Please write clearly in block capitals.

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

Surname ____________________

Forename(s) ____________________

Candidate signature ____________________
I declare this is my own work.

AS
PHYSICS

Paper 2

Friday 15 May 2020 Morning

Time allowed: 1 hour 30 minutes
You are advised to spend about 35 minutes on Section C

Materials
For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet.

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.
- 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.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 70.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5–34	
TOTAL	

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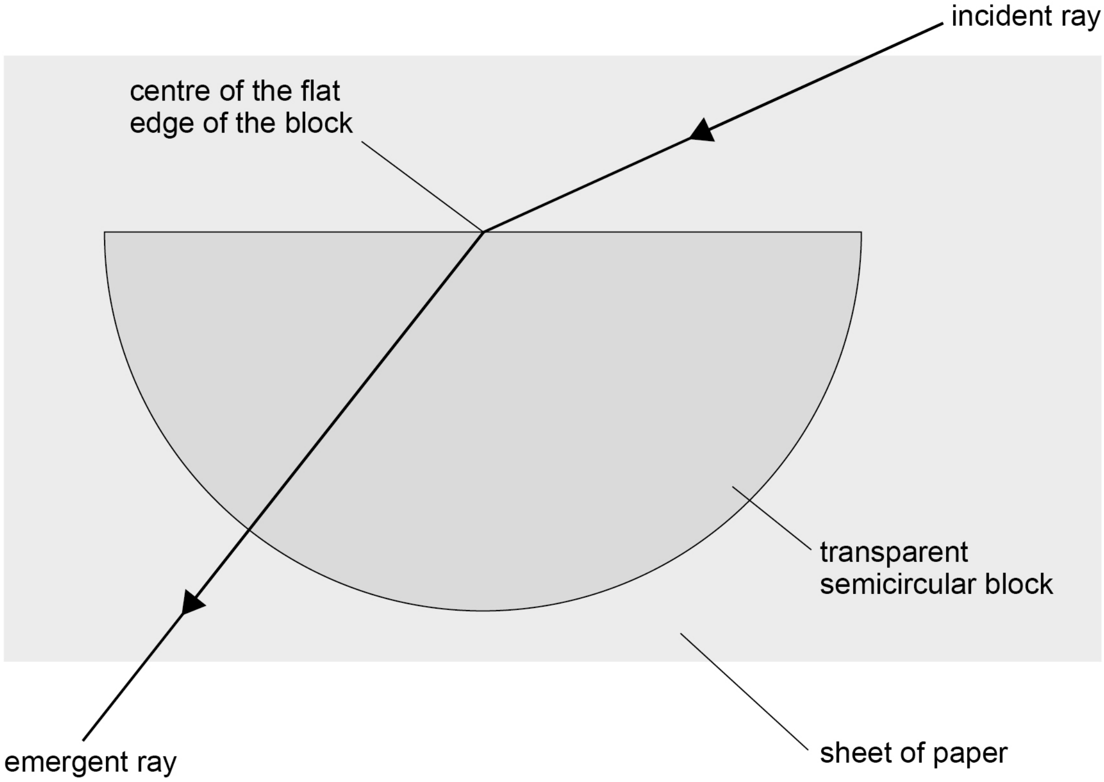
Section A

Answer **all** questions in this section.

0 1 A student places a transparent semicircular block on a sheet of paper and draws around the block. She directs a ray of light at the centre of the flat edge of the block.

Figure 1 shows the path of the ray through the block.

Figure 1



0 1 . 1 State why the emergent ray does not change direction as it leaves the block.

[1 mark]

____

____

0 1 . 2 The student draws an arrow on the paper to mark the incident ray. She marks the path of the emergent ray with crosses **A**, **B** and **C**.

She removes the block from the paper and places a protractor over the outline of the block, as shown in **Figure 2**.

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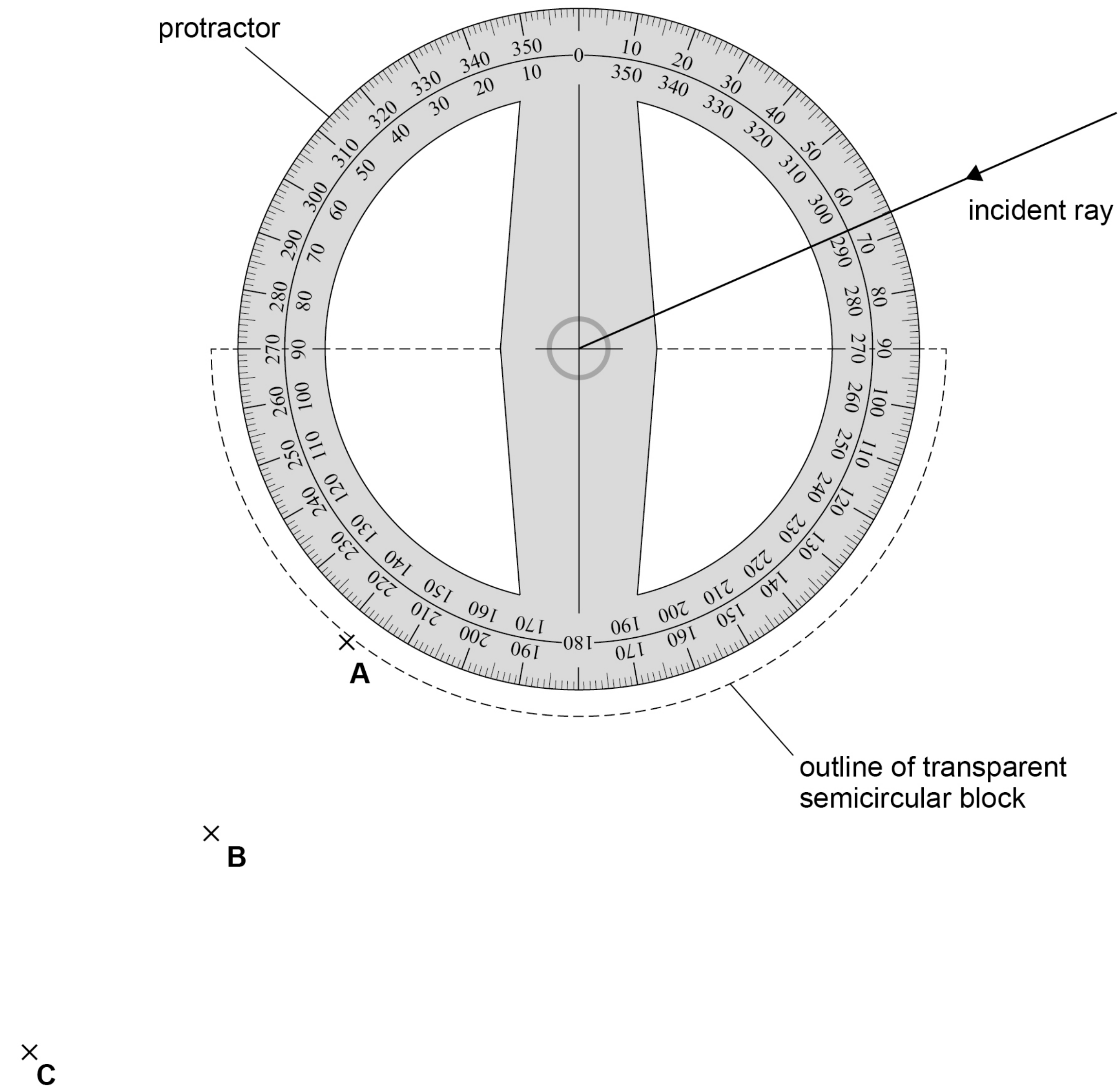
Figure 2



Determine, using **Figure 2**, the refractive index of the block.

