

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname *StemUp Model Solution*

Forename(s)

Candidate signature

OXFORD AQA INTERNATIONAL AS PHYSICS

Unit 2 Electricity, waves and particles

Thursday 25 January 2018

06:00 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.
- 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	
10–23	
TOTAL	



Section AAnswer **all** questions in this section.**0 1 . 1**

Outline what is meant by a superconductor.

[2 marks]

A superconductor is a material that has zero resistivity, so no resistance to an electric current,

when it is cooled to or below its critical temperature.

0 1 . 2State **one** application of superconductors.**[1 mark]**

Producing very powerful magnets (strong magnetic fields), for example in MRI scanners or Maglev trains.

3**0 2**

X-rays and ultrasound are used in medical imaging.

0 2 . 1State **one** advantage of using X-rays instead of ultrasound in medical imaging.**[1 mark]**

X-rays produce a clearer, more detailed image (better resolution), for example of bones.

0 2 . 2

Describe why ultrasound, rather than X-rays, is used to produce an image of a fetus.

[2 marks]

Ultrasound is non-ionising, whereas X-rays are ionising radiation.

X-rays could damage the cells (DNA) of the developing fetus, causing mutations or cancer, so ultrasound is much safer.

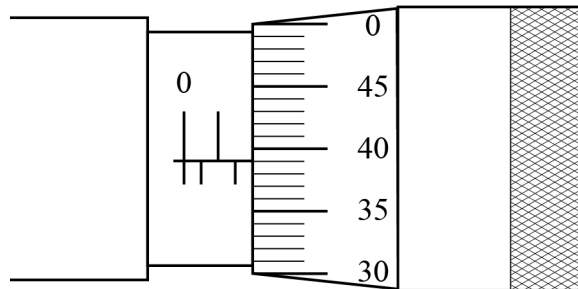
3

0 3

A student uses a micrometer, that has no zero error, to measure the diameter of a copper wire.

Figure 1 shows the micrometer scales as the diameter is measured.

Figure 1



0 3 . 1

Show that the cross-sectional area of the wire is about $2.8 \times 10^{-6} \text{ m}^2$

[2 marks]

$$\text{diameter} = 1.5 \text{ mm} + 0.39 \text{ mm} = 1.89 \text{ mm}$$

$$\text{radius } r = 1.89 / 2 = 0.945 \text{ mm} = 0.945 \times 10^{-3} \text{ m}$$

$$A = \pi r^2 = \pi \times (0.945 \times 10^{-3})^2$$

$$A = 2.81 \times 10^{-6} \text{ m}^2 \approx 2.8 \times 10^{-6} \text{ m}^2$$

0 3 . 2

The resistivity of copper is $1.7 \times 10^{-8} \Omega \text{ m}$
The wire has a length of 85 cm

Calculate the resistance of the wire.

Give your answer to an appropriate number of significant figures.

[3 marks]

$$R = \rho L / A$$

$$R = 1.7 \times 10^{-8} \times 0.85 / 2.81 \times 10^{-6}$$

$$R = 5.14 \times 10^{-3} \Omega$$

(2 sig. fig., the same as the data for ρ)

resistance = 5.1×10^{-3} Ω

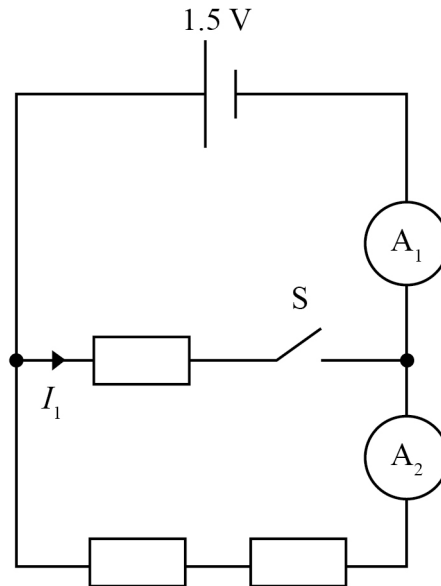
5

Turn over ►



0 4

Figure 2 shows three identical resistors, each with a resistance R , in a circuit connected to a cell with emf 1.5 V . The cell has negligible internal resistance.

Figure 2

0 4

. 1

When switch S is closed the reading of ammeter A_1 is 1.2 A and the reading of ammeter A_2 is 0.40 A .

State the value of the current I_1 when switch S is closed.

[1 mark]

$$I_1 = 1.2 - 0.40 = 0.80\text{ A}$$

$$I_1 = \underline{0.80}\text{ A}$$

0 4

. 2

Calculate R .

[1 mark]

$$2R = V / I = 1.5 / 0.40 = 3.75\ \Omega, \text{ so } R = 1.875\ \Omega$$

$$R = \underline{1.9}\ \Omega$$



0 4 . 3

Switch S is returned to the open position.

State and explain the effect this has on the readings of A_1 and A_2 .**[3 marks]***The reading of A_1 decreases (from 1.2 A to 0.40 A).**This is because the upper branch is disconnected, so the total resistance of the circuit increases (from $2R/3$ to $2R$) and the current from the cell falls: $I = 1.5 / 3.75 = 0.40$ A.**The reading of A_2 stays the same (0.40 A).**This is because the pd across the lower branch (1.5 V) and the resistance of this branch ($2R$) are both unchanged.*

5

Turn over for the next question**Turn over ►**

0 5

Figure 3 shows some of the energy levels for a hydrogen atom.

Figure 3

$n = 5$	_____	-0.54 eV
$n = 4$	_____	-0.85 eV
$n = 3$	_____	-1.51 eV
$n = 2$	_____	-3.40 eV

ground state $n = 1$ _____ -13.60 eV

0 5 . 1

A hydrogen atom is in the ground state. It absorbs all the energy of a photon and becomes excited to the $n = 3$ energy level.

Calculate the frequency of the photon absorbed by the hydrogen atom.

[3 marks]

$$\Delta E = -1.51 - (-13.60) = 12.09 \text{ eV}$$

$$\Delta E = 12.09 \times 1.60 \times 10^{-19} = 1.934 \times 10^{-18} \text{ J}$$

$$E = hf, \text{ so } f = E / h$$

$$f = 1.934 \times 10^{-18} / 6.63 \times 10^{-34} = 2.92 \times 10^{15} \text{ Hz}$$

frequency = 2.9×10^{15} Hz

0 5 . 2

State, in eV, the ionisation energy of a hydrogen atom.

