Surname	Centre Number	Candidate Number
Other Names		2

AS/A LEVEL

2420U20-1

S18-2420U20-1

PHYSICS – AS unit 2
Electricity and Light

FRIDAY, 18 MAY 2018 – MORNING

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**15**	
2.	**7**	
3.	**10**	
4.	**8**	
5.	**7**	
6.	**8**	
7.	**12**	
8.	**13**	
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 pencil or gel pen. Do not use correction fluid.

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 continuation 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 **7*(b)***.

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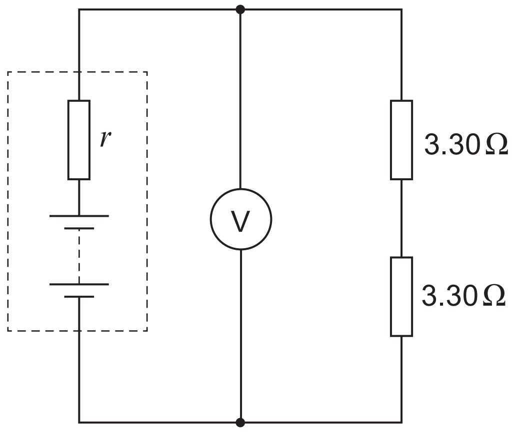
Answer **all** *questions.*

1. *(a)* Two 3.30 Ω resistors are connected in series across a battery of emf 4.80 V as shown. The voltmeter reads 4.33 V.

Diagram 1



(i) State in terms of work or energy what is meant by the emf of a battery. [2]

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(ii) Show that the internal resistance, r, of the battery is approximately 0.7 Ω. [2]

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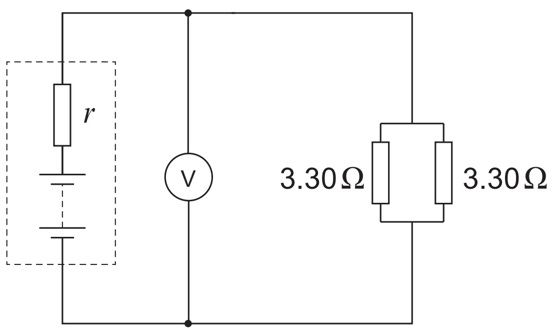
(iii) When the resistors are connected in parallel as shown below, the voltmeter reads 3.35 V.

Diagram 2



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(I) **Without further calculation** explain why you would expect the reading to be lower, now that there is a lower resistance across the cell terminals. [2]

(II) Calculate the number of electrons entering **either** of the resistors (shown in Diagram 2) per **minute**. [3]

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(b) The heating element (a coil of wire) in an electric heater dissipates energy at a rate of 1.00 kW, when connected across the 230 V mains supply. Calculate:

(i) the resistance of the coil; [2]

(ii) the energy dissipated per hour, giving your answer in megajoules (MJ). [1]

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(c) For each megajoule of heat from an electric heater, approximately 0.08 m^3 of gas would have to be burned in a gas-fired electricity power station. For each megajoule of heat from a domestic gas fire or boiler, approximately 0.03 m^3 of gas is burned. Discuss whether the use of electric heaters in houses should be discouraged. Calculations are not required. [3]

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Turn over.

