OXFORD
INTERNATIONAL
AQA EXAMINATIONS

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ______________________________

Forename(s) ______________________________

Candidate signature ______________________________
I declare this is my own work.

INTERNATIONAL AS
PHYSICS
Unit 2 Electricity, waves and particles

Monday 11 January 2021   07:00 GMT   Time allowed: 2 hours

Materials
For this paper you must have:
- a Data and Formulae Booklet as a loose insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate
- a protractor.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11–24	
TOTAL	

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Section A

Answer **all** questions in this section.

0 1 A metal has a resistivity of $4.9 \times 10^{-7}\ \Omega\ \text{m}$.

0 1 . 1 Define resistivity.

[1 mark]

____

____

____

0 1 . 2 A wire resistor of resistance $6.8\ \Omega$ is made from the metal.
The diameter of the wire is $2.4 \times 10^{-4}\ \text{m}$.

Calculate the length of the wire.

[2 marks]

length = ____________________ m

3

0 2 A string is stretched between two fixed points. It is plucked in the middle so that a stationary wave forms on the string.

Explain how the stationary wave is formed.

[3 marks]

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3

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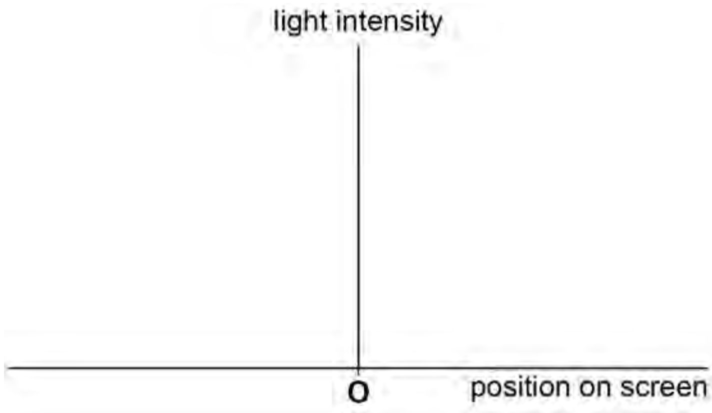
0 3 A narrow single slit of width w is illuminated with light from a laser.
A diffraction pattern is observed on a screen several metres away from the slit.

A total of five maxima is observed on the screen.

0 3 . 1 Sketch, on **Figure 1**, a graph showing how the light intensity varies with position on the screen.
O marks the central point of the pattern.

[2 marks]

Figure 1



The narrow single slit is replaced with a slit of width greater than w. Nothing else is changed.
A new diffraction pattern is formed.

0 3 . 2 Label, on the position axis of **Figure 1**, the position **M** of the first maximum to the left of **O** for the **new** diffraction pattern.

[1 mark]

0 3 . 3 Describe any change to the intensity of the maxima in the new diffraction pattern.

[1 mark]

____

____

____

4

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0 4 A car battery has an emf of $12.2\ \text{V}$ and an internal resistance of $0.015\ \Omega$.

0 4 . 1 A resistor of resistance $7.6 \times 10^{-3}\ \Omega$ is connected directly between the terminals of the battery.

Calculate the current in the resistor.

[2 marks]

current = ______________________ A

0 4 . 2 Calculate the rate of heating inside the battery as soon as the resistor is connected between the terminals.

[2 marks]

rate of heating = ______________________ W

4

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0 5 Photoelectrons are emitted from a sodium surface when it is illuminated with monochromatic electromagnetic radiation.
The stopping potential of these photoelectrons is 3.42 V.

0 5 . 1 Show that the maximum kinetic energy of the photoelectrons is approximately 5.5×10^{-19} J.

[1 mark]

0 5 . 2 Calculate the wavelength of the radiation that is incident on the sodium surface.

work function of sodium = 2.36 eV

[3 marks]

wavelength = ____________________________ m

Question 5 continues on the next page

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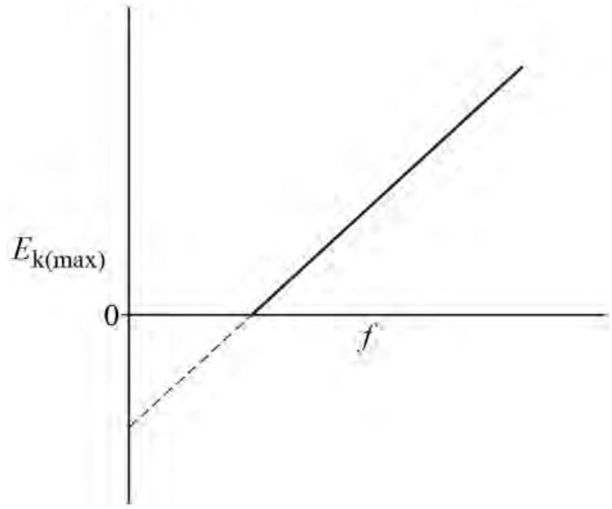
0 5 . 3 The frequency f of the electromagnetic radiation is now varied.

The maximum kinetic energy $E_{k(max)}$ of the photoelectrons is measured for each value of f.

Figure 2 shows the variation of $E_{k(max)}$ with f.

Figure 2



Magnesium and caesium surfaces are also illuminated with electromagnetic radiation and photoelectrons are emitted from the surfaces.

Draw, on **Figure 2**, lines to show the variation of $E_{k(max)}$ with f for magnesium **and** for caesium.

