Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Thursday 18 January 2024

Morning (Time: 1 hour 30 minutes) | **Paper reference** **WPH12/01**

Physics

International Advanced Subsidiary/Advanced Level
UNIT 2: Waves and Electricity

You must have:
Scientific calculator, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*
- **Show all your working out** in calculations and **include units** where appropriate.

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- The list of data, formulae and relationships is printed at the end of this booklet.

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 A ray of light in air is incident on a glass surface. The angle of incidence is less than the critical angle.

Which of the following describes what happens to the ray of light?

☒ **A** partially reflected and partially transmitted

☒ **B** refracted away from the normal

☒ **C** totally internally reflected

☒ **D** transmitted along the normal

(Total for Question 1 = 1 mark)

2 There is an increase in the intensity of light incident on a light dependent resistor (LDR). This causes a change in the number of conduction electrons and a change in the resistance of the LDR.

Which row of the table describes these changes?

		Number of conduction electrons	Resistance of LDR
☒	**A**	decreases	decreases
☒	**B**	decreases	increases
☒	**C**	increases	decreases
☒	**D**	increases	increases

(Total for Question 2 = 1 mark)

3 An electron has a de Broglie wavelength of 3.5×10^{-10} m.

Which of the following expressions gives the velocity of the electron in $m\,s^{-1}$?

☒ **A** $\dfrac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 3.5 \times 10^{-10}}$

☒ **B** $\dfrac{6.63 \times 10^{-34}}{3.5 \times 10^{-10}}$

☒ **C** $\dfrac{9.11 \times 10^{-31} \times 3.5 \times 10^{-10}}{6.63 \times 10^{-34}}$

☒ **D** $\dfrac{3.5 \times 10^{-10}}{6.63 \times 10^{-34}}$

(Total for Question 3 = 1 mark)

4 Which of the following describes a change in energy of 1 eV?

☒ **A** A charge of 1 C is accelerated across a potential difference of 1 V.

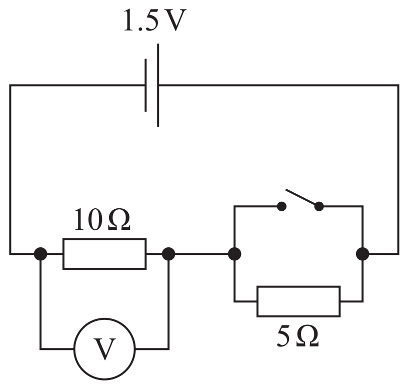
☒ **B** A charge of 1 C passes a point in a time of 1 s.

☒ **C** An electron is accelerated across a potential difference of 1 V.

☒ **D** There is a current of 1 A for a time of 1 s.

(Total for Question 4 = 1 mark)

5 The diagram shows a 1.5 V cell in a circuit with two resistors. The cell has negligible internal resistance.



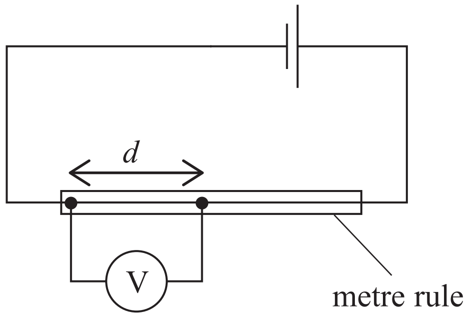
The switch is closed.

What is the reading on the voltmeter?

- ☒ **A** 0.15 V
- ☒ **B** 0.50 V
- ☒ **C** 1.00 V
- ☒ **D** 1.50 V

(Total for Question 5 = 1 mark)

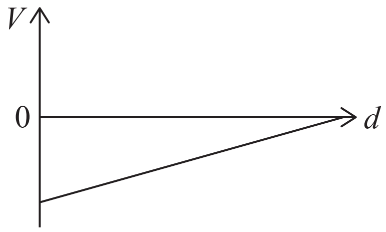
6 A uniform wire is attached to a metre rule. The wire is connected in a circuit as shown.



