

Please write clearly in block capitals.

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Candidate number

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Surname *StemUp Model Solution*

Forename(s)

Candidate signature

INTERNATIONAL AS PHYSICS

Unit 2 Electricity, waves and particles

Monday 13 May 2019

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	
3	
4	
5	
6	
7	
8	
9	
10	
11–24	
TOTAL	



J U N 1 9 P H 0 2 0 1

Section A

Answer **all** questions in this section.

0 1

An electron is travelling at $1.29 \times 10^6 \text{ m s}^{-1}$.

Calculate its de Broglie wavelength.

[2 marks]

$$\lambda = h / p = h / mv$$

$$\lambda = 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 1.29 \times 10^6)$$

$$\lambda = 5.64 \times 10^{-10} \text{ m}$$

wavelength = 5.64×10^{-10} m

2

0 2

Laser light is incident normally on a diffraction grating.

The diffraction grating has 250 slits per millimetre.

A third-order maximum is observed at an angle of 29° to the central maximum.

Calculate the frequency of the laser light.

[4 marks]

$$d = 1 / (250 \times 10^3) = 4.0 \times 10^{-6} \text{ m}$$

$$n\lambda = d \sin \theta, \text{ so } \lambda = d \sin \theta / n$$

$$\lambda = 4.0 \times 10^{-6} \times \sin 29^\circ / 3 = 6.46 \times 10^{-7} \text{ m}$$

$$c = f\lambda, \text{ so } f = c / \lambda = 3.00 \times 10^8 / 6.46 \times 10^{-7}$$

$$f = 4.64 \times 10^{14} \text{ Hz}$$

frequency = 4.64×10^{14} Hz

4



0 3

A student is provided with the following apparatus:

- a lamp
- a polarising filter
- a light meter that measures the intensity of incident light.

Describe how the student could use this apparatus to determine whether the light from the lamp is polarised.

[3 marks]

Place the polarising filter between the lamp and the light meter, so that the light from the lamp passes through the filter before reaching the meter.

Rotate the filter through 360° (in its own plane) while monitoring the intensity reading on the light meter continuously during the rotation.

If the intensity varies as the filter is rotated (with minima every 180°), the light from the lamp is polarised. If the intensity stays constant during the rotation, the light is not polarised.

3

Turn over for the next question

Turn over ►



0 4

A washing machine is loaded unevenly. When the machine is turned on, the drum rotates with an increasing frequency. At one particular frequency the system vibrates with a large amplitude. As the frequency increases further, the amplitude of the vibrations decreases.

0 4 . 1

Explain why the large amplitude vibrations occur.

[3 marks]

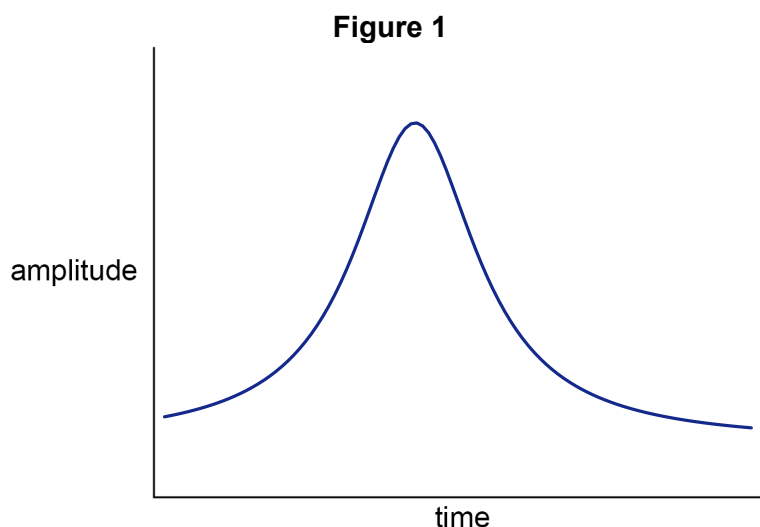
The uneven load produces a periodic driving force (a forced oscillation) on the machine as the drum rotates.

Resonance occurs: when the frequency of the driving force (the drum rotation) equals the natural (resonant) frequency of vibration of the machine, energy is transferred most efficiently and the amplitude is a maximum.

0 4 . 2

Sketch on **Figure 1** the variation with time of the amplitude of vibrations as the frequency of the drum's rotation increases.

[1 mark]



0 4 . 3

Explain how increasing the damping of the system affects the graph you sketched in question **04.2**.

[2 marks]

Damping removes energy from the system (dissipates energy as heat). So the amplitude is reduced at all frequencies: the peak of the graph is lower (and broader).



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ANSWER IN THE SPACES PROVIDED**

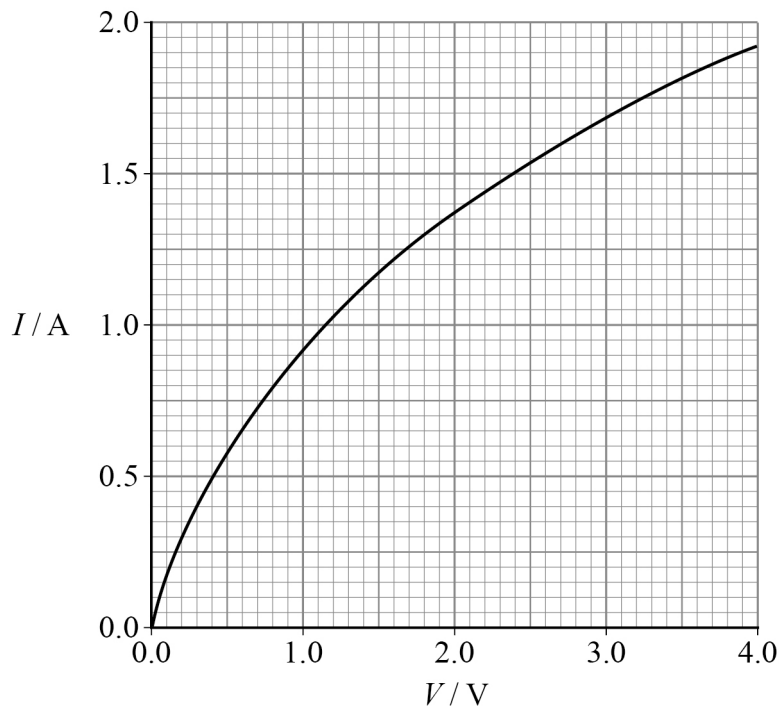
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0 5

Figure 2 shows the current-voltage (I - V) characteristic of a filament lamp.