Label your lines.

work function of magnesium = 3.68 eV
work function of caesium = 2.14 eV

[2 marks]

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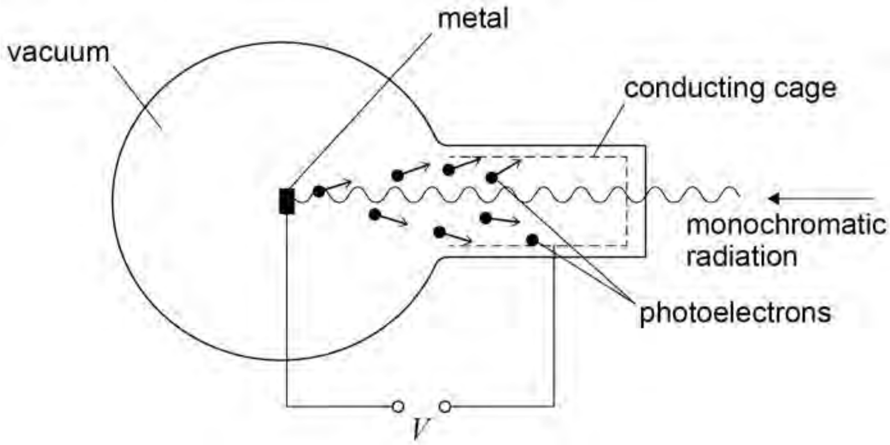
0 5 . 4 **Figure 3** shows apparatus that can be used to investigate the photoelectric effect.

Figure 3



The experiment is conducted in a vacuum.

The photoelectrons that are produced move towards the conducting cage.
The stopping potential V of the photoelectrons is measured using a circuit connected to the metal and the conducting cage.

A small amount of air now leaks into the apparatus.

Explain how the measured value of V is affected by the presence of the air.

[2 marks]

8

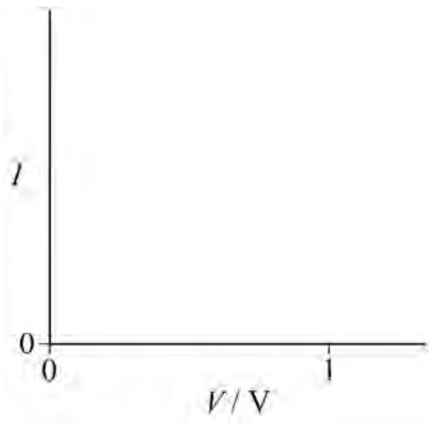
Do not write outside the box

0 6 . 1 A diode conducts only when connected the correct way round in a circuit.

Sketch, on **Figure 4**, a graph of the variation of current I with potential difference V over a range of 0 to $+1\ \mathrm{V}$ for a diode that becomes conducting.

[1 mark]

Figure 4

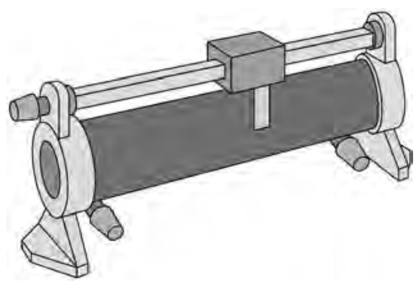


A student wants to obtain data to be able to draw the graph in **Figure 4**.

The student has a $1.5\ \mathrm{V}$ cell, the diode, an ammeter, a voltmeter, connecting wires and a rheostat like that shown in **Figure 5**.

The rheostat can be used as a variable resistor or as a potential divider.

Figure 5



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0 6 . 2 Draw a suitable circuit in which the rheostat is used as a variable resistor.

[2 marks]

0 6 . 3 Draw a suitable circuit in which the rheostat is used as a potential divider.

[1 mark]

0 6 . 4 Explain the advantage of using the rheostat as a potential divider rather than as a variable resistor.

[1 mark]

____

____

____

5

0 7 A student builds a circuit that uses a filament lamp to heat a tank for reptiles. The circuit includes components that are designed to control the temperature of the tank. A thermistor and the lamp are positioned inside the tank.

Figure 6 shows the circuit. The battery has negligible internal resistance.

Figure 7A shows the variation of resistance R_{th} with temperature T for the thermistor.

Figure 7B shows the variation of potential difference V_L with current I for the lamp.

