OXFORD AQA
INTERNATIONAL QUALIFICATIONS

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

Tuesday 21 May 2024 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 | |
| 12–25 | |
| **TOTAL** | |

Do not write outside the box

## Section A

Answer **all** questions in this section.

**0 1** A simple pendulum completes $39$ oscillations in $1.0$ minute.

Calculate the length of the pendulum.

**[2 marks]**

length = _____ m

**2**

**0 2** Monochromatic light is incident on a clean metal surface and photoelectrons are emitted from the surface.

A photon of this light has energy of $4.5 \times 10^{-19}$ J.

The stopping potential of the electrons is $1.1$ V.

Calculate, in eV, the work function of the metal.

**[2 marks]**

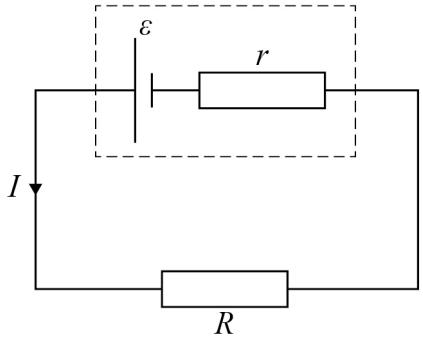
work function = _____ eV

**2**

Do not write outside the box

**0 3** **Figure 1** shows a cell in a series circuit with a load resistor.
The cell has an internal resistance $r$.

**Figure 1**




The emf $\varepsilon$ of the cell is given by

$$\varepsilon = IR + Ir$$

where $I$ is the current in the circuit and $R$ is the load resistance.

Explain how this equation is consistent with the law of conservation of energy.

**[2 marks]**

_____

_____

_____

_____

_____

_____

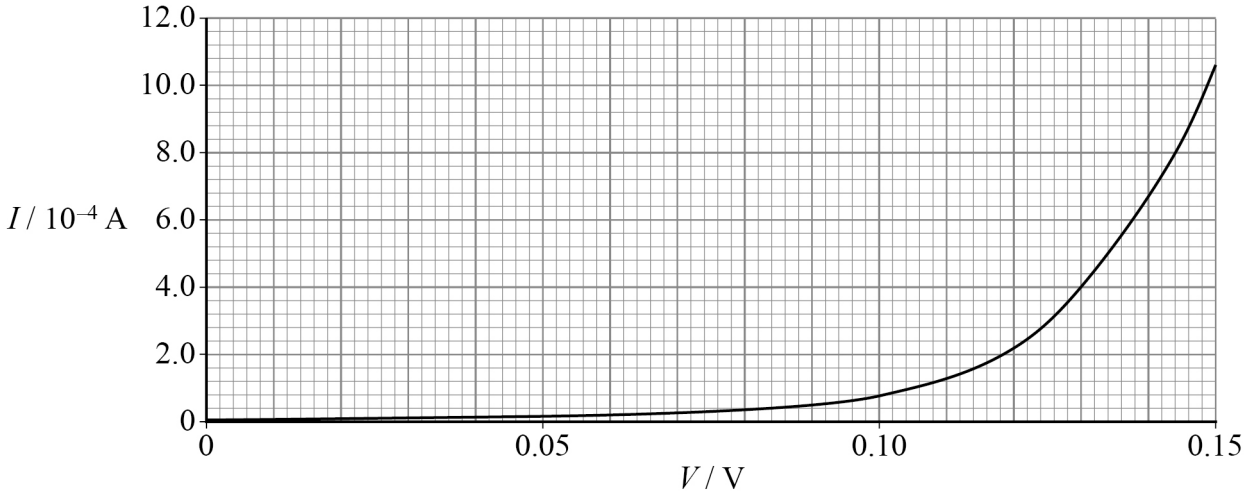
2

**Turn over for the next question**

Do not write outside the box

**0 4** **Figure 2** shows the $I$–$V$ characteristic for a component.

**Figure 2**




Calculate the resistance of the component when the current in it is $0.80$ mA.

**[2 marks]**

resistance = _____ Ω

2

Do not write outside the box

**0 5** An electrical toy normally needs six cells.

**Figure 3a** shows the inside of the cell compartment of the toy. The markings show how the cells **A** to **F** should be arranged.

**Figure 3b** shows the circuit diagram of the cells when they are placed correctly into the compartment.

**Figure 3a**

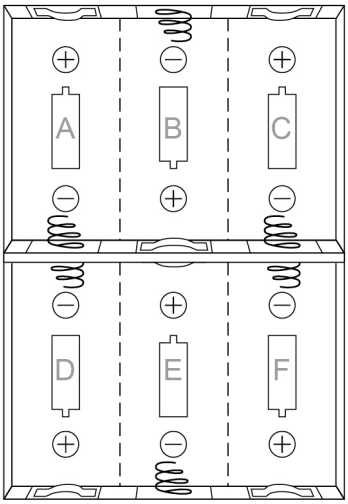
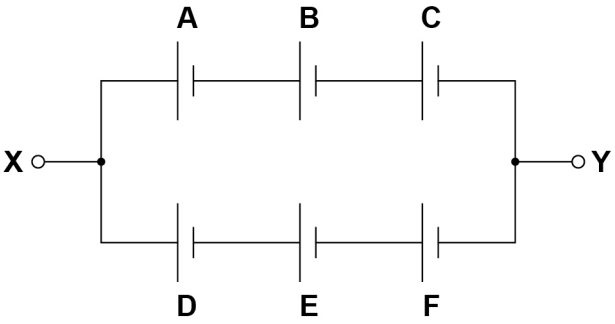