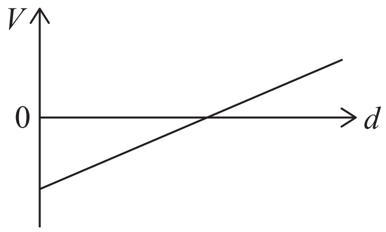
The distance *d* between the connections to the voltmeter is increased. The reading *V* on the voltmeter changes.

Which graph shows the relationship between *V* and *d*?

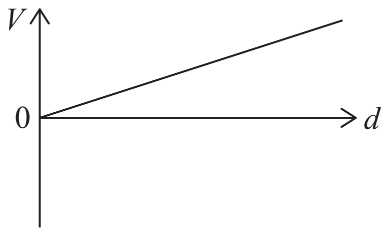
☒ **A**



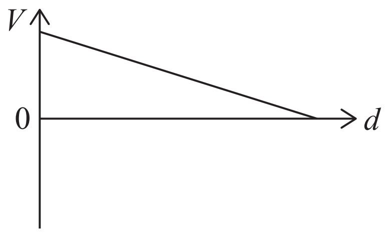
☒ **B**



☒ **C**



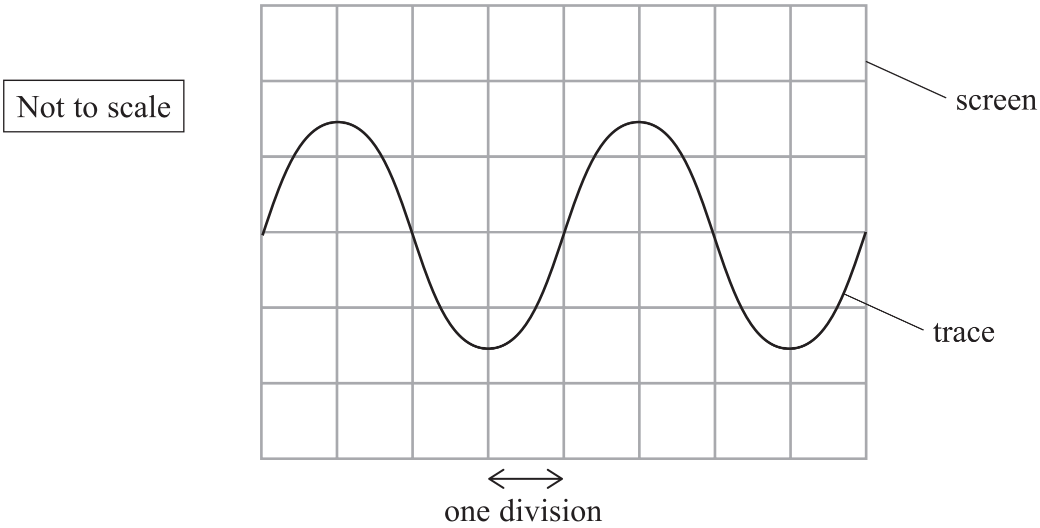
☒ **D**



(Total for Question 6 = 1 mark)

7 A microphone is attached to an oscilloscope. The microphone detects a sound.

The trace displayed on the oscilloscope screen is shown.



One horizontal division represents a time of 0.015 s.

Which of the following expressions gives the frequency of the sound in Hz?

☒ **A** 4×0.015

☒ **B** 2×0.015

☒ **C** $\dfrac{1}{2 \times 0.015}$

☒ **D** $\dfrac{1}{4 \times 0.015}$

(Total for Question 7 = 1 mark)

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P 7 5 5 9 7 A 0 6 3 6

8 At a distance d from a point source of light, the light intensity is I.

Which of the following expressions gives the light intensity at a distance $2d$ from the source?