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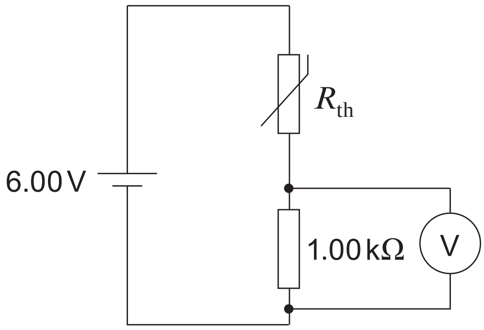
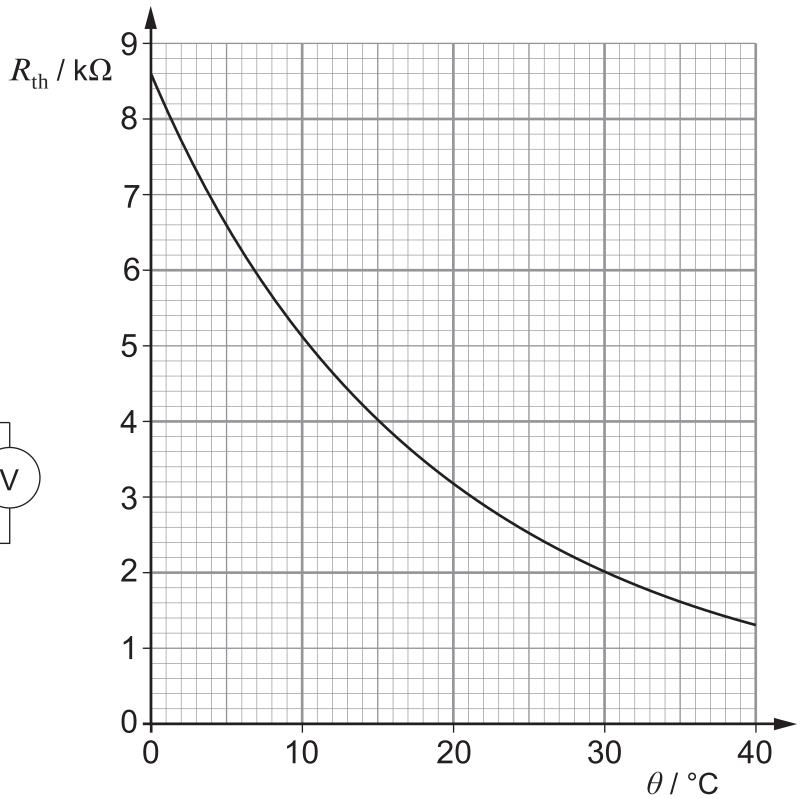
2. The resistance, R_{th}, of the thermistor in the circuit varies with temperature as shown in the graph.





(a) Determine the temperature of the thermistor when the voltmeter reads 1.20 V. [3]

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(b) The set-up can be used as a thermometer, with the thermistor used as a temperature probe. David suggests that there must be a simple rule of the type "an increase of 0.10 V in the voltmeter reading corresponds to a temperature increase of n°C in which n is a constant." Without further calculation, discuss whether he is right. [2]

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(c) Explain why the current through the thermistor must be very low, in order for it to work properly as a probe to measure the temperature of its surroundings. [2]

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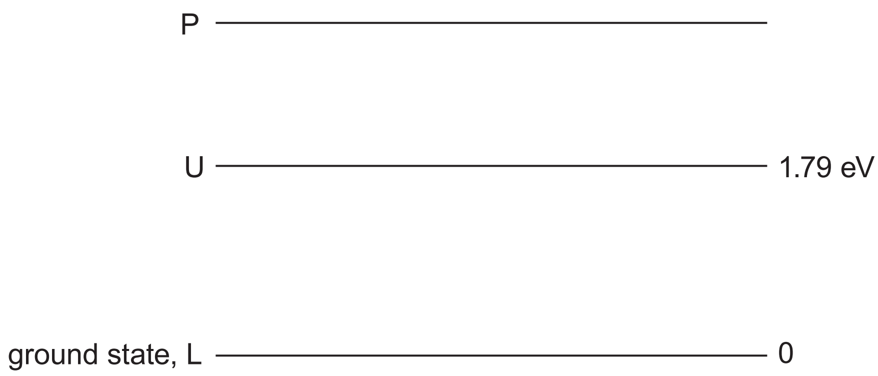
3. A simplified energy level diagram for a 3-level laser system is given.



(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]