Figure 6

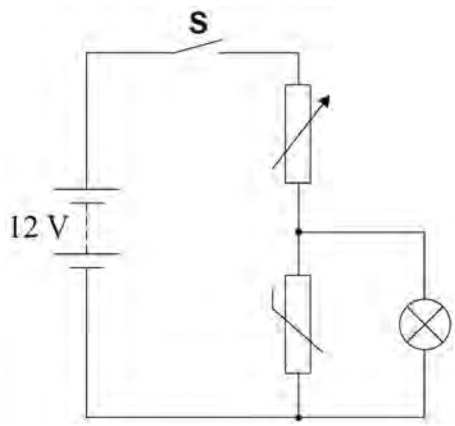


Figure 7A

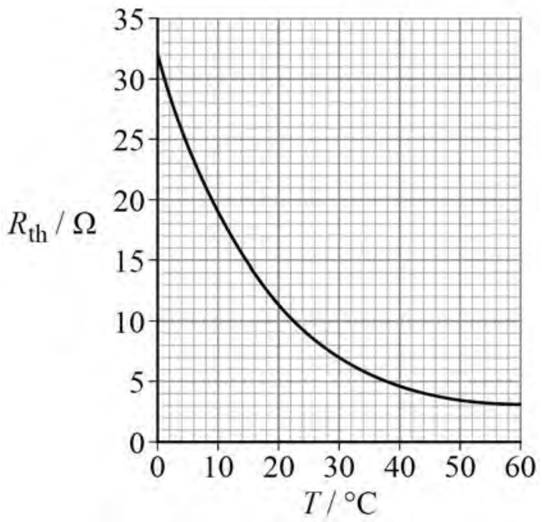
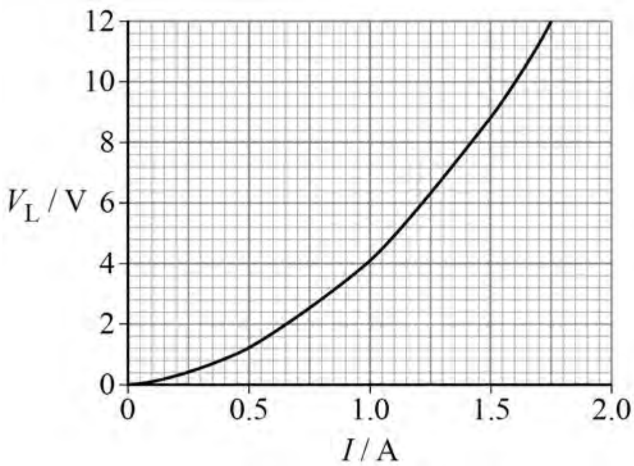


Figure 7B



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The initial temperature in the tank is $20\ °C$.

0 7 . 1 Switch **S** is closed and the potential difference across the lamp is $3.0\ V$.

Show that the resistance of the parallel combination of the thermistor and lamp immediately after **S** is closed is approximately $2.7\ \Omega$.

[4 marks]

0 7 . 2 Determine the resistance of the variable resistor.

[2 marks]

resistance = ____________________ Ω

0 7 . 3 Determine the power of the lamp immediately after **S** is closed.

[1 mark]

power = ____________________ W

Question 7 continues on the next page

Turn over ►

Do not write outside the box

0 7 . 4 Suggest how the resistance of the parallel combination of the lamp and thermistor is likely to change in the period immediately after **S** is closed.

[2 marks]

0 7 . 5 On another occasion the initial temperature in the tank is again 20 °C.
This time, the resistance of the variable resistor in **Figure 6** is increased before **S** is closed.

State and explain the effect of this change on the initial rate of temperature increase in the tank.

[2 marks]

11

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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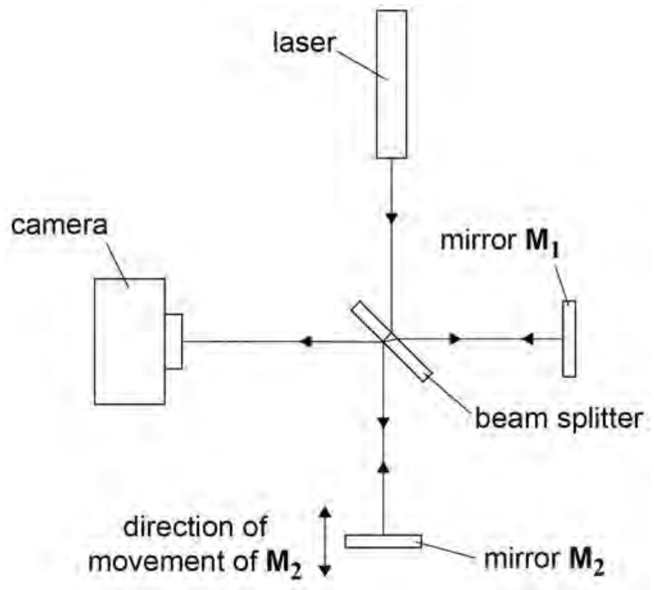
0 8 The interferometer shown in **Figure 8** uses interference to measure very small movements of the mirror $\mathbf{M_2}$.

Figure 8



Monochromatic light from a laser arrives at a beam splitter.
Half of the light is reflected to mirror $\mathbf{M_1}$. The other half of the light goes through the beam splitter and on to mirror $\mathbf{M_2}$.
Light is reflected from $\mathbf{M_1}$ and $\mathbf{M_2}$ and travels via the beam splitter to a camera.

Light from $\mathbf{M_1}$ interferes with light from $\mathbf{M_2}$ at the camera. The effects of the interference are observed.

When $\mathbf{M_2}$ moves, the interference observed at the camera changes. This enables a determination of the distance that $\mathbf{M_2}$ moves.

0 8 . 1 Explain why $\mathbf{M_1}$ and $\mathbf{M_2}$ act as coherent sources.

[2 marks]

Do not write outside the box

Mirror $\mathbf{M_2}$ is moved a distance d to a new position closer to the beam splitter.
As $\mathbf{M_2}$ moves, light entering the camera changes from maximum to minimum intensity.

0 8 . 2 Explain the change in light intensity.

[2 marks]

0 8 . 3 Explain, using an appropriate calculation, why the minimum value of d is approximately 1.6×10^{-7} m.

The wavelength of light from the laser is 650 nm.