Figure 2



0 5 . 1

Explain how **Figure 2** shows that the filament lamp is **not** an ohmic conductor.

[1 mark]

The graph is not a straight line through the origin: I is not proportional to V (resistance changes).

0 5 . 2

Explain, in terms of the particles in the filament, why the filament lamp is **not** an ohmic conductor.

[3 marks]

As the current increases, the (free) electrons collide more with the positive ions (atoms) of the metal lattice.

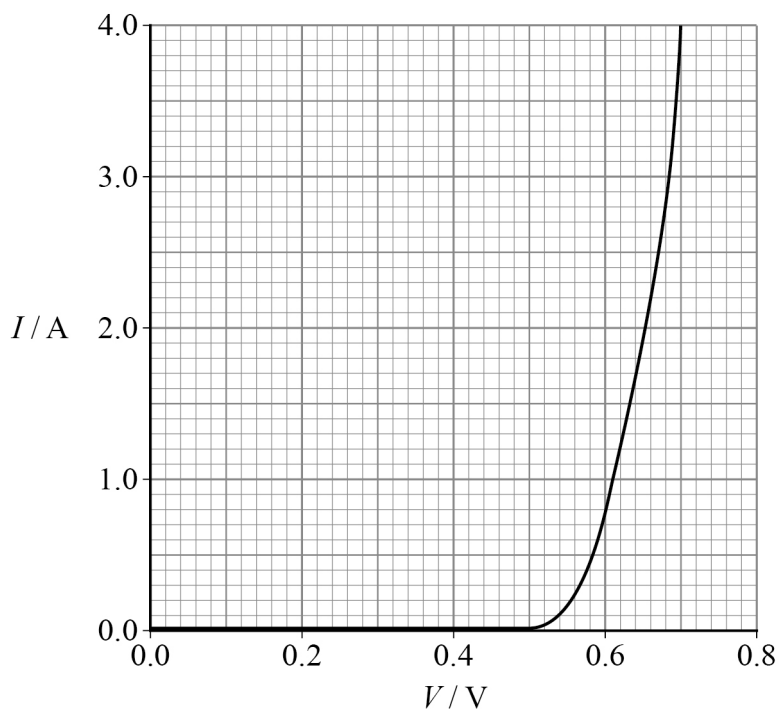
In the collisions energy is transferred from the electrons to the lattice ions, so the ions vibrate with greater amplitude and the temperature of the filament increases.

The vibrating ions impede the flow of electrons more, so the resistance increases: V / I is not constant.



Figure 3 shows the I - V characteristic of a diode.

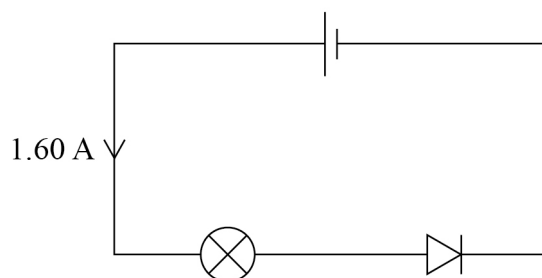
Figure 3



0 5 3

The filament lamp and the diode are connected in series with a cell of negligible internal resistance, as shown in Figure 4. The current in the circuit is 1.60 A.

Figure 4



Determine the emf of the cell.

[2 marks]

Series circuit: $I = 1.60$ A in both lamp and diode.

From Fig 2: $V_{\text{lamp}} = 2.70$ V From Fig 3: $V_{\text{diode}} = 0.64$ V

$\text{emf} = V_{\text{lamp}} + V_{\text{diode}} = 2.70 + 0.64 = 3.34$ V

emf = 3.34 V

6

Turn over ►

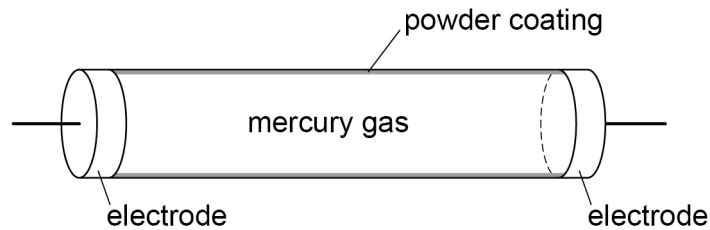


0 6

Figure 5 shows a fluorescent tube. A fluorescent tube contains low-pressure mercury gas.

The inner surface of the tube is coated with a special powder as shown in **Figure 5**.

Figure 5



The mercury atoms are excited, and this eventually leads to the excitation of the atoms in the powder.

0 6 . 1

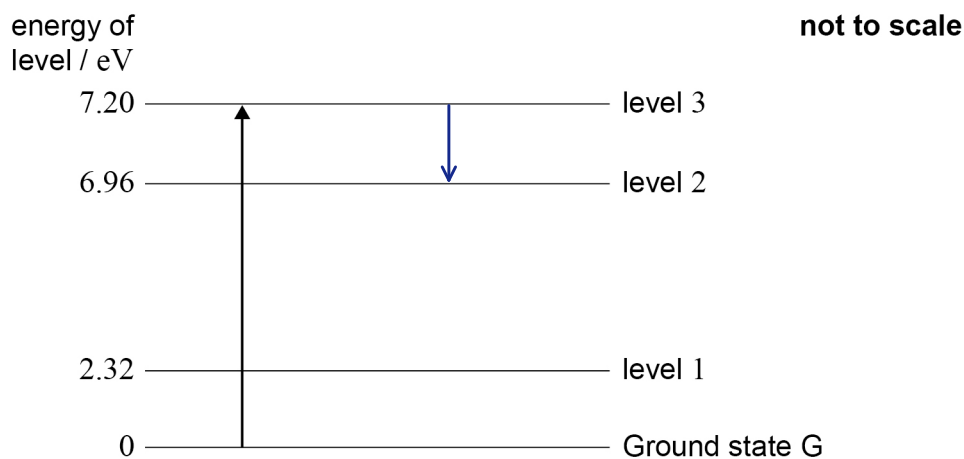
Explain how the mercury atoms are excited.