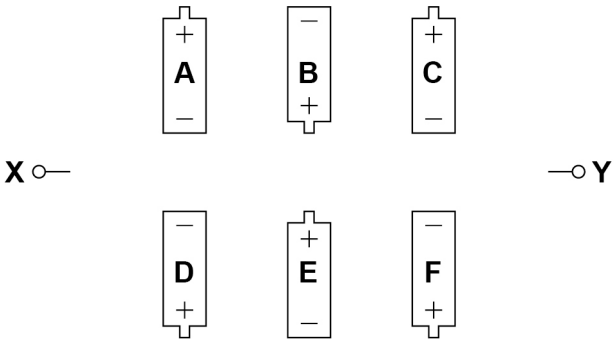

**Figure 3b**




**0 5 . 1** Draw lines on **Figure 4** to show how the cells should be connected in the compartment.

**[1 mark]**

**Figure 4**




**Question 5 continues on the next page**

Do not write outside the box

Each cell has an emf of $1.50\ \mathrm{V}$ and an internal resistance of $0.25\ \Omega$.

**0 5 . 2** On one occasion, a child fits five cells into the toy but leaves out cell **B**.

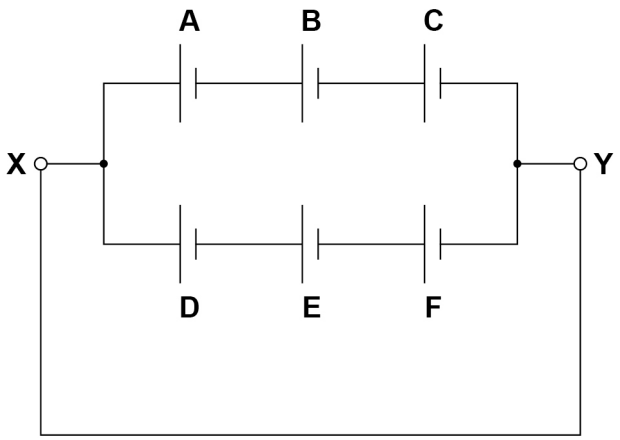
Suggest and explain the consequences of leaving out cell **B**.

**[2 marks]**

Do not write outside the box

**0 5 . 3** On another occasion, a fault occurs that causes a connection between **X** and **Y** as shown in **Figure 5**. All six cells are fitted correctly.
The connection has zero resistance.

**Figure 5**




Calculate the current in the connection between **X** and **Y**.

**[3 marks]**

current = _____ A

6

**Turn over for the next question**

Do not write outside the box

**0 6** A sodium lamp contains low-pressure sodium gas.
An electric current in the sodium gas causes the sodium atoms to emit light.

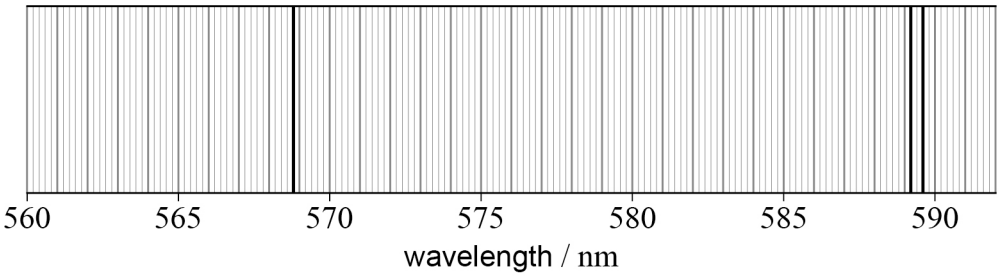
**0 6 . 1** Explain how the sodium atoms become excited.

**[2 marks]**

Do not write outside the box

**Figure 6** shows part of the line spectrum for the light emitted from the sodium lamp.

**Figure 6**




**0 6 . 2** Explain why the spectrum produced by the sodium lamp has light of only certain wavelengths.

**[3 marks]**

**0 6 . 3** Calculate, in J, the energy of the **least** energetic photon that corresponds to a spectral line in **Figure 6**.

**[3 marks]**

photon energy = _____ J

8

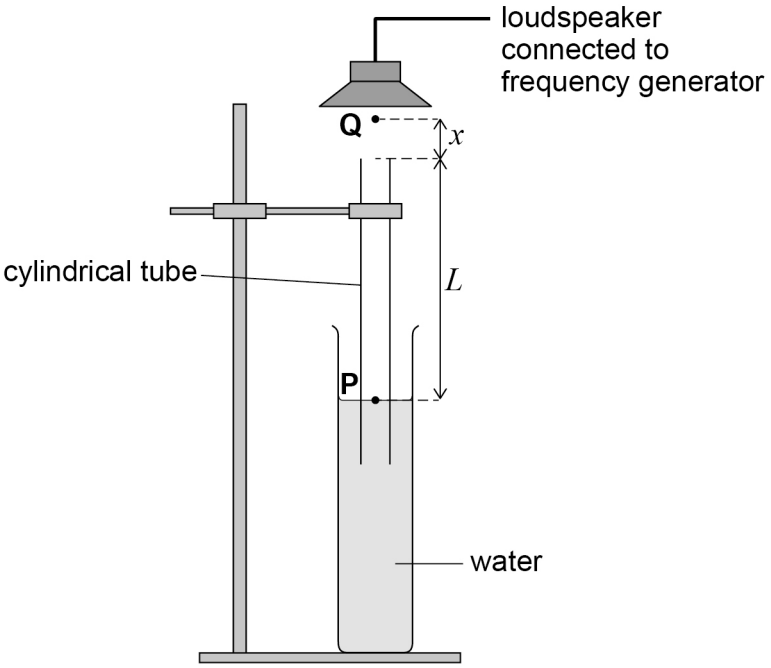
**Turn over ►**

Do not write outside the box

**0 7** **Figure 7** shows apparatus used to investigate stationary waves in a column of air inside a cylindrical tube.

A loudspeaker, connected to a frequency generator, emits a sound wave with a single frequency into the open end of the tube.

