Surname	Centre Number	Candidate Number
First name(s)		2

GCE AS/A LEVEL

2420U20-1

Z22-2420U20-1

MONDAY, 6 JUNE 2022 – MORNING

PHYSICS – AS unit 2
Electricity and Light

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**9**	
2.	**16**	
3.	**6**	
4.	**11**	
5.	**10**	
6.	**12**	
7.	**8**	
8.	**8**	
Total	**80**	

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ADDITIONAL MATERIALS

In addition to this paper you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space use the additional page at the back of the booklet taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The total number of marks available for this paper is 80.

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question **3**.

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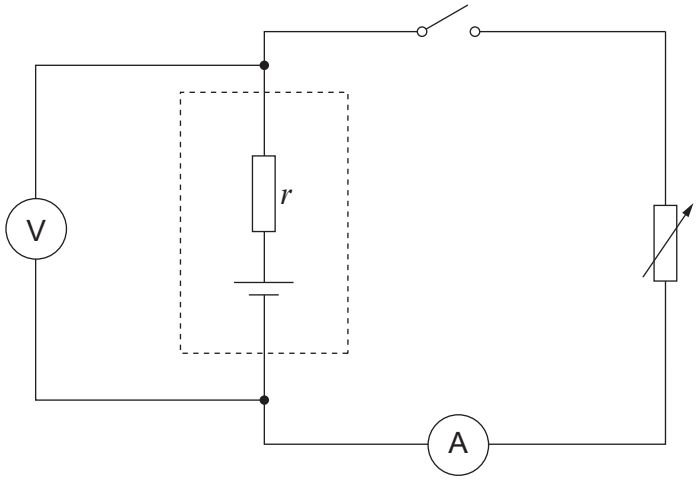
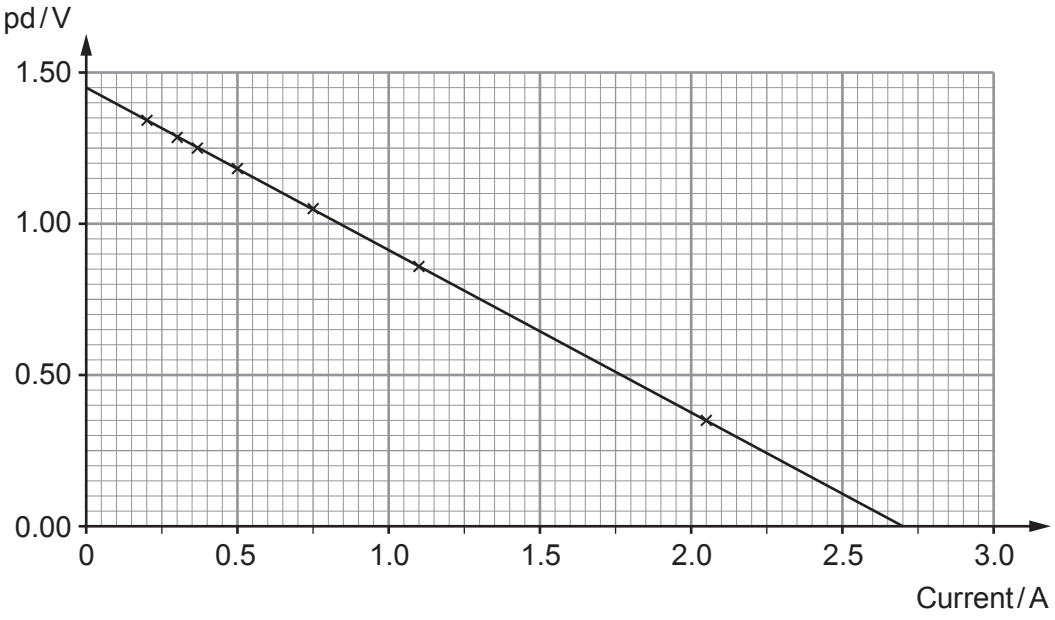
Answer **all** questions.

1. Anwen sets up the circuit shown in order to investigate a cell. The variable resistor is adjusted and readings are obtained from the voltmeter and ammeter.



The readings are plotted as shown.