☒ **A** $\frac{I}{2}$

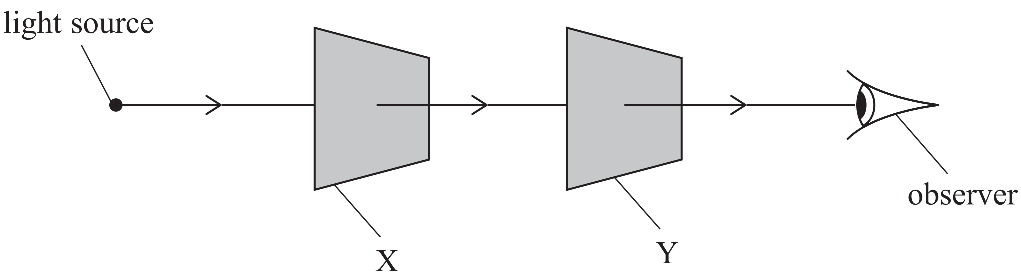
☒ **B** $\frac{I}{4}$

☒ **C** $\frac{I}{2\pi d^2}$

☒ **D** $\frac{I}{4\pi d^2}$

(Total for Question 8 = 1 mark)

9 Two polarising filters, X and Y, are arranged between a light source and an observer as shown.



The intensity of light reaching the observer is a maximum.

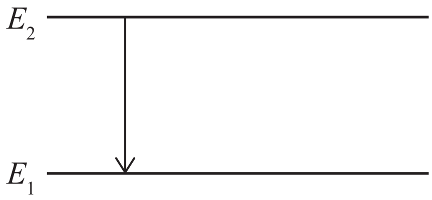
The observer rotates filter X. The observer then rotates filter Y so that the intensity of light is a maximum again.

Which row of the table shows possible angles of rotation for the filters?

		Angle of rotation of X	Angle of rotation of Y
☒	**A**	90°	180°
☒	**B**	180°	270°
☒	**C**	270°	90°
☒	**D**	360°	270°

(Total for Question 9 = 1 mark)

10 In an atom, an electron drops from energy level E_2 to energy level E_1, as shown.



A photon of wavelength λ is emitted.

Which of the following expressions gives the energy E_2?

☒ **A** $\frac{hc}{\lambda} - E_1$

☒ **B** $\frac{hc}{\lambda} + E_1$

☒ **C** $\frac{h\lambda}{c} - E_1$

☒ **D** $\frac{h\lambda}{c} + E_1$

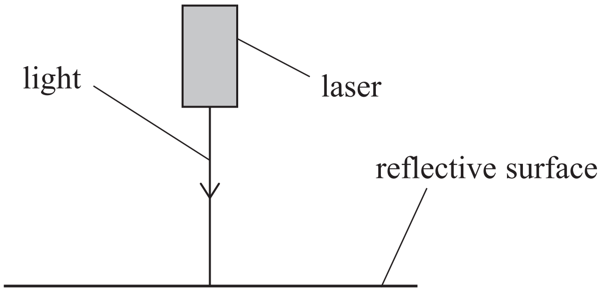
(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 Light from a laser is incident at 90° to a reflective surface, as shown.



(a) Light from the laser is coherent.

State what is meant by coherent.

(1)

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(b) State why a standing wave forms between the laser and the reflective surface.

(1)

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(Total for Question 11 = 2 marks)

12 A circuit contains a filament bulb. When the potential difference across the filament is 8.9 V, the resistance of the filament is 7.5 Ω.

Calculate the time taken for a charge of 5.0 C to flow past a point in the filament.

Time taken = ...

(Total for Question 12 = 3 marks)

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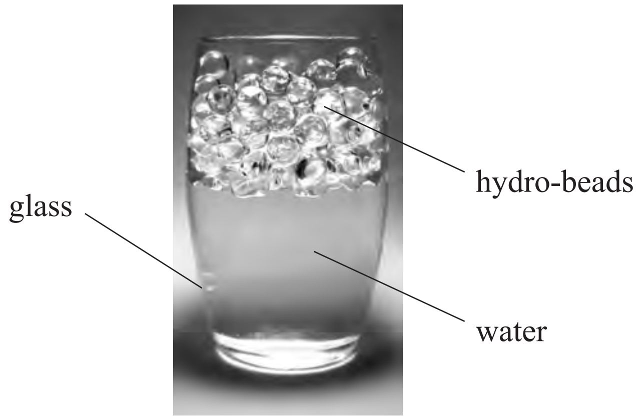
13 A glass is filled with transparent 'hydro-beads'. The glass is then half-filled with water. The beads under the surface of the water seem to disappear, as shown.



(a) The refractive index of the hydro-beads is very similar to the refractive index of water.

