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

Thursday 16 January 2020 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.

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	
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11–24	
TOTAL	

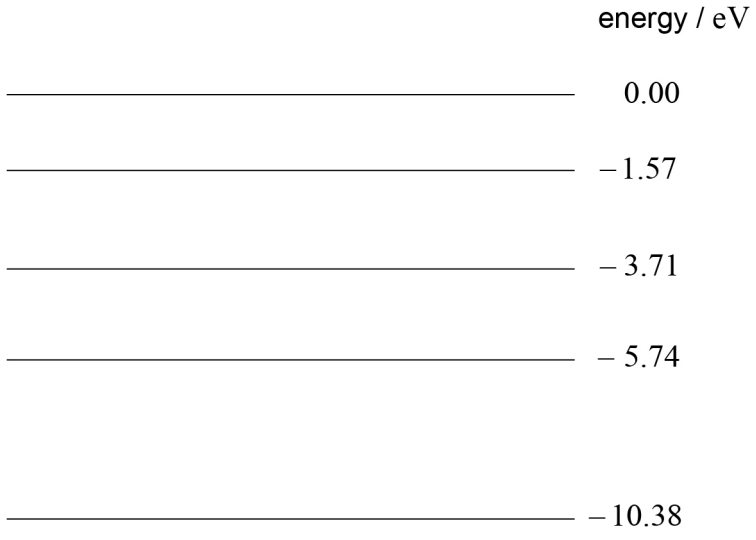
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Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows some of the energy levels of a single atom.

Figure 1



0 1 . 1 The atom is in its ground state. A photon of energy $8.81\ \text{eV}$ is incident on the atom.

Describe a likely outcome of this event.

[2 marks]

0 1 . 2 Multiple atoms, with the same energy levels as shown in **Figure 1**, return to the ground state.

State how many different photon wavelengths can be observed.

[1 mark]

number of wavelengths = _____

3

Do not write outside the box

0 2 Light passing from glass to water has a critical angle of $61°$.

0 2 . 1 State what is meant by critical angle.

[1 mark]

0 2 . 2 Glass has a refractive index of 1.52

Calculate the speed of light in water.

[3 marks]

speed = _____ $m\ s^{-1}$

4

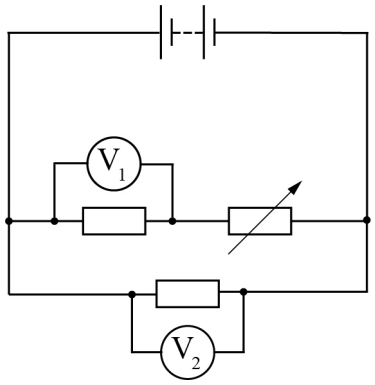
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0 3 **Figure 2** shows a circuit containing two fixed resistors, a variable resistor and a battery with negligible internal resistance.

Voltmeters V_1 and V_2 are connected across the fixed resistors.

Figure 2



The resistance of the variable resistor is increased.

State and explain how the readings on V_1 and V_2 are affected by this change.

[4 marks]

V_1

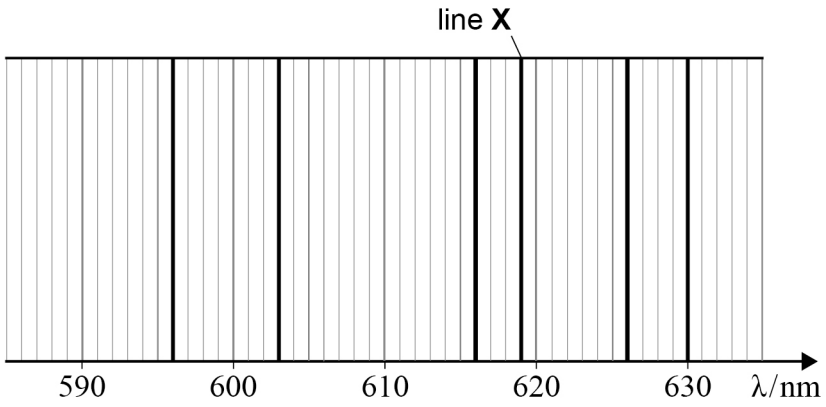
V_2

4

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0 4 **Figure 3** shows part of the line spectrum for light emitted from a neon lamp.
A wavelength scale is shown.

Figure 3



0 4 . 1 Outline how a diffraction grating can produce a line spectrum.