[2 marks]

Question 8 continues on the next page

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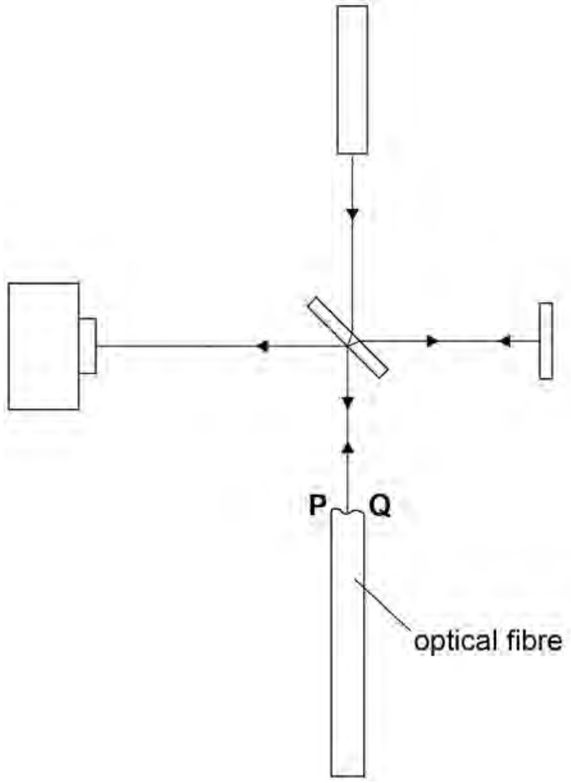
0 8 . 4 The interferometer is used to examine the end of an optical fibre.

Mirror $\mathbf{M_2}$ is replaced with the end of an optical fibre. The end of the optical fibre reflects light back to the beam splitter as shown in **Figure 9**.

Figure 9



The end of the optical fibre between **P** and **Q** is uneven because it varies in height.

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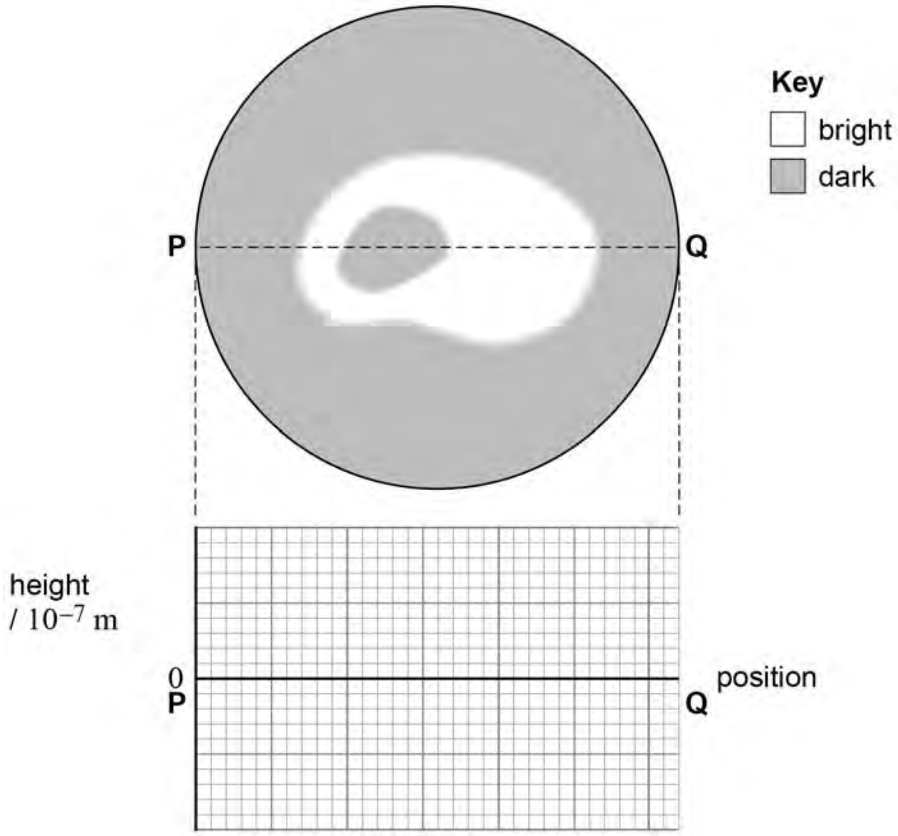
Figure 10 shows the interference pattern of light observed at the camera.
PQ is a diameter of the circular end of the optical fibre.

Figure 10



Draw, on **Figure 10**, a graph showing the variation of height with position along **PQ**.

Add a suitable scale to your height axis.

[3 marks]

Question 8 continues on the next page

Do not write outside the box

0 8 . 5 A different laser is now used. This laser emits light with a smaller wavelength.

Suggest how this change affects the resolution of the interferometer.

[1 mark]

0 8 . 6 The optical fibre with an uneven end is used to transmit information.

Explain why the uneven end of the optical fibre increases modal dispersion.

