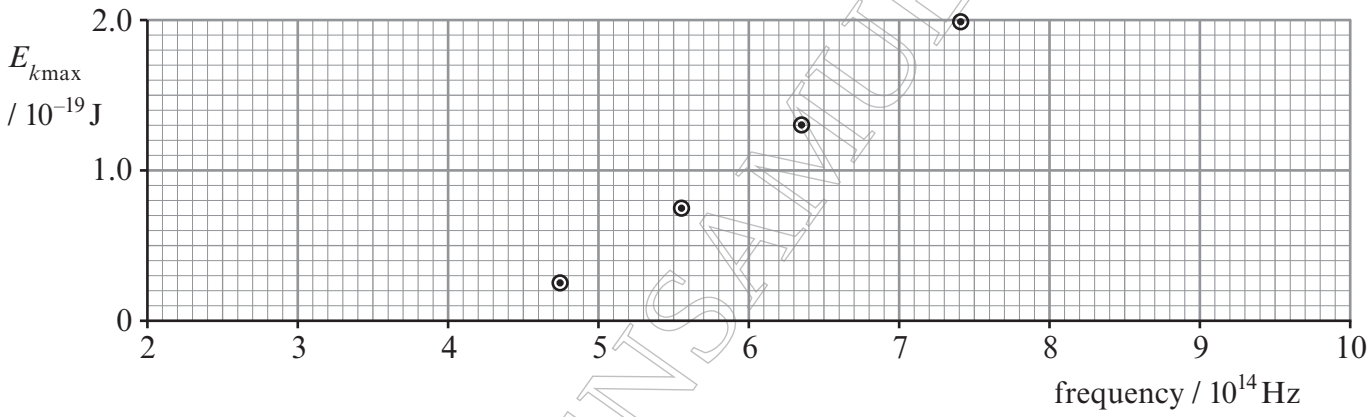
(i) $E_{k\max}$ ..... [1]

(ii) hf ..... [1]

(iii) ϕ .....

..... [1]

(b) Monochromatic light of frequency 7.40×10^{14} Hz is shone on to a caesium surface, and $E_{k\max}$ is measured. The procedure is repeated for three other frequencies, enabling four points to be plotted on the grid below.



(i) Showing your working, determine from the grid above

(I) a value for the Planck constant, [2]

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(II) the work function of caesium. [2]

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Examiner only

(ii) When a lithium surface is used instead of a caesium surface, $E_{k\max}$ is found to be 0.40×10^{-19} J for light of frequency 7.40×10^{14} Hz.

(I) Draw the expected line of $E_{k\max}$ against frequency on the same grid. [2]

(II) This line cannot be checked satisfactorily by experiment using visible light. Name the region of the electromagnetic spectrum which is required. [1]

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(III) What is different about lithium, as compared to caesium, which makes it necessary to use this region of the electromagnetic spectrum? [1]

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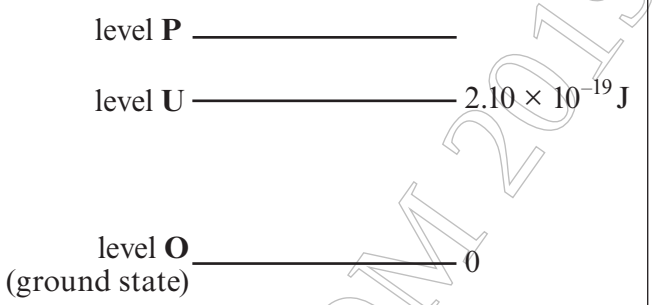
Examiner only

7. A simplified energy level diagram for the amplifying medium of a 3-level laser is given.



(a) Suppose that the laser is at room temperature and that it is **not being pumped**.

(i) Compare the (electron) populations of the three levels. [1]

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(ii) A photon of energy 2.10×10^{-19} J in the laser cavity could interact with the amplifying medium. Name the process involved, and explain briefly what happens. [2]

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(b) The laser is now pumped, to create a *population inversion* between levels **U** and **O**.

(i) Explain what is meant by a population inversion. [1]

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(ii) Draw **two** arrows on the diagram to show how the population inversion is achieved. [1]

(iii) Explain in detail how light amplification takes place. [4]

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(iv) Calculate the wavelength of the radiation emitted. [2]

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Examiner only

(c) In a 4-level laser the light output results from a transition to a lower level which is above the ground state. Explain the advantage over a 3-level system. [2]

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