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

(i) Show that the number of photons emitted per second is approximately $2 \times 10^{16}\ s^{-1}$. [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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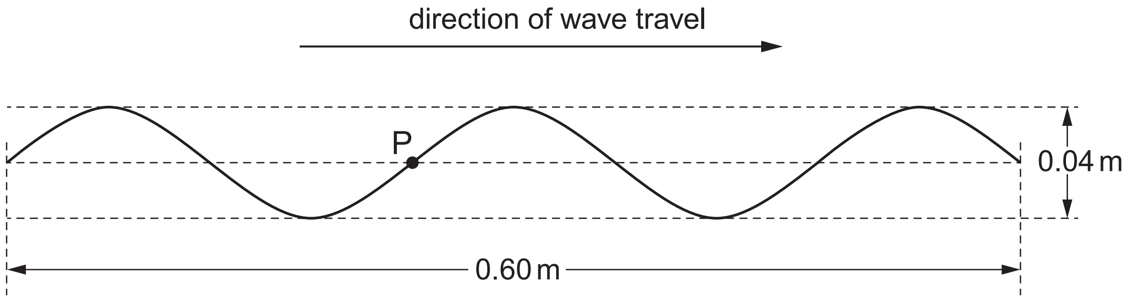
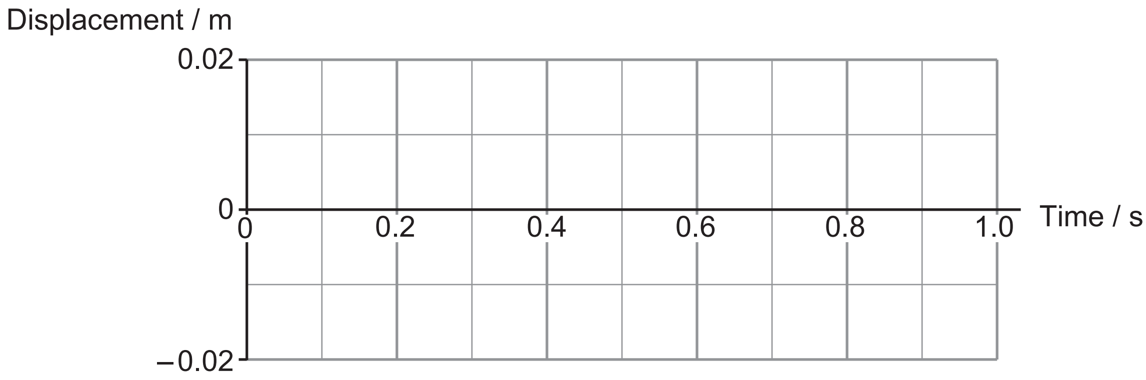
4. *(a)* A progressive wave is travelling from left to right along a stretched string at a speed of $0.40\,m\,s^{-1}$. The diagram shows the string at time $t = 0$.



Carefully sketch, **on the grid below**, a displacement–time graph for point **P** on the string between $t = 0$ and $t = 1\,s$. The space below the grid is for your working. [3]



Space for working:

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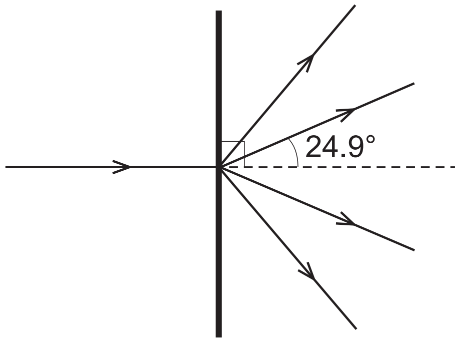
(b) The distance between the centres of the slits in a diffraction grating is 1 500 nm. Monochromatic light is shone normally on to the grating.



(i) First order beams emerge at angles of 24.9° to the normal (see diagram). Calculate the wavelength of the light. [2]

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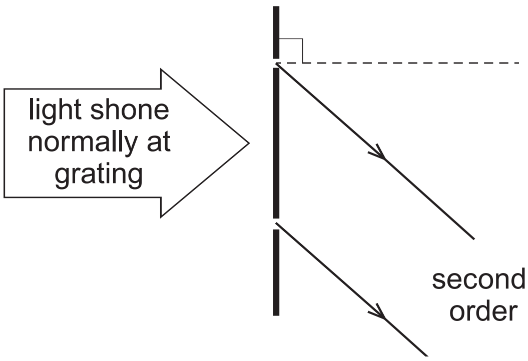
(ii) Explain **in terms of path difference** why the **second** order beams emerge from the diffraction grating at 57.4° to the normal. You will need to add to the diagram (which shows two adjacent slits in the grating). [3]