[2 marks]

0 4 . 2 Calculate the energy of the photon responsible for line **X** in the spectrum in **Figure 3**.

[3 marks]

photon energy = _____ J

5

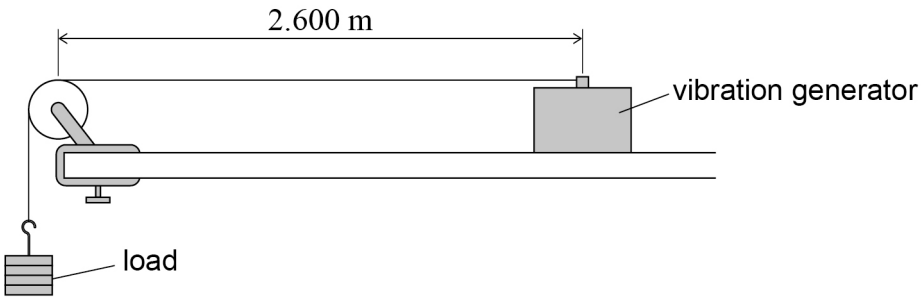
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0 5 **Figure 4** shows the apparatus used to investigate stationary waves on a string.

The frequency of the vibration generator is adjusted until the first-harmonic stationary wave is observed on the string. This is repeated for different loads.

Figure 4



0 5 . 1 Show that the frequency f of the first harmonic is related to the tension T in the string by the following equation:

$$f^2 = \left(\frac{1}{4lm}\right)T$$

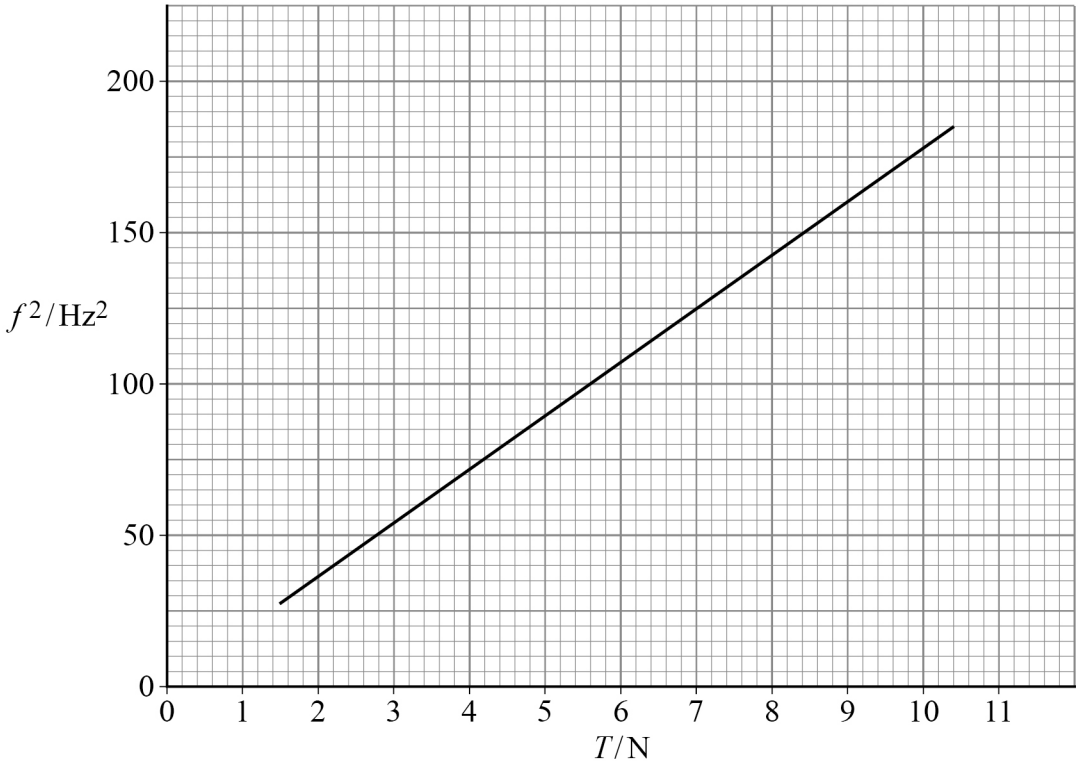
where l = length of the vibrating part of the string
m = mass of the vibrating part of the string.