(a) The manufacturer claims that the emf of the cell is 1.50 V. Explain, in terms of energy, what this statement means. [2]

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(b) An equation applying to a cell of emf, E, and internal resistance, r, is:

$$V = E - Ir$$

(i) Explain how Anwen's graph is in good agreement with this equation. [2]

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(ii) Calculate the gradient of the line and hence determine a value for the cell's internal resistance. [2]

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(iii) Evaluate the manufacturer's claim that the emf is 1.50 V. [1]

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(c) (i) Use the graph to determine the greatest current the cell can supply. [1]

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(ii) State the resistance of the variable resistor when the current is at its maximum. [1]

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2. The current, I, in a wire of cross-sectional area, A, is given by the equation:

$$I = nAve$$

(a) (i) State what the letter n represents in this equation. [1]

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(ii) Using a labelled diagram, derive the equation above. [4]

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(iii) In a physics experiment there is a current of 1.8 A in a nichrome wire of diameter 0.19 mm. For nichrome, $n = 9.0 \times 10^{28}\,m^{-3}$. Calculate the drift velocity. [2]

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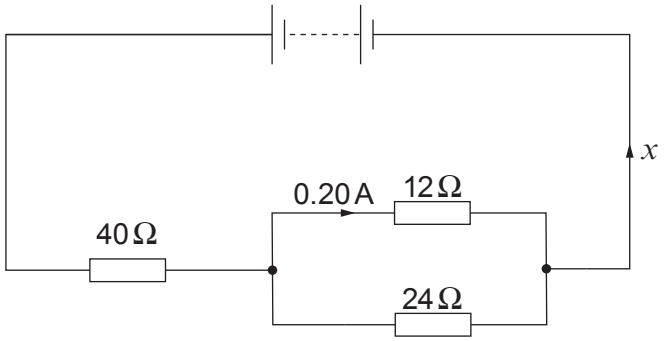
(b) The nichrome wire is cut into different lengths to make three resistors. The resistors are connected in the circuit as shown. The battery has negligible internal resistance.



(i) Explain, in clear steps, why the current, x, is 0.30 A. [3]

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(ii) Calculate the pd across the supply. [3]

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(iii) Show that the power dissipated by the 12 Ω and 24 Ω parallel arrangement is **one fifth** that dissipated by the 40 Ω resistor. [3]

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Turn over.

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3. Explain what is meant by a *progressive wave*, **and** explain the difference between a *longitudinal* **and** a *transverse* progressive wave, giving **one** example of each of these types of wave. [6 QER]

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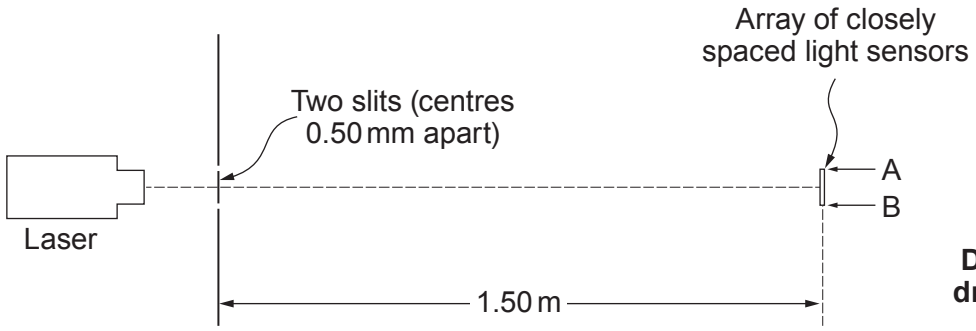
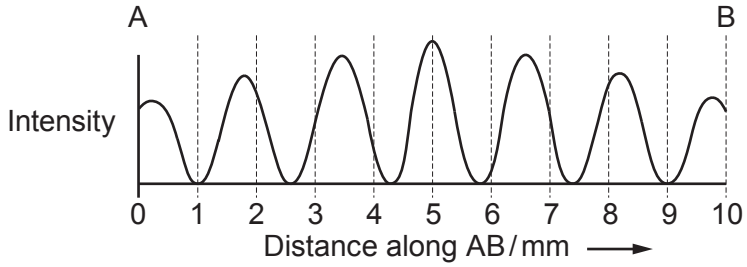
4. (a) A modern version of Young's double slit experiment is set up as shown.



Diagrams not drawn to scale

The array of light sensors is connected to circuitry that displays a graph of light intensity along the line AB.



(i) Calculate a value for the wavelength of light from the laser. [3]

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(ii) Each slit is several wavelengths wide. Suggest why the intensity of the bright fringes decreases the further the fringes are from the centre of the pattern. [2]

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(iii) A student suggests that replacing the laser with one that emits near infra-red (that is infra-red just beyond the end of the visible spectrum) will increase the fringe separation.