Explain why the hydro-beads are difficult to see when surrounded by water.

(2)

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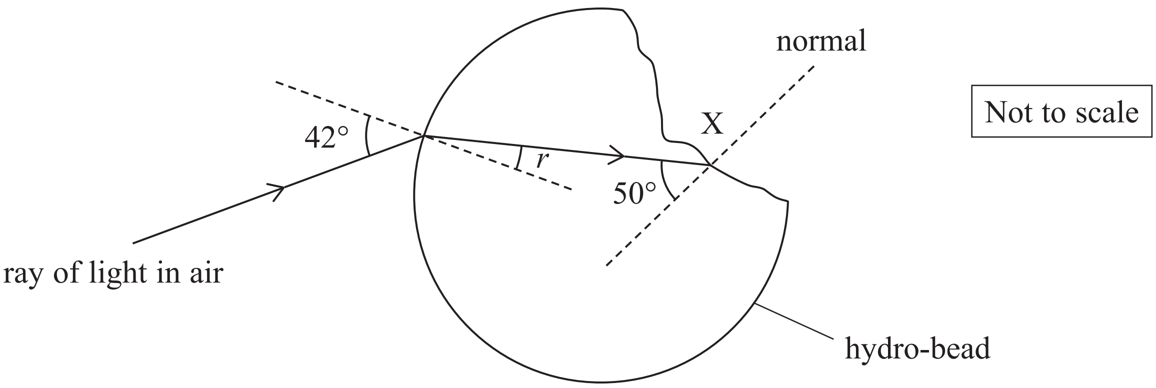
(b) A ray of light in air is incident on a damaged hydro-bead. The diagram shows the ray until it is incident on the damaged surface at position X.

The refractive index of the material of the hydro-bead is 1.38



(i) Calculate the angle of refraction r.

(2)

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r = ...

(ii) Complete the diagram to show what happens to the ray at position X.

Your answer should include a calculation.

(3)

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(Total for Question 13 = 7 marks)

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14 A student investigated the e.m.f. and internal resistance of a battery.

(a) The student connected a high resistance voltmeter across the battery. The battery was not connected to any other components.

Explain why the reading on the voltmeter gave the e.m.f. of the battery.

(2)

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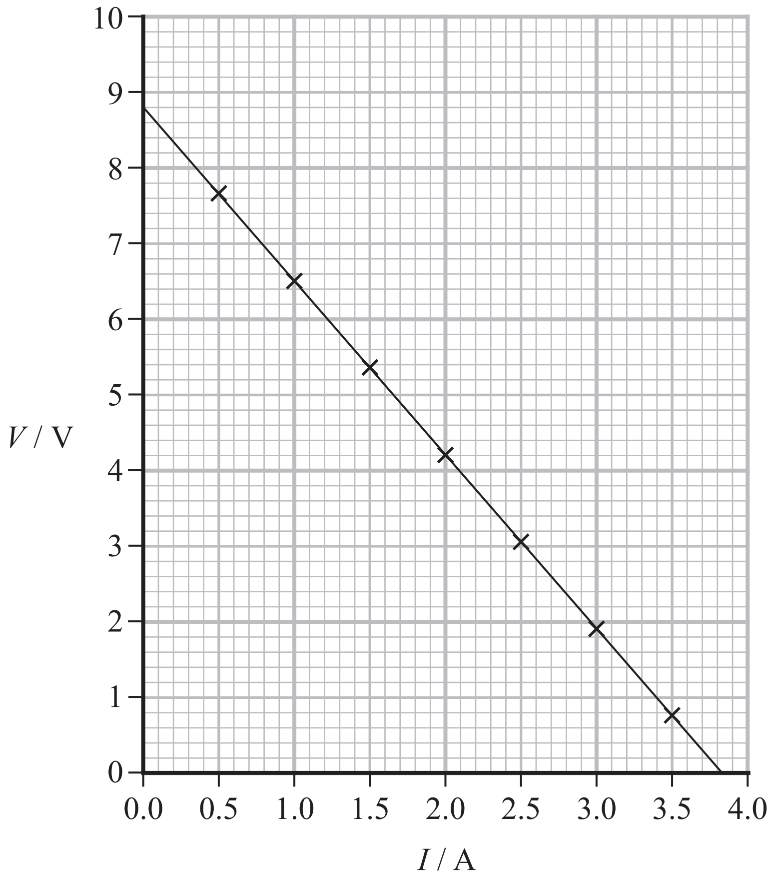
(b) The student investigated how the potential difference *V* across the battery varied with the current *I* in the battery.

