A

Surname ______________________

Other Names ______________________

Centre Number ______________________

Candidate Number ______________________

Candidate Signature ______________________

I declare this is my own work.

AS
PHYSICS

Paper 2

7407/2

Friday 15 May 2020 Morning

Time allowed: 1 hour 30 minutes

At the top of the page, write your surname and other names, your centre number, your candidate number and add your signature.

[Turn over]

J U N 2 0 7 4 0 7 2 0 1

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

You are advised to spend about 35 minutes on Section C

INSTRUCTIONS

- **Use black ink or black ball-point pen.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do not write 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.

DO NOT TURN OVER UNTIL TOLD TO DO SO

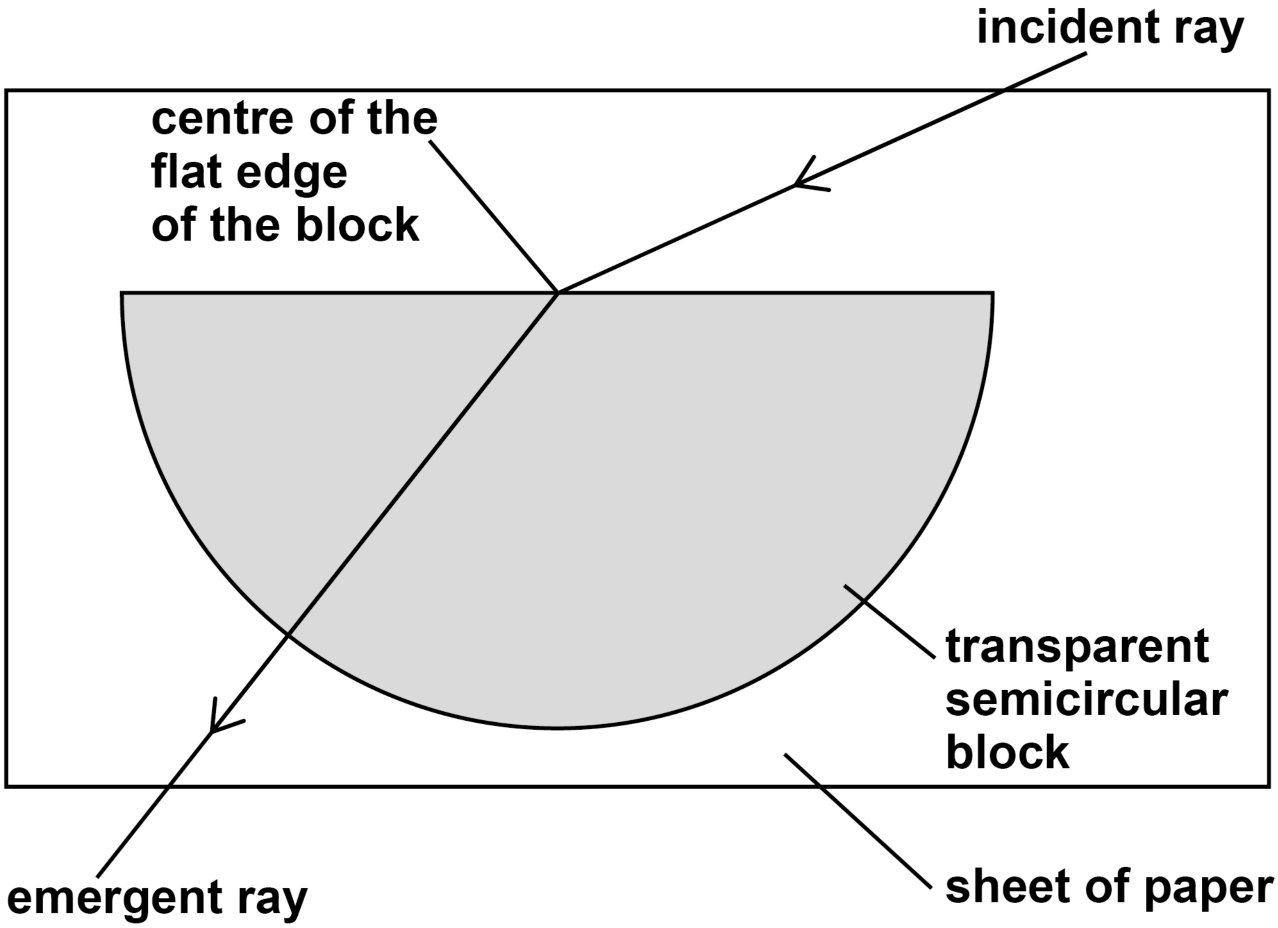
SECTION A

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.