I. Explain whether or not the student is right. [2]

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II. State **one** way in which the fringe separation could be increased without changing the laser. [1]

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(b) More than 200 years ago Thomas Young drew a conclusion from his 'fringes' experiment. It was not generally accepted for several years. State what conclusion Young drew, **and** suggest what needed to be done by the scientific community for the conclusion to be accepted. [3]

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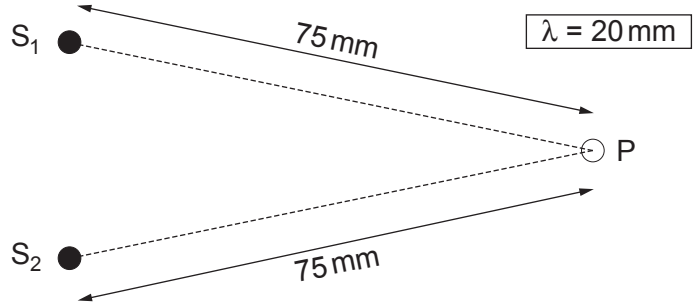
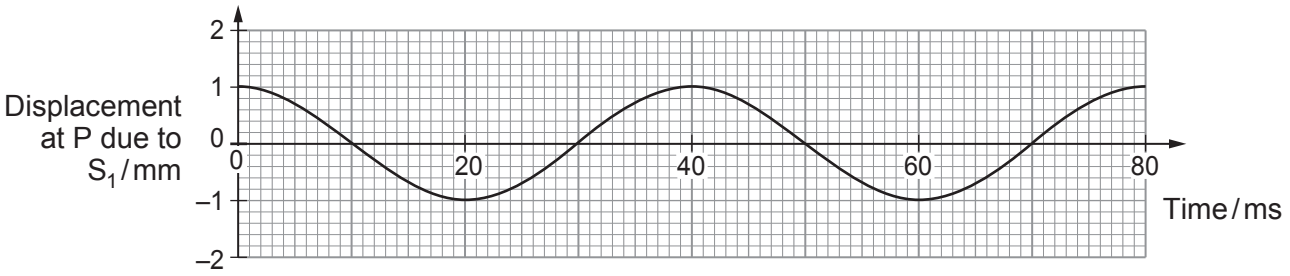
5. (a) The diagram shows where two metal spheres, S_1 and S_2, touch the surface of water (in a tray).

VIEW FROM ABOVE



S_2 remains stationary while S_1 is made to vibrate up and down, so waves spread outwards from it across the water. The wavelength of the waves is 20 mm. A displacement-time graph is given for point P.



(i) Calculate the wave speed. [2]

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(ii) S_1 and S_2 are now made to vibrate **in phase**, to act as wave sources of equal amplitude. Carefully sketch, on the lower two grids **opposite**, displacement-time graphs for point P, due to:

I. waves from S_2; [1]

II. the superposition of waves from S_1 and S_2. [1]

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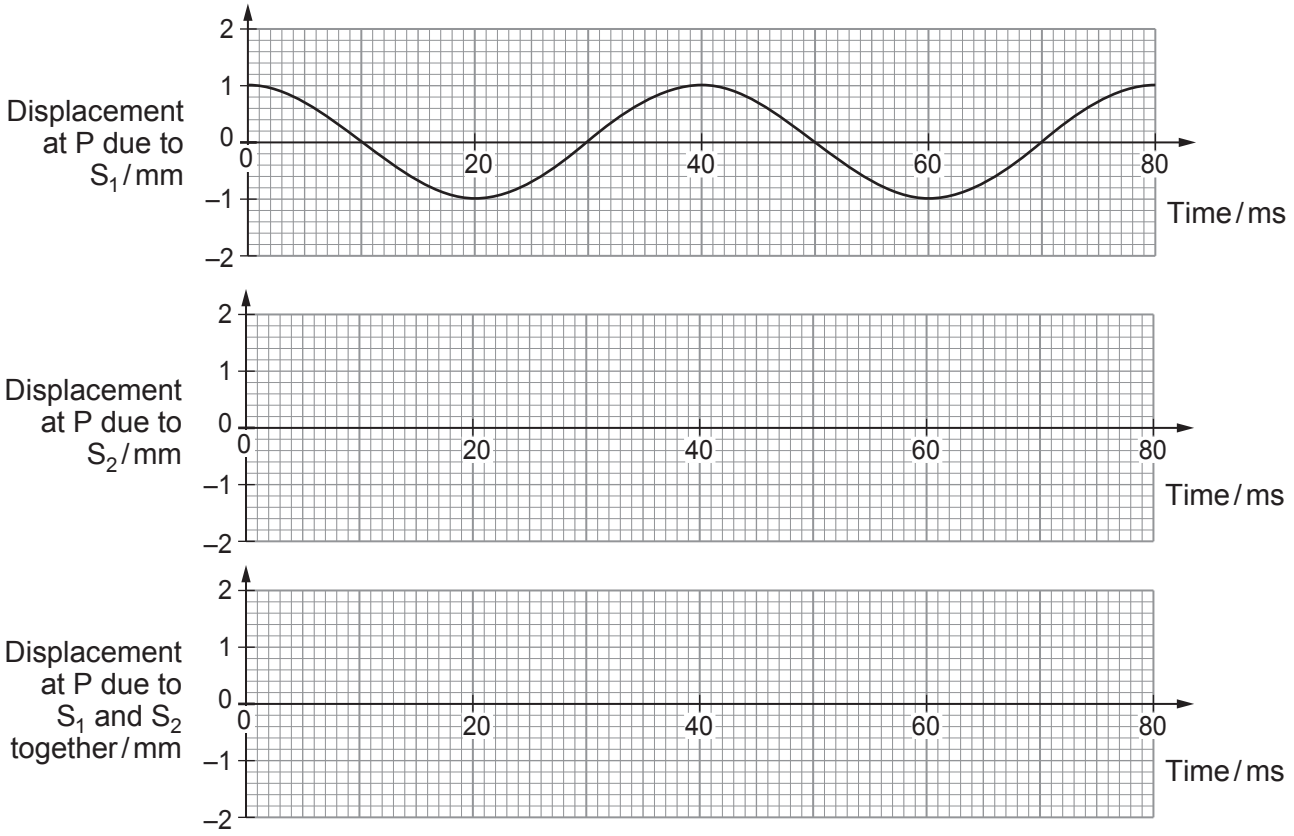
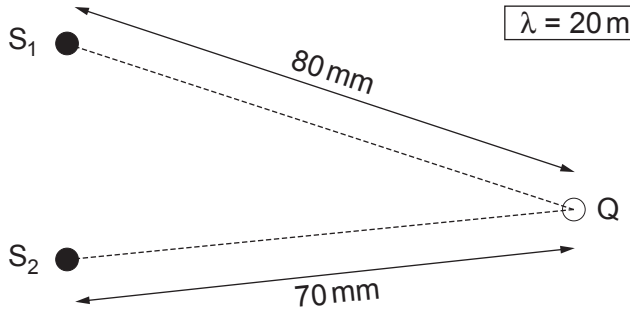


(iii) A student suggests that, with S_1 and S_2 vibrating as before, the displacement at Q (see diagram below) will be zero all the time.

VIEW FROM ABOVE



Evaluate whether or not she is correct, explaining your reasoning. [3]

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(b) Light of wavelength 590 nm is incident normally on a plane diffraction grating. The centres of the grating's slits are 2 000 nm apart.

(i) Calculate the angle to the normal at which **third** order beams emerge. [2]

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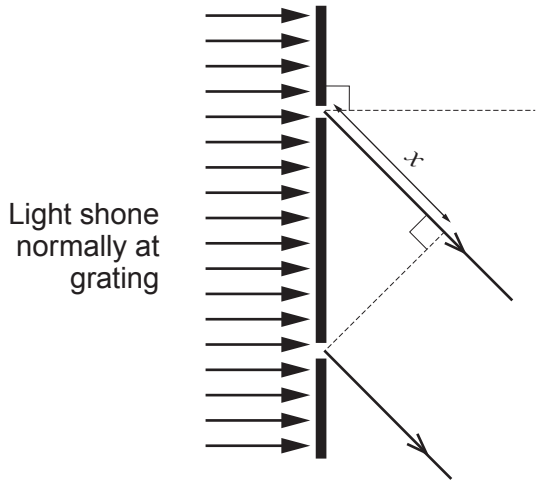
(ii) The diagram shows light emerging **at this angle** from two adjacent slits in the grating.



State the value of x. [1]

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6. (a) The work function of the metal rubidium is 3.62×10^{-19} J. Explain what this statement means. [2]

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(b) The minimum frequency of light that will eject electrons from a surface of work function ϕ is $\frac{\phi}{h}$. Explain in terms of photons why this is so. [3]