[2 marks]

12

END OF SECTION A

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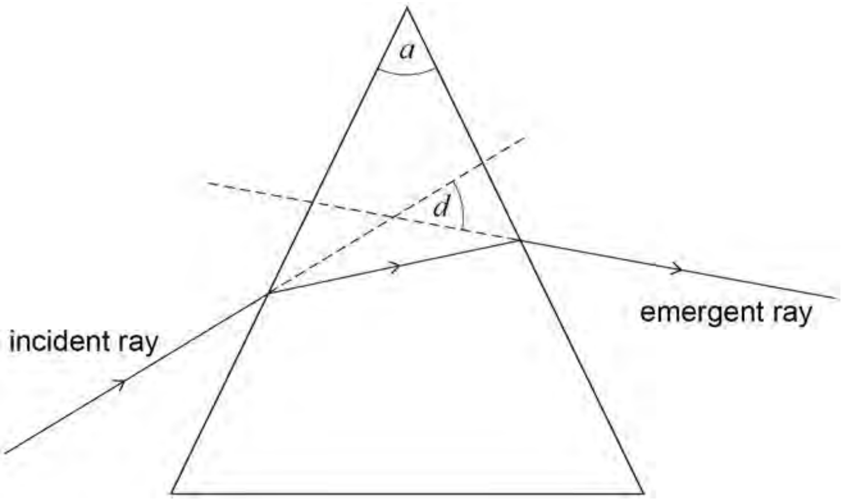
Section B

Answer **all** questions in this section.

0 9 **Figure 11** shows a ray of monochromatic light passing through a glass prism.

Figure 11



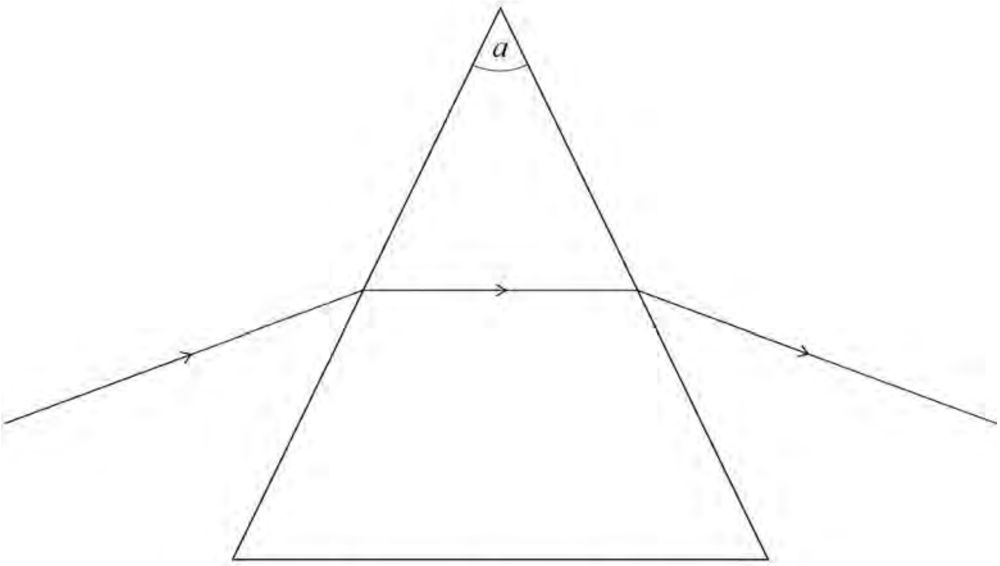
The angle a is the refracting angle of the prism.

The angle of deviation d of the ray is the angle between the direction of the incident ray and the direction of the emergent ray as shown on **Figure 11**.

Question 9 continues on the next page

0 9 . 1 **Figure 12** shows a ray passing through a prism on a symmetrical path.

Figure 12



this diagram is drawn to scale

Measure d for this light ray.

[2 marks]

$d =$ ____________________ °

0 9 . 2 Estimate the absolute uncertainty in your value for d.

[1 mark]

absolute uncertainty in $d =$ ____________________ °

0 9 . 3 Explain the reasoning for your answer to Question **09.2**.

[1 mark]

____

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For the ray diagram in **Figure 12**, the refractive index n of the glass in the prism is given by

$$n = \frac{\sin\dfrac{(a+d)}{2}}{\sin\left(\dfrac{a}{2}\right)}$$

0 9 . 4 In **Figure 12**, $a = (50.0 \pm 0.5)°$.

Calculate $\dfrac{(a+d)}{2}$ and estimate its percentage uncertainty.

[2 marks]

$\dfrac{(a+d)}{2} =$ ____________________ °

percentage uncertainty = ____________________

0 9 . 5 Calculate n and estimate its percentage uncertainty.

Assume that the percentage uncertainty in the sine of the angles is the same as the percentage uncertainty in the angles themselves.

[2 marks]

$n =$ ____________________

percentage uncertainty = ____________________

8

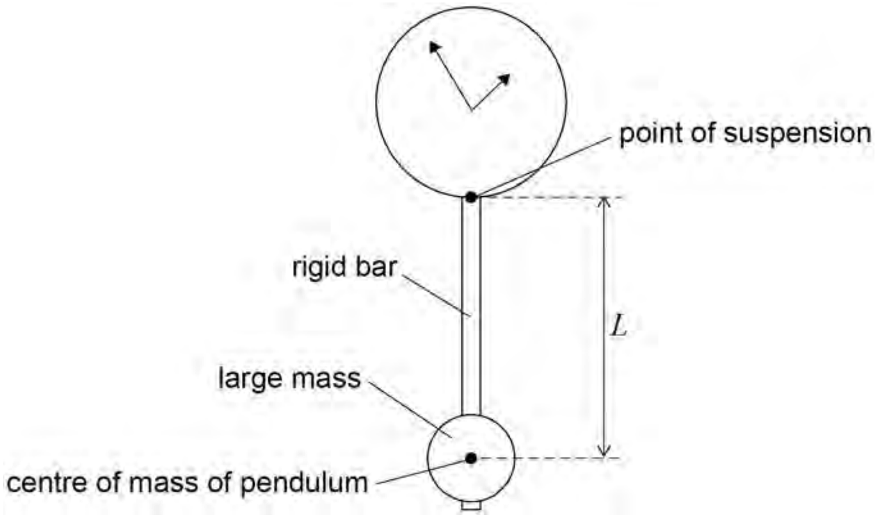
Turn over ►

Do not write outside the box

1 0 Pendulums are used to make some clocks keep the correct time.