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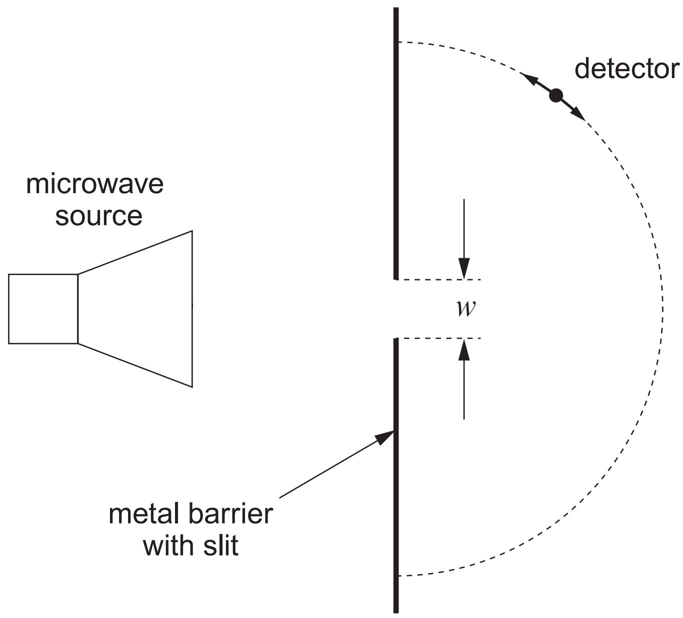
5. *(a)* In the set-up shown, a microwave detector moved along the semi-circular path detects diffracted waves at **all** points around the semicircle.



(i) The width, w, of the gap is 25 mm. What can be deduced about the wavelength of the microwaves? [1]

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(ii) Rhian suggests that making the gap wider will increase the intensity of the microwaves detected. Discuss to what extent she is correct. [2]

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(b) In the set-up shown, slits S_1 and S_2 act as in-phase sources. Rhian detects **minima** of wave intensity at P and Q, and a single maximum between P and Q.

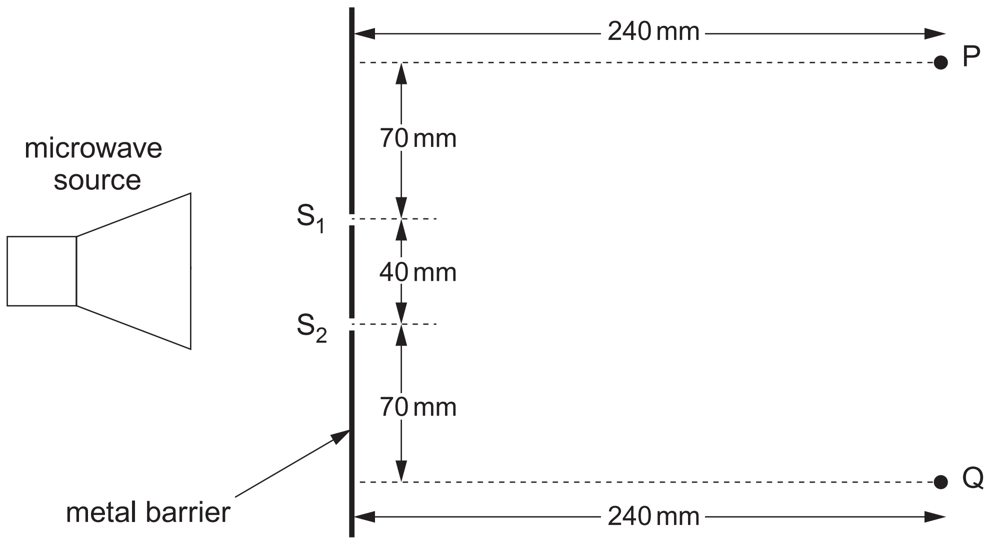

Diagram not to scale

Calculate the path lengths S_1P and S_2P, and **hence** the wavelength of the microwaves. [4]

