Surname	Centre Number	Candidate Number
First name(s)		2

GCE AS/A LEVEL

2420U20-1

S23-2420U20-1

WEDNESDAY, 24 MAY 2023 – AFTERNOON

PHYSICS – AS unit 2
Electricity and Light

1 hour 30 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**13**	
2.	**11**	
3.	**12**	
4.	**10**	
5.	**10**	
6.	**8**	
7.	**7**	
8.	**9**	
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(s) at the back of the booklet taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

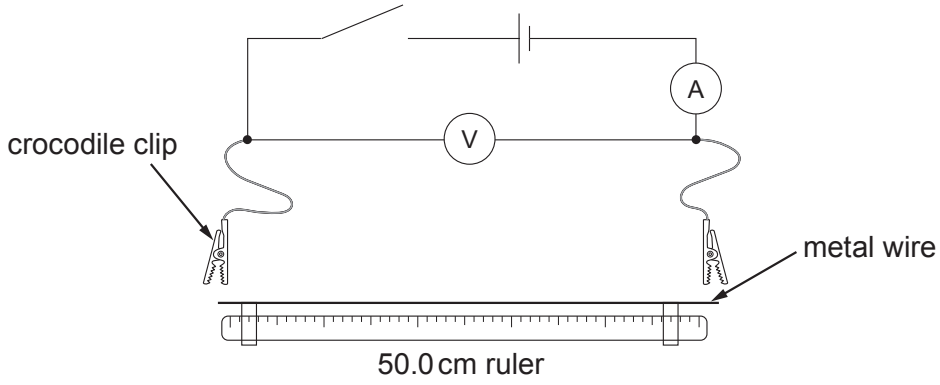
The total number of marks available for this paper is 80.

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

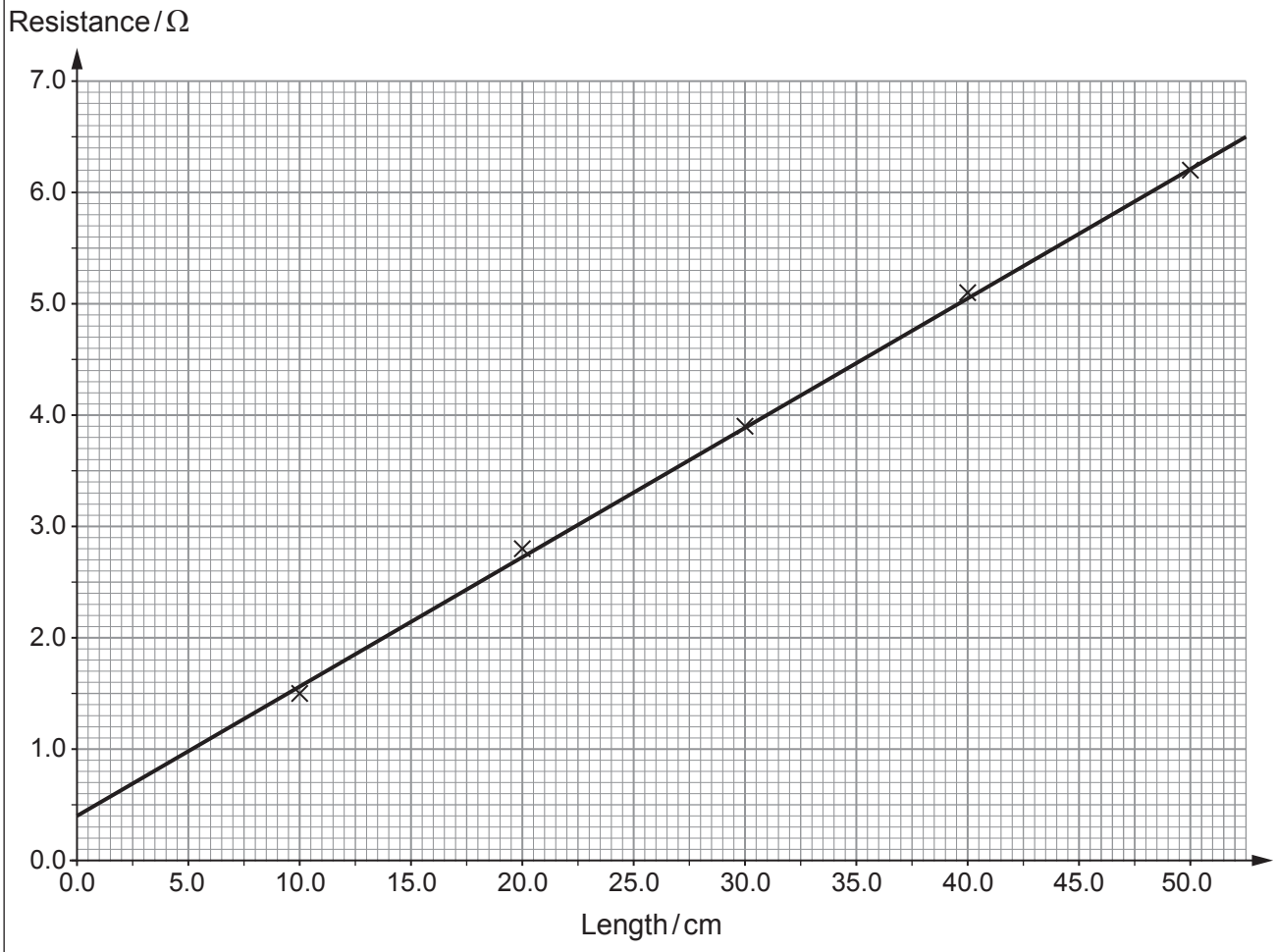
The assessment of the quality of extended response (QER) will take place in question **3**(b).