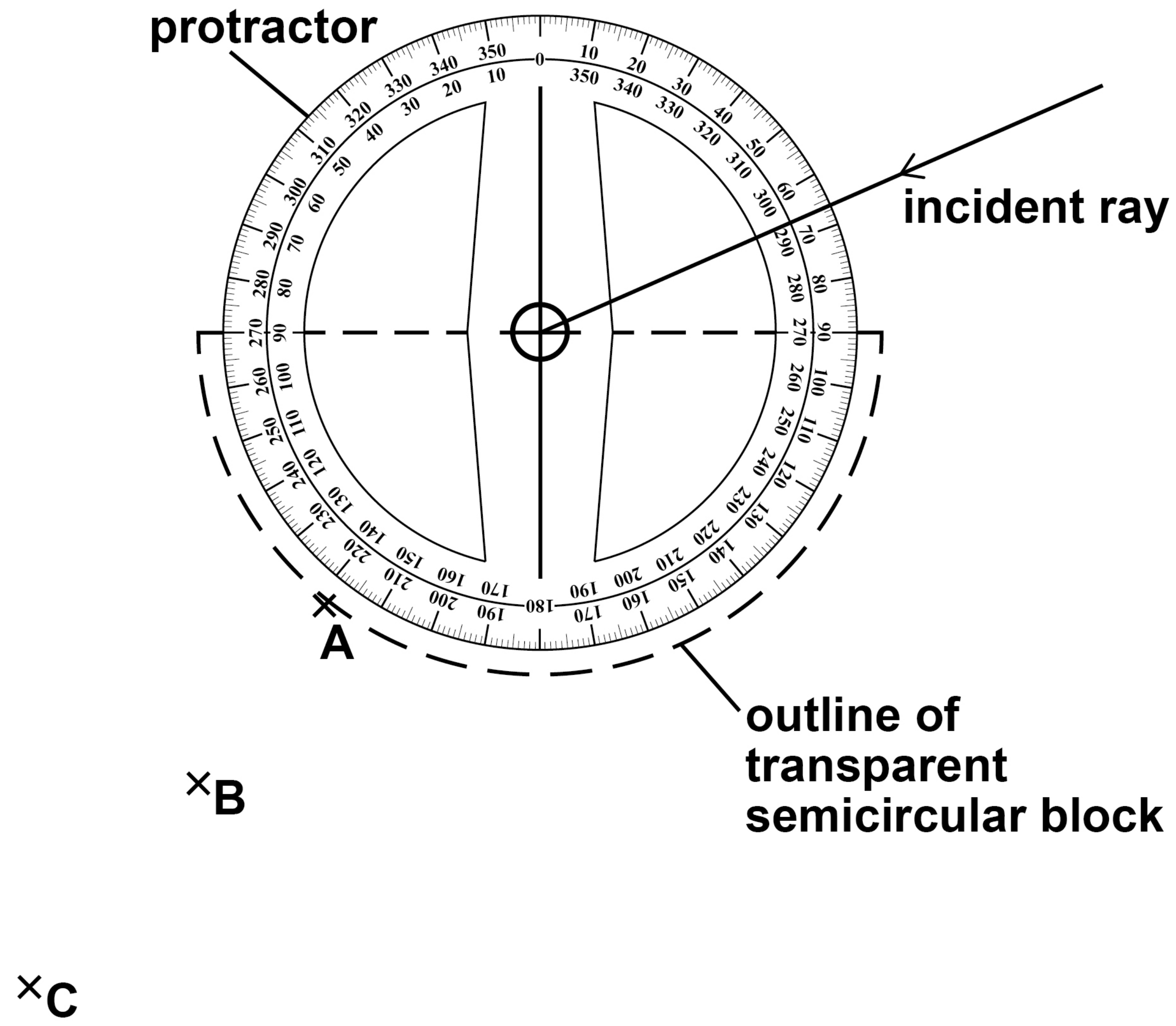
FIGURE 1



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

[Turn over]

FIGURE 2


protractor
incident ray
A
B
C
outline of
transparent
semicircular block

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, on the opposite page.

Determine, using FIGURE 2, the refractive index of the block. [4 marks]

refractive index = ______________________________

[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

The diagram is not drawn accurately.