[2 marks]

Do not write outside the box

0 5 . 2 **Figure 5** is a graph showing the variation of f^2 with T for this investigation.

Figure 5



Length l is 2.600 m.

Determine, using **Figure 5**, an accurate value for m.

[3 marks]

m = _____ kg

Question 5 continues on the next page

Do not write outside the box

0 5 . 3 To measure the length of $2.600\ \text{m}$, a metre ruler or a $5\ \text{m}$ tape measure may be used. Both the metre ruler and the tape measure have a $1\ \text{mm}$ resolution.

Explain the advantage of using the $5\ \text{m}$ tape measure.

[2 marks]

7

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ANSWER IN THE SPACES PROVIDED

Do not write outside the box

0 6 Electrons are accelerated from rest through a potential difference V as part of an electron-diffraction experiment.

0 6 . 1 Each electron gains a kinetic energy of 1.5×10^{-15} J.

Calculate V.

[2 marks]

$V =$ _____ V

0 6 . 2 Show that the momentum of an electron after acceleration is approximately 5×10^{-23} kg m s^{-1}.

[3 marks]

Do not write outside the box

0 6 . 3 The electrons are then incident on a graphite crystal. The crystal diffracts the electrons, creating a second-order maximum at an angle of $10°$ to the zero-order maximum.

The crystal can be modelled as a diffraction grating where the gap between each layer in the crystal behaves like the slit spacing of the grating.

Calculate the effective slit spacing of this diffraction grating.

[4 marks]

slit spacing = _____ m

9

Turn over for the next question

Do not write outside the box

0 7 . 1 State what is meant by the threshold frequency of radiation in the photoelectric effect.

[2 marks]

0 7 . 2 Monochromatic light with a photon energy of 3.7×10^{-19} J is incident on a metal surface.

Photoelectrons with a maximum kinetic energy of 5.7×10^{-20} J are emitted from the surface.

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

[2 marks]

work function = _____ eV

Do not write outside the box

0 7 . 3 The total power of the monochromatic light incident on the surface is 1.3×10^{-2} W.

Calculate the maximum number of photoelectrons that can be emitted from the surface per second.

[2 marks]

maximum number per second = _____

0 7 . 4 The light is replaced with a different monochromatic light with half the wavelength but the same incident power.

Describe and explain any effect on the photoelectrons.

[3 marks]

_____

_____

_____

_____

_____

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9

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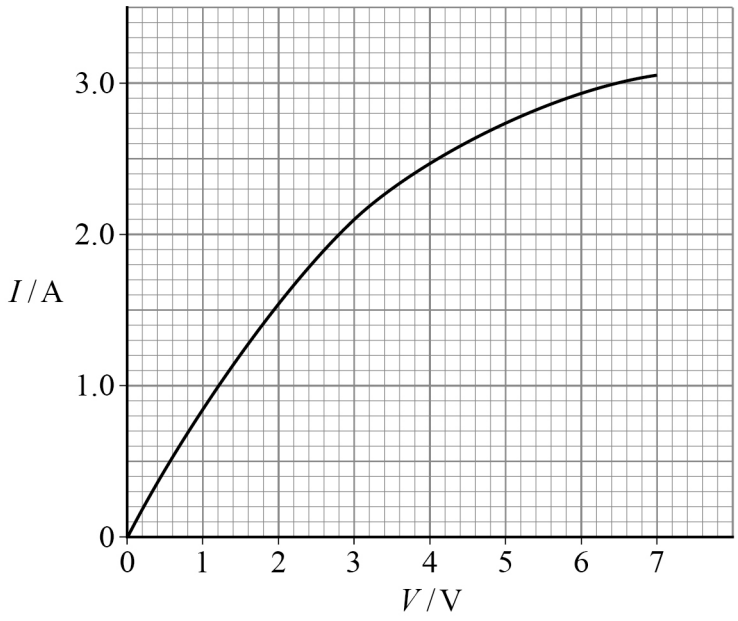
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0 8 . 1 Define electrical resistance.

[1 mark]

Figure 6 shows the I-V characteristic of a filament lamp **X**.

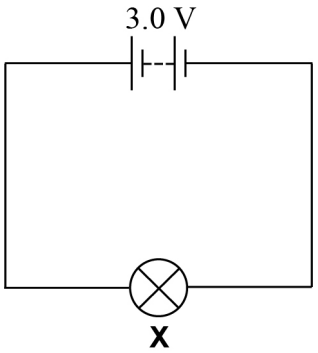
Figure 6



Do not write outside the box

0 8 . 2 **Figure 7** shows a battery of emf 3.0 V and negligible internal resistance connected to **X**.