Answer **all** questions.

1. (a) Emily sets up the following circuit in order to investigate how the resistance of a metal wire varies with length.



Emily connects one crocodile clip on the wire at the 0.0 cm mark while the other clip is moved along at suitable intervals to cover the whole range of the wire. She obtains results as shown in the graph below.



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(i) Use the graph to obtain a value for the resistance at 0.0 cm and suggest the cause of this resistance. [2]

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(ii) Discuss to what extent Emily's results confirm that the variation of resistance of the wire with length is consistent with the equation: [3]

$$R = \frac{\rho l}{A}$$

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(iii) The wire used in the experiment has a mean **diameter** of 0.23 mm. Name a measuring instrument that could have been used to take this reading **and** state its likely resolution. [2]

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(iv) Use the graph and the mean diameter to determine the resistivity of the metal of the wire. [4]

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(b) Emily used a 1.5 V cell in her experiment as she was concerned about the size of the electrical current in the wire. Suggest her reasons for using the 1.5 V cell. [2]

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2. (a) Define the emf of a cell. [2]

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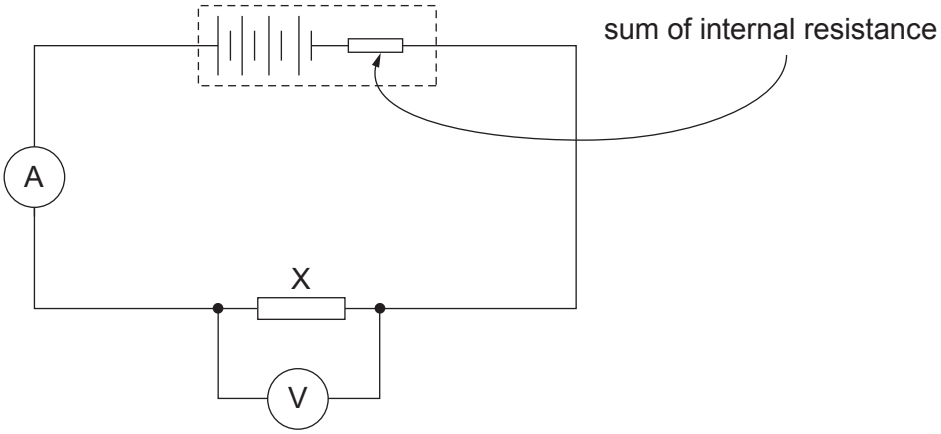
(b) Four identical cells each having an emf of 1.50 V are connected in series to form a 6.00 V battery. The battery is connected across resistor X as shown.