[4 marks]

refractive index = ____________________

Question 1 continues on the next page

Turn over ►

The student uses a different method to determine the refractive index of the block. She focuses a travelling microscope on some dots on a sheet of paper for each of the three situations shown in **Figure 3**.

Figure 3

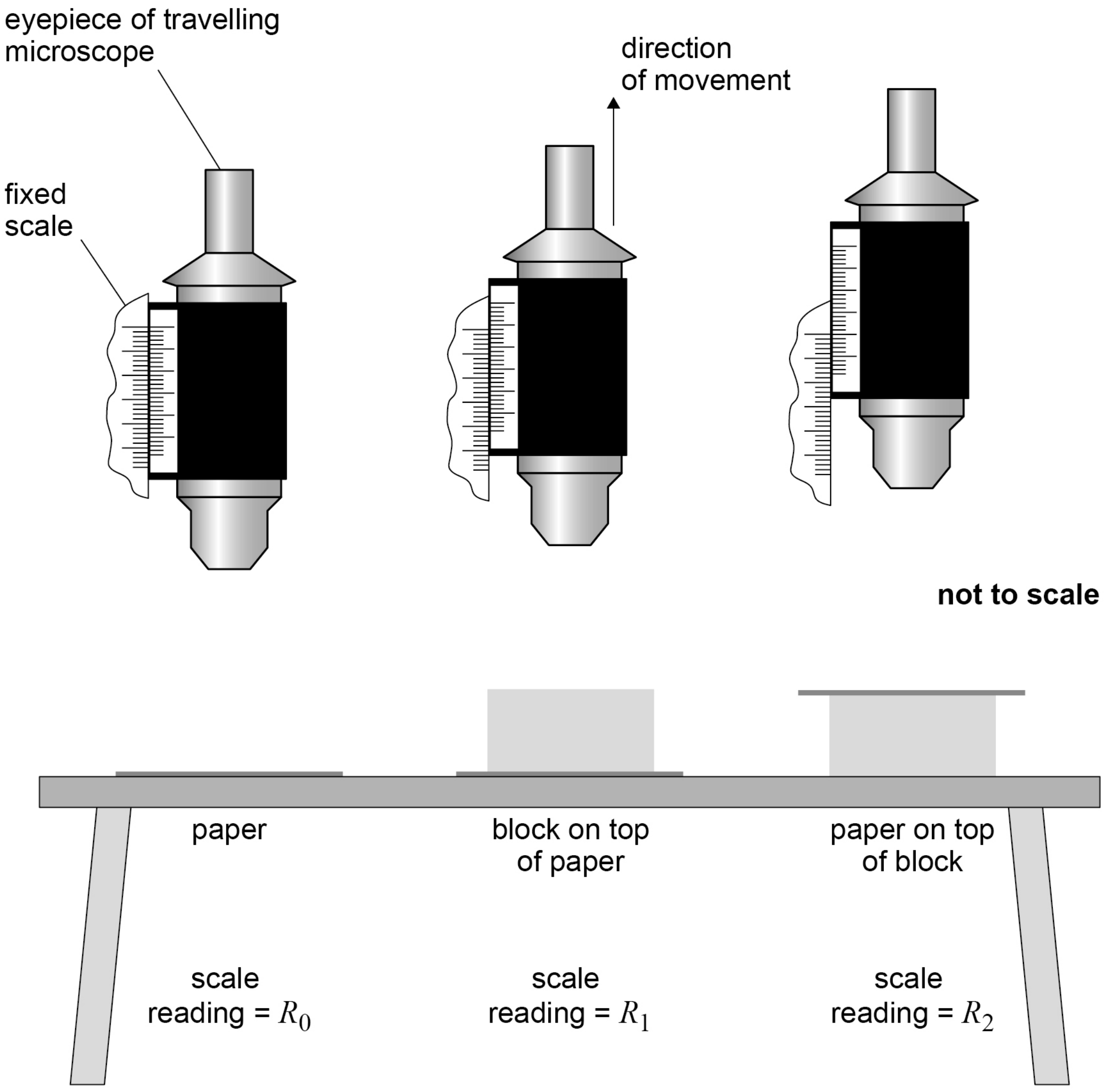


Table 1 shows the readings made by the student.

Table 1

R_0 / mm	R_1 / mm	R_2 / mm
5.74	10.31	20.02

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0 1 . 3 The refractive index n of the block is given by

$$n = \frac{R_2 - R_0}{R_2 - R_1}$$

Determine n.

[1 mark]

$n =$ ____________________

0 1 . 4 The absolute uncertainty in each of the readings R_0, R_1 and R_2 is $0.04\,\text{mm}$.

State the absolute uncertainty in $R_2 - R_0$.

[1 mark]

absolute uncertainty in $R_2 - R_0 =$ ____________________ mm

0 1 . 5 The absolute uncertainty in $R_2 - R_1$ is the same as the absolute uncertainty in $R_2 - R_0$.

Calculate the percentage uncertainty in n.

[3 marks]

percentage uncertainty in $n =$ ____________________ %

10

Turn over ►

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There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED

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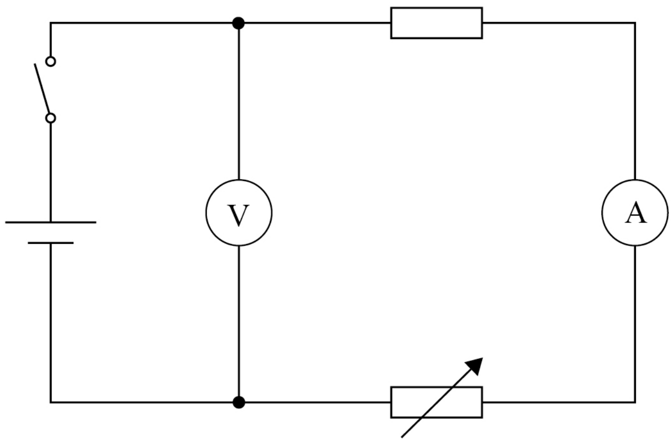
0 2 **Figure 4** shows a circuit used by a student to determine the emf and the internal resistance of a cell.

The cell is connected to a switch, a fixed resistor and a variable resistor.
When the switch is closed, a voltmeter measures the potential difference V across the cell.
An ammeter measures the current I in the circuit.

Readings of V and I are taken as the resistance of the variable resistor is changed from zero to its maximum value.

Figure 4



0 2 . 1 Explain why the student included the fixed resistor in this circuit.