[1 mark]

ionisation energy = 13.6 eV



0 5 . 3

A photon with an energy of 18.4 eV interacts with a hydrogen atom in its ground state.

Describe how the principle of energy conservation could apply in this situation.

[3 marks]

The photon energy (18.4 eV) is greater than the ionisation energy of hydrogen (13.6 eV).

All of the photon's energy is absorbed by the atom and the photon disappears.

The atom is ionised: 13.6 eV of the energy is used to remove the electron from the atom.

The surplus energy, $18.4 - 13.6 = 4.8$ eV, becomes the kinetic energy of the emitted electron (a tiny amount goes into the recoil of the nucleus), so the total energy is conserved.

7

Turn over for the next question

Turn over ►



06.1

Describe the nature of an electromagnetic wave.

[3 marks]

An electromagnetic wave consists of periodically varying (oscillating) electric and magnetic fields.

The electric and magnetic fields are perpendicular to each other and in phase with each other.

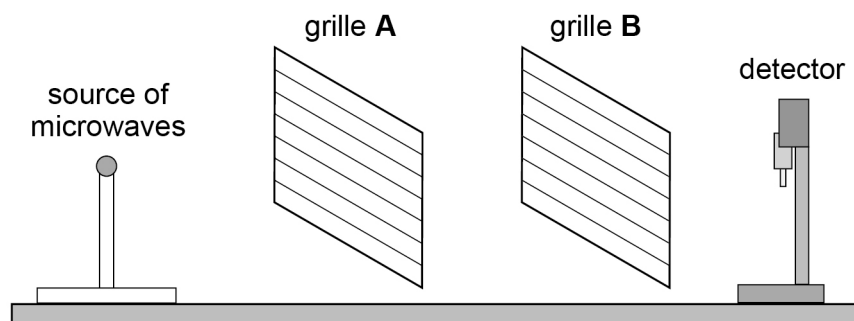
Both fields oscillate perpendicular to the direction of propagation, so it is a transverse wave.

All electromagnetic waves travel at the same speed, $3.00 \times 10^8 \text{ m s}^{-1}$, in a vacuum.

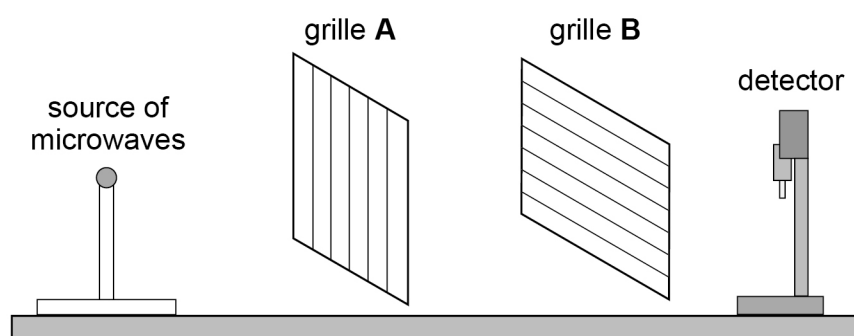


0 6 . 2

A source of microwaves and a detector are set up with two metal grilles **A** and **B** between them, as shown in **Figure 4**. The reading on a voltmeter connected to the detector is 5 mV. Each grille consists of a series of parallel, thin, metal rods.

Figure 4

Grille **A** is rotated through 90° about a horizontal axis as shown in **Figure 5**.

Figure 5

Explain the changes in the voltmeter reading as grille **A** is rotated.

[2 marks]

The voltmeter reading decreases and falls to zero when grille A has been rotated through 90° .

Each grille polarises the microwaves (only lets through waves oscillating in one plane). After the rotation the rods of grille A are at 90° to the rods of grille B, so B absorbs the remaining (polarised) waves and none reach the detector.

Question 6 continues on the next page

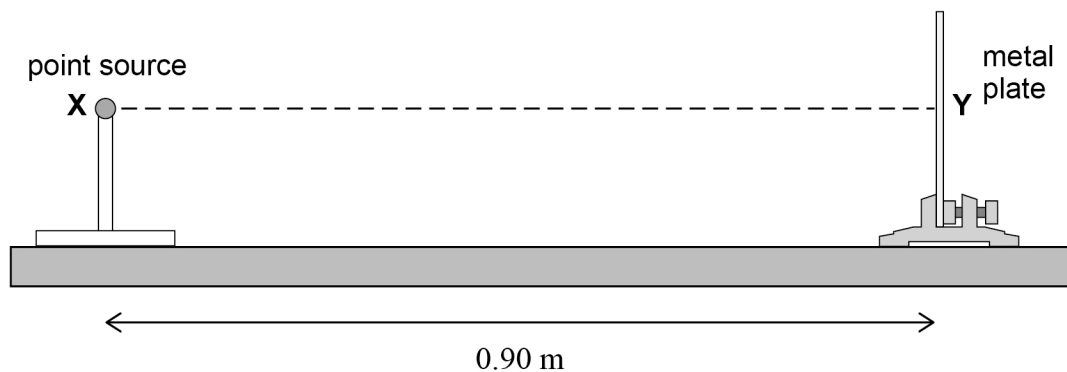
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0 6 . 3

In another experiment the source is placed 0.90 m away from a metal plate, as shown in **Figure 6**.

Figure 6



Explain how a stationary wave is formed along the line **XY** between the source and the metal plate.

[3 marks]

The microwaves travel from the source to the metal plate and are reflected back along XY.

The outward (incident) wave and the reflected wave have the same frequency and speed and travel in opposite directions, so they superpose (interfere).

Where the two waves are in phase, constructive interference occurs and antinodes form (maximum intensity).

Where the two waves are in antiphase (180° or π radians out of phase), destructive interference occurs and nodes form (zero intensity).