Draw a circuit diagram for this investigation.

(2)

(c) The student plotted her results on a graph as shown.



(i) Determine the e.m.f. and internal resistance of the battery.

(3)

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e.m.f. = ...

Internal resistance = ...

(ii) Explain why there is a maximum current that can be supplied by the battery.

(2)

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(Total for Question 14 = 9 marks)

15 The photograph shows a musical instrument called a harp.

When a harp string is plucked, transverse waves travel along the string forming a standing wave.

(a) State what is meant by a transverse wave.

(1)

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(b) The diagram represents one string of the harp.

The string is fixed at both ends.

The string is made to vibrate at its lowest frequency.

Add to the diagram to show the stationary wave on the string. You should label any nodes and antinodes.

(2)

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(c) One string produces sound with a frequency of 196 Hz. The wavelength of the wave on the string is 0.72 m. The tension in the string is 41 N.

This string breaks and needs replacing with a new string.

The table shows the mass of four new strings, A, B, C and D.
Each new string has a length of 1.5 m.

String	Mass of string / g
A	1.5
B	3.1
C	4.4
D	6.3

The new string is cut to the same length as the broken string, and is placed under the same tension.

Deduce which new string, A, B, C or D, should be used to replace the broken string.

(4)

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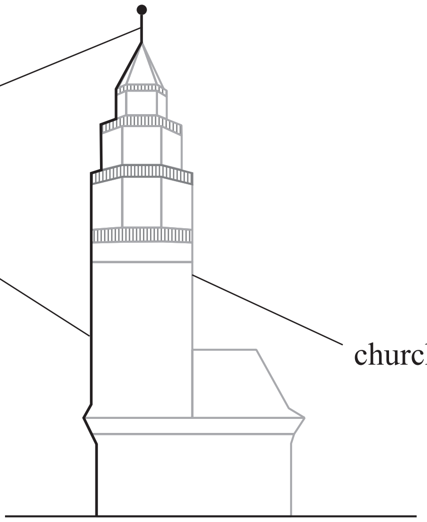
(Total for Question 15 = 7 marks)

16 A metal rod on top of a church may have been the world's first lightning conductor.

The metal rod is connected to the ground by a steel cable as shown.



When lightning strikes, charge is transferred to the metal rod and is conducted to the ground through the steel cable.

(a) The steel cable has a diameter of 12 mm. The total resistance of the cable is 0.078 Ω.

Calculate the total length of the cable.

resistivity of steel = $1.4 \times 10^{-7}\,\Omega\,m$

(3)

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Total length of cable = ...

(b) During a lightning strike, there was a potential difference (p.d.) of 1.5×10^8 V between the metal rod and the ground. This p.d. caused a current of 1.2×10^4 A in the cable for a time of 70 μs.

Calculate the work done as the charge is conducted to the ground.

(2)

Work done = ...

(c) The steel cable is replaced with a copper cable. The copper cable has the same length and diameter as the steel cable.

During a thunderstorm, the p.d. between the metal rod and the ground is the same for the copper cable as it was for the steel cable.

Copper has a lower resistivity than steel. There is a greater number of conduction electrons per unit volume in copper than in steel.

A student states that the drift velocities of electrons will be the same in both cables.

Assess the student's statement.