[2 marks]

Question 2 continues on the next page

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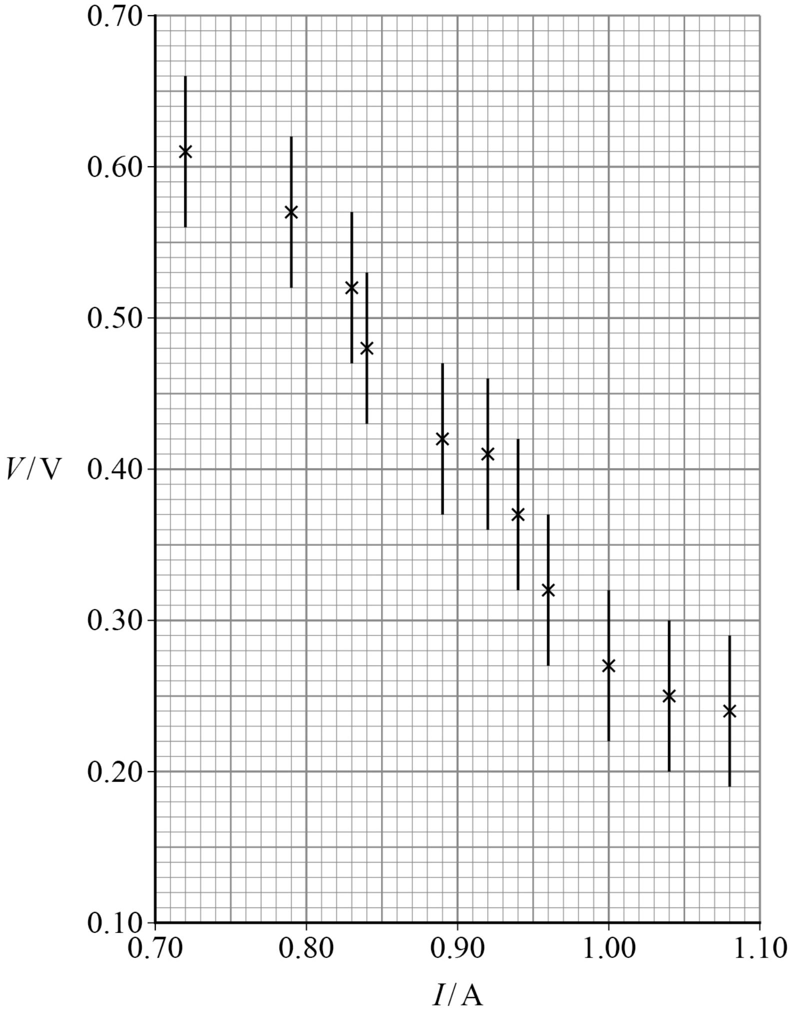
Figure 5 is a graph of the data recorded for this experiment.

Figure 5



0 2 . 2 Determine the magnitude of the minimum gradient G_{min} of a line that passes through all the error bars in **Figure 5**.

[3 marks]

magnitude of G_{min} = ____________________

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0 2 . 3 The maximum gradient G_{max} / V A^{-1} of a line passing through all the error bars in **Figure 5** is -1.3

Determine, using G_{max} and G_{min}, the internal resistance of the cell.

[2 marks]

internal resistance = ____________________ Ω

0 2 . 4 The line of best fit passes through the data point (0.94, 0.37).

Determine the emf of the cell.

[3 marks]

emf = ____________________ V

10

END OF SECTION A

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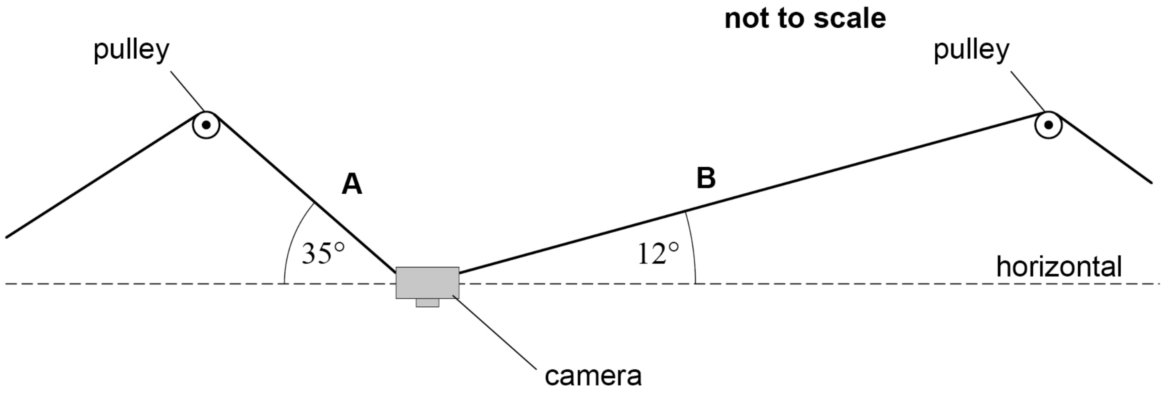
Section B

Answer **all** questions in this section.

0 3 **Figure 6** shows a camera filming a sports event from above. The position of the camera is controlled by two steel cables, **A** and **B**, that pass over fixed, smooth pulleys.

Figure 6



0 3 . 1 In **Figure 6** the camera is stationary. The tension in **A** is 430 N and **A** makes an angle of $35°$ to the horizontal. **B** makes an angle of $12°$ to the horizontal.

Calculate the tension in **B**.

[2 marks]

tension in **B** = ________________________ N

Do not write outside the box

0 3 . 2 The cross-sectional area of **A** is 7.0×10^{-6} m^2. The unstretched length of **A** is 150 m.

Calculate the extension of **A** when the tension in it is 430 N.

Young modulus of steel = 210 GPa

[2 marks]

extension = ____________________ m

0 3 . 3 The camera is moved horizontally to the right to a new stationary position.
The tension in **A** is now different from that in **Figure 6**.

Deduce whether the tension in **A** has increased or decreased.

[3 marks]

___

___

___

___

___

___

___

___

___

Question 3 continues on the next page

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0 3 . 4 The camera's signal is transmitted as a series of pulses through an optical fibre. **Table 2** shows data for two optical fibres **X** and **Y**. Both optical fibres are identical except for their core diameter.

Table 2

Optical fibre	Core diameter / μm
X	8
Y	50

Deduce which fibre allows a greater pulse transmission rate.

[3 marks]

10

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

0 4 Scintillation counters are used to detect beta particles. A scintillation counter consists of a scintillation material and a photomultiplier tube (PMT).

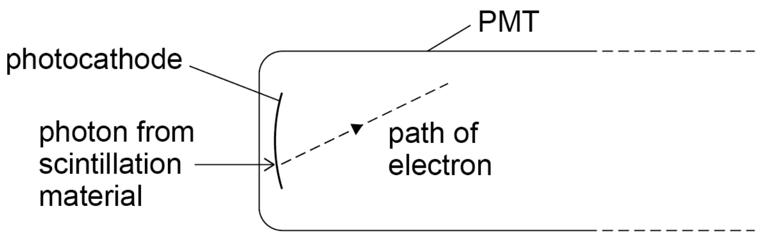
0 4 . 1 Beta particles collide with atoms in the scintillation material, which emits photons of light as a result.

Explain how photons are produced by collisions between beta particles and atoms.

[2 marks]

0 4 . 2 A photon of light from the scintillation material enters the PMT, as shown in **Figure 7**. The front of the PMT contains a thin photocathode. The photon strikes the photocathode to release an electron.

Figure 7



The longest wavelength of light that releases an electron from this photocathode is 630 nm.