**Figure 7**




The sound wave from the loudspeaker travels through the air in the tube and reflects at the surface of the water.

**0 7 . 1** The frequency of the sound is increased from zero. At a certain frequency $f$, the loudness of the sound in the tube increases significantly.

Explain, with reference to resonance, why the sound is loud at this frequency.

**[1 mark]**

Do not write outside the box

There is an increase in loudness when a stationary wave forms in the air in the tube. This stationary wave corresponds to the first harmonic.

**Figure 7** shows:

- the position **P** of a node at the surface of the water
- the position **Q** of an antinode.

**Q** is a constant distance $x$ above the top of the tube.

**0 7 . 2** Describe the motion of the air molecules at **P** and at **Q** due to the stationary wave.

**[2 marks]**

at **P** _____

_____

_____

at **Q** _____

_____

_____

The length $L$ of the column of air is varied.
The frequency $f$ of the first harmonic is recorded for each value of $L$.

**0 7 . 3** When a stationary wave of the first harmonic is formed, the distance **PQ** is equal to $\frac{\lambda}{4}$, where $\lambda$ is the wavelength of the stationary wave.

Show that $f$ is given by $$\frac{1}{f} = \frac{4L}{v} + \frac{4x}{v}$$

where $v$ is the speed of sound in air.

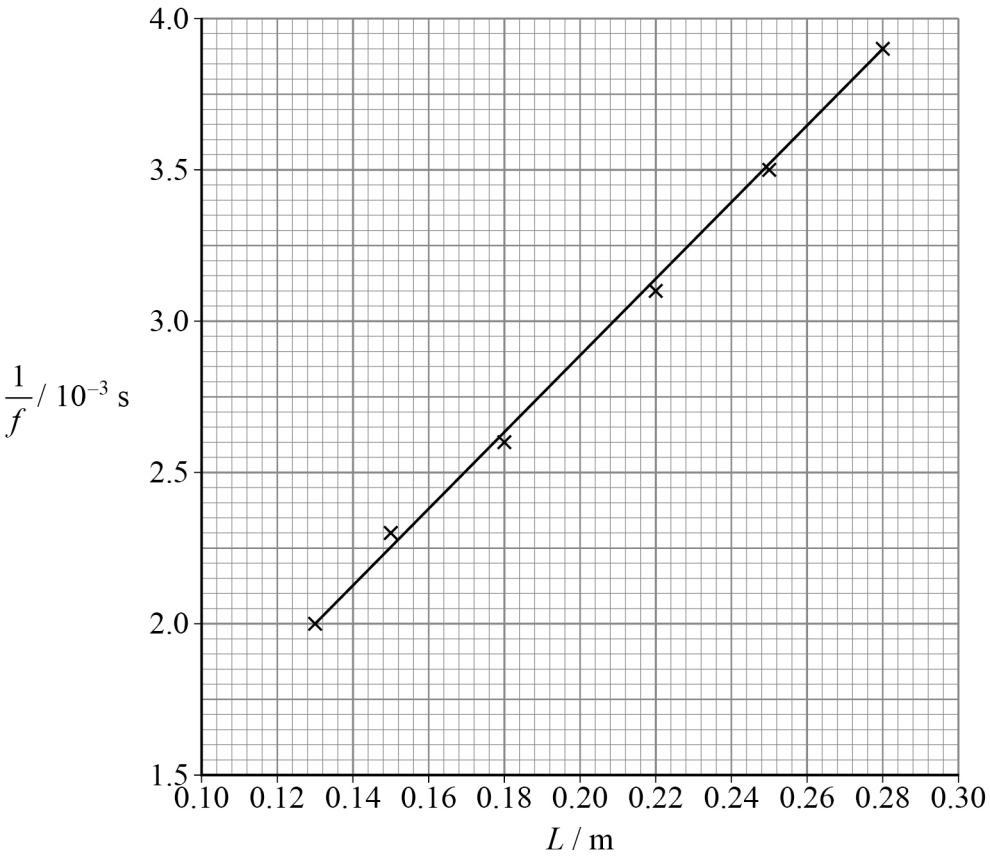
**[1 mark]**

**Question 7 continues on the next page**

Do not write outside the box

**Figure 8** shows the variation of $\frac{1}{f}$ with $L$. The best-fit line has been drawn.

**Figure 8**




**0 7 . 4** Determine $v$ using **Figure 8**.

**[3 marks]**

$v$ = _____ m s$^{-1}$

Do not write outside the box

**0 7 . 5** Explain how you would use **Figure 8** to determine $x$.
Calculations are not required.

**[2 marks]**

9

**Turn over for the next question**

Do not write outside the box

**0 8 . 1** Explain what is meant by modal dispersion in an optical fibre.

**[2 marks]**

The speed of light in the glass core of an optical fibre is $1.97 \times 10^8$ m s$^{-1}$.