Figure 7



Calculate the resistance of **X** in the circuit shown in **Figure 7**.

[2 marks]

resistance = _____ Ω

0 8 . 3 Calculate the power dissipated by **X** in this circuit.
State the unit for your answer in fundamental (base) units.

[3 marks]

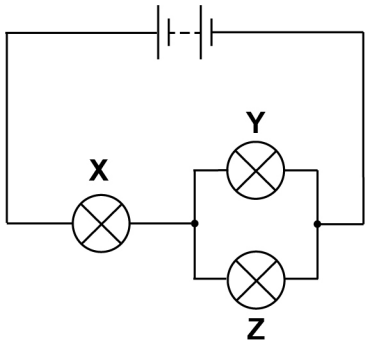
power = _____ unit = _____

Question 8 continues on the next page

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0 8 . 4 **Figure 8** shows **X** connected to two other lamps, **Y** and **Z**.
All three lamps have identical I-V characteristics.

Figure 8



Explain for this circuit how the resistance of **Y** compares with the resistance of **X**.
Calculations are **not** required.

[3 marks]

9

END OF SECTION A

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

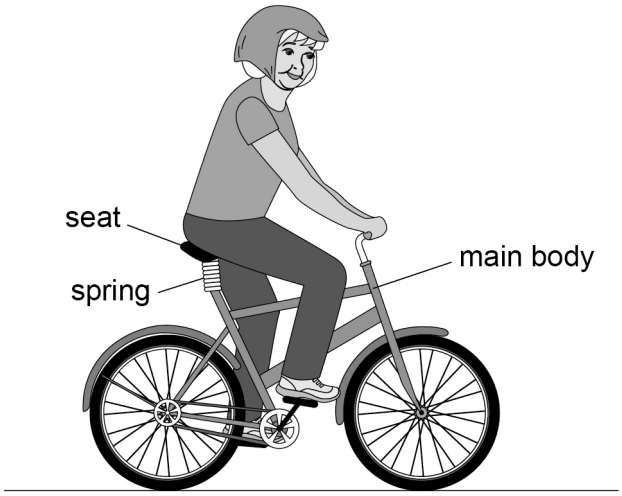
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Section B

Answer **all** questions in this section.

0 9 The seat of a bicycle is attached to the main body of the bicycle by a single vertical spring, as shown in **Figure 9**.

Figure 9



The spring has a spring constant of $7.2 \times 10^4\ \text{N m}^{-1}$. The mass of the rider is $68\ \text{kg}$. Assume that the weight of the rider is fully supported by the spring and that the mass of the seat is negligible.

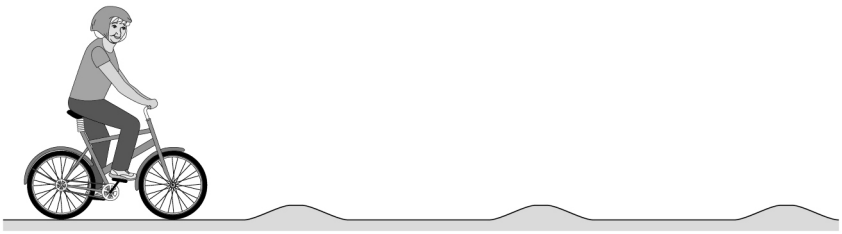
0 9 . 1 Show that the time period for free oscillations of the seat is approximately $0.2\ \text{s}$ when the rider is sitting on it.

[2 marks]

Do not write outside the box

0 9 . 2 **Figure 10** shows the bicycle and rider approaching a series of speed bumps that are equally spaced.

Figure 10



When the bicycle travels over the speed bumps at a certain speed, the rider experiences large-amplitude vertical oscillations.

Identify and explain the effect that causes the large-amplitude oscillations.

[3 marks]

0 9 . 3 The rider experiences large-amplitude oscillations when the bicycle travels at $5.8\ \text{m s}^{-1}$.

Calculate the distance between adjacent speed bumps.