[1 mark]

Free electrons accelerated by the pd collide with the mercury atoms and transfer energy to them.

Figure 6 shows the energy levels of one type of atom in the powder.

Figure 6



0 6 . 2

Explain how atoms in the powder become excited to the 7.20 eV energy level.

[2 marks]

The excited mercury atoms de-excite and emit photons of ultraviolet light (of energy 7.20 eV).

These UV photons are absorbed by the atoms of the powder coating, each photon transferring all its energy (7.20 eV) to an electron, which moves up from the ground state to level 3.

0 6 . 3

With reference to **Figure 6**, explain how photons of visible light are emitted by the powder. Calculations are not required.

[2 marks]

The atoms de-excite in steps, via the intermediate levels (e.g. level 3 to 2 to 1 to G).

Each smaller energy drop emits a lower energy photon, of lower frequency and longer wavelength, in the visible range.

0 6 . 4

Draw an arrow on **Figure 6** to represent the transition that leads to the emission of the longest wavelength of radiation.

[1 mark]

0 6 . 5

Calculate the **wavelength** of radiation emitted as a result of the transition you identified in question **06.4**.

[3 marks]

$$\Delta E = 7.20 - 6.96 = 0.24 \text{ eV}$$

$$\Delta E = 0.24 \times 1.60 \times 10^{-19} = 3.84 \times 10^{-20} \text{ J}$$

$$E = hc / \lambda, \text{ so } \lambda = hc / E$$

$$\lambda = 6.63 \times 10^{-34} \times 3.00 \times 10^8 / 3.84 \times 10^{-20}$$

$$\lambda = 5.18 \times 10^{-6} \text{ m}$$

wavelength = 5.18 × 10⁻⁶ m

9

Turn over ►



0 7

Figure 7 shows a circuit used to determine the emf and internal resistance of a battery.

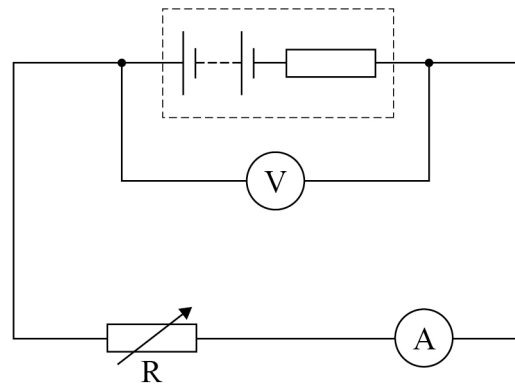
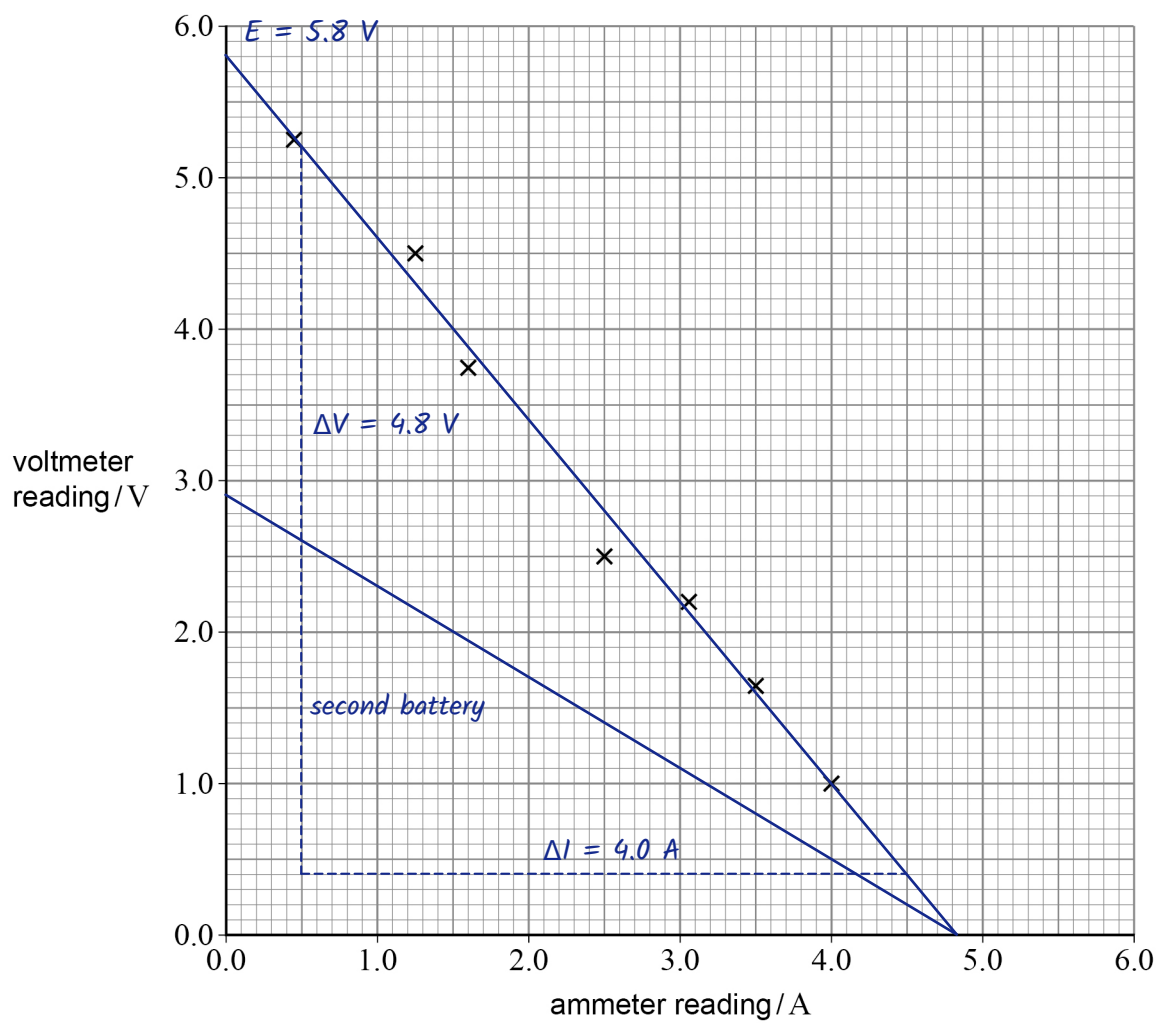
Figure 7

Figure 8 shows data from this experiment.