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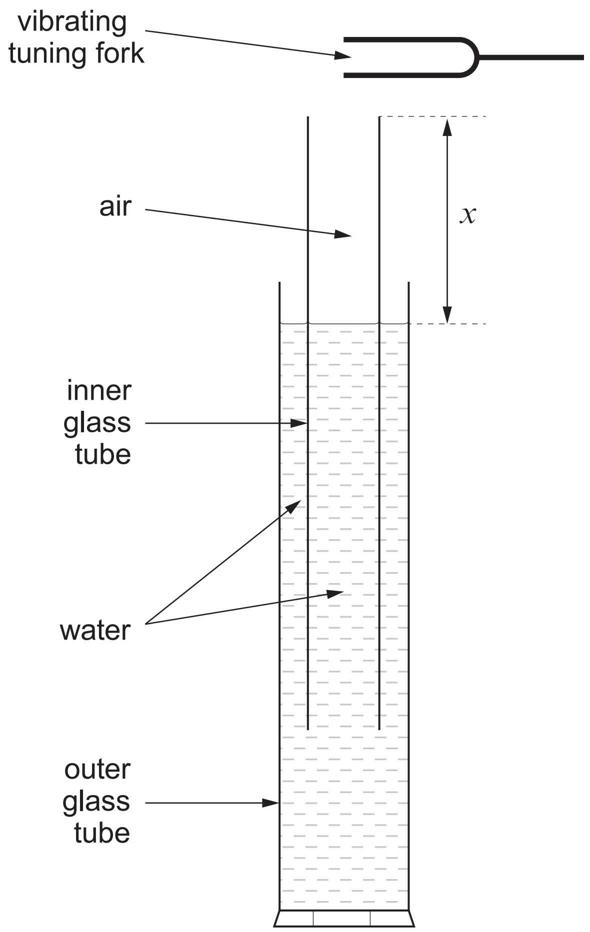
6. Matthew uses the apparatus shown to find a value for the speed of sound in air using stationary waves.



Starting with a very low value of distance x, he gradually raises the inner glass tube. At a certain value of x, the note of the tuning fork is heard loudly. Matthew then measures and records x.

He repeats the procedure several times, obtaining these results.

x / m	0.327	0.329	0.322	0.328	0.332	0.323

The tuning fork frequency, f, is given as 256.0 Hz ± 1%.

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(a) The speed of sound in air, v_s, can be found from the equation:

$$v_s = 4fx$$

(i) Calculate the mean value of x along with its **percentage** uncertainty. [2]

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(ii) Hence calculate the value of v_s along with its **absolute** uncertainty. [2]

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(b) The loud sound is due to stationary waves of frequency, f, in the air column. There is a node of displacement at the water surface and an antinode of displacement close to the open end (top) of the inner glass tube.

(i) Derive the equation: [2]

$$v_s = 4fx$$

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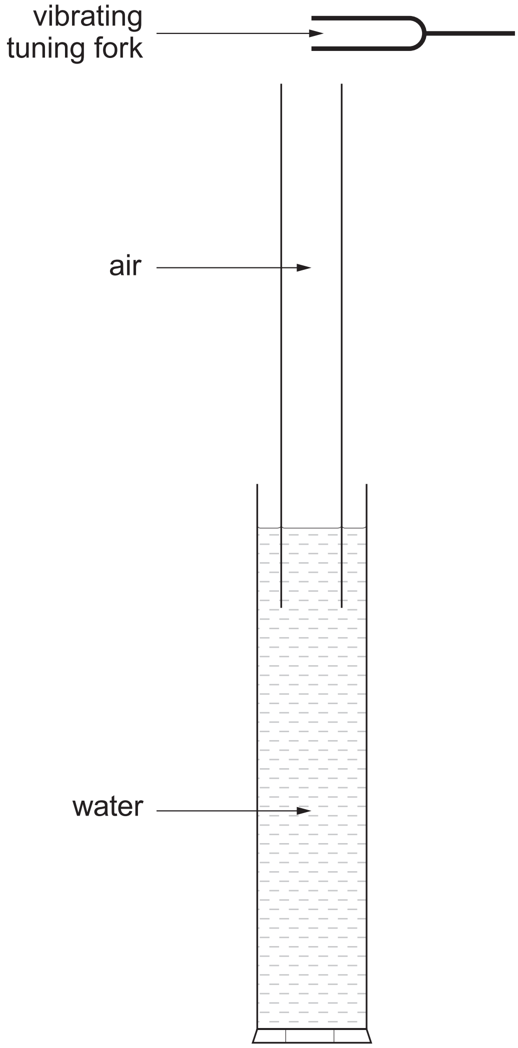
(ii) If the inner glass tube is raised considerably further a second distance is found at which a loud note of frequency, f, is heard. This again corresponds to a stationary wave in the air column. Show the positions of its nodes and antinodes of displacement **on the diagram below**. [2]