[2 marks]

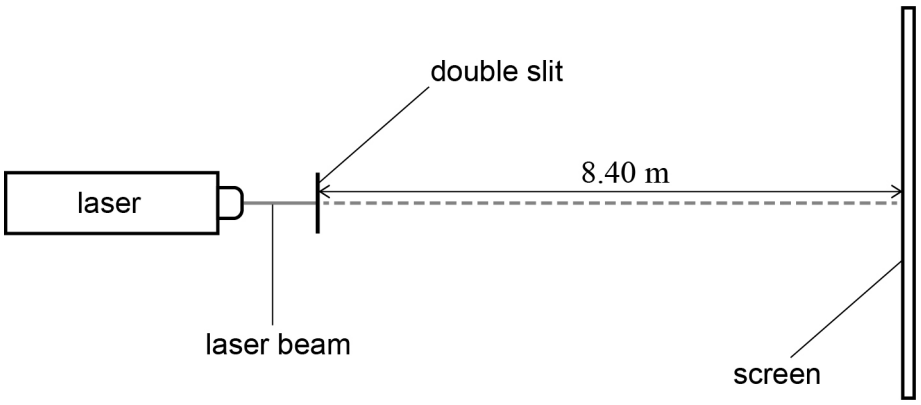
distance = _____ m

7

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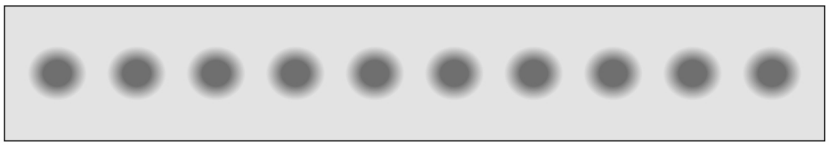
1 0 **Figure 11** shows apparatus used to determine the wavelength of laser light using Young's double-slit method.

Figure 11



1 0 . 1 **Figure 12** shows the actual size of part of the interference fringe pattern seen on the screen.

Figure 12



actual size

Determine, in mm, an accurate measurement for the fringe spacing w.

[2 marks]

$w =$ _____ mm

Do not write outside the box

1 0 . 2 Calculate the percentage uncertainty in your value for w.

[2 marks]

percentage uncertainty = _____

1 0 . 3 The distance between the slits is 0.420 mm with an uncertainty of $\pm 1.2\%$.
The distance from the slits to the screen is 8.40 m with an uncertainty of $\pm 0.6\%$.

Calculate, in nm, the wavelength of the laser light.

[2 marks]

wavelength = _____ nm

1 0 . 4 Calculate the absolute uncertainty in your value for the wavelength.

[3 marks]

absolute uncertainty = _____ nm

9

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 sheets for this working.

1 1 A cell has an emf of $1.5\ \text{V}$ and an internal resistance of $2.0\ \Omega$.
A wire of negligible resistance is connected directly from one terminal of the cell to the other.

What is the energy dissipated in the cell in 5 minutes?

[1 mark]

A $5.6\ \text{J}$ 

B $340\ \text{J}$ 

C $900\ \text{J}$ 

D $1400\ \text{J}$ 

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1 2 A metal wire has resistance R.
A second wire made from the same metal is 50% longer but has the same volume as the first wire.

What is the resistance of the second metal wire?

[1 mark]

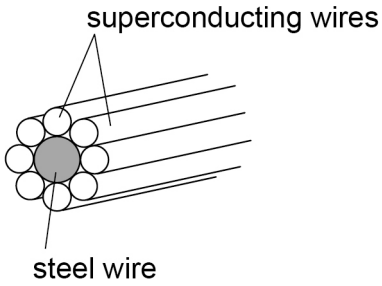
A $0.67R$ ⬭

B $1.5R$ ⬭

C $2.0R$ ⬭

D $2.3R$ ⬭

1 3 A cable consists of superconducting wires attached in parallel to a steel wire.



What is the purpose of the steel wire in the cable?

[1 mark]

A to increase the critical temperature of the superconductor ⬭

B to increase the strength of the cable ⬭

C to reduce the resistance of the cable when it is superconducting ⬭

D to reduce the current in the cable ⬭

Do not write outside the box

1 4 Two resistors **X** and **Y** have resistances R_X and R_Y.
R_Y is greater than R_X.
When **X** and **Y** are combined in parallel, the equivalent resistance is R_T.

Which is correct?