The reading on the ammeter is 0.30 A and the reading on the voltmeter is 5.40 V.

(i) Show that the resistance of resistor X is 18 Ω. [1]

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(ii) Determine the value of the internal resistance of **each individual cell**. [3]

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(iii) Calculate the total power dissipated in the internal resistance of the 6.00 V battery. [2]

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(iv) Resistor X is now replaced with a different resistor, Y. Resistor Y has half the resistance of resistor X. Seren states 'as the resistance is halved, the power dissipated in the internal resistance of the battery will be twice that with resistor X.' Evaluate Seren's claim. [3]

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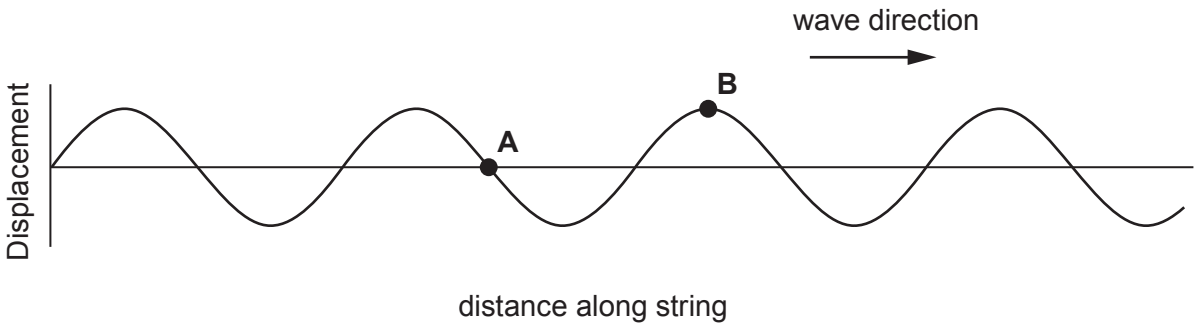
3. (a) A vibration generator attached to one end of a string produces a progressive wave on the string as shown in the diagram (for time $t = 0$). The wavelength of the waves is 15.0 cm.



(i) State what is meant by the amplitude of a progressive wave. [1]

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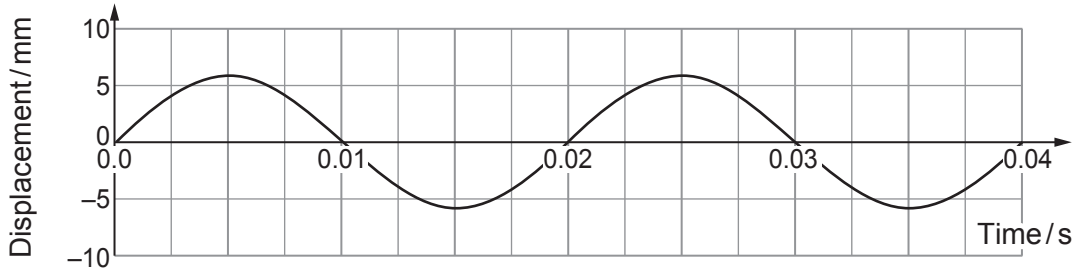
(ii) The following graph shows the displacement of point **A** with respect to time.



Determine the speed of the wave. [3]

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(iii) Sketch the displacement-time graph of point B **on the grid in** (a)(ii). [2]

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(b) The progressive wave set-up in part (a) can be modified in order to create a stationary wave pattern. Explain how a stationary wave is formed **and** describe the similarities and differences between a stationary wave and a progressive wave. [6 QER]

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4. Some students investigate the superposition of sound waves. Two identical loudspeakers (S_1 and S_2) are connected to the same signal generator and act as coherent sources.