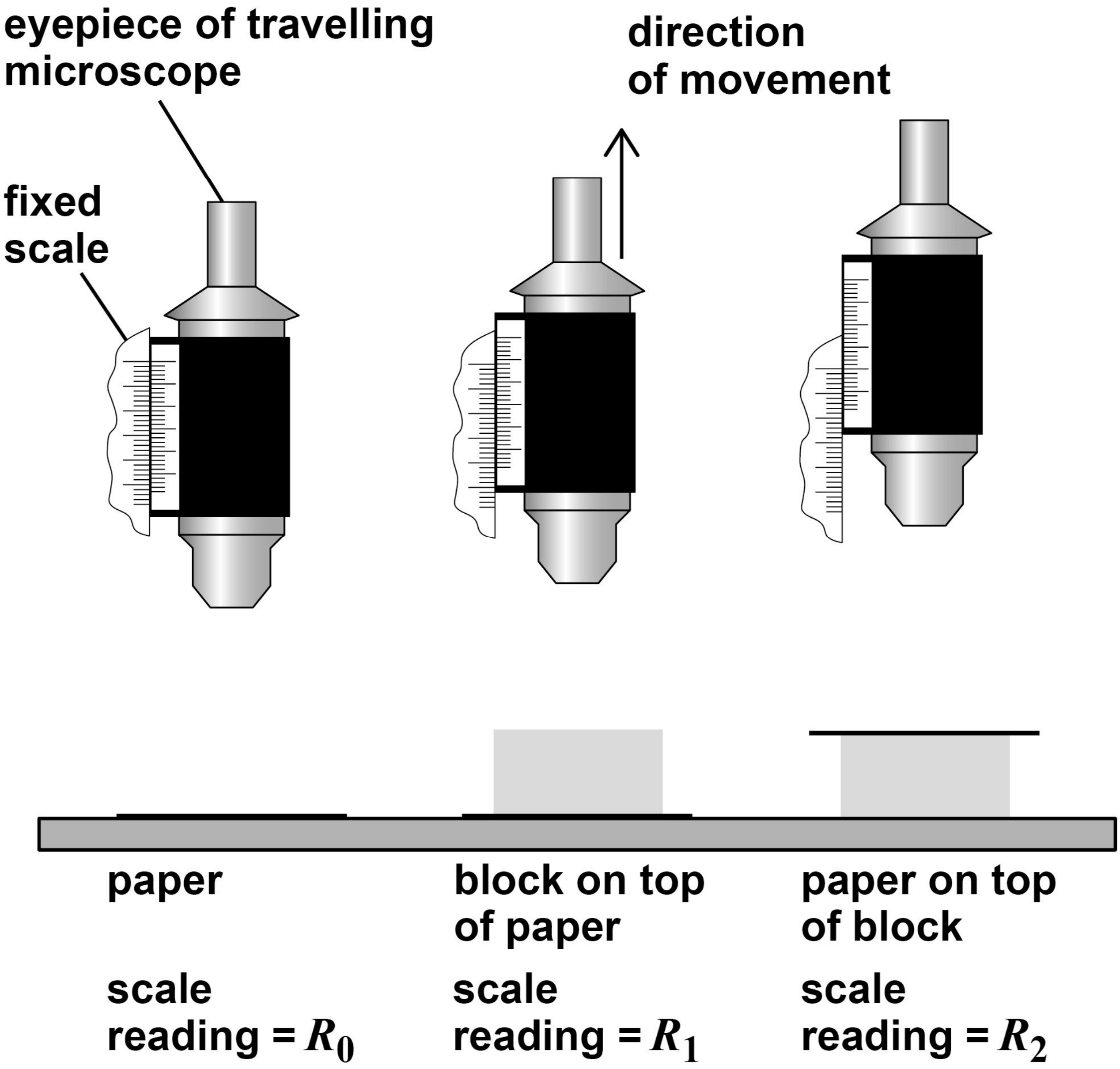


TABLE 1 shows the readings made by the student.

TABLE 1

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

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 = ______________________________

[Turn over]

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