[1 mark]

A $R_T < R_X < R_Y$ ⬭

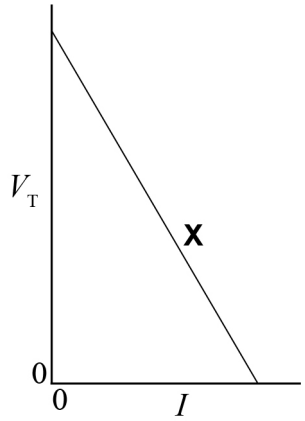
B $R_X < R_T < R_Y$ ⬭

C $R_X < R_Y < R_T$ ⬭

D $R_T < R_Y < R_X$ ⬭

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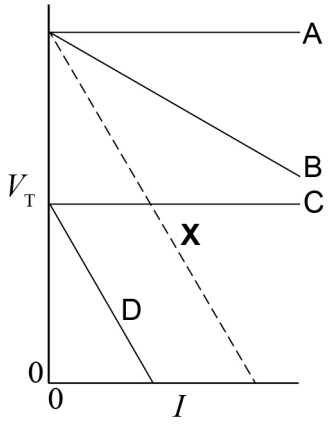
1 5 A battery **X** has emf ε and internal resistance r. The graph shows the variation of terminal pd V_T with current I for the battery.



The line for battery **X** is shown again below as a dashed line.

Which line shows the variation of V_T with I for a battery of emf $\frac{\varepsilon}{2}$ and negligible internal resistance?

[1 mark]



A ⬭

B ⬭

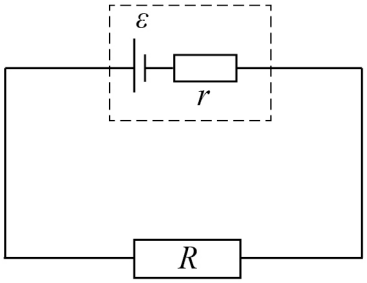
C ⬭

D ⬭

Turn over ►

Do not write outside the box

1 6 A resistor of resistance R is connected to a cell of emf ε and internal resistance r.
The current in the circuit is I.



What is the power dissipated in the resistor of resistance R?

[1 mark]

A $I\varepsilon$ ⬭

B $I^2(R+r)$ ⬭

C $\dfrac{\varepsilon^2}{R+r}$ ⬭

D $\dfrac{\varepsilon^2 R}{(R+r)^2}$ ⬭

1 7 Two pendulums have the same length and perform undamped small-angle oscillations with the same amplitude.
One pendulum bob has a greater mass than the other.

Which quantity is **not** the same for both pendulums?

[1 mark]

A average speed ⬭

B time period ⬭

C total energy ⬭

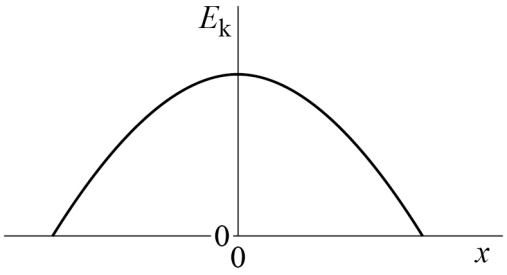
D maximum speed ⬭

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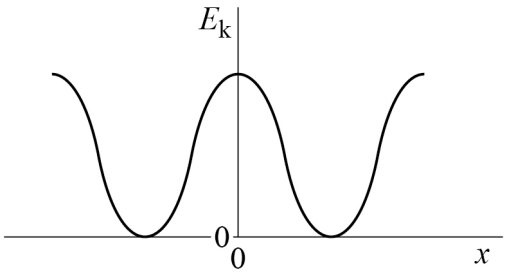
1 8 Which graph shows the variation of kinetic energy E_k with displacement x for a mass–spring system performing simple harmonic motion?

[1 mark]

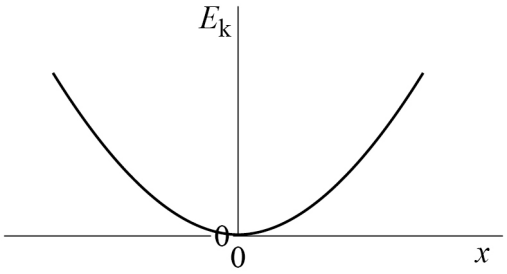
A



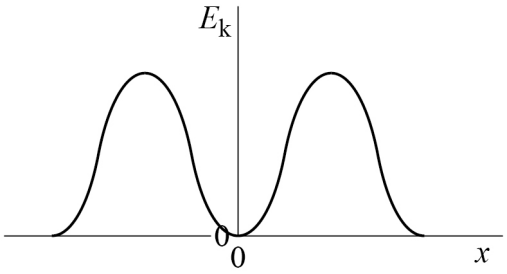
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

1 9 What **cannot** be observed with sound waves?