Calculate the minimum photon energy required to remove an electron from the photocathode.

[2 marks]

minimum photon energy = ____________ J

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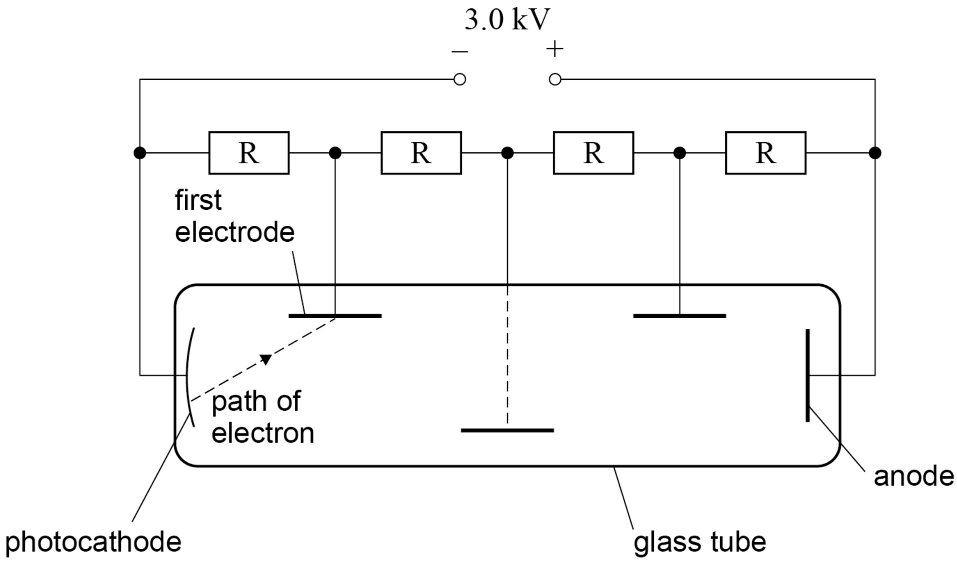
0 4 . 3 The PMT consists of an evacuated glass tube containing the photocathode, an anode and three metal electrodes, as shown in **Figure 8**.

Figure 8



The electrodes, anode and photocathode are connected to a potential divider consisting of four identical resistors R. The emf of the electrical supply is 3.0 kV.

The potential difference between the photocathode and the first electrode accelerates the electron along the path shown in **Figure 8**.

Calculate, in J, the maximum kinetic energy transferred to the electron when it accelerates from the photocathode to the first electrode.

[2 marks]

maximum kinetic energy = ______________________ J

Question 4 continues on the next page

Turn over ►

Do not write outside the box

0 4 . 4 The electron hits the first electrode and causes the release of several electrons. **Figure 9** shows how a series of accelerations and collisions produces a large number of electrons. These electrons hit the anode and produce a pulse of current in an ammeter.

Figure 9

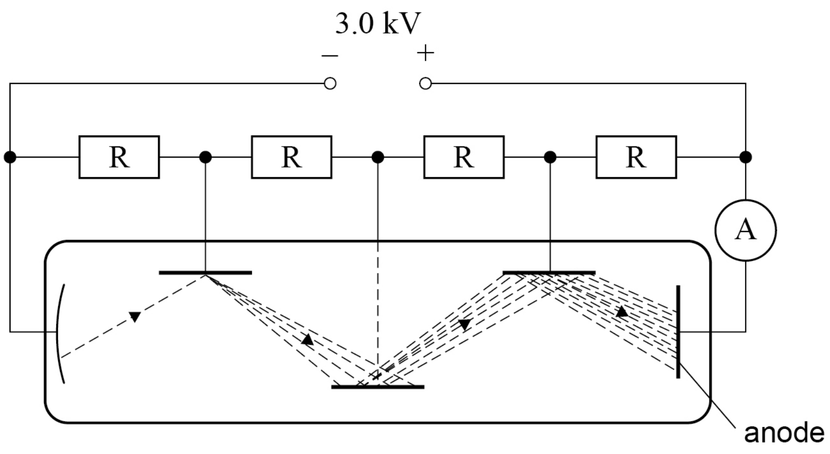
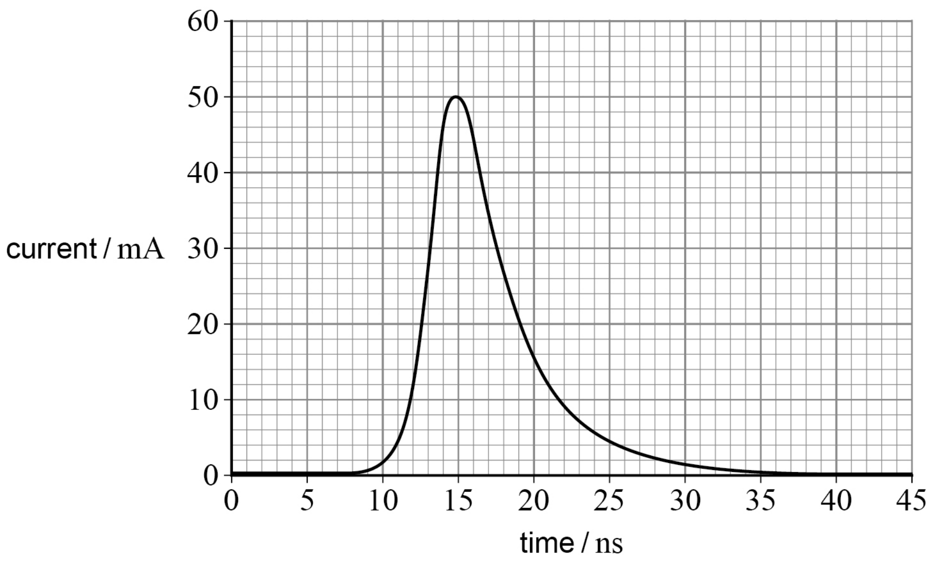


Figure 10 shows the variation of current in the ammeter with time due to this pulse.

Figure 10



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Determine the number of electrons that flow through the ammeter.

[4 marks]

number of electrons = ____________________

10

END OF SECTION B

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Section C

Each of Questions **05** to **34** 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.

0 5 Which row shows SI unit prefixes in order of smallest value to largest value?

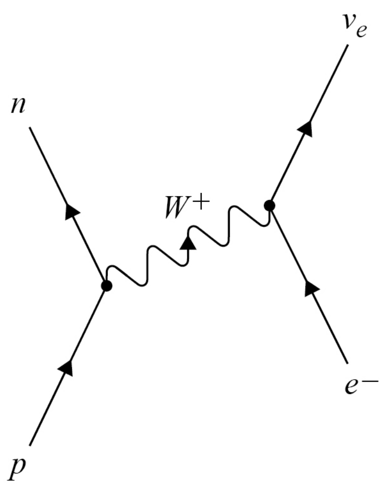
[1 mark]

	Smallest			**Largest**
A	p	n	c	μ
B	p	n	μ	c
C	n	p	c	μ
D	n	p	μ	c

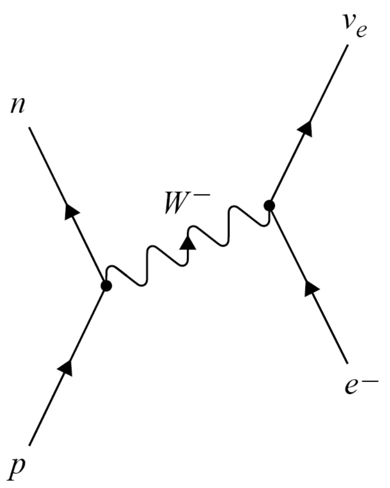
0 6 Which diagram represents electron capture?