**0 8 . 2** Calculate the refractive index of the glass.

**[1 mark]**

refractive index = _____

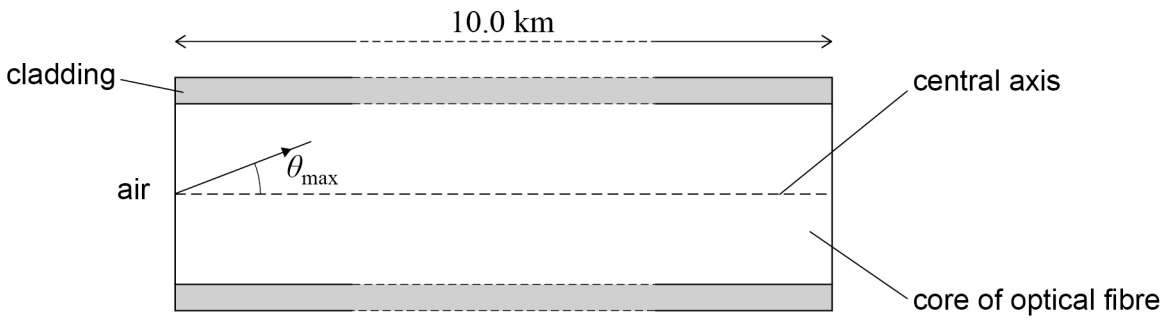
A pulse of light is passed along the optical fibre and experiences modal dispersion. The fibre is straight and has a length of $10.0$ km.

The longest path of light along the fibre is at an angle $\theta_{max}$ to the central axis as shown in **Figure 9**.

The shortest path of light along the fibre is along the central axis.

**Figure 9**

**not to scale**



Do not write outside the box

There is a time delay of $13.7\ \mu s$ between the arrival of the pulse when it follows the longest path and when it follows the shortest path.

**0 8 . 3** Show that the length of the longest path is approximately $12.7\ km$.

**[2 marks]**

**0 8 . 4** Calculate $\theta_{max}$.

**[1 mark]**

$\theta_{max}$ = _____ °

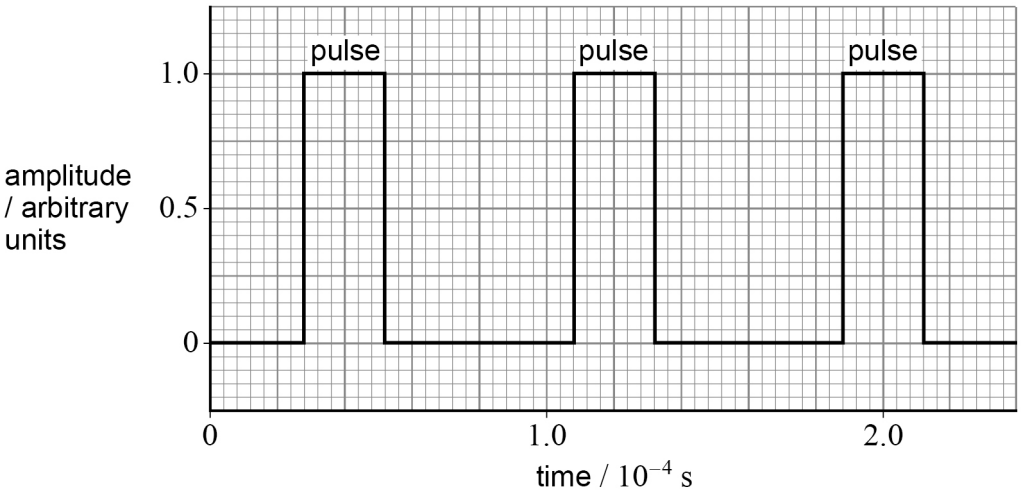
**Question 8 continues on the next page**

Do not write outside the box

A laser sends a signal along the optical fibre. The signal is made up of a series of repeated pulses as shown in **Figure 10**.

**Figure 10** shows the signal as it enters the fibre.

**Figure 10**




**0 8 . 5** Calculate the frequency of repetition of the pulses.

**[2 marks]**

frequency = _____ Hz

**0 8 . 6** Calculate the maximum duration of each pulse that is received at the end of this fibre.

**[2 marks]**

maximum duration = _____ s

Do not write outside the box

**0 8 . 7** Explain how pulse broadening limits the frequency at which pulses in a signal can be received through this optical fibre.

**[1 mark]**

_____

_____

_____

11

**Turn over for the next question**

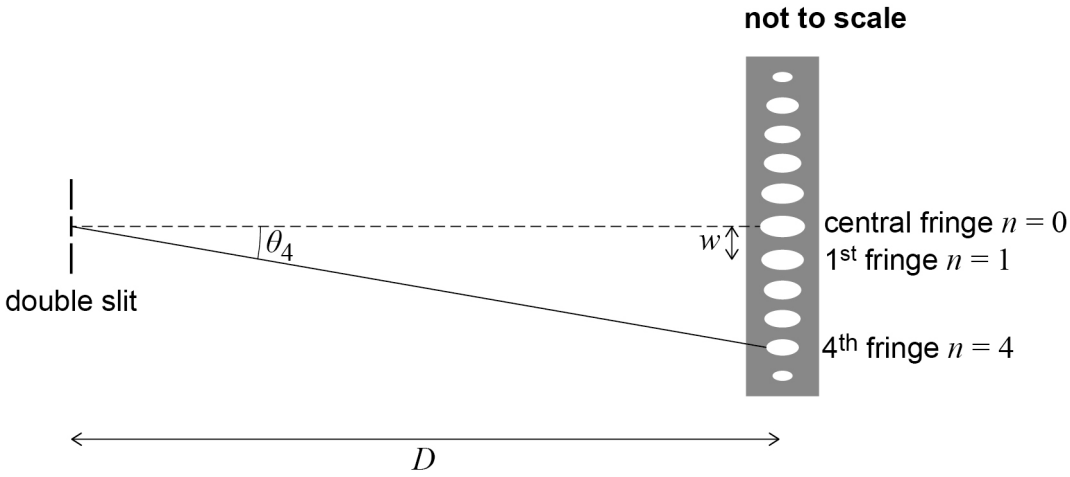
Do not write outside the box

**0 9** In an experiment, a beam of electrons is accelerated from rest through a potential difference.
The beam is split into two coherent beams by a device that acts as a double slit. The two electron beams interfere to form an interference pattern as shown in **Figure 11**.