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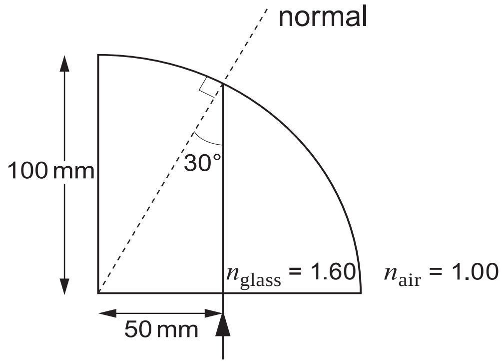
7. *(a)* (i) A narrow beam of light enters a glass block of quarter-circle cross-section, as shown. The refractive index of the glass is 1.60.



Calculate the angle of refraction into the air at the curved surface and carefully sketch the refracted beam **on the diagram**. [Use of a protractor is not required.][3]

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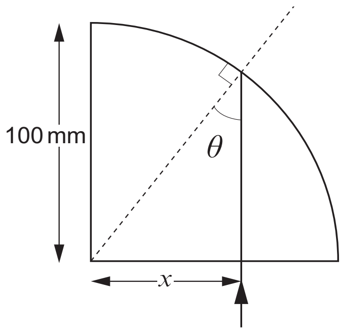
(ii) Calculate the largest distance, x, along the bottom face of the block, at which the beam can enter the block normally, for it to emerge from the curved face. You should refer to the angle θ in your calculation. [3]



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(b) Explain how a multimode (thick) glass fibre transmits light, and why rapid streams of data cannot be transmitted successfully through long lengths of multimode fibre. [6 QER]

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8. *(a)* (i) Light of frequency less than $\frac{\phi}{h}$ cannot eject electrons from a surface of work function ϕ, even if the light intensity is increased. Explain this in terms of photons. [3]

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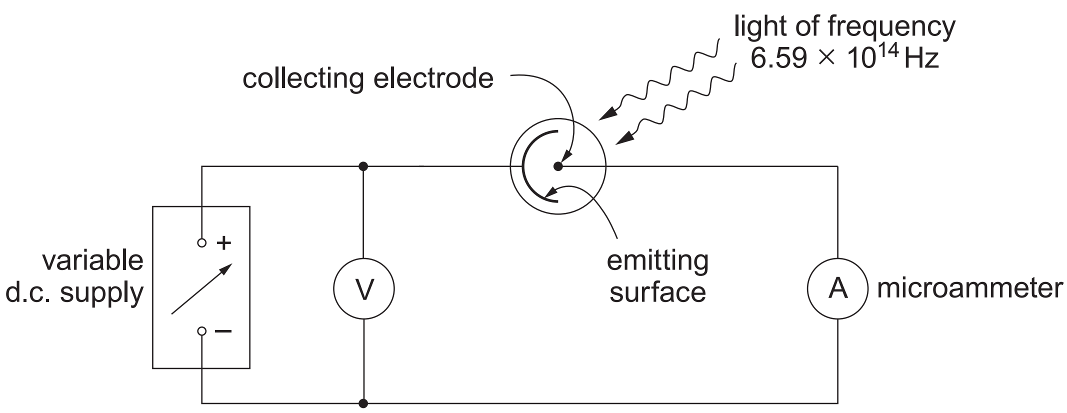
(ii) The emitting surface in a vacuum photocell is known to be made of one of the metals listed below (with their work functions).

Metal	caesium	potassium	barium	calcium	zinc
Work function / 10^{-19} J	3.12	3.68	4.03	4.59	5.81

The photocell is included in the circuit shown, and illuminated with light of frequency 6.59×10^{14} Hz.



With zero pd applied, the microammeter indicates a current. At some pd between 0 V and 0.35 V the microammeter reading drops to zero.