Figure 8

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0 7 . 1

Explain why the voltmeter reading decreases as the current increases.

[2 marks]

As the current increases, the pd across the internal resistance r (the lost volts, Ir) increases.

The emf E is fixed, so the terminal pd $V = E - Ir$, shown by the voltmeter, decreases.

0 7 . 2

Determine the emf of the battery.

[2 marks]

Line of best fit drawn on Figure 8, extended to $I = 0$:

emf = intercept on the voltage axis = 5.8 V

emf = 5.8 V

0 7 . 3

Determine the internal resistance of the battery.

[3 marks]

$V = E - Ir$, so gradient of the line = $-r$

triangle on graph: (0.5 A, 5.2 V) and (4.5 A, 0.4 V)

gradient = $(0.4 - 5.2) / (4.5 - 0.5) = -4.8 / 4.0 = -1.2 \Omega$

$r = 1.2 \Omega$

internal resistance = 1.2 Ω

0 7 . 4

A second battery has half the emf and half the internal resistance of the first battery.

Draw a line on **Figure 8** to show the variation of voltmeter reading with ammeter reading for the second battery.

[2 marks]

9

Turn over ►



0 8 . 1

Progressive waves transfer energy along the wave; stationary waves do not.

Describe **two other** differences between stationary waves and progressive waves.

[2 marks]

Difference 1 *A stationary wave has nodes and antinodes;
a progressive wave does not.*

Difference 2 *In a stationary wave all points between adjacent
nodes are in phase; in a progressive wave the phase
varies continuously along one wavelength.*

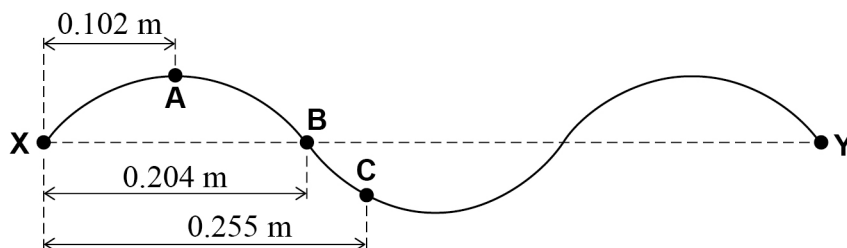
A string of mass 0.98 g vibrates between two fixed ends **X** and **Y**.

The distance between **X** and **Y** is 0.612 m.

The tension in the string is 69 N.

Figure 9 shows one position of the string when vibrating at the third harmonic.

Figure 9



0 8 . 2

Determine the frequency of the third harmonic.

[4 marks]

$$\mu = m / l = 0.98 \times 10^{-3} / 0.612 = 1.60 \times 10^{-3} \text{ kg m}^{-1}$$

$$f_1 = (1 / 2l) \sqrt{T / \mu} = (1 / 1.224) \times \sqrt{69 / 1.60 \times 10^{-3}}$$

$$f_1 = 0.817 \times 207.6 = 170 \text{ Hz}$$

$$\text{third harmonic: } f_3 = 3 \times f_1 = 3 \times 169.6$$

$$f_3 = 509 \text{ Hz}$$

frequency = 509 Hz



0 8 . 3 Calculate the speed of the waves on the string.

[3 marks]

third harmonic: 1.5 wavelengths between X and Y

$$\lambda = 2 \times 0.612 / 3 = 0.408 \text{ m}$$

$$c = f\lambda = 509 \times 0.408$$

$$c = 208 \text{ m s}^{-1}$$

speed = 208 m s⁻¹

0 8 . 4 Point **B** is shown on **Figure 9**.

Describe the behaviour of the string at point **B**.

[1 mark]

B is a node: the string there is motionless (zero amplitude).

0 8 . 5 Points **A** and **C** are shown on **Figure 9**.

State the phase difference between the motion of the string at points **A** and **C**.

[1 mark]

phase difference = π (3.14) rad

11

END OF SECTION A

Turn over ►



Section BAnswer **all** questions in this section.**0 9**

Light undergoes total internal reflection in an optical fibre with no cladding.
The critical angle of light in this fibre without cladding is 43.6° .

0 9 . 1

Show that the speed of light in the fibre is approximately $2.1 \times 10^8 \text{ m s}^{-1}$.

[2 marks]

$$\sin \theta_c = 1 / n, \text{ so } n = 1 / \sin 43.6^\circ$$

$$n = 1 / 0.6896 = 1.450$$

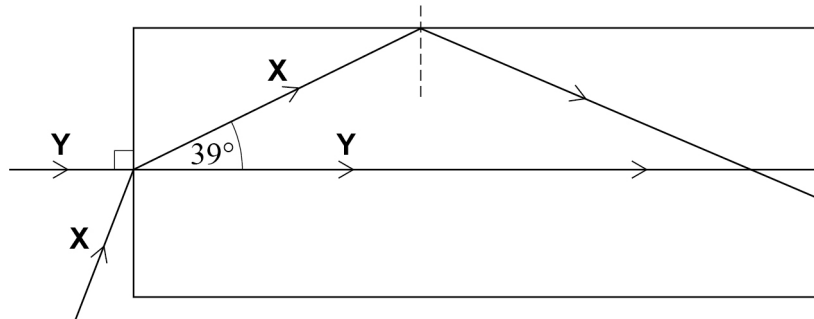
$$n = c / v, \text{ so } v = c / n = 3.00 \times 10^8 / 1.450$$

$$v = 2.07 \times 10^8 \text{ m s}^{-1} \approx 2.1 \times 10^8 \text{ m s}^{-1}$$



0 9 . 2

Figure 10 shows the paths followed by two pulses of light, **X** and **Y**, entering the straight optical fibre at the same time. **X** travels through the fibre at 39° to the axis of the fibre. **Y** travels along the axis of the fibre.

Figure 10

The fibre is 320 m long.