The path from the centre of the double slit to the $n^{th}$ bright fringe makes an angle $\theta_n$ with the path to the central fringe.

The fringe separation is $w$.
The distance between the double slit and the interference pattern is $D$.
$D$ is much larger than $w$.

**Figure 11**



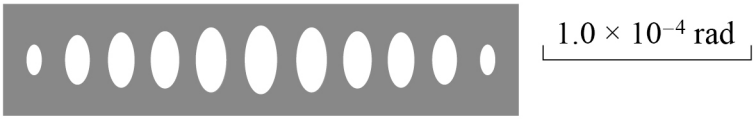

**0 9 . 1** Explain why $\theta_n$ in radians is approximately equal to $\frac{nw}{D}$.

**[1 mark]**

Do not write outside the box

**Figure 12** shows the interference pattern from this experiment.
The scale of the image is shown.

**Figure 12**




The slit separation of the double slit is $496\ \text{nm}$.

**0 9 . 2** Show that the de Broglie wavelength of the electrons is approximately $1 \times 10^{-11}\ \text{m}$.

In your answer:

- annotate **Figure 12** to show how you made your measurements
- use the relationship given in Question **09.1**.

**[4 marks]**

**Question 9 continues on the next page**

Do not write outside the box

**0 9 . 3** Calculate the accelerating potential difference for the electrons.
Ignore relativistic effects.

**[3 marks]**

accelerating potential difference = _____ V

8

**END OF SECTION A**

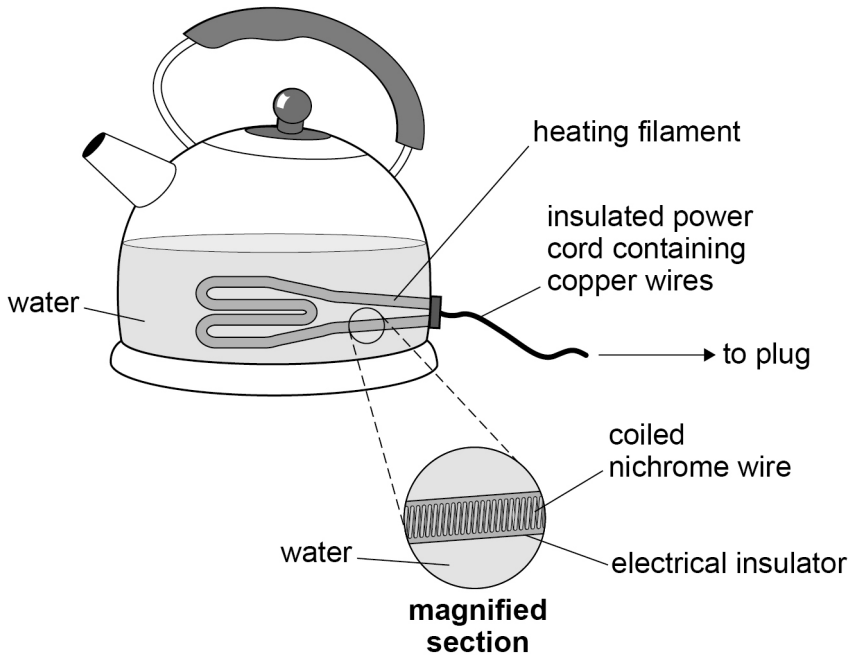
Do not write outside the box

## Section B

Answer **all** questions in this section.

**1 0** **Figure 13** shows a diagram of an electric kettle.

**Figure 13**




This kettle contains a heating filament that consists of coiled nichrome wire surrounded by an electrical insulator.
The heating filament is connected to the plug by a power cord that is made from copper wires surrounded by an electrical insulator.

When the kettle is switched on, energy is transferred from the filament to the water.

**1 0 . 1** The resistance of the nichrome wire is $18\ \Omega$ at its operating temperature.
The voltage across the nichrome wire is $230\ \text{V}$.

Calculate the power transferred by the nichrome wire.

**[1 mark]**

power = _____ W

**Question 10 continues on the next page**

Do not write outside the box

The resistance of the copper wire in the power cord must be much less than the resistance of the nichrome wire.

**1 0 . 2** Explain why.

**[3 marks]**

**1 0 . 3** The resistivity of nichrome is $1.12 \times 10^{-6}\ \Omega\ \mathrm{m}$ at its operating temperature.
The resistance of the nichrome wire is $18\ \Omega$ at this temperature.
The radius of the nichrome wire is $0.16\ \mathrm{mm}$.

Calculate the length of the nichrome wire.

**[2 marks]**

length = _____ m

Do not write outside the box

**1 0 . 4** When the kettle is switched on, the temperature of the nichrome wire increases rapidly for about $5\ \text{ms}$, until the nichrome wire reaches its operating temperature. The temperature then remains constant.

Explain how the power consumption of the kettle varies for the first $10\ \text{ms}$. Calculations are not required.