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Determine which metal the emitting surface is made of, giving your reasoning clearly. [4]

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TURN OVER FOR THE REST OF THE QUESTION

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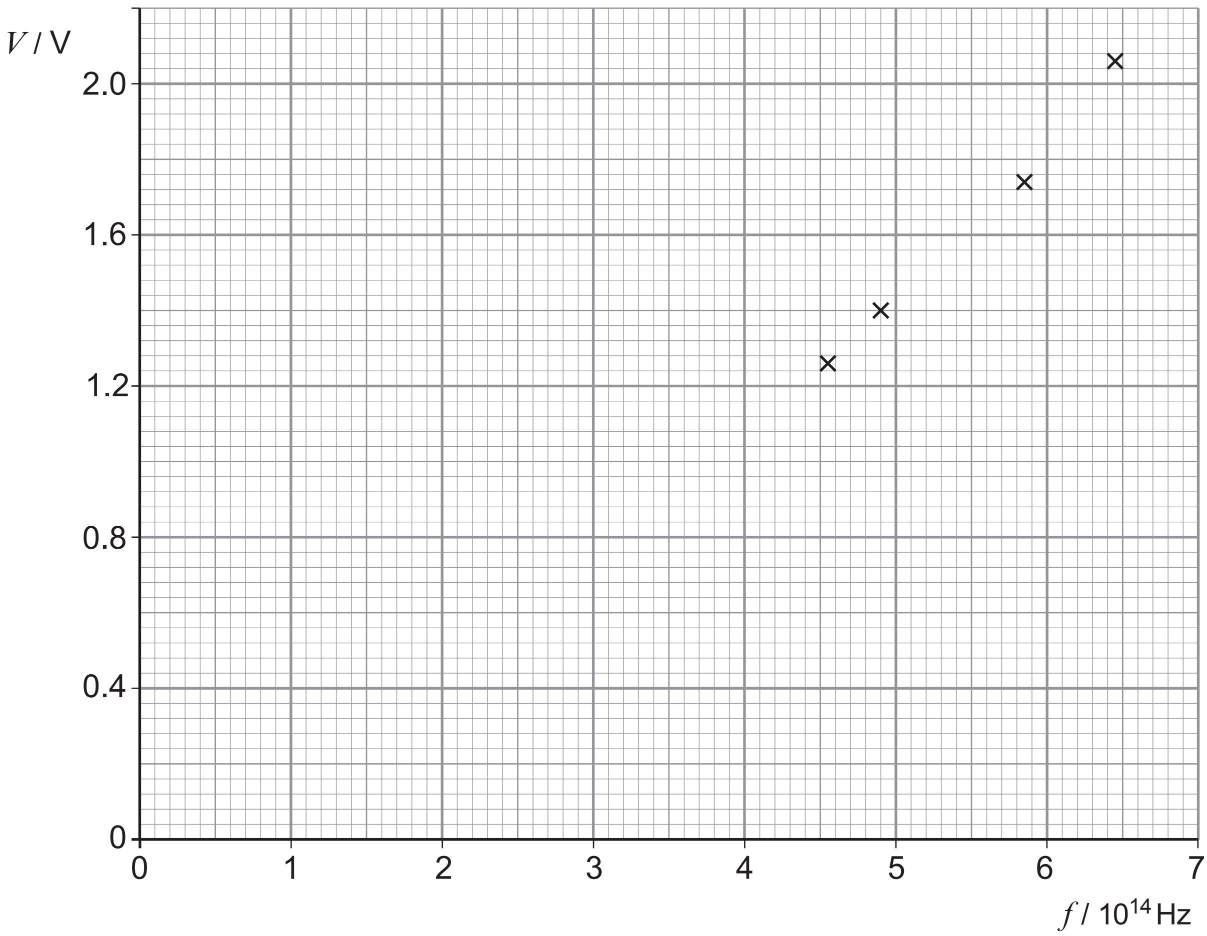
(b) Rachel varies the pd across a light-emitting diode (LED) and notes the value, V, for which she can just see light from the LED. She also notes the frequency, f, of the light, as supplied by the LED's makers. She does the same for three other LEDs and plots V against f (below).



It has been suggested that V and f are related by the equation:

$$V = \frac{h}{e} f$$

(i) **On the graph** draw the line of best fit. [1]

(ii) Discuss the extent to which the graph supports an equation of this form. [2]

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(iii) Determine the gradient of the graph, and hence a value for h to an appropriate number of significant figures. Assume that the equation predicts $\dfrac{\Delta V}{\Delta f}$ correctly. [3]
Show your working clearly.

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END OF PAPER

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

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