Calculate the time delay between pulse **Y** leaving the fibre and pulse **X** leaving the fibre.

[4 marks]

$$\text{path length of X: } D = 320 / \cos 39^\circ = 320 / 0.777 = 412 \text{ m}$$

$$\text{extra distance: } \Delta D = 412 - 320 = 92 \text{ m}$$

$$\Delta t = \Delta D / v = 91.8 / 2.07 \times 10^8$$

$$\Delta t = 4.44 \times 10^{-7} \text{ s}$$

$$\text{time delay} = \underline{4.44 \times 10^{-7}} \text{ s}$$

Question 9 continues on the next page

Turn over ►



09.3

Modern optical fibres are made with cladding around the core.

Explain how using cladding reduces pulse broadening.

[2 marks]

The cladding has a refractive index only slightly lower than the core, so it increases the critical angle at the core to cladding boundary (compared with core to air).

Rays at large angles to the axis are now incident below the critical angle and leave the core, so a smaller range of paths is available. The difference in path length, and so in arrival time, is smaller: less pulse broadening.

8



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1 0

A student determines the period T of oscillation for a mass–spring system by measuring ten oscillations of the system. The measurements were repeated.

Table 1 shows these measurements.

Table 1

$10T / \text{s}$	12.63	12.60	12.73	12.80	12.71
------------------------------------	-------	-------	-------	-------	-------

1 0**. 1**

Calculate the mean value for T .

[1 mark]

$$\text{mean } 10T = (12.63 + 12.60 + 12.73 + 12.80 + 12.71) / 5$$

$$10T = 12.69 \text{ s}, \quad T = 12.69 / 10 = 1.27 \text{ s}$$

$$\text{mean value for } T = \underline{1.27 \text{ s}}$$

1 0**. 2**

Calculate the percentage uncertainty in your mean value for T .

[1 mark]

$$\text{uncertainty in } 10T = \text{half range} = (12.80 - 12.60) / 2 = 0.10 \text{ s}$$

$$\% \text{ uncertainty} = 0.10 / 12.69 \times 100 = 0.79 \% \approx 0.8 \%$$

$$\text{percentage uncertainty in } T = \underline{0.8 \%}$$



1 0 . 3

The mass m on the spring was (0.400 ± 0.008) kg.

Calculate the spring constant k .

[1 mark]

$$T = 2\pi \sqrt{m/k}, \text{ so } k = 4\pi^2 m / T^2$$

$$k = 4\pi^2 \times 0.400 / 1.27^2 = 9.8 \text{ N m}^{-1}$$

$$k = \underline{\quad 9.8 \quad} \text{ N m}^{-1}$$

1 0 . 4

Calculate the percentage uncertainty in your answer for k .

[2 marks]

$$\% \text{ uncertainty in } m = 0.008 / 0.400 \times 100 = 2.0 \%$$

$$\% \text{ in } k = \% \text{ in } m + 2 \times \% \text{ in } T = 2.0 + 2 \times 0.8$$

$$\% \text{ uncertainty in } k = 3.6 \%$$

$$\text{percentage uncertainty in } k = \underline{\quad 3.6 \% \quad}$$

Question 10 continues on the next page

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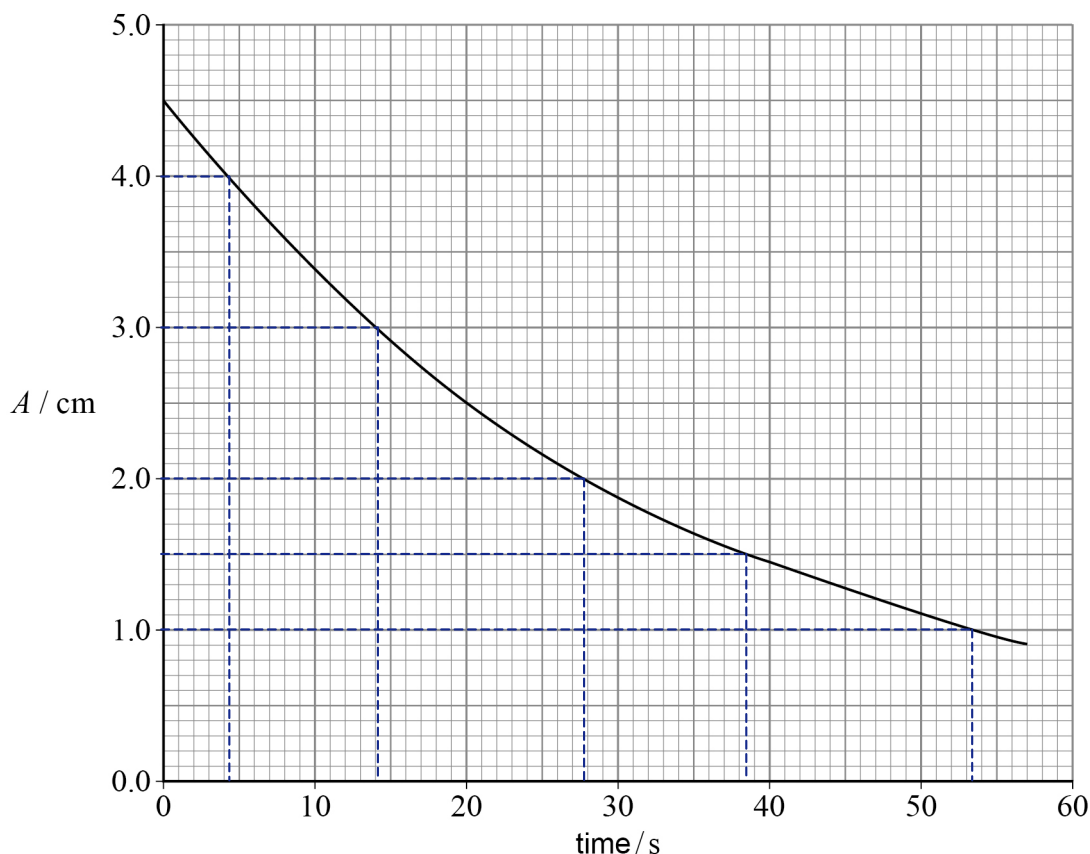


1 0 . 5

To investigate damping in the system, the amplitude A of the oscillations was measured until a total of fifty oscillations were completed.