**[3 marks]**

9

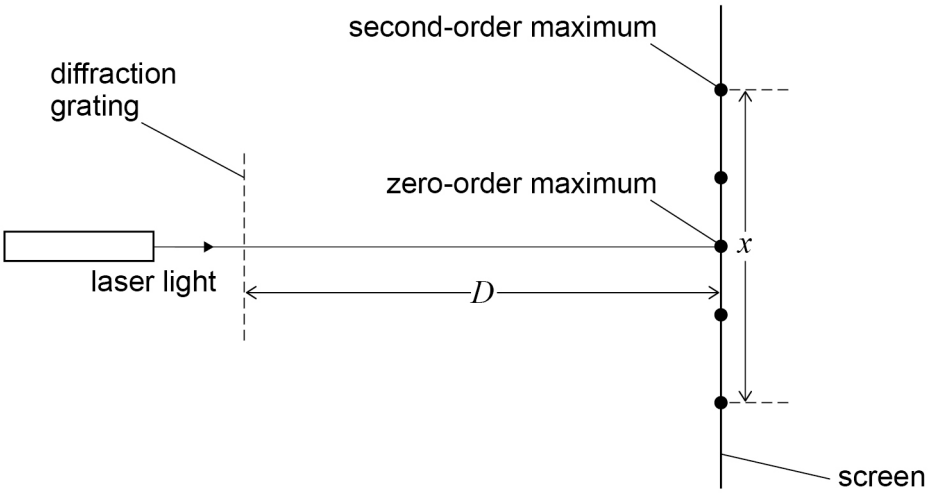
**Turn over for the next question**

Do not write outside the box

**1 1** **Figure 14** shows an arrangement used to determine the wavelength of laser light.
The light is incident normally on a diffraction grating.
The diffraction pattern is viewed on a screen a distance $D$ from the diffraction grating.

**Figure 14**

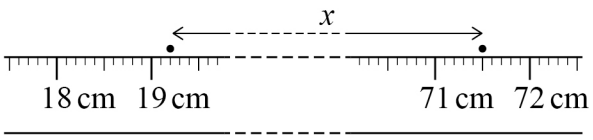
**not to scale**




The distance between the two second-order maxima is $x$.

A student uses a metre ruler to measure $x$, as shown in **Figure 15**.

**Figure 15**




**1 1 . 1** Determine $x$ using **Figure 15**.
State an appropriate unit for your answer.

**[1 mark]**

$x$ = _____

unit = _____

Do not write outside the box

**1 1 . 2** Calculate the percentage uncertainty in your value of $x$.

**[1 mark]**

percentage uncertainty = _____

**1 1 . 3** The student measures $D$ as $200.0\ \text{cm}$.
The diffraction grating has $100$ lines per $\text{mm}$.

Calculate, in $\text{nm}$, the wavelength $\lambda$ of the laser light.

**[3 marks]**

$\lambda$ = _____ $\text{nm}$

**1 1 . 4** The diffraction grating is now replaced with a grating that has a larger number of lines per $\text{mm}$. The uncertainty in the grating spacing is negligible.

Discuss how this will affect the percentage uncertainty in the measured value of $\lambda$.

**[2 marks]**

_____

_____

_____

_____

7

**END OF SECTION B**

**Turn over ►**

Do not write outside the box

## 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 2** What is the unit for resistivity in SI fundamental (base) units?

**[1 mark]**

**A** $kg\ m^3\ s^{-2}\ A^{-1}$

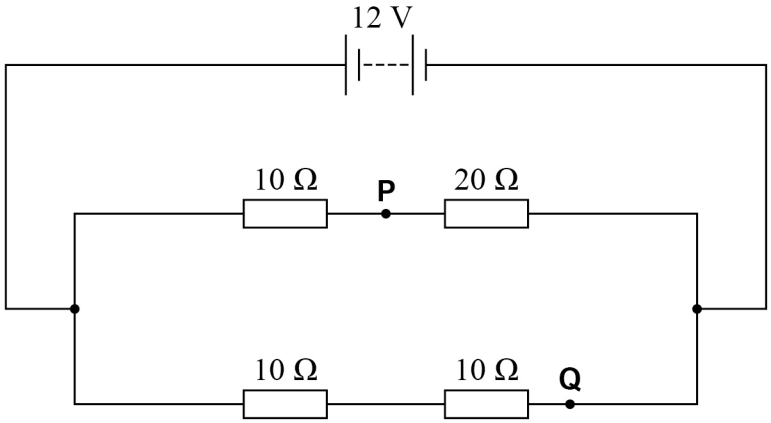
**B** $kg\ m^3\ s^{-3}\ A^{-1}$

**C** $kg\ m^3\ s^{-2}\ A^{-2}$

**D** $kg\ m^3\ s^{-3}\ A^{-2}$

Do not write outside the box

**1 3** The circuit shown contains a battery of emf 12 V with negligible internal resistance.




What is the potential difference between **P** and **Q**?

**[1 mark]**

**A** 4 V ⬭

**B** 6 V ⬭

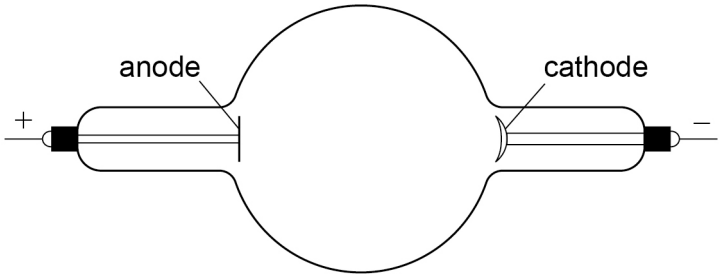
**C** 8 V ⬭

**D** 12 V ⬭

**Turn over for the next question**

Do not write outside the box

**1 4** A potential difference is applied across a neon gas-discharge tube.




In the tube, neon ions ($Ne^+$) with a charge of $+e$ travel from the anode to the cathode. Free electrons move in the opposite direction.