(3)

(Total for Question 16 = 8 marks)

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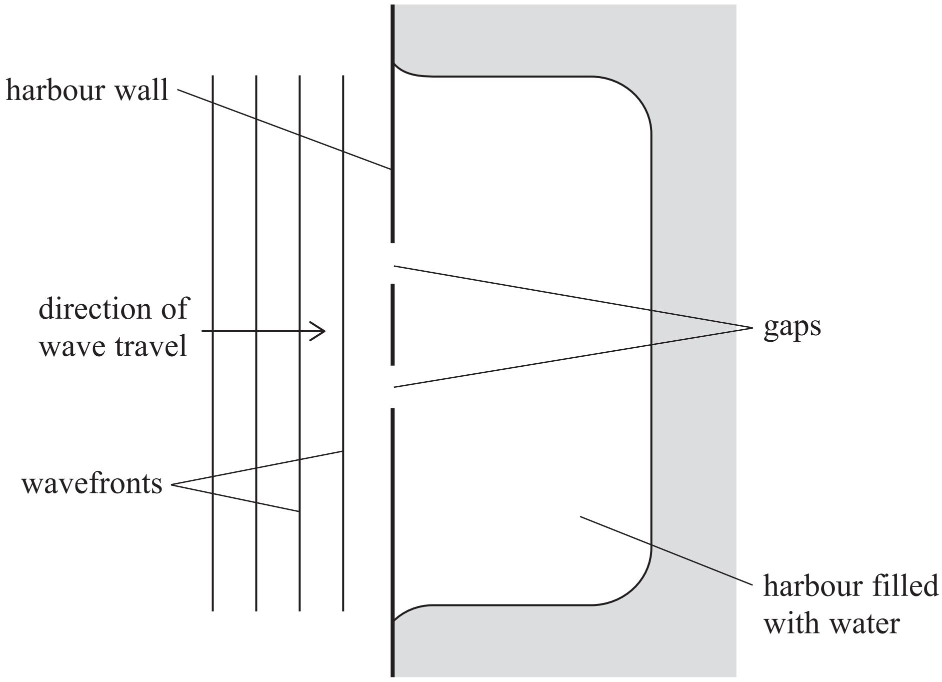
17 Boats can shelter from waves on the sea in a harbour.

The diagram shows a harbour where boats can enter and leave through two gaps in the harbour wall.



Waves on the sea are diffracted as they pass through the gaps in the harbour wall.

(a) Describe how Huygens' construction can be used to predict the shape of diffracted wavefronts.

(2)

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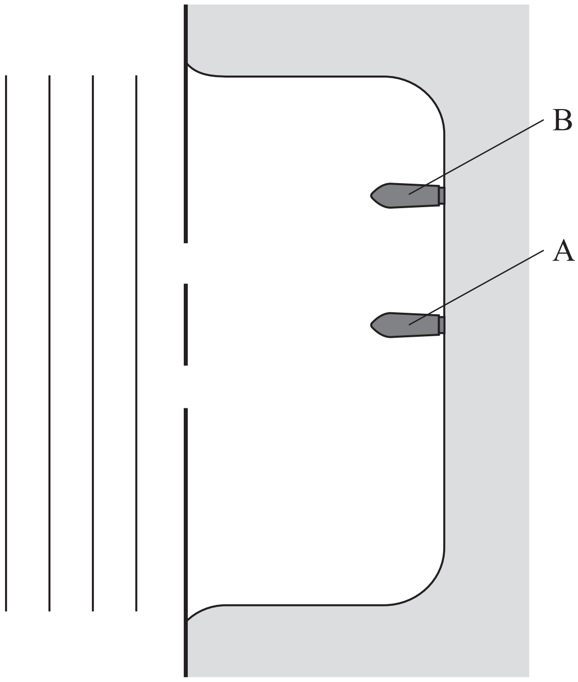
*(b) The wavefronts in the sea arrive parallel to the harbour wall. The wavelength of the waves varies as the weather varies.

There are identical boats at two positions, A and B, in the harbour, as shown.