Figure 11 shows the variation of amplitude with time.

Figure 11



The damping in the mass–spring system causes the amplitude to decrease. The time taken for the amplitude of this system to decrease by half is constant, and is called the half-life.

Determine a reliable value for the half-life of this system.

[3 marks]

A from 4.0 cm to 2.0 cm: $t = 4.5 \text{ s}$ to 28.0 s , half-life = 23.5 s

A from 3.0 cm to 1.5 cm: $t = 14.0 \text{ s}$ to 38.5 s , half-life = 24.5 s

A from 2.0 cm to 1.0 cm: $t = 28.0 \text{ s}$ to 53.5 s , half-life = 25.5 s

mean half-life = $(23.5 + 24.5 + 25.5) / 3 = 24.5 \text{ s}$

half-life = 24.5 s

END OF SECTION B

8



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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.

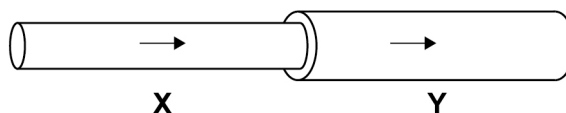


You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sheets for this working.

1 1

Two wires, **X** and **Y**, are connected in series.

X and **Y** are made of the same material and have the same length. The diameter of **Y** is larger than the diameter of **X**.



Which statement is correct?

[1 mark]

A The resistance of **X** is smaller than the resistance of **Y**.



B The current in **X** is smaller than the current in **Y**.



C The pd across **X** is equal to the pd across **Y**.



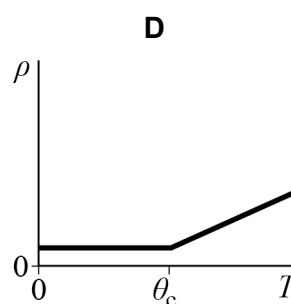
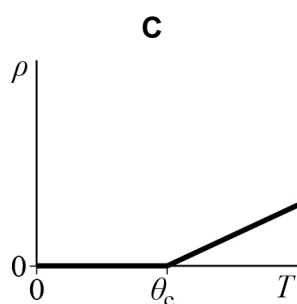
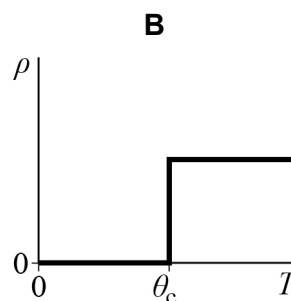
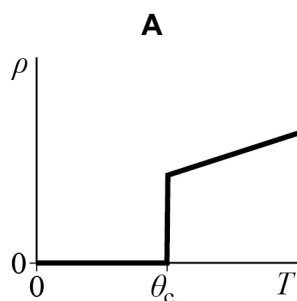
D The power dissipated by **X** is larger than the power dissipated by **Y**.



1 2

A superconductor has critical temperature θ_c .

Which graph shows the variation of resistivity ρ with temperature T for this superconductor?

[1 mark]

- | | |
|----------|----------------------------------|
| A | ☒ |
| B | ☐ |
| C | ☐ |
| D | ☐ |

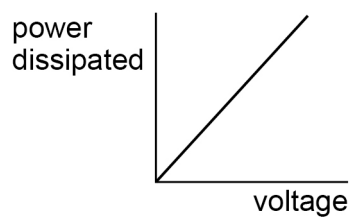
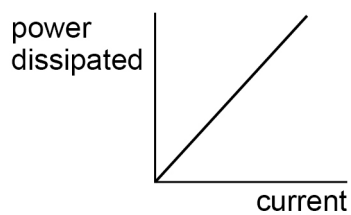
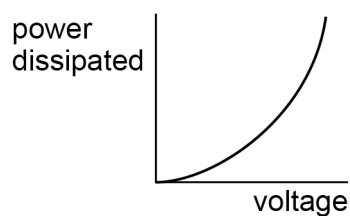
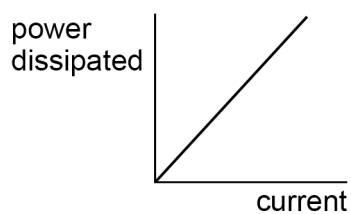
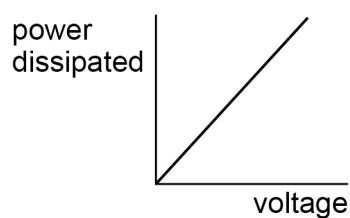
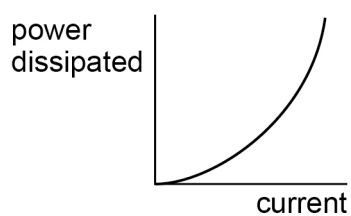
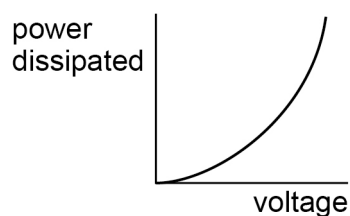
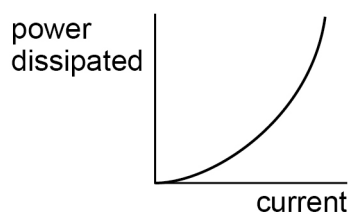
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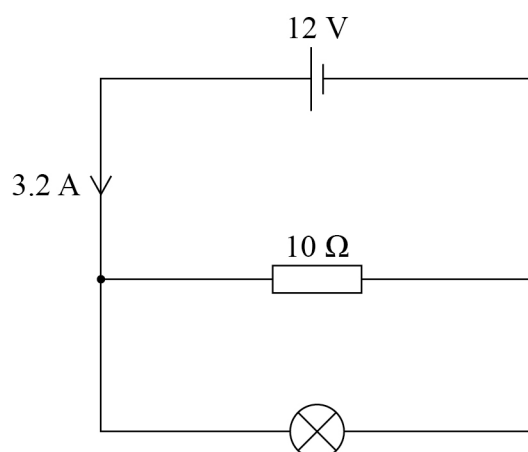
1 3

Which pair of graphs shows the variation of power dissipated with current, and the variation of power dissipated with voltage, for a resistor of constant resistance?