In 3.0 minutes, $4.4 \times 10^{20}$ $Ne^+$ ions arrive at the cathode and $4.4 \times 10^{20}$ free electrons reach the anode.

What is the total current between the cathode and the anode?

**[1 mark]**

**A** 0

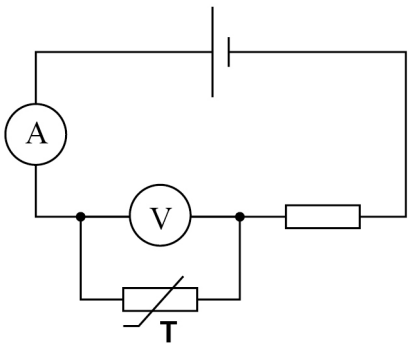
**B** 0.39 A

**C** 0.78 A

**D** 23 A

Do not write outside the box

**1 5** In the circuit shown, the cell has negligible internal resistance.
**T** is a negative temperature coefficient thermistor.




The temperature of the thermistor changes, causing an increase in the current.

Which row shows the change in temperature and the effect this change has on the voltmeter reading?

**[1 mark]**

| | Change in temperature | Effect on voltmeter reading | |
|---|---|---|---|
| **A** | increase | increase | ⬭ |
| **B** | increase | decrease | ⬭ |
| **C** | decrease | increase | ⬭ |
| **D** | decrease | decrease | ⬭ |

**Turn over for the next question**

Do not write outside the box

**Questions 16 and 17 are about the following experiment.**

A student uses a stopwatch to investigate the time period of a pendulum.

There is an absolute uncertainty of 0.2 s at the beginning and the end of each timing.

**1 6** The student measures ten oscillations of the pendulum. The stopwatch records the time for ten oscillations to be 15.07 s.

What is the best estimate for the percentage uncertainty of the time period of the pendulum?

**[1 mark]**

**A** 2.7% ⬭

**B** 1.3% ⬭

**C** 0.27% ⬭

**D** 0.13% ⬭

**1 7** The student repeats the measurement three more times. His four measurements of the time for ten oscillations are:

15.07 s 15.35 s 15.02 s 14.92 s

What is the best estimate for the percentage uncertainty in this set of measurements?

**[1 mark]**

**A** 0.14% ⬭

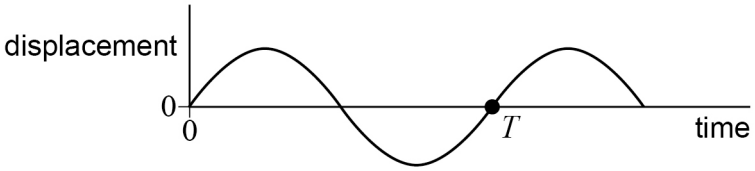
**B** 1.4% ⬭

**C** 2.7% ⬭

**D** 2.8% ⬭

Do not write outside the box

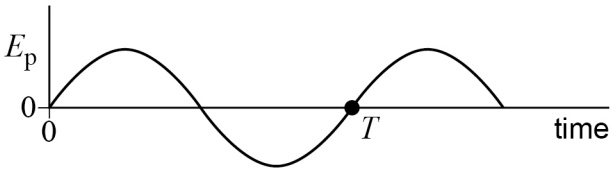
**1 8** An oscillating mass–spring system has a time period $T$.
The graph shows the variation with time of the displacement of the oscillating mass.



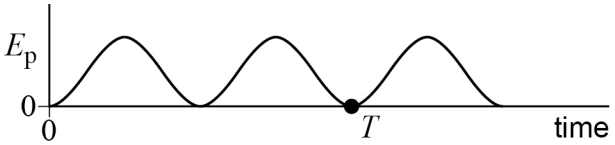

Which graph shows the variation with time of potential energy $E_p$ for the system?

**[1 mark]**

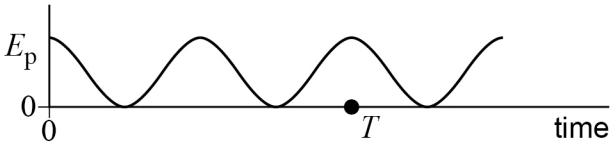
**A**



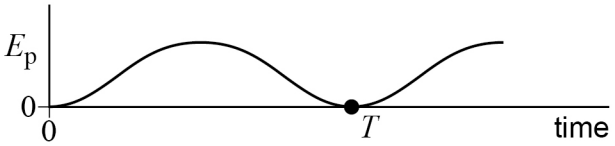

**B**




**C**




**D**




**Turn over for the next question**

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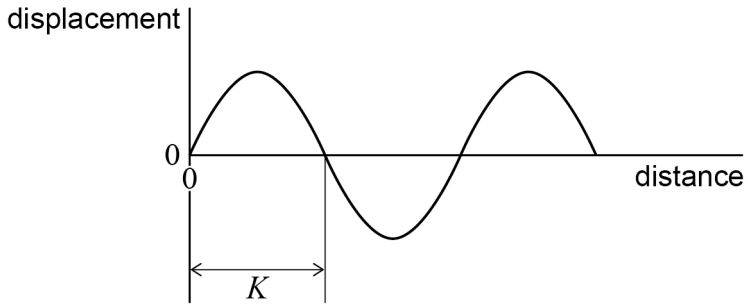
**1 9** A transverse wave is created by oscillating a string of beads.