[1 mark]

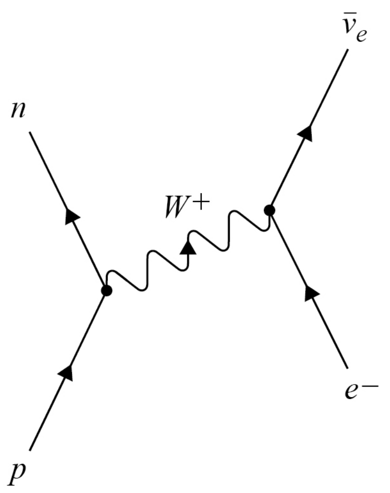
A



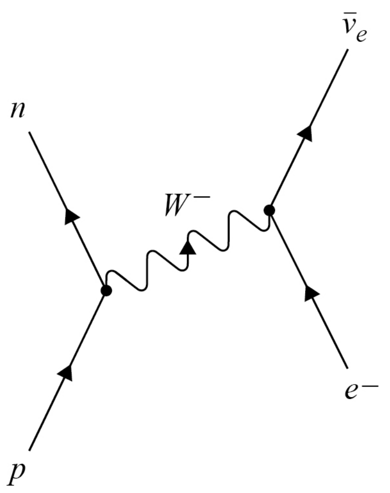
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

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0 7 $^{x}_{81}\mathrm{Tl}$ decays to $^{206}_{82}\mathrm{Pb}$ by a series of four radioactive decays.

Each decay involves the emission of either a single α particle or a single β^- particle.

What is x?

[1 mark]

A 207

B 209

C 210

D 212

0 8 What is the number of up quarks and down quarks in a $^{9}_{4}\mathrm{Be}$ nucleus?

[1 mark]

	Number of up quarks	Number of down quarks
A	11	16
B	13	14
C	14	13
D	16	11

0 9 Which decay of a positive kaon (K^+) particle is possible?

[1 mark]

A $K^+ \rightarrow \pi^0 + e^+ + \bar{\nu}_e$

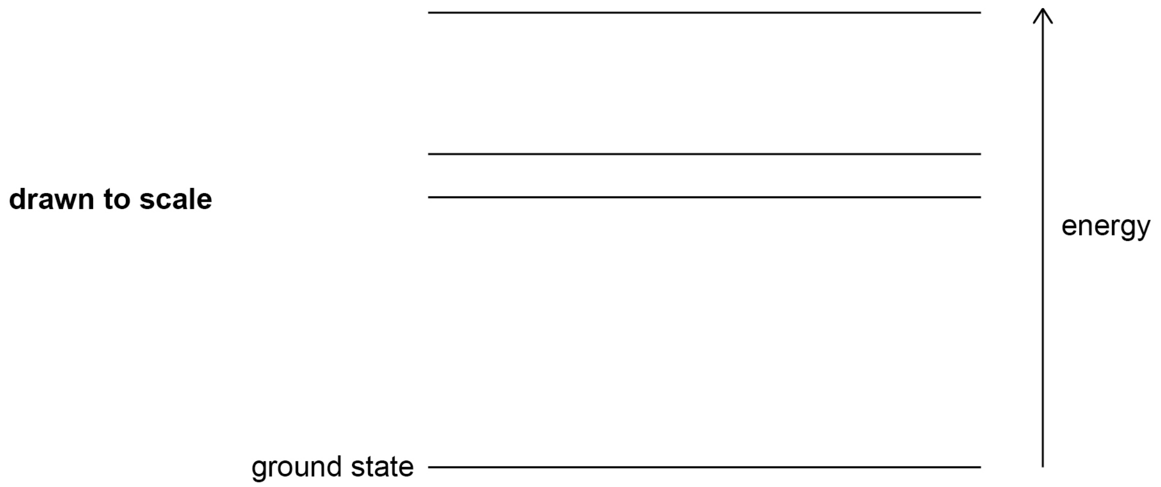
B $K^+ \rightarrow p + \nu_\mu$

C $K^+ \rightarrow \pi^+ + \pi^+ + \pi^0$

D $K^+ \rightarrow \mu^+ + \nu_\mu$

Do not write outside the box

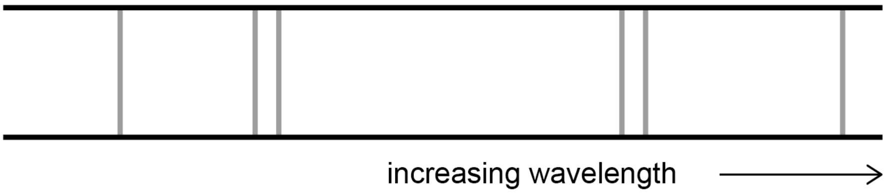
1 0 The diagram shows four energy levels of an atom drawn to scale.
These energy levels give rise to part of an emission spectrum.



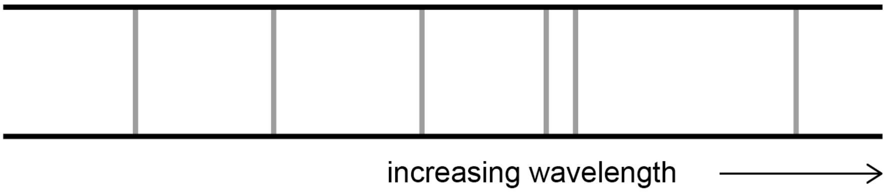
Which pattern of lines will be observed from these energy levels?

[1 mark]

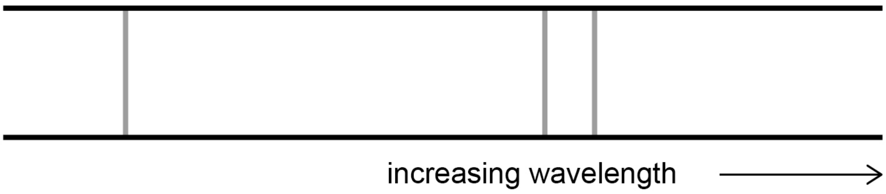
A



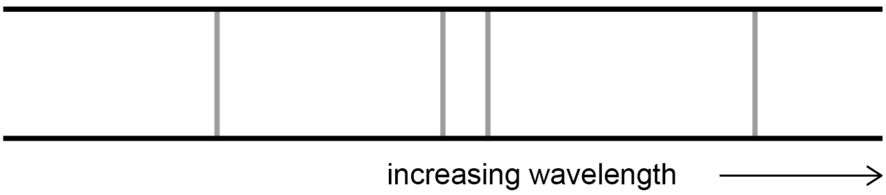
B



C



D



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1 1 A particle has a kinetic energy of E_k and a de Broglie wavelength of λ.

What is the de Broglie wavelength when the particle has a kinetic energy of $4E_k$?