Figure 13 shows a clock with a pendulum. The pendulum is made from a rigid bar of negligible mass with a large mass near the lower end.

Figure 13



Assume that the pendulum behaves as a simple pendulum with a length equal to the distance L between the point of suspension and the centre of mass of the pendulum.

The pendulum must oscillate with a time period of 1.400 s for the clock to keep correct time.

1 0 . 1 The pendulum oscillates with a period of 1.402 s.

Calculate the error in the time measured by the clock in 24 hours.

[3 marks]

error = ______________________ s

Do not write outside the box

1 0 . 2 Show that L is approximately $0.5\ \mathrm{m}$.

[2 marks]

1 0 . 3 The owner of the clock wants to make the clock more accurate by attaching a small additional mass to the pendulum.

Explain where the owner should attach the small additional mass.

[2 marks]

1 0 . 4 The clock is moved to a warmer room, causing the rigid bar to increase in length.

Explain how the owner must move the small additional mass in order for the clock to keep accurate time.

[1 mark]

8

END OF SECTION B

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Section C

Each of the questions in this section is followed by four responses, **A**, **B**, **C** and **D**.

For each question select the best response.

Only **one** answer per question is allowed.
For each question, completely fill in the circle alongside the appropriate answer.

CORRECT METHOD   WRONG METHODS

If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional pages for this working.

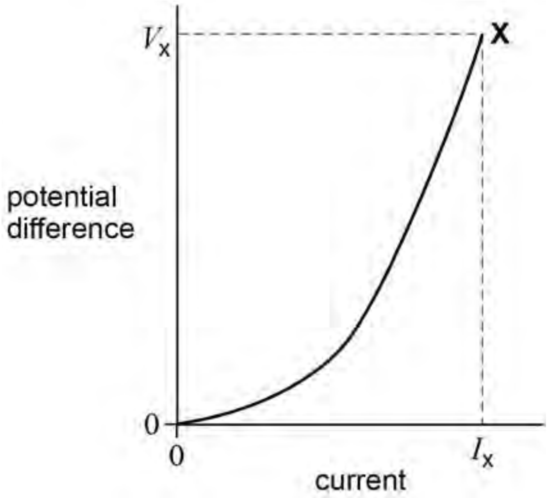
1 1 Which row correctly relates a type of wave to its direction of oscillation and its polarisation?

[1 mark]

	Type of wave	Direction of oscillation	Polarisation	
A	transverse	parallel to the direction of energy transfer	can be polarised	○
B	transverse	perpendicular to the direction of energy transfer	cannot be polarised	○
C	longitudinal	parallel to the direction of energy transfer	cannot be polarised	○
D	longitudinal	perpendicular to the direction of energy transfer	can be polarised	○

Do not write outside the box

1 2 The graph shows the variation of potential difference V with current I for a device.



Which row shows the resistance of the device at point **X** and the power transferred in the device at point **X**?

[1 mark]

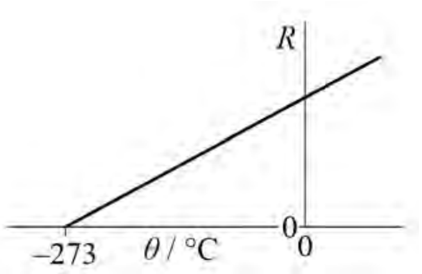
	Resistance	Power transferred	
A	the gradient at **X**	the area under the curve	○
B	the gradient at **X**	$V_X I_X$	○
C	$\frac{V_X}{I_X}$	the area under the curve	○
D	$\frac{V_X}{I_X}$	$V_X I_X$	○

Turn over for the next question

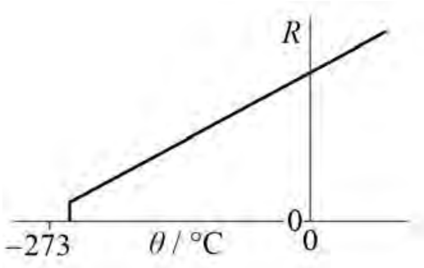
1 3 Which graph shows the variation of resistance R with Celsius temperature θ for a superconductor?