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 =

________________________________ %

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

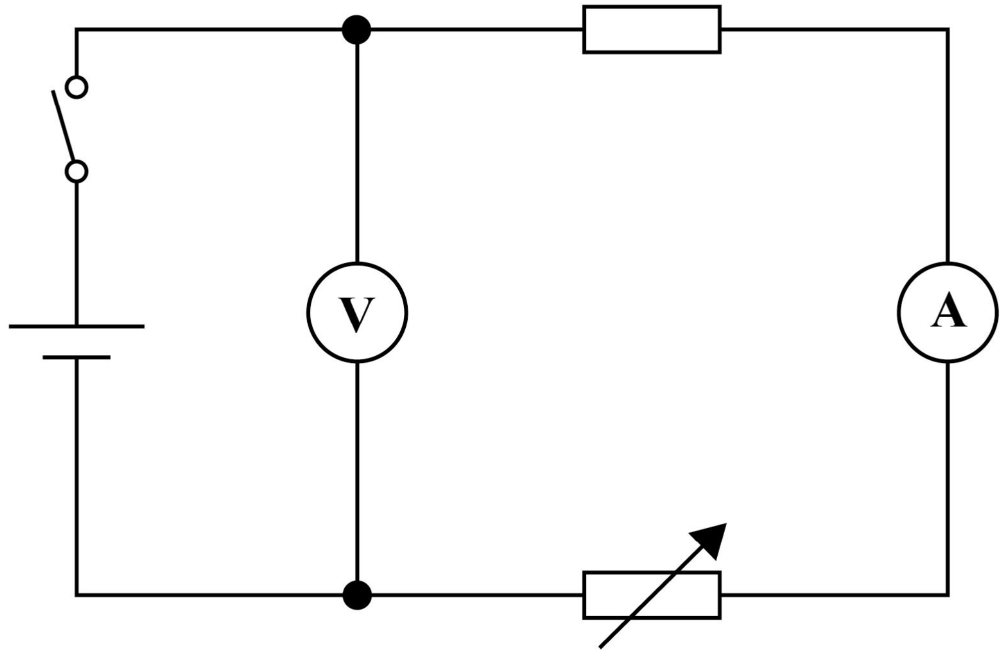
The cell is connected to a switch, a fixed resistor and a variable resistor.