[1 mark]**A****B****C****D**

1 4

A cell of negligible internal resistance is connected to a resistor and a lamp in parallel as shown.



What is the power dissipated by the lamp?

[1 mark]

A 14 W

☐

B 16 W

☐

C 24 W

☒

D 38 W

☐

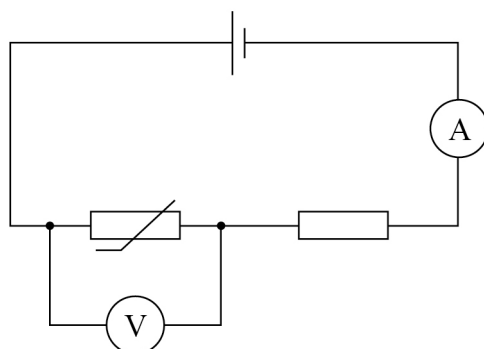
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1 5

A negative temperature coefficient thermistor is connected to a resistor and a cell as shown.



The temperature of the thermistor increases.

What are the changes in the ammeter reading and the voltmeter reading?

[1 mark]

	Ammeter reading	Voltmeter reading	
A	decreases	decreases	☐
B	decreases	increases	☐
C	increases	decreases	☒
D	increases	increases	☐



1 6 A pendulum of length l oscillates at frequency f .

Which length of pendulum oscillates at frequency $2f$?

[1 mark]

A $\frac{l}{4}$ ☒

B $\frac{l}{2}$ ☐

C $\frac{l}{\sqrt{2}}$ ☐

D $l\sqrt{2}$ ☐

1 7 A stationary wave forms on a string when progressive waves are reflected at the fixed ends. For a real string, energy is transferred from the progressive waves when they are reflected at the fixed ends.

The effect of this energy transfer on the stationary wave is that

[1 mark]

A the antinodes and nodes no longer form. ☐

B the nodes are not positions of zero amplitude. ☒

C the distance between antinodes increases. ☐

D the speed of the waves on the string is decreased. ☐

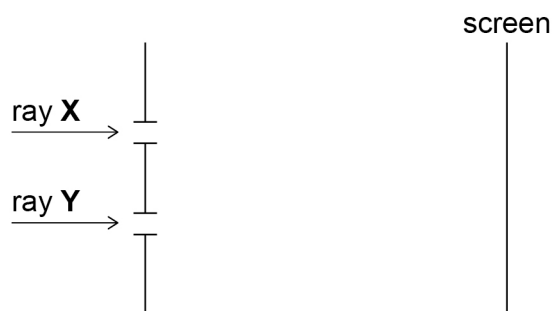
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1 8

Ray **X** is incident on one slit and ray **Y** is incident on another slit of a double slit arrangement as shown below.



A fringe pattern is **not** observed on the screen.

What is a possible explanation?

[1 mark]

A **X** and **Y** are not incident at 90° to the slits.



B **X** and **Y** do not have the same wavelength.



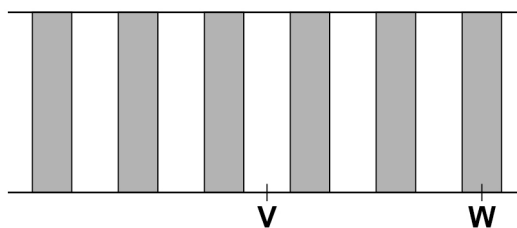
C **X** and **Y** are too bright.



D **X** and **Y** are out of phase at the position of the slits.

**1 9**

Light of wavelength 500 nm is incident on a double slit and the resulting fringe pattern is shown below. **V** is the central bright fringe and the dark fringes are shown shaded.



What is the path difference that results in fringe **W**?

[1 mark]

A 1250 nm



B 1000 nm



C 750 nm



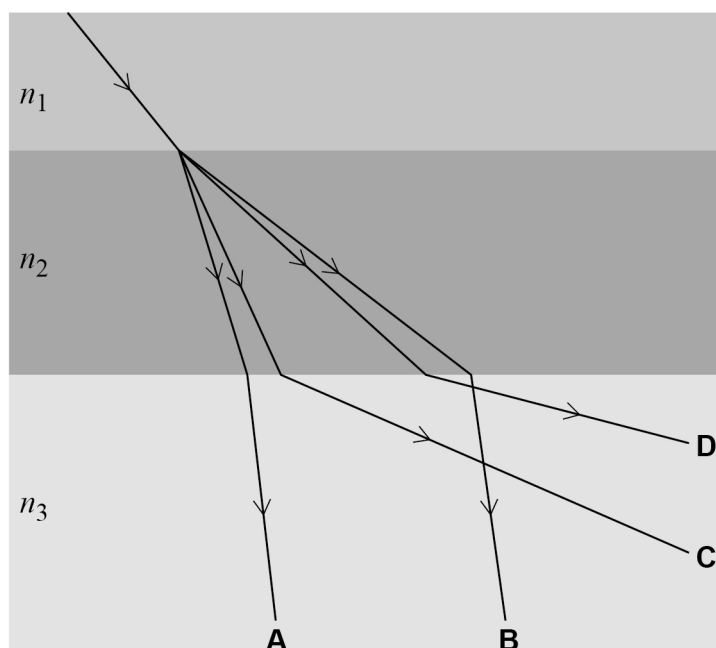
D 500 nm



2 0

A ray of light travels through three materials, with refractive indices n_1 , n_2 and n_3 , where $n_3 < n_1 < n_2$.

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Which is a possible path for the ray?