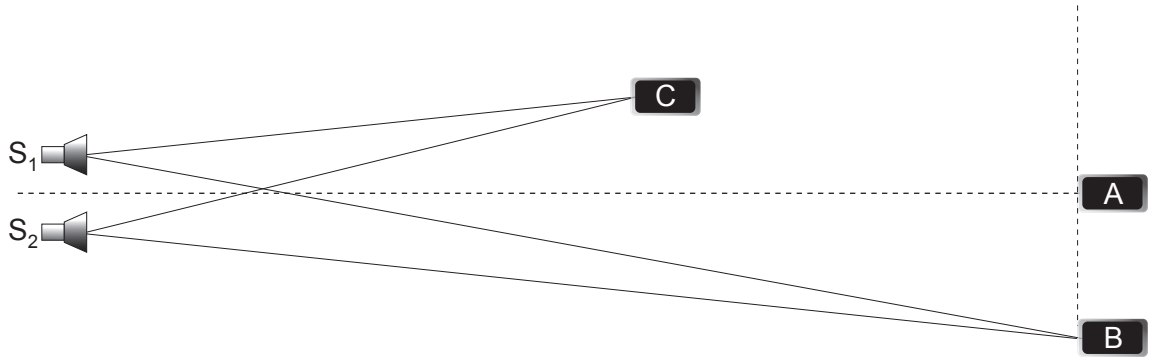

Diagram not drawn to scale

The students use an app on their mobile phones to measure the intensity of the sound signal at different positions in the classroom. Mobile phone A detects a maximum of intensity on the central line. Mobile phone B detects the **first** maximum away from the central maximum.

(a) Explain what is meant by coherent sources. [1]

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(b) (i) The distance S_1B is 8.0 m and the distance S_2B is 7.4 m. State what is meant by the term path difference **and** hence explain why the wavelength of the sound wave must be 0.60 m. [2]

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(ii) Mobile phone C detects a minimum intensity. Determine **two** possible values of the distance ($S_2C - S_1C$). [2]

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(c) (i) State the principle of superposition. [2]

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(ii) Loudspeaker S_2 develops a fault whose only effect is to reduce the amplitude of the sound waves it emits. Explain why the intensities at A and B decrease **and** the intensity at C increases. [3]

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5. (a) Define the refractive index of a material. [1]

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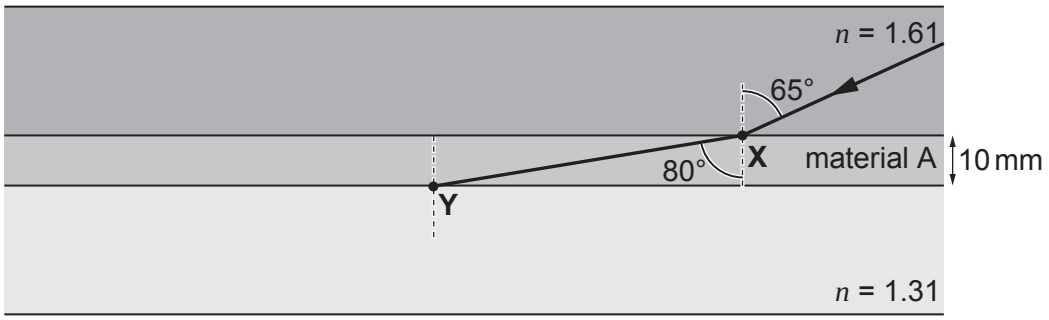
(b) Material A of unknown refractive index, n, is sandwiched between two rectangular blocks of different refractive indices. A ray of light travels from the top block into material A as shown.



(i) Show that the refractive index of material A is approximately 1.5. [2]

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(ii) Determine the time taken for the ray of light to travel through material A from X to Y. [3]

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(c) (i) Confirm that total internal reflection will occur at Y. [3]

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(ii) **On the diagram opposite** continue the path of the light ray inside material A. [1]

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6. (a) State what is meant by the work function, ϕ , of a metal surface. [1]

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(b) Sodium will undergo the photoelectric effect when illuminated by visible light, but zinc requires ultraviolet radiation. **Explain** which material has the greater work function. [1]