[1 mark]

A diffraction ⬭

B dispersion ⬭

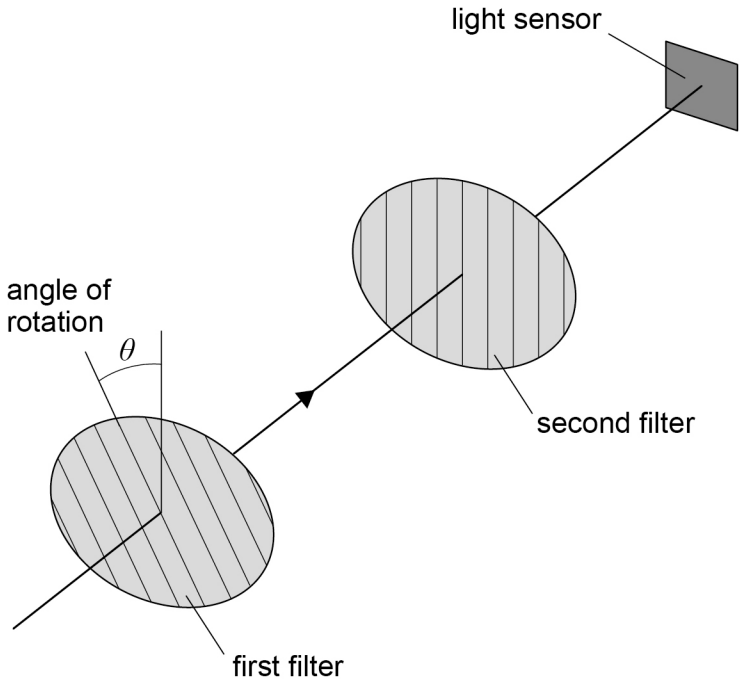
C polarisation ⬭

D refraction ⬭

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2 0 Unpolarised light passes perpendicularly through two polarising filters before reaching a sensor that detects its intensity I.



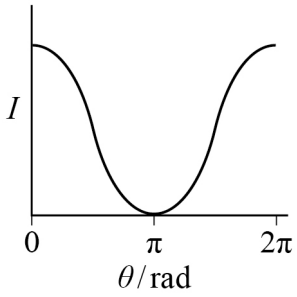
The first filter is rotated through an angle θ about an axis parallel to the light beam.

Which graph on page 29 shows the variation of intensity I with angle θ?

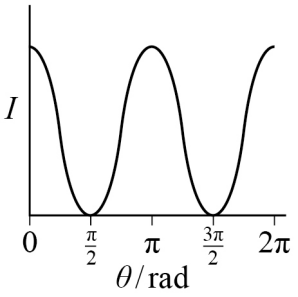
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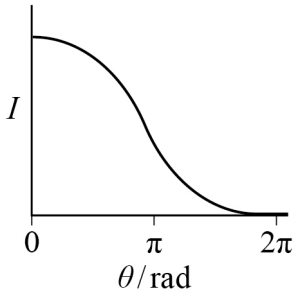
A