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]**

[Turn over]

FIGURE 5

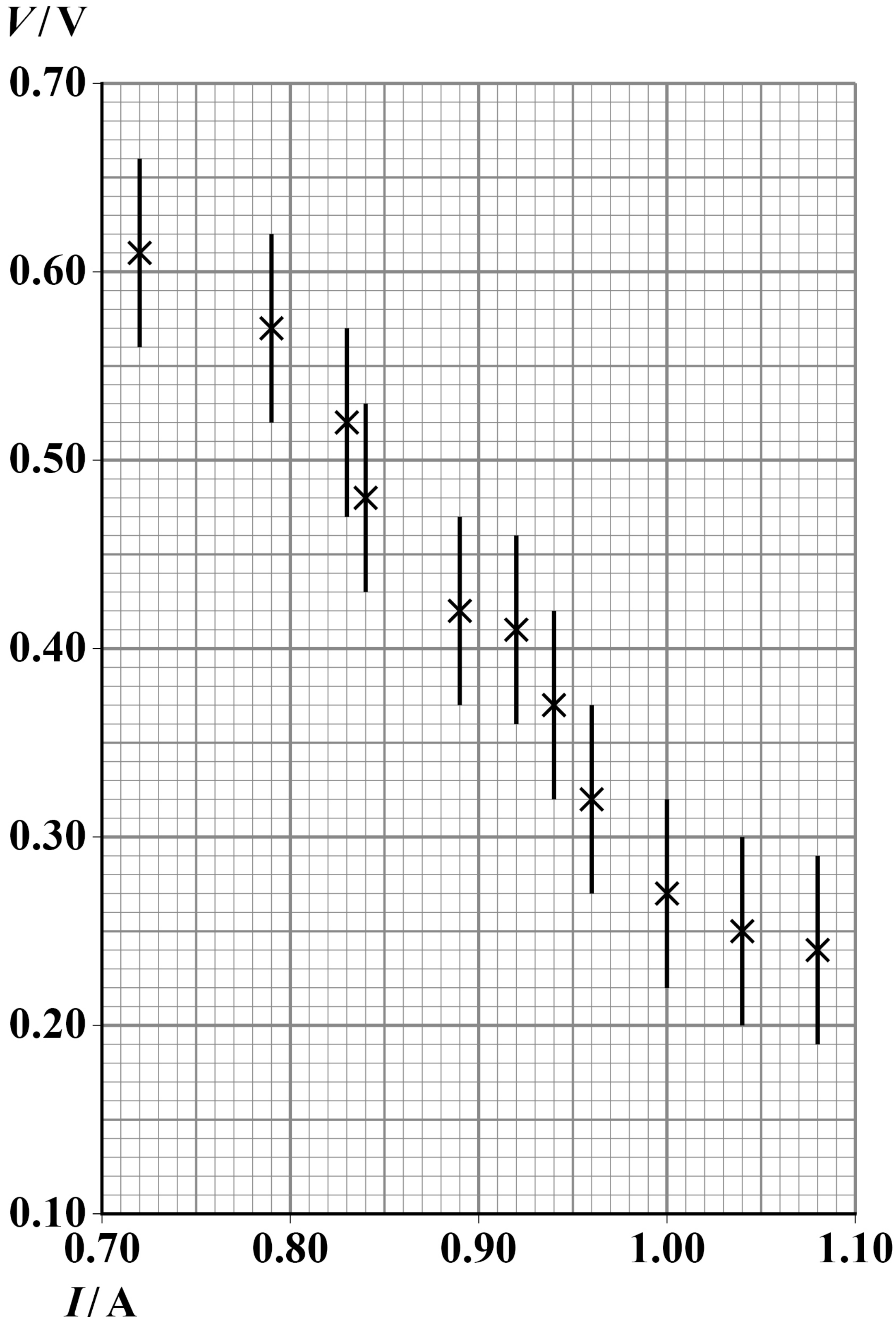


FIGURE 5, on the opposite page, is a graph of the data recorded for this experiment.