As the wavelength of the waves varies:

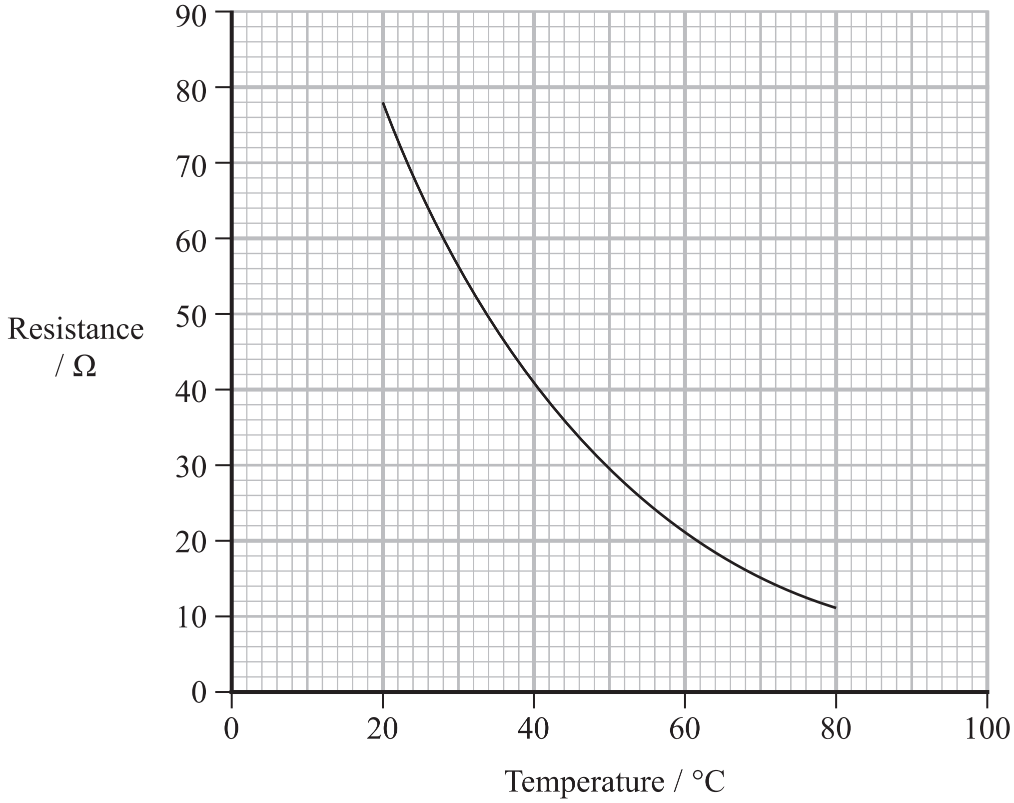
- the boat at position A always oscillates with a large amplitude
- the boat at position B sometimes oscillates with a large amplitude and sometimes oscillates with a very small amplitude.

Explain why the boats oscillate as described.

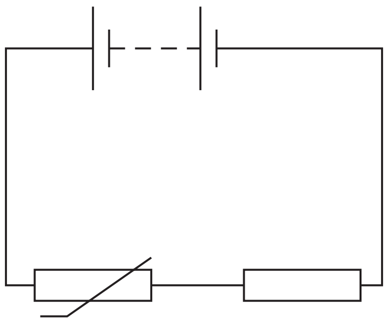
(6)

(Total for Question 17 = 8 marks)

18 The resistance of a particular thermistor varies with temperature, as shown.



(a) A student connected the thermistor in series with a battery and a resistor, as shown. The resistor was made from a long length of wire.



At a temperature of 45 °C, the resistance of the thermistor was four times the resistance of the resistor. The power P dissipated in the resistor was 0.38 W.

(i) Derive the equation $P = \dfrac{V^2}{R}$

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(ii) Determine the potential difference across the battery.

(4)

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Potential difference = ...

(b) (i) Explain why the resistance of a thermistor decreases as the temperature increases.

(2)

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(ii) The student increased the temperature of both the wire resistor and the thermistor from 80 °C to 90 °C.

Explain why the current in the circuit decreased.

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(Total for Question 18 = 13 marks)

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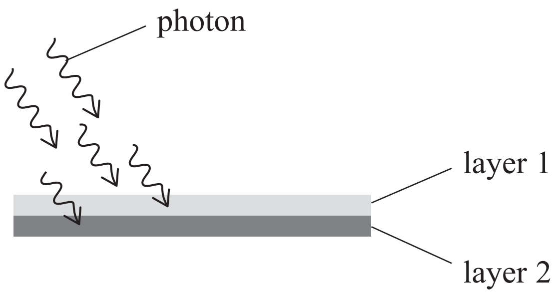
19 Solar cells are made from semiconductor materials.