[1 mark]

A $\frac{\lambda}{2}$ ○

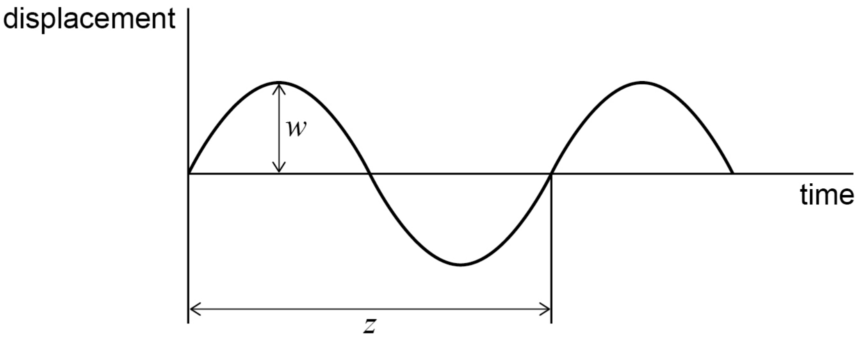
B $\frac{\lambda}{\sqrt{2}}$ ○

C $\sqrt{2}\lambda$ ○

D 2λ ○

1 2 A wave travels along a water surface.

The variation with time of the displacement of a water particle at the surface is shown.



What properties of the wave are represented by w and z?

[1 mark]

	w	z	
A	phase	frequency	○
B	amplitude	wavelength	○
C	wavelength	phase	○
D	amplitude	period	○

Do not write outside the box

1 3 Two points on a progressive wave are out of phase by 0.41 rad.

What is this phase difference?

[1 mark]

A $23°$

B $47°$

C $74°$

D $148°$

1 4 Light of wavelength λ is incident normally on two parallel slits of separation s.
Fringes of spacing w are seen on a screen at a distance D from the slits.

Which row gives another arrangement that produces a fringe spacing of w?

[1 mark]

	Wavelength	Slit separation	Distance between slits and screen
A	2λ	$2s$	$2D$
B	2λ	$4s$	$2D$
C	2λ	$2s$	$4D$
D	4λ	$2s$	$2D$

1 5 A narrow beam of monochromatic light is incident normally to a diffraction grating.
The first-order diffracted beam makes an angle of $20°$ with the normal to the grating.

What is the highest order visible with this grating at this wavelength?

[1 mark]

A 2

B 3

C 4

D 5

Turn over ►

1 6 The speed of light decreases by 40% when it travels from air into a transparent medium.

What is the refractive index of the medium?

[1 mark]

A 0.6 ⬭

B 1.4 ⬭

C 1.7 ⬭

D 2.5 ⬭

1 7 Which row describes charge and impulse?

[1 mark]

	Charge	**Impulse**	
A	scalar	scalar	⬭
B	scalar	vector	⬭
C	vector	scalar	⬭
D	vector	vector	⬭

Do not write outside the box

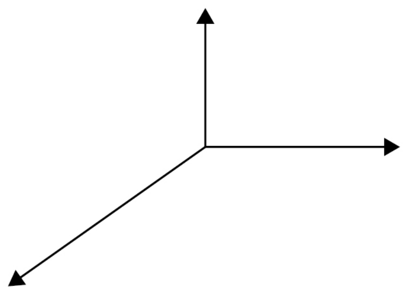
1 8 An object is in equilibrium when acted on by three coplanar forces.

Which free-body diagram is correct?

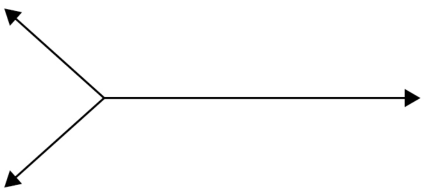
Each diagram is drawn to scale.

[1 mark]

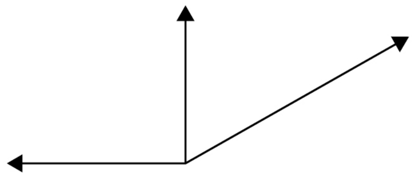
A



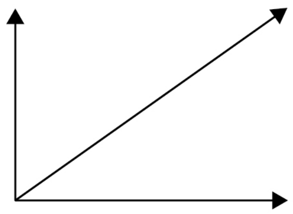
B



C



D



A ⬭

B ⬭

C ⬭

D ⬭

1 9 Which quantity is represented by the area under a force–time graph?

[1 mark]

A average power ⬭

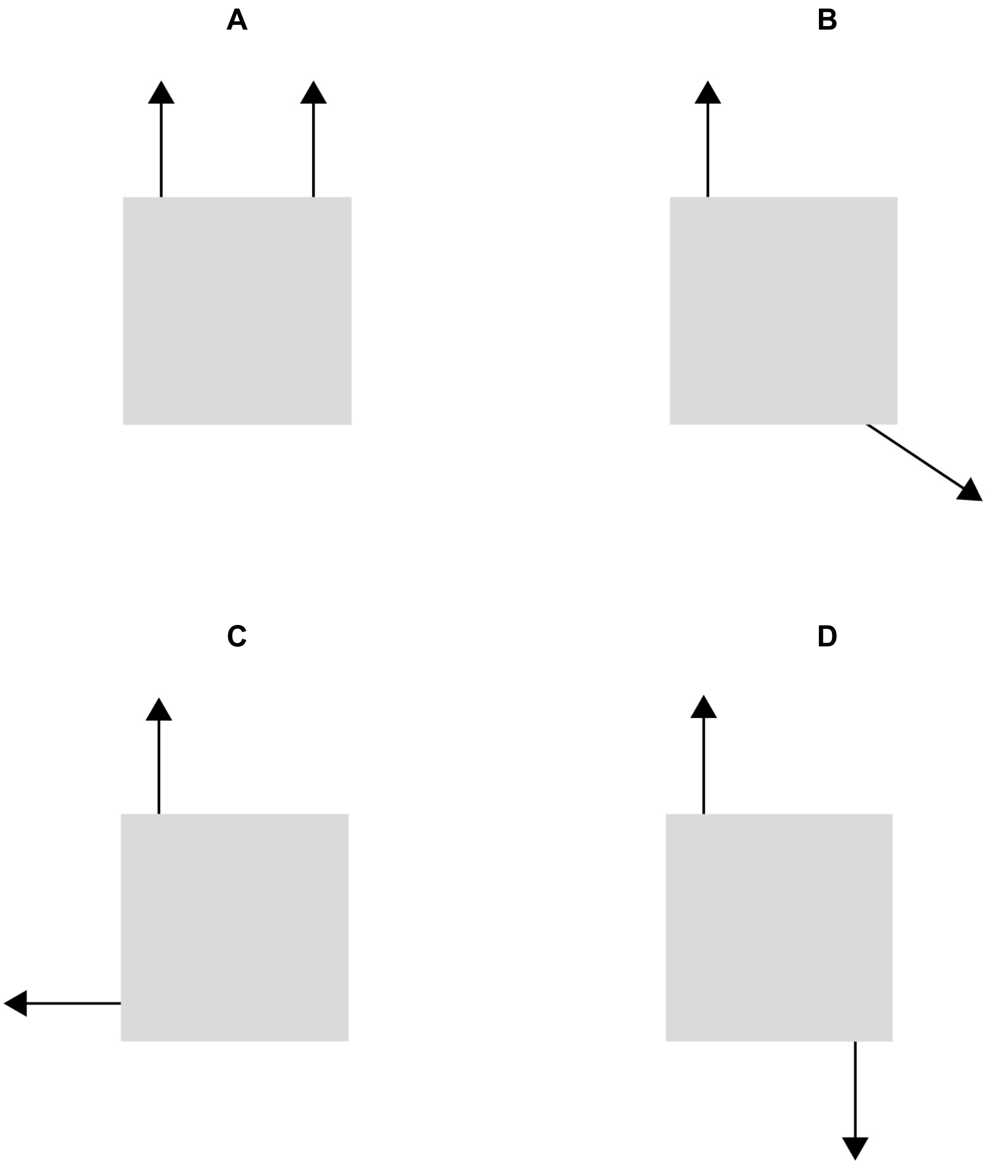
B elastic strain energy stored ⬭

C momentum change ⬭

D work done ⬭

2 0 Each diagram shows two horizontal forces acting on a solid square object seen from above.