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} = ______________________

0 2 . 3 **The maximum gradient G_{max} / V A^{-1} of a line passing through all the error bars in FIGURE 5, on page 14, 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

[Turn over]

10

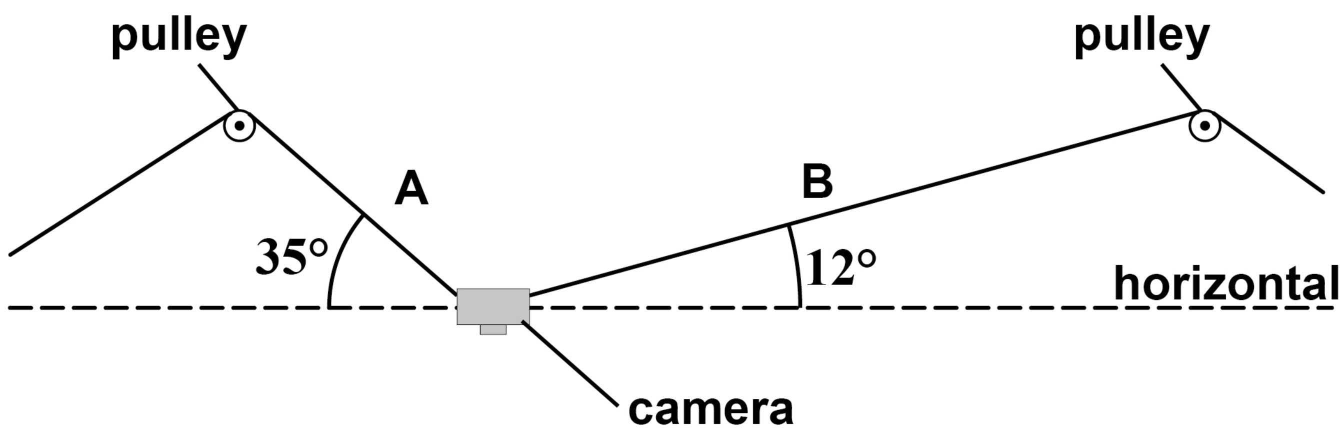
SECTION B

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

The diagram is not drawn accurately.



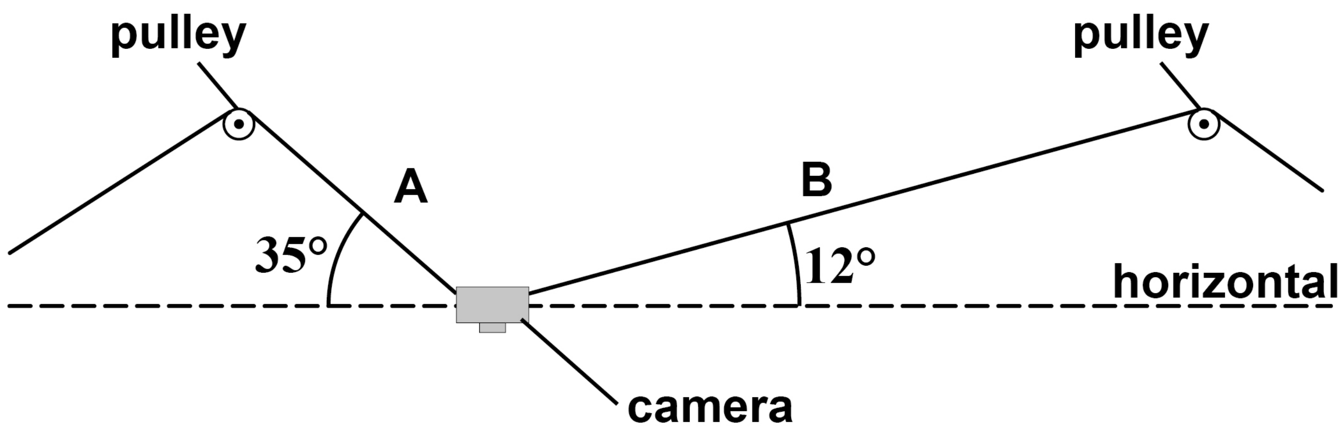
0 3 . 1 In FIGURE 6 the camera is stationary. The tension in A is $430\ \mathrm{N}$ and A makes an angle of $35°$ to the horizontal. B makes an angle of $12°$ to the horizontal.