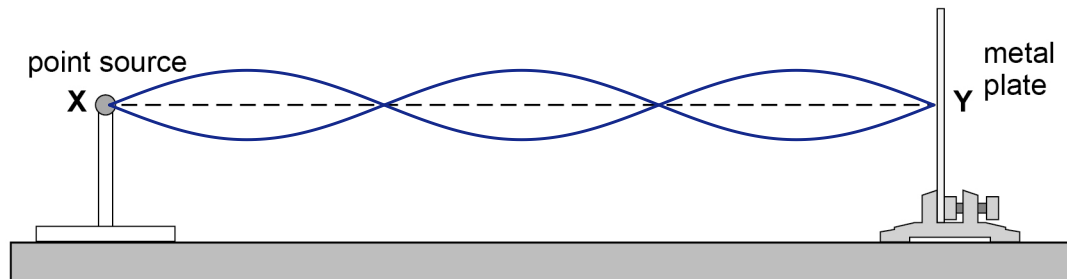


- 0 6 . 4** The microwaves emitted from the source have a wavelength of 60 cm

Sketch on **Figure 7** the shape of the stationary wave formed.

[1 mark]

Figure 7



- 0 6 . 5** A detector connected to a voltmeter can be moved along the line **XY** in **Figure 6**.

Explain how the voltmeter readings vary as the detector is moved along the line **XY**.

[2 marks]

As the detector is moved along XY the voltmeter reading varies from zero to a maximum and back to zero several times.

The reading is zero at the nodes, 30 cm and 60 cm from X (and at the plate), and a maximum at the antinodes, 15 cm, 45 cm and 75 cm from X.

Adjacent nodes (or antinodes) are half a wavelength, 30 cm, apart.



0 7 . 1

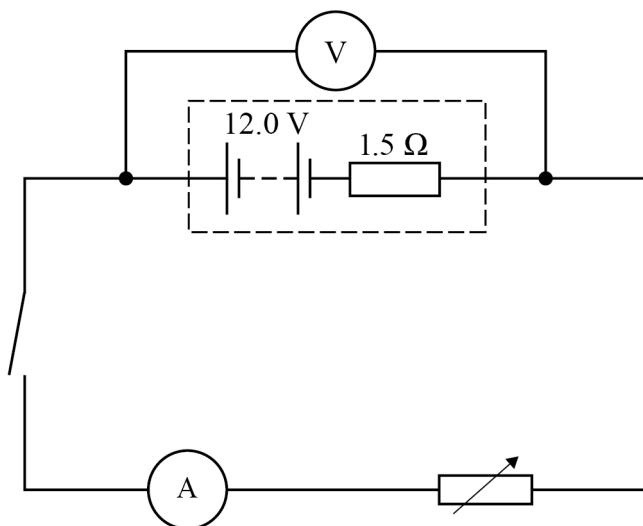
Define the electromotive force (emf) of a battery.

[2 marks]

The emf is the work done (energy transferred) by the battery per unit charge passing through it, in moving the charge round the entire circuit, including through the internal resistance.

0 7 . 2

A battery with an emf of 12.0 V and an internal resistance of 1.5 Ω is connected in the circuit shown in **Figure 8**.

Figure 8

The voltmeter reading is 9.0 V when the current in the circuit is 2.0 A

Calculate the resistance of the variable resistor when the voltmeter reads 9.0 V

[2 marks]

the voltmeter reads the pd across the variable resistor: $V = 9.0 \text{ V}$

(lost volts = $Ir = 2.0 \times 1.5 = 3.0 \text{ V}$, and $12.0 - 3.0 = 9.0 \text{ V}$)

$R = V / I = 9.0 / 2.0 = 4.5 \Omega$

resistance = 4.5 Ω



0 7 . 3

Determine the maximum current that can be provided by the battery.

[2 marks]

maximum current when the external resistance $R = 0$

$$\mathcal{E} = I(R + r): 12.0 = I(0 + 1.5)$$

$$I = 12.0 / 1.5 = 8.0 \text{ A}$$

maximum current = 8.0 A

0 7 . 4

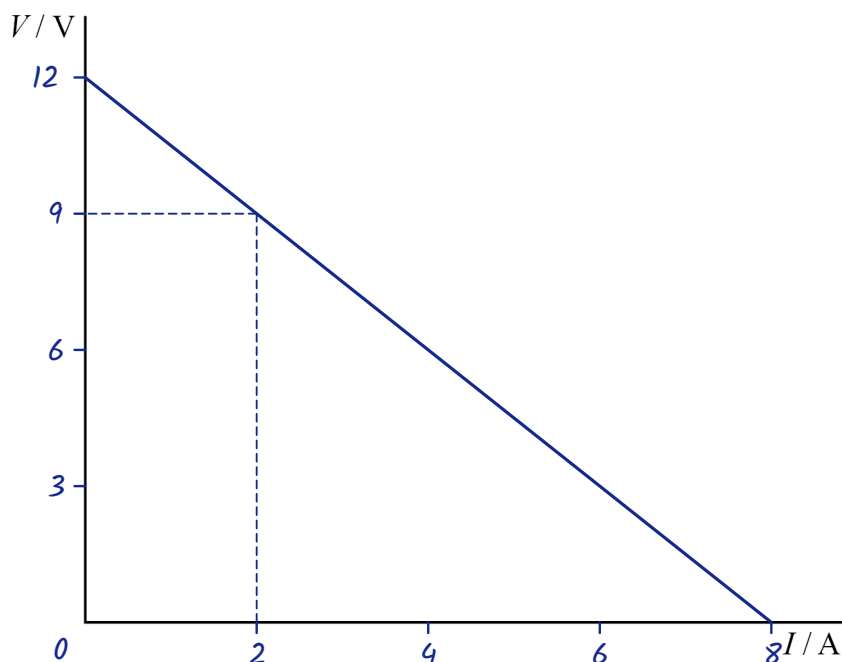
With the switch closed the variable resistor is adjusted to obtain a range of ammeter and voltmeter readings. Finally the switch is opened and a final ammeter and voltmeter reading are obtained.

Sketch on **Figure 9** a graph to show the variation of voltmeter reading V with current I .

Label your axes with suitable numerical values.

[2 marks]

Figure 9



Question 7 continues on the next page

Turn over ►



07.5

The battery, when fully charged, can deliver a total charge of $1.15 \times 10^4 \text{ C}$

For a particular application, the fully-charged battery is required to supply a constant current to an external circuit of resistance 0.1Ω for 30 minutes.

Discuss the suitability of the battery for this application.

You should use calculations to support your answer.