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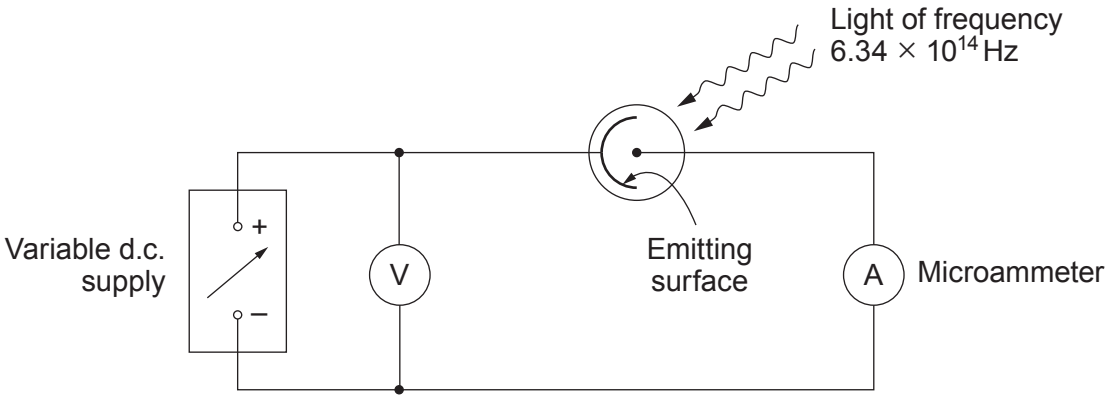
(c) A student has the task of determining whether or not the emitting electrode in a vacuum photocell might be made of rubidium. A light source of known frequency (6.34×10^{14} Hz) is provided. The student sets up the circuit shown.



The student shines the light on the emitting electrode and increases the pd from zero until the current has just fallen to zero. She records this pd (*the stopping pd*) and repeats the procedure, obtaining these results.

Stopping pd / V	0.381	0.366	0.388	0.373	0.371	0.380

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(i) Calculate the mean value and the **absolute** uncertainty of the stopping pd, giving your answers to an appropriate number of significant figures. [3]

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(ii) Evaluate whether or not the student should conclude that the emitting electrode might be made of rubidium. [Work function of rubidium = 3.62×10^{-19} J.] [4]

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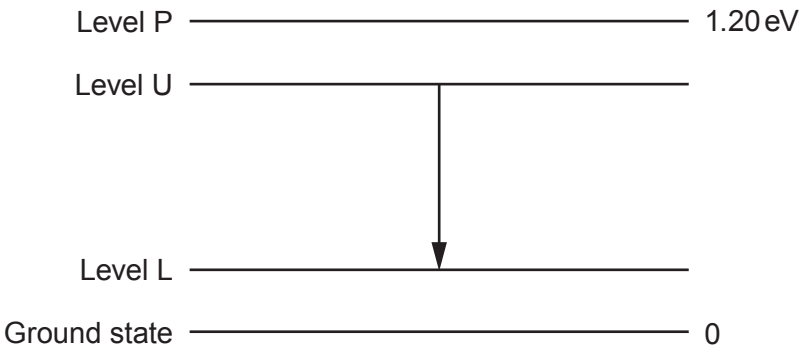
7. A simplified energy level diagram for the amplifying medium of a 4-level laser is shown below. The lasing transition occurs between level U and level L.



(a) (i) The laser is pumped to create a population inversion between level U and level L. State what is meant by a population inversion for **this** laser. [1]

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(ii) **Draw three arrows** on the diagram to show the transitions required for this population inversion to be sustained. [1]

(iii) Explain why a population inversion is needed for light amplification to take place. [3]

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(b) Determine whether or not visible light will be produced by the lasing transition from level U to level L, giving your reasoning. [3]

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TURN OVER FOR THE LAST QUESTION

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8. (a) (i) Explain how *multimode dispersion* arises in a glass fibre. [2]

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(ii) State what feature of a *monomode* fibre prevents multimode dispersion. [1]

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(b)

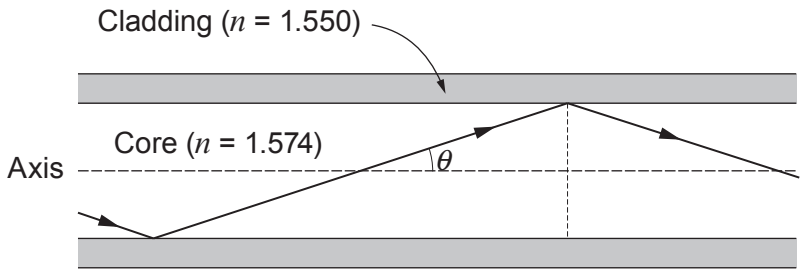

Diagram not drawn to scale

(i) Calculate the largest angle, θ, to the axis (see diagram) at which light can travel for long distances through the core of a multimode fibre, if the refractive index of the core is 1.574, and that of the cladding is 1.550. [3]

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(ii) Explain what would happen to light entering the fibre at an angle to the axis greater than the angle calculated in (b)(i). [2]

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END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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