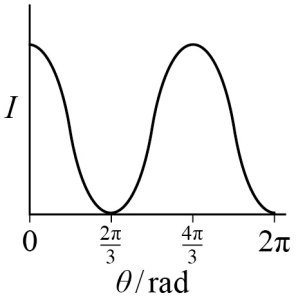
B



C



D



A ⬭

B ⬭

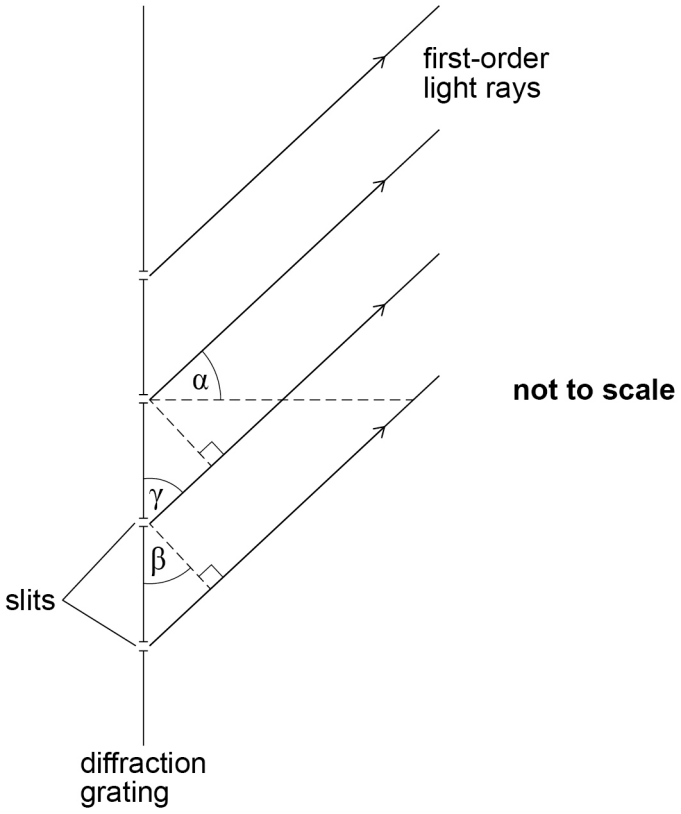
C ⬭

D ⬭

Turn over for the next question

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2 1 In the derivation of the diffraction grating equation $n\lambda = d\sin\theta$, a diagram similar to the one below can be used.



not to scale

Which of the labelled angles α, β or γ is equivalent to the angle θ in the equation?

[1 mark]

A α only ⬭

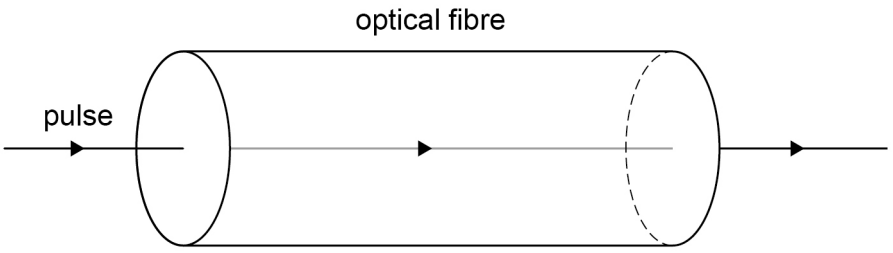
B α and β only ⬭

C γ only ⬭

D β and γ only ⬭

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2 2 A pulse of white light passes along the axis of a straight optical fibre. The pulse is broader when it leaves the optical fibre.



What causes this effect?

[1 mark]

A absorption ⬭

B attenuation ⬭

C material dispersion ⬭

D modal dispersion ⬭

2 3 Light crosses the boundary from air into a substance that has a refractive index of 2

What happens to the speed, frequency and wavelength of the light as it crosses the boundary?

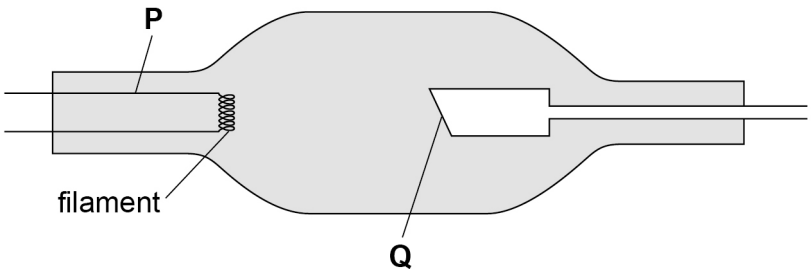
[1 mark]

	Speed	**Frequency**	**Wavelength**	
A	halves	stays the same	halves	⬭
B	doubles	stays the same	doubles	⬭
C	doubles	doubles	stays the same	⬭
D	halves	halves	doubles	⬭

Turn over ►

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2 4 The diagram shows an X-ray tube.



Which row identifies parts **P** and **Q**, and the direction of travel of the electrons?

[1 mark]

	P	Q	Direction of electron travel	
A	anode	cathode	from **P** to **Q**	⬭
B	anode	cathode	from **Q** to **P**	⬭
C	cathode	anode	from **P** to **Q**	⬭
D	cathode	anode	from **Q** to **P**	⬭

14

END OF QUESTIONS

There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**

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