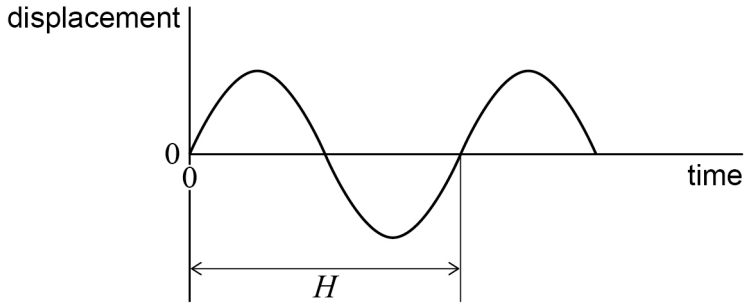
**Graph 1** shows the variation of the displacement of each bead with the distance measured from a fixed point along the wave.

**Graph 1**




**Graph 2** shows the variation of the displacement of a particular bead with time.

**Graph 2**




Which row gives the wavelength and frequency of the wave?

**[1 mark]**

| | Wavelength | Frequency | |
|---|---|---|---|
| **A** | $K$ | $H$ | ⬭ |
| **B** | $K$ | $\frac{1}{H}$ | ⬭ |
| **C** | $2K$ | $H$ | ⬭ |
| **D** | $2K$ | $\frac{1}{H}$ | ⬭ |

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**2 0** Sound travels at a speed $v$ in air and at a speed $4.5v$ in water.

A sound wave with a wavelength $\lambda$ is produced in air. The wave passes from air into water.

Which row shows the wavelength and the nature of the wave in water?

**[1 mark]**

| | Wavelength | Nature | |
|---|---|---|---|
| **A** | $4.5\lambda$ | longitudinal | ⬭ |
| **B** | $\lambda$ | longitudinal | ⬭ |
| **C** | $4.5\lambda$ | transverse | ⬭ |
| **D** | $\lambda$ | transverse | ⬭ |

**2 1** The frequency of the first harmonic of a violin string is 440 Hz.

The tension in the string is increased by 8%. The length and mass of the string do not change.

What is the new frequency of the first harmonic of the string?

**[1 mark]**

**A** 475 Hz ⬭

**B** 457 Hz ⬭

**C** 452 Hz ⬭

**D** 422 Hz ⬭

**Turn over ►**

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**2 2** Monochromatic light is incident normally on a diffraction grating.

The first-order maximum is observed at an angle of $18°$ to the zero-order maximum.

What is the largest angle at which a maximum can be found?

**[1 mark]**

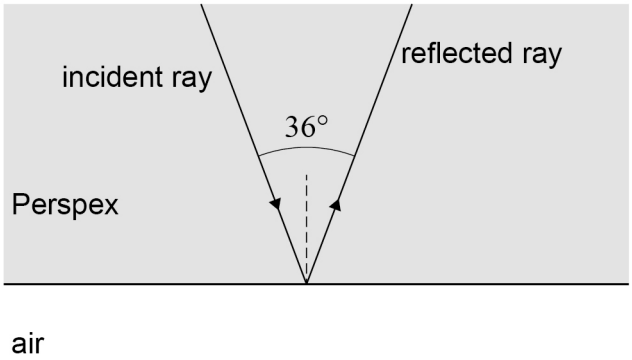
**A** $90°$ ⬭

**B** $72°$ ⬭

**C** $68°$ ⬭

**D** $54°$ ⬭

**2 3** Light is incident on a Perspex–air boundary and is partially reflected and partially refracted. The incident and reflected rays are shown. The refracted ray is not shown.




**not to scale**

The reflected ray is deflected by a total angle of $36°$ from the incident ray.
The refractive index of Perspex is $1.5$

What is the angle of refraction in air for the refracted ray?

**[1 mark]**

**A** $12°$ ⬭

**B** $23°$ ⬭

**C** $28°$ ⬭

**D** $62°$ ⬭

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**2 4** A monochromatic light source **X** produces $N_X$ photons per second, each with energy $E_X$.
A monochromatic light source **Y** has the same power as **X** and emits light with a smaller frequency than **X**.
**Y** produces $N_Y$ photons per second, each with energy $E_Y$.

Which row shows how $N_X$ compares with $N_Y$ and how $E_X$ compares with $E_Y$?

**[1 mark]**

| | | | |
|---|---|---|---|
| **A** | $N_X < N_Y$ | $E_X > E_Y$ | ⬭ |
| **B** | $N_X < N_Y$ | $E_X = E_Y$ | ⬭ |
| **C** | $N_X = N_Y$ | $E_X > E_Y$ | ⬭ |
| **D** | $N_X = N_Y$ | $E_X = E_Y$ | ⬭ |

**Turn over for the next question**

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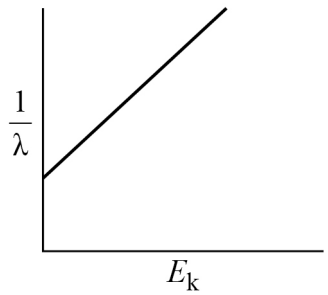
**2 5** Radiation of wavelength $\lambda$ is incident on a metal surface. Photoelectrons are emitted with maximum kinetic energy $E_k$.

The graph shows how $\frac{1}{\lambda}$ varies with $E_k$.




What is the gradient of the graph?

**[1 mark]**

**A** $h$ ⬭

**B** $hc$ ⬭

**C** $\frac{1}{h}$ ⬭

**D** $\frac{1}{hc}$ ⬭

14

**END OF QUESTIONS**

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**ANSWER IN THE SPACES PROVIDED**

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