[1 mark]

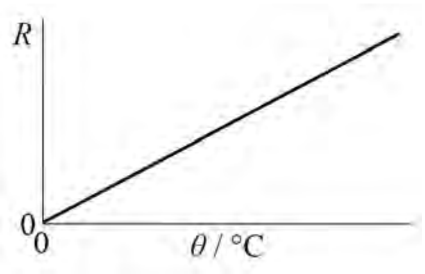
A



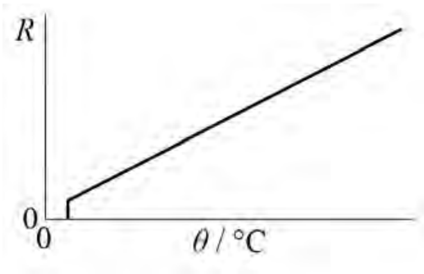
B



C



D



A ○

B ○

C ○

D ○

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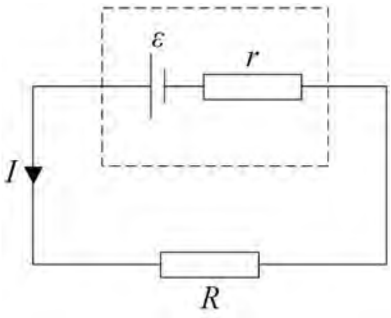
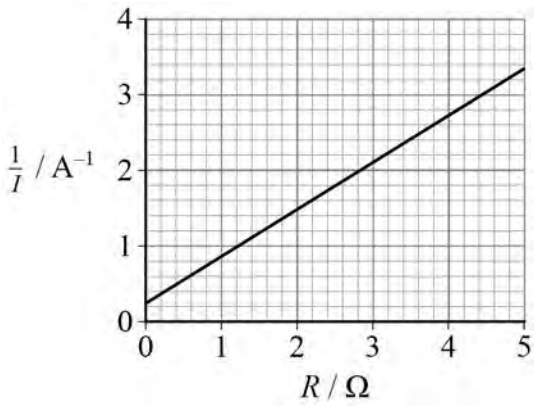
1 4 A cell of emf ε and internal resistance r is connected to an external resistor.
The current I is measured for a range of values of R, the resistance of the external resistor.



The graph shows the variation of $\frac{1}{I}$ with R.



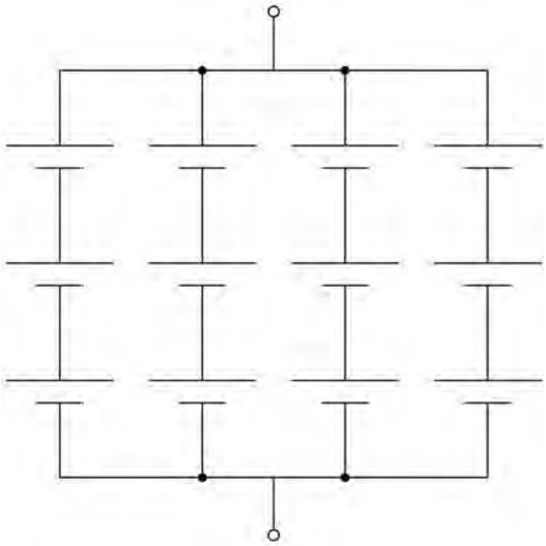
What are the values of ε and r?

[1 mark]

	ε / V	**r / Ω**	
A	0.63	0.16	⬭
B	0.63	0.40	⬭
C	1.6	0.16	⬭
D	1.6	0.40	⬭

Turn over ►

1 5 Twelve identical cells are placed in a network.
Each cell has an emf ε and internal resistance r.



What are the emf and the internal resistance of the network?

[1 mark]

	Emf	Internal resistance	
A	3ε	$\frac{3}{4}r$	⬭
B	3ε	$\frac{4}{3}r$	⬭
C	4ε	$\frac{4}{3}r$	⬭
D	4ε	$\frac{3}{4}r$	⬭

Do not write outside the box

1 6 A mass–spring system oscillates with a period of T.
The spring constant is k and the mass is m.
A second mass–spring system has a spring constant of $3k$ and a mass of $5m$.

What is the period of oscillation of the second system?

[1 mark]

A $0.36T$ ⬭

B $0.78T$ ⬭

C $1.3T$ ⬭

D $2.8T$ ⬭

1 7 A mass–spring system will resonate only when the forcing oscillation has:

[1 mark]

A an amplitude that is any multiple of the amplitude of the resonating system. ⬭

B an amplitude that is equal to the amplitude of the resonating system. ⬭

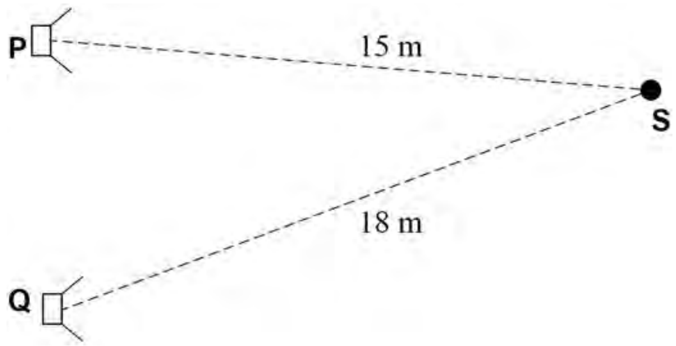
C a frequency that is any multiple of the natural frequency of the resonating system. ⬭

D a frequency that is equal to the natural frequency of the resonating system. ⬭

Turn over for the next question

Do not write outside the box

1 8 Sound from two loudspeakers **P** and **Q** is emitted in antiphase.
P and **Q** produce sound of frequency $510\ \text{Hz}$.



The speed of sound is $340\ \text{m s}^{-1}$.
S is $15\ \text{m}$ from **P** and $18\ \text{m}$ from **Q**.