[3 marks]

$$I = \varepsilon / (R + r) = 12.0 / (0.1 + 1.5) = 7.5 \text{ A}$$

(this is less than the 8.0 A maximum current, so it is possible)

$$\text{time the battery lasts: } t = Q / I = 1.15 \times 10^4 / 7.5$$

$$t = 1533 \text{ s} = 25.6 \text{ minutes}$$

$$\text{charge needed for 30 min: } Q = It = 7.5 \times 30 \times 60 = 1.35 \times 10^4 \text{ C}$$

The current of 7.5 A is possible, but the battery can only supply this current for about 25.6 minutes, which is less than 30 minutes.

The charge needed, $1.35 \times 10^4 \text{ C}$, is more than the $1.15 \times 10^4 \text{ C}$ the battery can deliver, so the battery is unsuitable for this application.

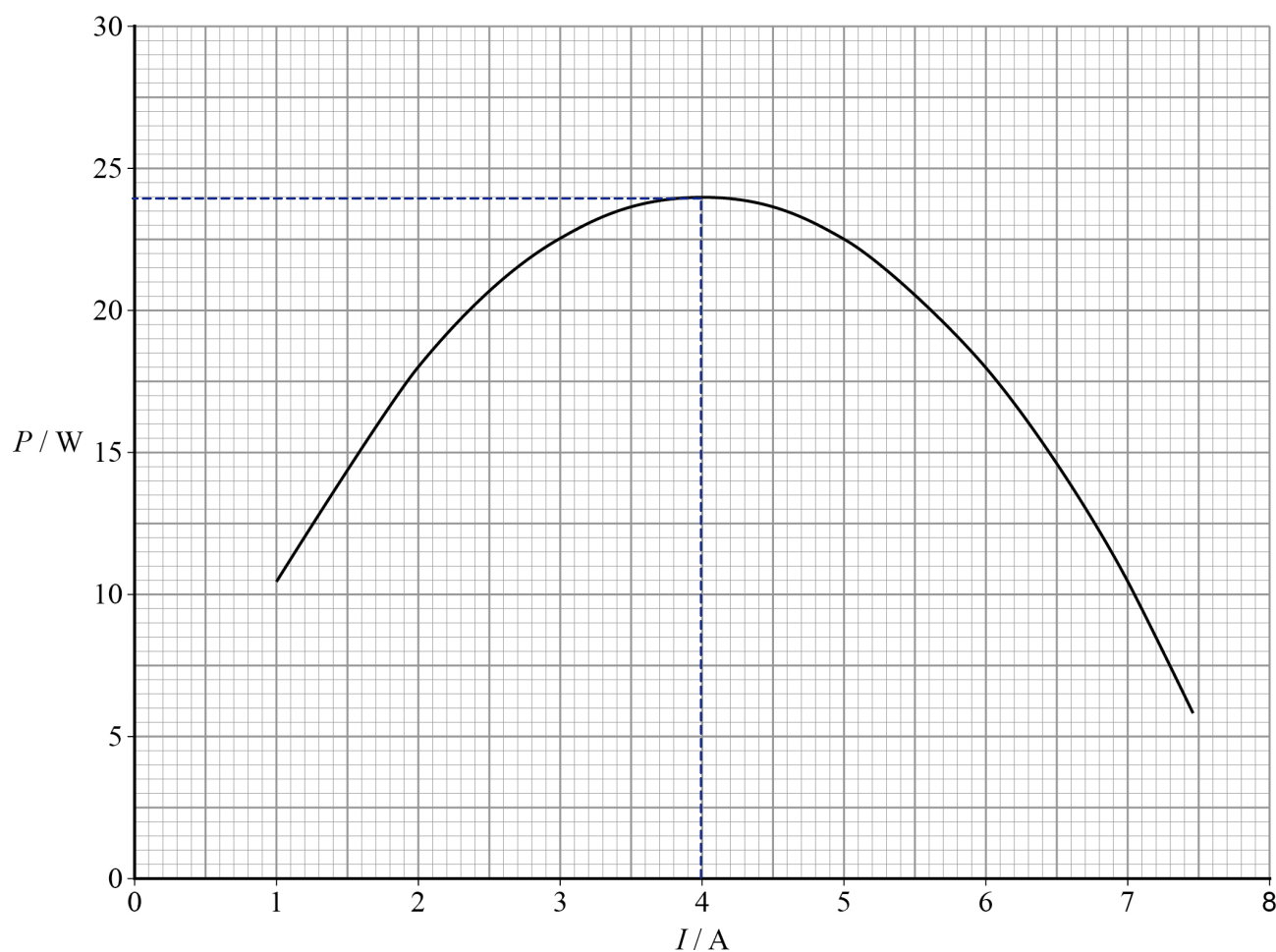


0 7 . 6

Figure 10 shows the variation with current of the power dissipated in the variable resistor.

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Figure 10



Calculate using data from **Figure 10** the value of the variable resistance when P is a maximum.

[3 marks]

from Figure 10, maximum $P = 24 \text{ W}$ when $I = 4.0 \text{ A}$

$$P = I^2 R, \text{ so } R = P / I^2$$

$$R = 24 / 4.0^2 = 1.5 \, \Omega$$

variable resistance = 1.5 Ω

Question 7 continues on the next page

Turn over ►



0 7 . 7

Figure 10 suggests that as the current increases past 7.5 A, the power dissipated in the variable resistor eventually reaches zero.

Explain why the circuit behaves in this way.

[2 marks]

To obtain the maximum current (8.0 A) the resistance of the variable resistor is reduced to zero.

Then $P = I^2 R = 0$ for the variable resistor: all of the power is dissipated in the internal resistance of the battery.

16

END OF SECTION A



Section B

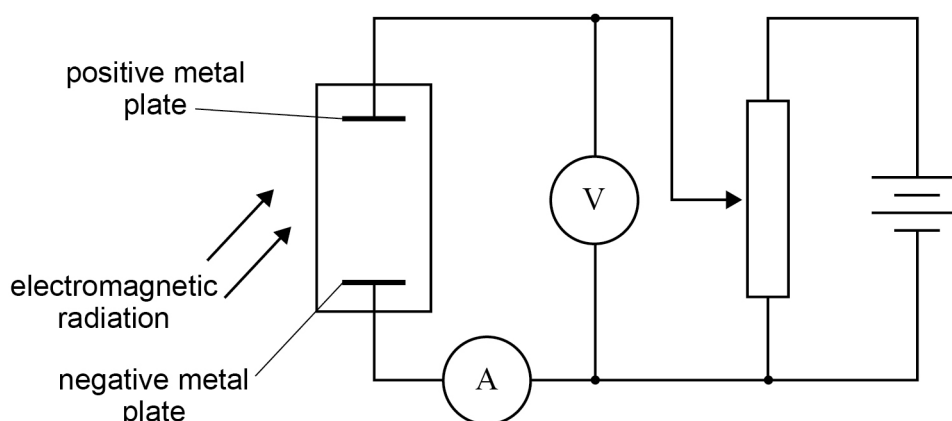
Answer **all** questions in this section.