[1 mark]

- | | |
|----------|----------------------------------|
| A | ☐ |
| B | ☐ |
| C | ☒ |
| D | ☐ |

Turn over for the next question

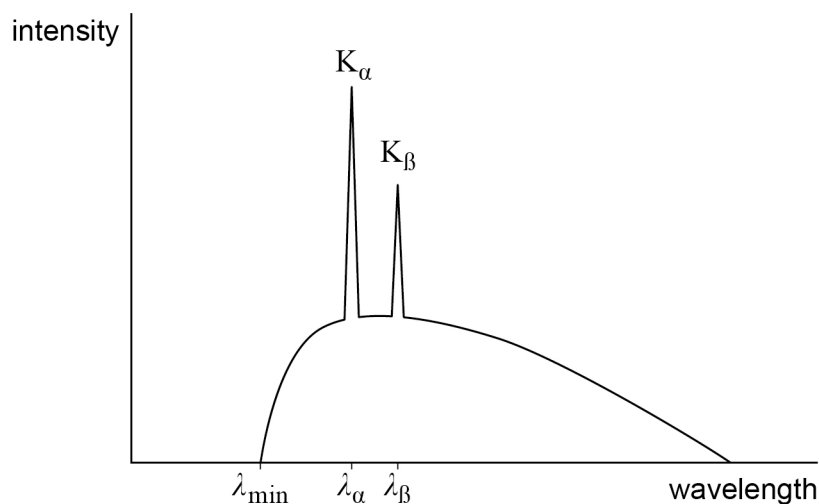
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2 1

The graph shows the X-ray spectrum emitted by an X-ray tube with a tungsten target, operated at 50 kV.

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The same X-ray tube, with the same tungsten target, is now operated at 100 kV.

What happens to the minimum wavelength $\lambda_{\min}$ of the spectrum and the wavelengths λ_{α} and λ_{β} of the characteristic K-lines K_{α} and K_{β} ?

[1 mark]

	$\lambda_{\min}$	λ_{α}	λ_{β}	
A	halves	halves	halves	☐
B	doubles	doubles	doubles	☐
C	halves	unchanged	unchanged	☒
D	doubles	unchanged	unchanged	☐



2 2

In the photoelectric effect, what is the relationship between the work function ϕ of a material and its stopping potential V_s ?

[1 mark]

A $\phi = hf - V_s e$

☒

B $\phi = V_s h$

☐

C $\phi = \frac{hc}{V_s}$

☐

D $\phi = hf + V_s e$

☐

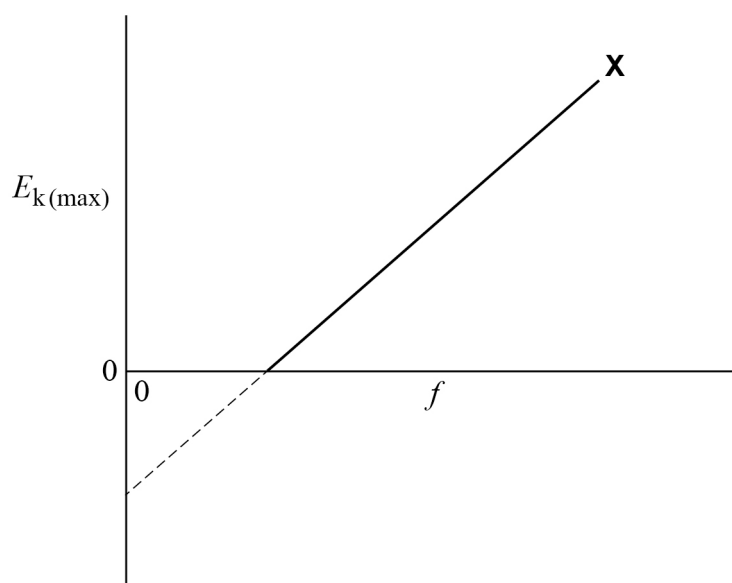
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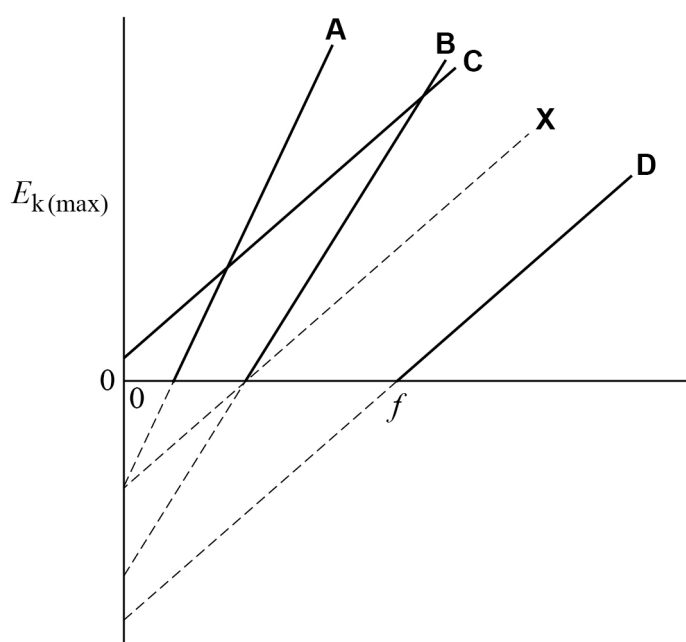


2 3

The graph shows the relationship between the maximum kinetic energy $E_{k(\max)}$ of photoelectrons emitted from material **X**, and the frequency f of incident light.

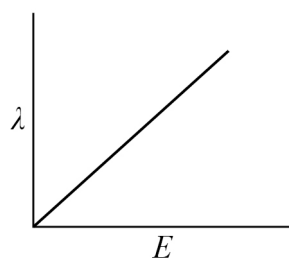
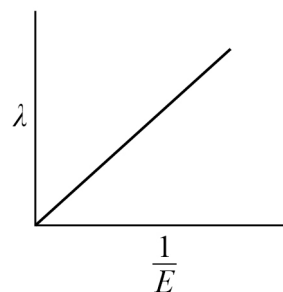
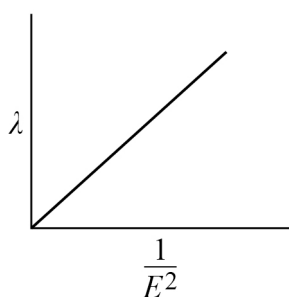
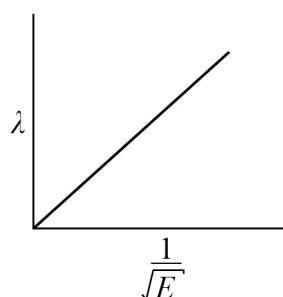


Which line shows the variation of $E_{k(\max)}$ with f for a different material?

[1 mark]**A****B****C****D**

2 4

Which graph shows the relationship between the de Broglie wavelength λ of an electron and its kinetic energy E ?

[1 mark]**A****B****C****D****A****B****C****D****14****END OF QUESTIONS**

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