All the forces have the same magnitude.



Which system produces a couple about any point inside the object?

[1 mark]

A ○

B ○

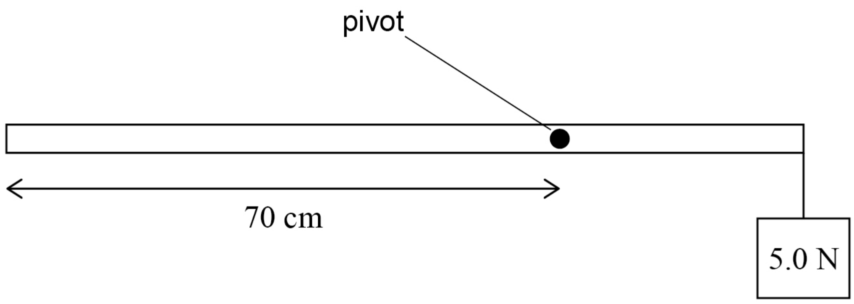
C ○

D ○

Do not write outside the box

2 1 A uniform metre ruler of weight 2.0 N is freely pivoted at the 70 cm mark.

A student holds the ruler in a horizontal position and suspends a 5.0 N weight from the 100 cm end.



What is the magnitude of the resultant moment when the student releases the ruler?

[1 mark]

A 0.15 N m ⬭

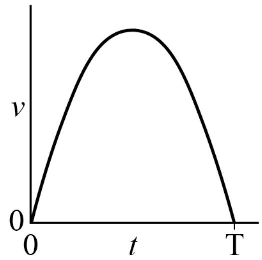
B 0.19 N m ⬭

C 1.1 N m ⬭

D 1.9 N m ⬭

Turn over for the next question

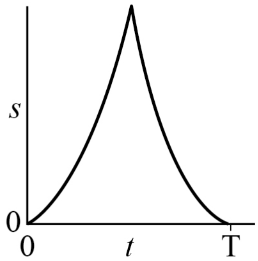
2 2 The diagram shows how the speed v of an object varies with time t.



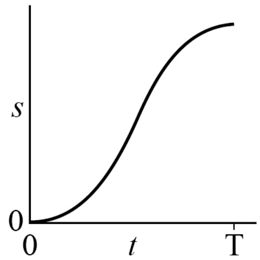
Which graph shows the variation of distance s with t for the object?

[1 mark]

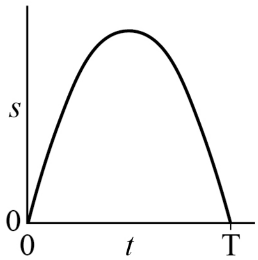
A



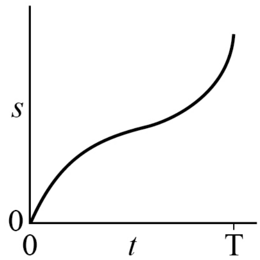
B



C



D



A ☐

B ☐

C ☐

D ☐

2 3 Two ball bearings **X** and **Y** are projected from horizontal ground at the same time.

X has mass $2m$ and is projected vertically upwards with speed u.

Y has mass m and is projected at $30°$ to the horizontal with speed $2u$.

Air resistance is negligible.

Which statement is correct?

[1 mark]

A **X** and **Y** have the same initial momentum.

B **X** and **Y** reach their maximum heights at different times.

C The maximum height reached by **Y** is half that reached by **X**.

D **X** and **Y** reach the ground at the same time.

2 4 Which row is true for an elastic collision between two objects in an isolated system?

[1 mark]

	Kinetic energy	**Momentum**
A	conserved	conserved
B	not conserved	conserved
C	conserved	not conserved
D	not conserved	not conserved

Turn over for the next question

2 5 The drag force on a boat is kv^2, where v is the speed and $k = 64\ \mathrm{kg\ m^{-1}}$.

The boat's engine has a useful power output of $8000\ \mathrm{W}$.

What is the maximum speed of the boat?

[1 mark]

A $0.2\ \mathrm{m\ s^{-1}}$

B $5\ \mathrm{m\ s^{-1}}$

C $11\ \mathrm{m\ s^{-1}}$

D $125\ \mathrm{m\ s^{-1}}$

2 6 A tensile force F_1 causes a wire to stretch to length x_1.

When the tensile force is increased to F_2 the length of the wire is x_2.

The wire obeys Hooke's Law.

What is the additional energy stored in the wire as the length increases from x_1 to x_2?

[1 mark]

A $\dfrac{F_1 + F_2}{2} \times \dfrac{x_2 - x_1}{2}$

B $\dfrac{F_1 + F_2}{2} \times \dfrac{x_2 + x_1}{2}$

C $\dfrac{F_1 + F_2}{2} \times (x_2 - x_1)$

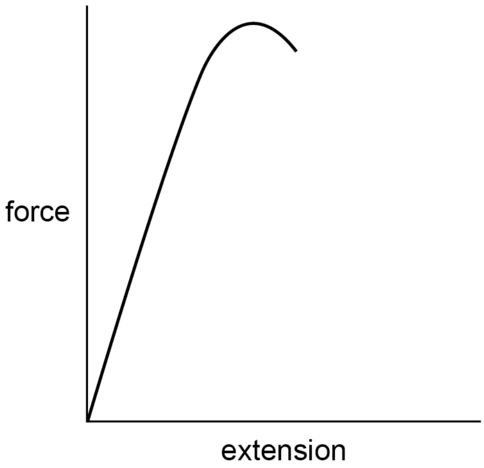
D $\dfrac{F_1 + F_2}{2} \times (x_2 + x_1)$

Do not write outside the box

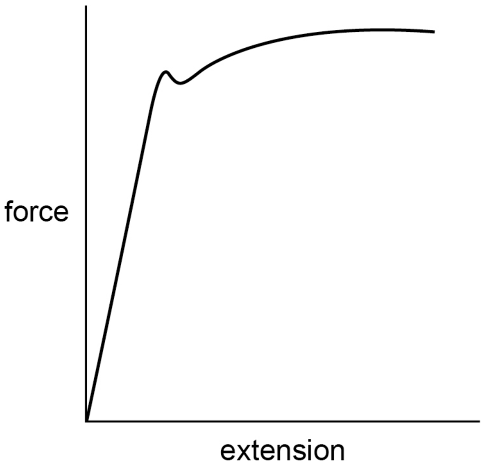
2 7 Which is a force–extension graph for a brittle material?