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0 8

The variation of the maximum kinetic energy of photoelectrons with the wavelength of incident electromagnetic radiation may be investigated using the apparatus in **Figure 11**.

Figure 11



When the positive metal plate is illuminated with monochromatic electromagnetic radiation of a sufficiently high frequency, electrons are emitted and move towards the negative plate, causing a current in the circuit. The potential difference between the positive plate and the negative plate is adjusted until the current is zero. When this happens, the potential difference measured by the voltmeter is called the stopping potential V_s .

The maximum kinetic energy of the photoelectrons $E_{k(\max)}$ is eV_s .

Question 8 continues on the next page

Turn over ►



0 8 . 1 In one experiment, the results in **Table 1** were obtained:

Table 1

Frequency of incident radiation / 10^{14} Hz	V_s / V	$E_{k(max)}$ / 10^{-20} J
6.0	$0.15 \pm \underline{0.05}$	2.4 ± 0.8
6.8	$0.55 \pm \underline{0.05}$	8.6 ± 0.8
7.5	$0.80 \pm \underline{0.05}$	12.8 ± 0.8
8.6	$1.25 \pm \underline{0.05}$	20.0 ± 0.8

Complete **Table 1** by calculating the values of the absolute uncertainties of V_s .

[1 mark]

0 8 . 2 The values of frequency and $E_{k(max)}$ have been plotted on **Figure 12**.

Complete the graph by adding error bars for each point and by drawing a best fit straight line.

Assume that there is negligible uncertainty in the values of frequency.

[2 marks]

0 8 . 3 The equation for the graph is:

$$E_{k(max)} = hf - \phi$$

where h is the Planck constant and ϕ is the work function of the metal from which the positive plate is made.

Determine using your graph a value for h .

[2 marks]

gradient of the best fit line = h

from my line: (6.0, 2.8) and (8.5, 19.5)

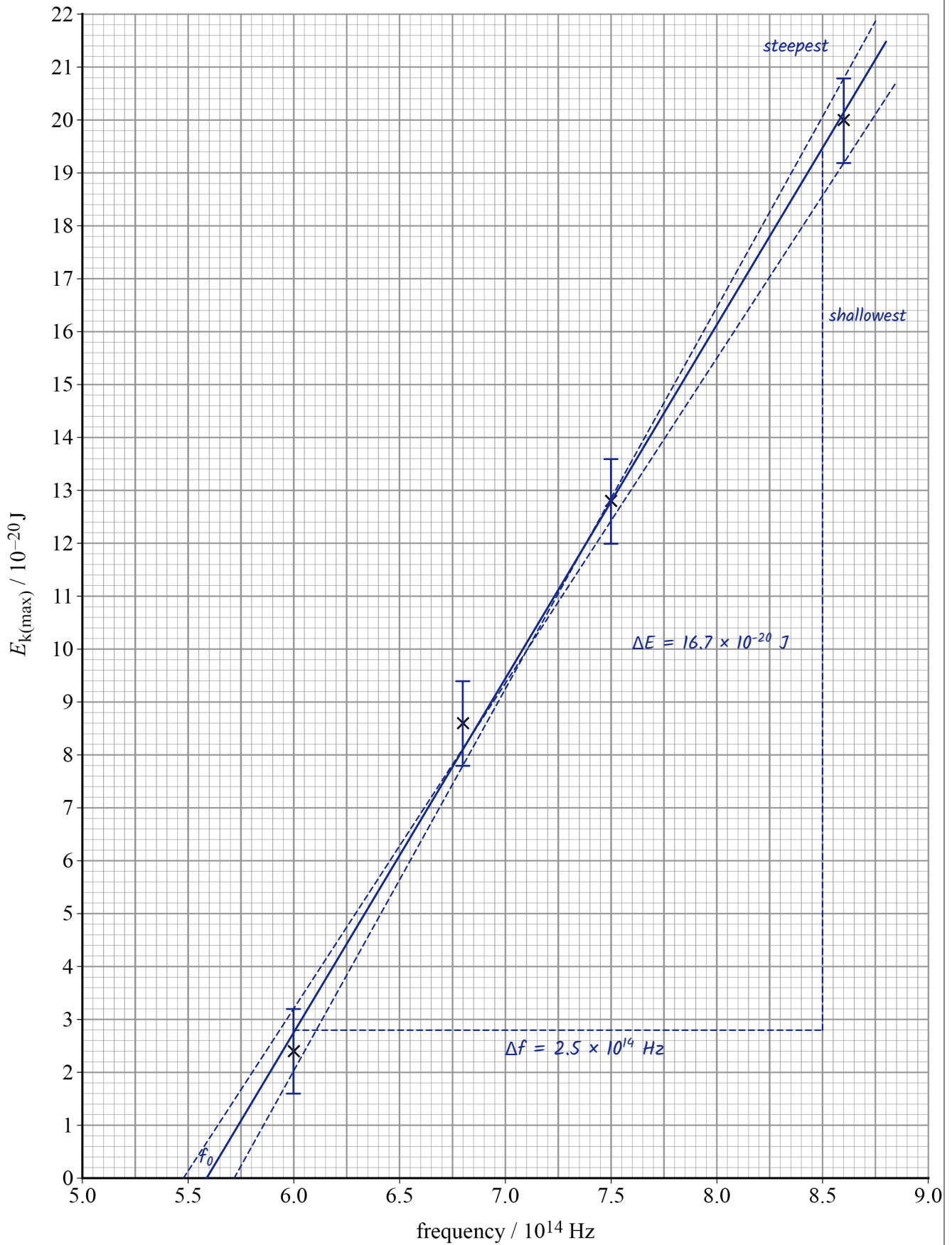
$$h = (19.5 - 2.8) \times 10^{-20} / (8.5 - 6.0) \times 10^{14}$$

$$h = 6.7 \times 10^{-34} \text{ J s}$$

$$h = \underline{6.7 \times 10^{-34}} \text{ J s}$$



Figure 12



Question 8 continues on the next page

Turn over ►



08.4

Photoelectrons are not emitted below a threshold frequency f_0 .