Calculate the tension in B. [2 marks]

tension in B = ______________________ N

REPEAT OF FIGURE 6

The diagram is not drawn accurately.



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

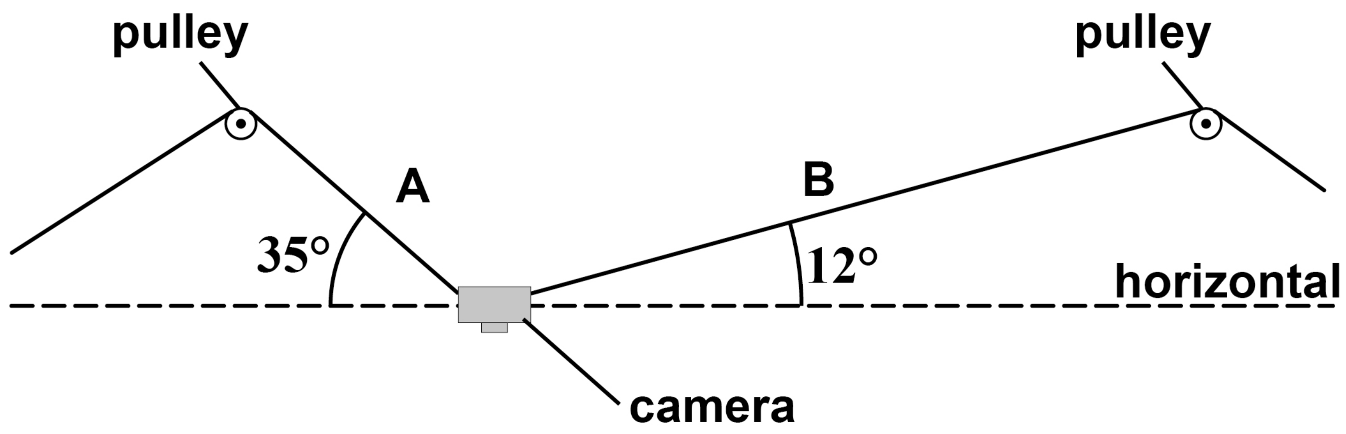
Calculate the extension of A when the tension in it is 430 N.

Young modulus of steel = 210 GPa [2 marks]

extension = ____________________ m

REPEAT OF FIGURE 6

The diagram is not drawn accurately.



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]

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]

[Turn over]

10

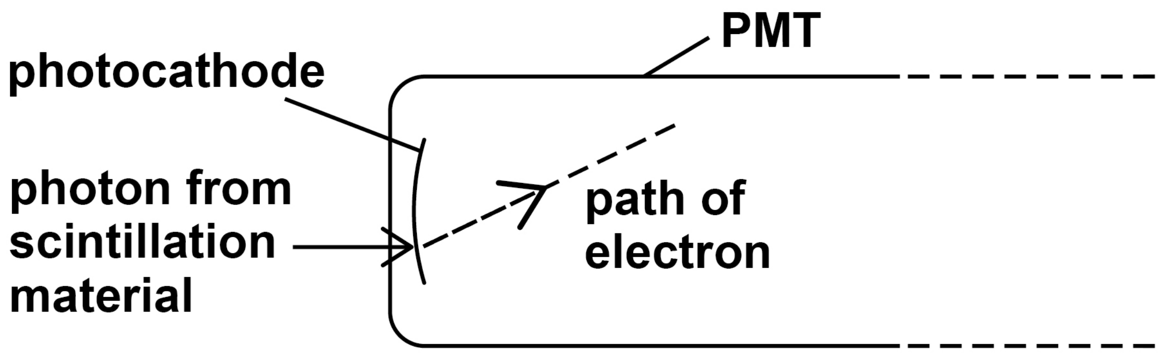
0 4 Scintillation counters are used to detect beta particles. A scintillation counter consists of a scintillation material and a photomultiplier tube (PMT).

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.