[1 mark]

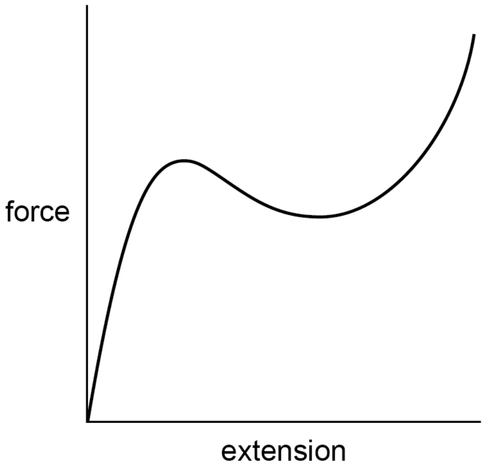
A



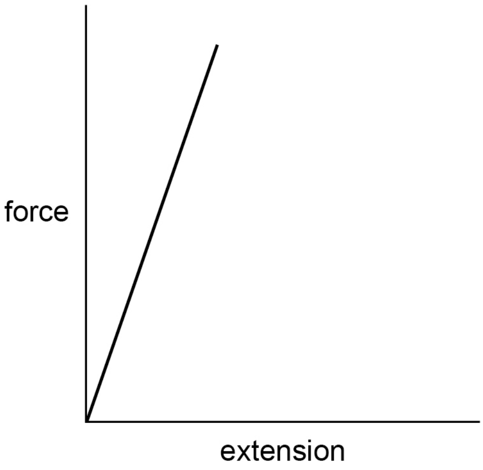
B



C



D



A ☐

B ☐

C ☐

D ☐

Turn over ►

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2 8 The table shows corresponding values of potential difference V and current I for four electrical components **A**, **B**, **C** and **D**.

	A	**B**	**C**	**D**
V / V	I / A	I / A	I / A	I / A
0	0.0	0.0	0.0	0.0
2	0.0	0.3	0.4	0.3
4	0.1	0.6	0.8	0.6
6	0.7	0.9	1.2	0.9
8	1.4	1.2	1.6	1.1
10	2.1	1.5	2.0	1.3
12	2.8	1.8	2.4	1.4

Which component is an ohmic conductor with the greatest resistance?

[1 mark]

A ⬭

B ⬭

C ⬭

D ⬭

2 9 Which row shows the resistances of an ideal ammeter and an ideal voltmeter?

[1 mark]

	Ideal ammeter	**Ideal voltmeter**	
A	infinite	infinite	⬭
B	infinite	zero	⬭
C	zero	infinite	⬭
D	zero	zero	⬭

3 0 The capacity of a portable charger is rated in ampere hours (A h).
A charger of capacity 1 A h can provide 1 A for 1 hour at its working voltage.

One charger has a capacity of 1800 mA h at a working voltage of 3.7 V.

What is the energy stored in this charger?

[1 mark]

A 6.5 kJ

B 24 kJ

C 400 kJ

D 24 MJ

3 1 A filament lamp with resistance 12 Ω is operated at a power of 36 W.

How much charge flows through the filament lamp during 15 minutes?

[1 mark]

A 26 C

B 1.6 kC

C 2.7 kC

D 6.5 kC

Turn over for the next question

3 2 A resistor with resistance R is made from metal wire of resistivity ρ.
The length of the wire is L.

What is the diameter of the wire?

[1 mark]

A $\sqrt{\dfrac{2\rho R}{\pi L}}$ ⬭

B $\sqrt{\dfrac{2\rho L}{\pi R}}$ ⬭

C $2\sqrt{\dfrac{\rho L}{\pi R}}$ ⬭

D $2\sqrt{\dfrac{\rho R}{\pi L}}$ ⬭

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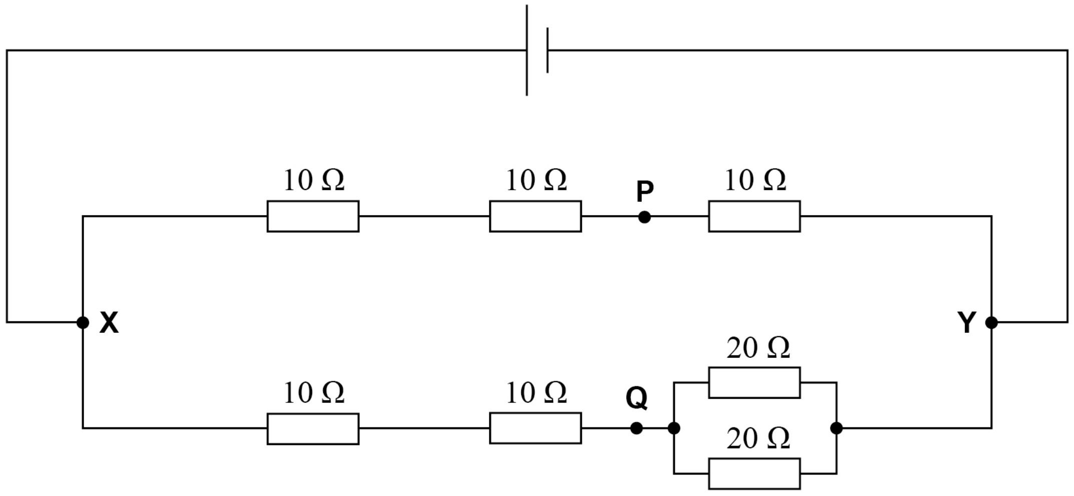
3 3 The potential difference between points **X** and **Y** is V.



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

[1 mark]

A zero

B $\frac{V}{3}$

C $\frac{V}{2}$

D $\frac{2V}{3}$

Turn over for the next question

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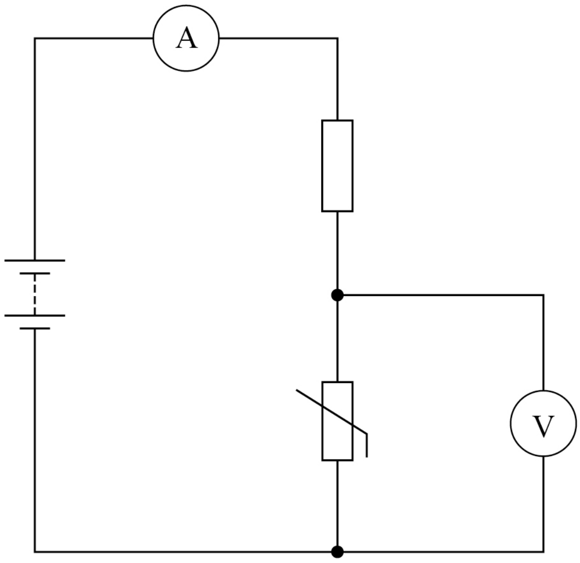
3 4 The diagram shows a temperature-sensing circuit.



The temperature of the thermistor is decreased.

Which row shows the changes to the ammeter reading and the voltmeter reading?

[1 mark]

	Ammeter reading	Voltmeter reading	
A	increases	increases	⬭
B	increases	decreases	⬭
C	decreases	decreases	⬭
D	decreases	increases	⬭

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END OF QUESTIONS

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