Determine using your graph the value of f_0 .

[1 mark]

$f_0 = \text{intercept of the best fit line on the } f \text{ axis } (E_{k(\text{max})} = 0)$

$$f_0 = 5.6 \times 10^{14} \text{ Hz}$$

08.5

Determine using your graph the uncertainty in your value of f_0 .

[2 marks]

intercepts of extreme lines: $5.72 \times 10^{14} \text{ Hz}$ and $5.48 \times 10^{14} \text{ Hz}$

uncertainty = half the range = $(5.72 - 5.48) \times 10^{14} / 2$

$$\text{uncertainty in } f_0 = \pm 1.2 \times 10^{13} \text{ Hz}$$

08.6

Suggest **one** way in which the results in question 08.1 could be improved.

[1 mark]

Repeat each measurement of V_s several times and calculate a mean value for each frequency.



Turn over for the next question

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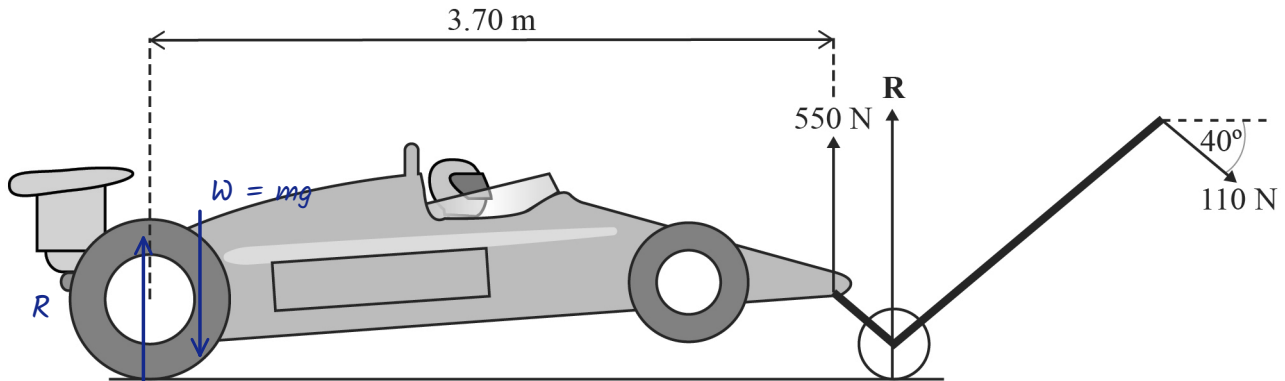
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ANSWER IN THE SPACES PROVIDED**

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0 9

A racing car of mass 760 kg stops for a tyre change.
A mechanic uses a lever to hold the car in equilibrium as shown in **Figure 13**.
The lever exerts a vertical force of 550 N on the car.

Figure 13

0 9 . 1

Draw and label **two** other vertical forces acting on the car in **Figure 13**.

[2 marks]

0 9 . 2

Calculate the horizontal distance between the centre of the rear wheel and the centre of mass of the car.

[2 marks]

take moments about the centre of the rear wheel (point of contact):

sum of clockwise moments = sum of anticlockwise moments

$$760 \times 9.81 \times d = 550 \times 3.70$$

$$d = 2035 / 7456 = 0.273 \text{ m}$$

distance = 0.27 m



0 9 . 3

The mechanic exerts a force on the lever of 110 N at 40° to the horizontal as shown in **Figure 13**. The normal reaction force of the ground on the lever is **R**.

Calculate the magnitude of **R**.

[3 marks]

vertical component of 110 N force = $110 \sin 40^\circ = 70.7 \text{ N (down)}$

the car pushes down on the lever with 550 N

$$R = 550 + 70.7 = 621 \text{ N}$$

magnitude of **R** = 621 N

7

END OF SECTION B

Turn over ►



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 answer 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. 

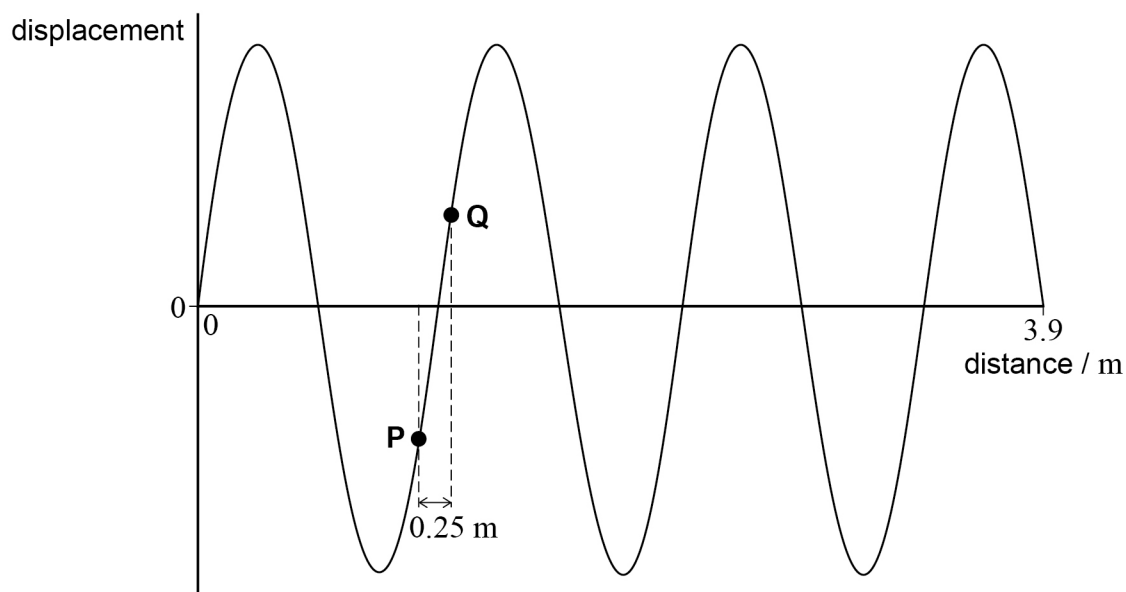
If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

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 0

The graph shows the variation with distance of the displacement of a progressive wave.