One type of solar cell has two layers of semiconducting material, layer 1 and layer 2. Photons of light are incident on the solar cell as shown. The minimum energy to release an electron from a semiconductor layer is the work function.



(a) The work function of layer 1 is 1.86 eV.

Calculate the minimum frequency of light needed to release an electron from layer 1.

(3)

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Minimum frequency = ...

(b) Light from the Sun is incident on the solar cell. The intensity of the incident light is constant.

Layer 1 has a greater work function than layer 2. Photons not absorbed by layer 1 are transmitted to layer 2.

Layer 1 is removed from the solar cell so that all photons now reach layer 2.

Explain how removing layer 1 affects the rate at which electrons are released in the solar cell.

You should assume that each layer absorbs all photons with a frequency greater than the minimum frequency for that layer.

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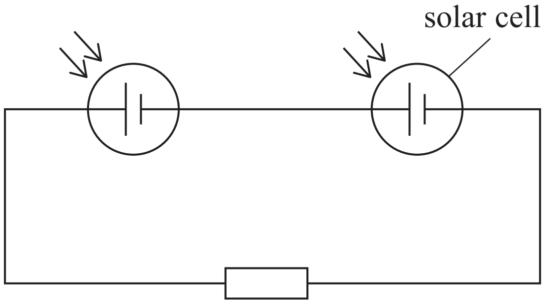
(c) A student connected two solar cells in series with a 4.0 Ω resistor as shown.



The student adjusted the light conditions so that each solar cell had an e.m.f. of 5.0 V and an internal resistance of 0.80 Ω.

The power dissipated in the resistor was 13 W.

The student suggested that connecting the cells in parallel would cause the power dissipated in the resistor to be less than half this value.

Deduce whether the student's suggestion is correct.

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(Total for Question 19 = 13 marks)

TOTAL FOR SECTION B = 70 MARKS
TOTAL FOR PAPER = 80 MARKS

List of data, formulae and relationships

Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to Earth's surface)
Electron charge	$e = -1.60 \times 10^{-19}\ \text{C}$	
Electron mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to Earth's surface)
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	

Unit 1

Mechanics

Kinematic equations of motion

$$s = \frac{(u + v)t}{2}$$

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

Forces

$$\Sigma F = ma$$

$$g = \frac{F}{m}$$

$$W = mg$$

Momentum

$$p = mv$$

Moment of force

$$\text{moment} = Fx$$

Work and energy

$$\Delta W = F\Delta s$$

$$E_k = \frac{1}{2}mv^2$$

$$\Delta E_{grav} = mg\Delta h$$

Power

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

Efficiency

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

$$\text{efficiency} = \frac{\text{useful power output}}{\text{total power input}}$$

Materials

Density $\rho = \dfrac{m}{V}$

Stokes' law $F = 6\pi\eta rv$

Hooke's law $\Delta F = k\Delta x$

Elastic strain energy $\Delta E_{el} = \dfrac{1}{2}F\Delta x$

Young modulus $E = \dfrac{\sigma}{\varepsilon}$ where

Stress $\sigma = \dfrac{F}{A}$

Strain $\varepsilon = \dfrac{\Delta x}{x}$

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Unit 2

Waves

Wave speed	$v = f\lambda$
Speed of a transverse wave on a string	$v = \sqrt{\frac{T}{\mu}}$
Intensity of radiation	$I = \frac{P}{A}$
Refractive index	$n_1 \sin\theta_1 = n_2 \sin\theta_2$
	$n = \frac{c}{v}$
Critical angle	$\sin C = \frac{1}{n}$
Diffraction grating	$n\lambda = d\sin\theta$

Electricity

Potential difference	$V = \frac{W}{Q}$
Resistance	$R = \frac{V}{I}$
Electrical power, energy	$P = VI$
	$P = I^2R$
	$P = \frac{V^2}{R}$
	$W = VIt$
Resistivity	$R = \frac{\rho l}{A}$
Current	$I = \frac{\Delta Q}{\Delta t}$
	$I = nqvA$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

Particle nature of light

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2}mv^2_{max}$
de Broglie wavelength	$\lambda = \frac{h}{p}$

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