When observed at **S**, the sound from **P** is:

[1 mark]

A in phase with the sound from **Q**. ⬭

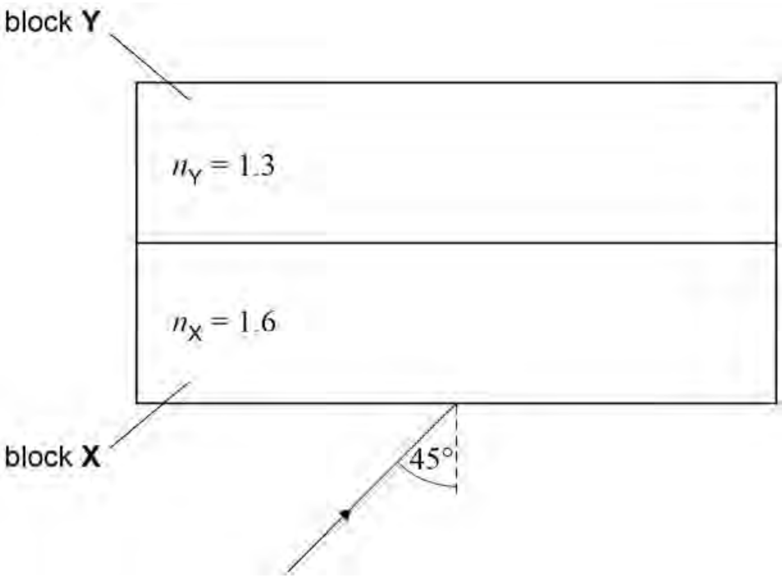
B in antiphase with the sound from **Q**. ⬭

C $\frac{\pi}{2}$ rad ahead of the sound from **Q**. ⬭

D $\frac{\pi}{4}$ rad ahead of the sound from **Q**. ⬭

Do not write outside the box

Questions 19 and **20** relate to two parallel-sided blocks **X** and **Y** joined together as shown.



A ray of light enters block **X** with an angle of incidence of 45°.
The ray passes through the blocks and emerges from the top surface of block **Y**.
The refractive indices for block **X** and block **Y** are shown on the diagram.

1 9 The ratio $\dfrac{\text{speed of light in block } \mathbf{X}}{\text{speed of light in block } \mathbf{Y}}$ is

[1 mark]

A 0.20

B 0.81

C 1.2

D 2.8

2 0 The ray emerges from the top surface of block **Y** at an angle of θ to the normal.

Which is correct?

[1 mark]

A $\theta = 90°$

B $\theta > 45°$

C $\theta = 45°$

D $\theta < 45°$

Turn over ►

Do not write outside the box

2 1 Which is true about fluorescent tubes?

[1 mark]

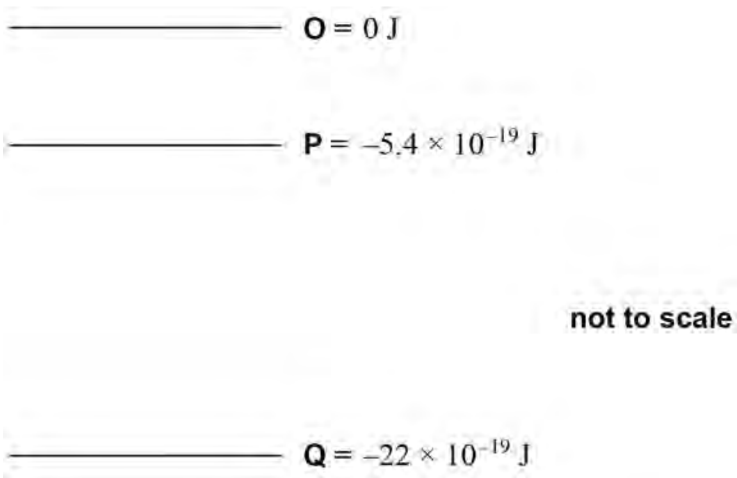
A An electric current in the tube ionises the phosphor.

B Phosphor atoms emit only UV photons as they de-excite.

C Mercury ions become excited by collisions in the tube.

D Mercury ions emit only visible photons as they de-excite.

2 2 The diagram shows three of the energy levels, **O**, **P** and **Q**, in an atom.



A photon is emitted during a transition between two energy levels.

Which row correctly identifies the transition and the frequency of the emitted photon?

[1 mark]

	Transition	Frequency of emitted photon / 10^{15} Hz
A	**Q** to **O**	3.3
B	**P** to **O**	8.1
C	**O** to **Q**	3.3
D	**O** to **P**	8.1

Do not write outside the box

2 3 The photoelectric effect shows that when photoelectrons are emitted:

[1 mark]

A the atoms have accumulated sufficient energy gradually. ⬭

B energy is always absorbed in discrete amounts. ⬭

C the photoelectrons can only have certain permitted kinetic energies. ⬭

D the photoelectrons show wave-like properties as they are emitted. ⬭

2 4 The momentum p of a particle is given by $p = \sqrt{2E_k m}$ where E_k is the kinetic energy and m is the mass of the particle.

An electron and a proton are given the same kinetic energy.

What is the ratio $\dfrac{\text{de Broglie wavelength of the electron}}{\text{de Broglie wavelength of the proton}}$?

[1 mark]

A 2.3×10^{-2} ⬭

B 4.3×10^{1} ⬭

C 1.8×10^{3} ⬭

D 3.4×10^{6} ⬭

14

END OF QUESTIONS

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