What is the phase difference between points **P** and **Q**?

[1 mark]

A 0.22 rad

☐

B 0.40 rad

☐

C 1.2 rad

☐

D 1.4 rad

☒
1 1

Which is equivalent to the SI unit of resistivity?

[1 mark]

A $\text{A V}^{-1} \text{m}^{-1}$

☐

B $\text{C}^{-1} \text{V s m}$

☒

C V A m

☐

D C V m s^{-1}

☐

Turn over ►



1 2

When a mass m , suspended from a spring with spring constant k , is set into simple harmonic motion it oscillates with time period T .

What is the time period of a mass $2m$ suspended from a spring with a spring constant $\frac{k}{2}$?
[1 mark]

A $\frac{T}{2}$

☐

B $\frac{T}{\sqrt{2}}$

☐

C $\sqrt{2} T$

☐

D $2T$

☒
1 3

The cladding of a step-index optical fibre

[1 mark]

A reduces material dispersion.

☐

B reduces signal loss.

☒

C must have a higher refractive index than the core.

☐

D must be opaque.

☐
1 4

Monochromatic light of wavelength 610 nm illuminates a double slit. An interference pattern is observed on a screen 4.5 m from the slits. Consecutive bright fringes are 1.1 cm apart.

What is the slit separation?

[1 mark]

A 0.0025 mm

☐

B 0.025 mm

☐

C 0.25 mm

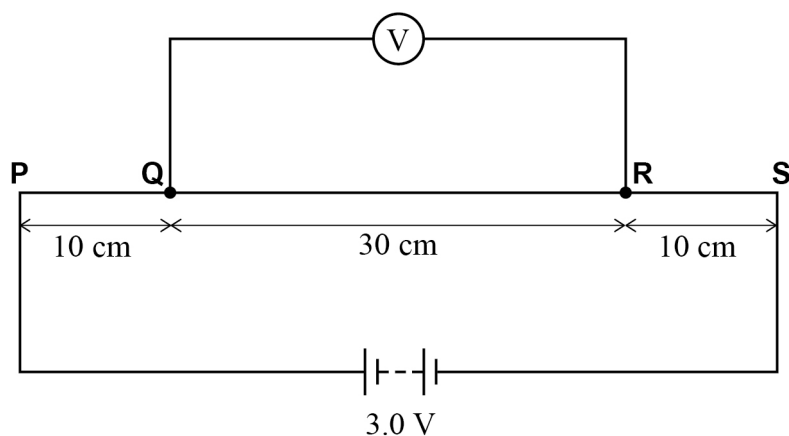
☒

D 2.5 mm

☐


1 5

A length **PQRS** of resistance wire of uniform cross-section is connected to a battery of emf 3.0 V and negligible internal resistance.



What is the reading on the voltmeter?

[1 mark]

A 0.6 V

☐

B 1.2 V

☐

C 1.8 V

☒

D 2.4 V

☐

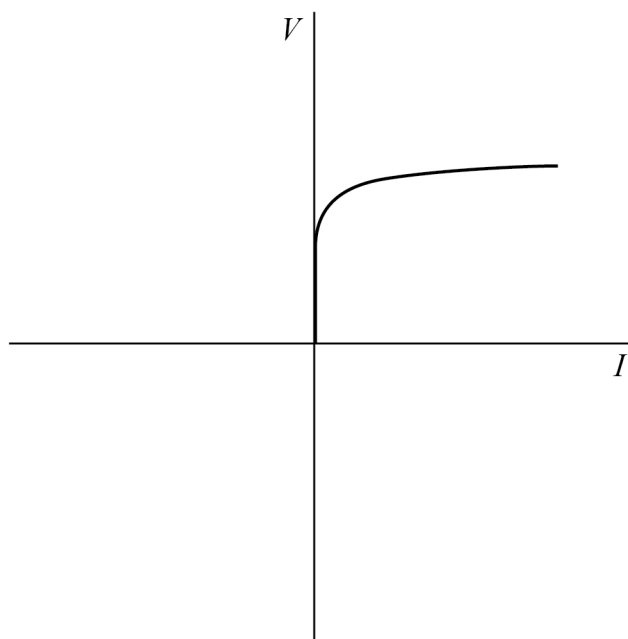
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1 6

Which component has the voltage–current (V – I) characteristics shown by the graph below?

[1 mark]

A filament lamp

☐

B metal conductor at constant temperature

☐

C semiconductor diode

☒

D thermistor

☐
1 7

A diffraction grating has a spacing of $3.0\ \mu\text{m}$

Light of wavelength $610\ \text{nm}$ is incident normally on the diffraction grating.

What is the largest order obtained?

[1 mark]

A 2nd

☐

B 4th

☒

C 5th

☐

D 8th

☐


1 8

What is the de Broglie wavelength of an electron travelling at 30% of the speed of light?

Ignore any relativistic effects.

[1 mark]

A $2.4 \times 10^{-14} \text{ m}$

☐

B $8.1 \times 10^{-14} \text{ m}$

☐

C $2.4 \times 10^{-12} \text{ m}$

☐

D $8.1 \times 10^{-12} \text{ m}$

☒
1 9

The refractive index for light passing from air into medium **A** is 1.3

The refractive index for light passing from air into medium **B** is 1.6

Which statement is **not** correct?

[1 mark]

A The critical angle for light travelling from **A** into **B** is about 54°

☒

B Light travelling from **B** into **A** will refract away from the normal.

☐

C The speed of light in **A** is about $0.77c$

☐

D Light travels slower in **B** than in **A**.