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(c) (i) Use Einstein's photoelectric effect equation to show that the maximum wavelength, λ_{max}, for emission is given by the equation: [2]

$$\lambda_{max} = \frac{hc}{\phi}$$

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(ii) A mixture of red (λ = 650 nm), green (λ = 550 nm) and blue (λ = 450 nm) light is incident on a metal surface of work function of 3.7×10^{-19} J. Determine which wavelength or wavelengths of light will be **unable** to release electrons from the metal surface. [2]

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(iii) Explain, in terms of photons, whether or not the intensity of the light will affect the maximum kinetic energy of the released electrons. [2]

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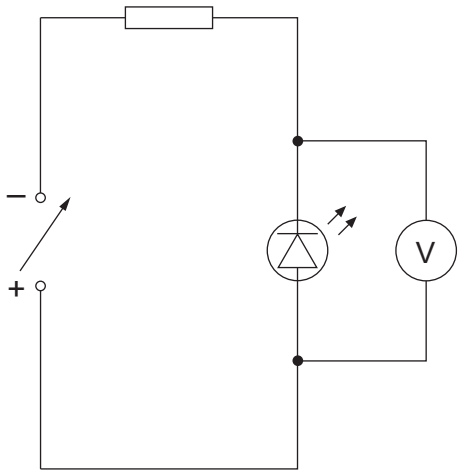
7. (a) Lewis uses the following circuit to find the minimum pd, V_{min}, across an LED at which light is emitted by the diode. He collects his data in a dark room where he varies the pd of the power supply until the LED lights.



Lewis measures the minimum pd, V_{min}, five times and his results are shown below.

V_{min}/V	1.81	1.87	1.93	1.84	1.90

(i) Determine the mean value for V_{min} along with its **percentage** uncertainty. [3]

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(ii) Lewis uses the following equation to calculate the wavelength of the light expected to be produced by the LED:

$$eV_{\min} = \frac{hc}{\lambda}$$

Calculate the mean value for λ and its **absolute** uncertainty. [3]

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(b) Lewis noted the value for $V_{\min}$ when he noticed that the LED had turned on. Suggest an improvement to his method. [1]

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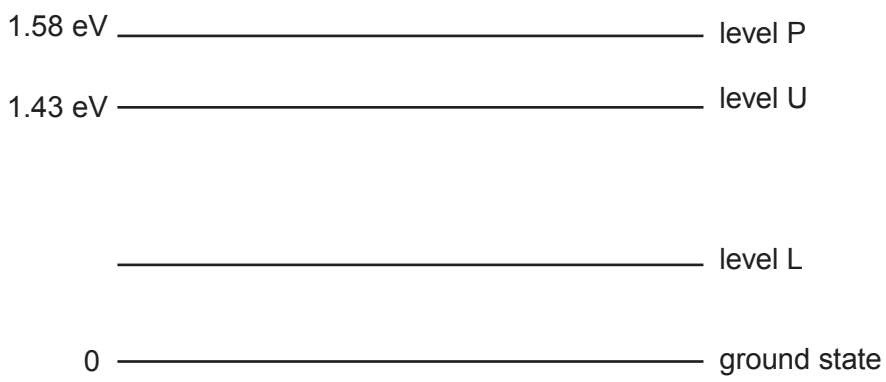
8. The following diagram shows the energy levels for the amplifying medium in a 4-level gas laser.



(a) The laser transition between level U and level L produces stimulated photons of wavelength 1.06×10^{-6} m. Determine the value of energy level L in **eV**. [3]

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(b) When explaining the operation of this laser, a student writes the following:

Pumping is required to move electrons from ground level to level P which is a metastable state. This creates a population inversion between P and ground which is needed for the laser to work.

State **two** mistakes in the student's explanation. [2]

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(c) Semiconductor lasers are regularly used in DVD players and bar code scanners. State **two** advantages that these semiconductor lasers have over gas lasers. [2]

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(d) As electronic technology advances, outdated electronic devices and their components are discarded. It has been estimated that 50 million tonnes of electronic waste is produced each year and roughly 80% of this is finding its way into landfill. Discuss the effects this electronic waste may have on society. [2]

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END OF PAPER

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