☐

Turn over for the next question

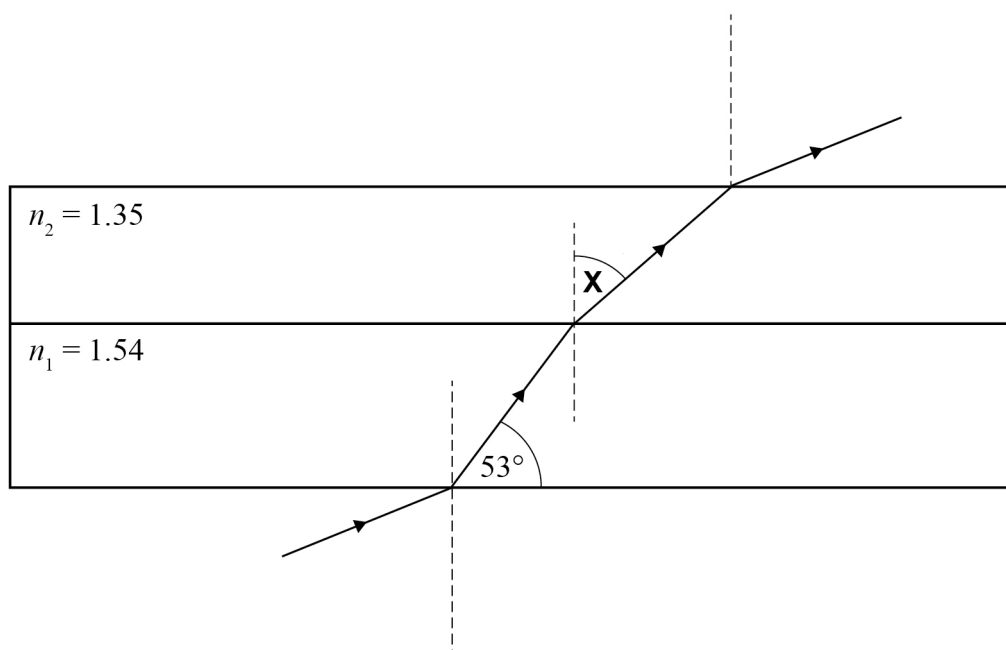
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2 0

The diagram shows the path of a ray of light through two transparent parallel layers.

The refractive indices shown on the diagram are for light travelling from air into each medium.

[1 mark]

What is angle X ?

A 32°

☐

B 37°

☐

C 43°

☒

D 67°

☐


2 1

A student wishes to measure the slit separation of a double slit using the interference pattern produced by the slit.

Which row shows the source she should choose and the reason for her choice?

[1 mark]

	Source	Reason	
A	Monochromatic red light	The fringes will be brighter	
B	Monochromatic red light	The interference patterns do not overlap	
C	White light	The fringes will be brighter	
D	White light	The interference patterns do not overlap	

Turn over for the next question

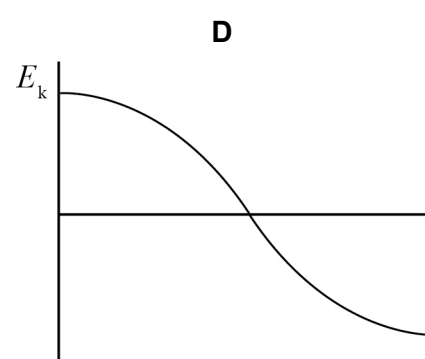
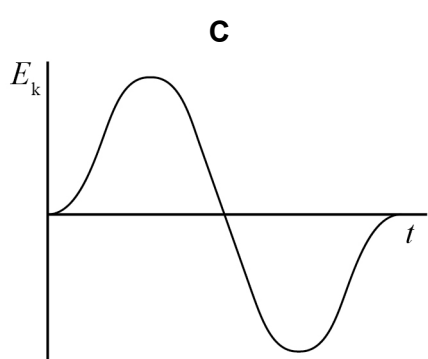
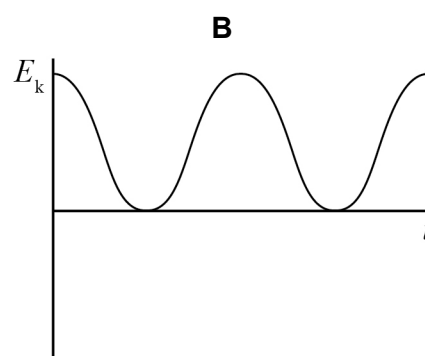
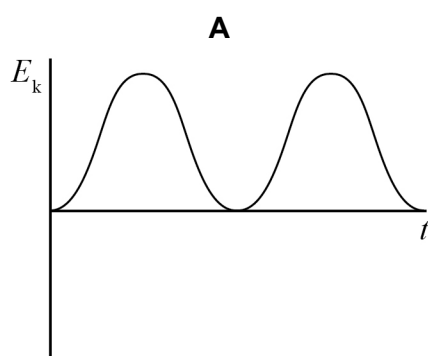
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2 2

A simple pendulum is released from its extreme position and completes one oscillation.

Which graph shows the variation of kinetic energy E_k with time t for the oscillation?

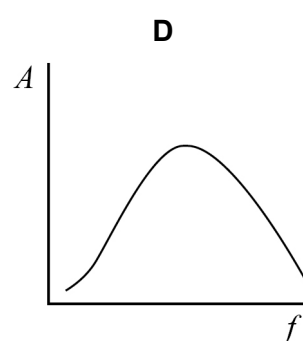
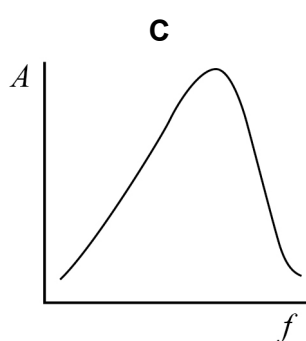
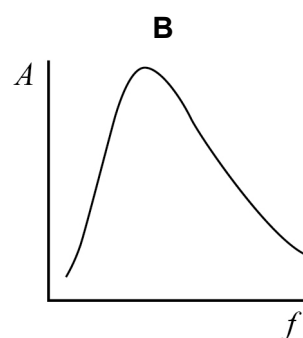
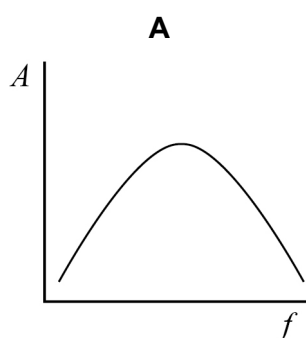
[1 mark]

- A** ☒
- B** ☐
- C** ☐
- D** ☐



2 3

Which graph shows the variation of amplitude A with driving frequency f for a damped system undergoing forced oscillations?

[1 mark]**A****B****C****D****END OF QUESTIONS**

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