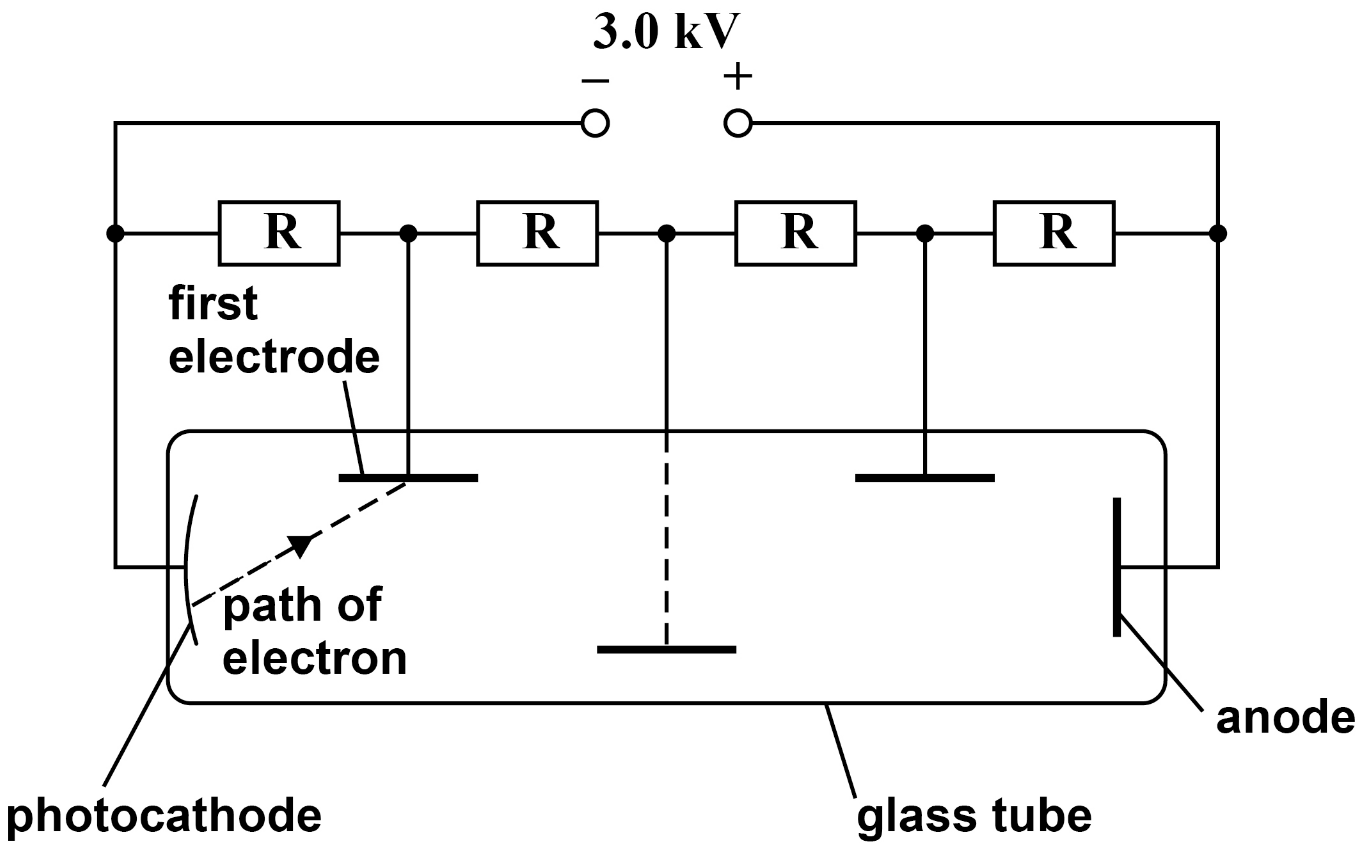
Calculate the minimum photon energy required to remove an electron from the photocathode. [2 marks]

minimum photon energy = ______________ J

[Turn over]

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

[Turn over]

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

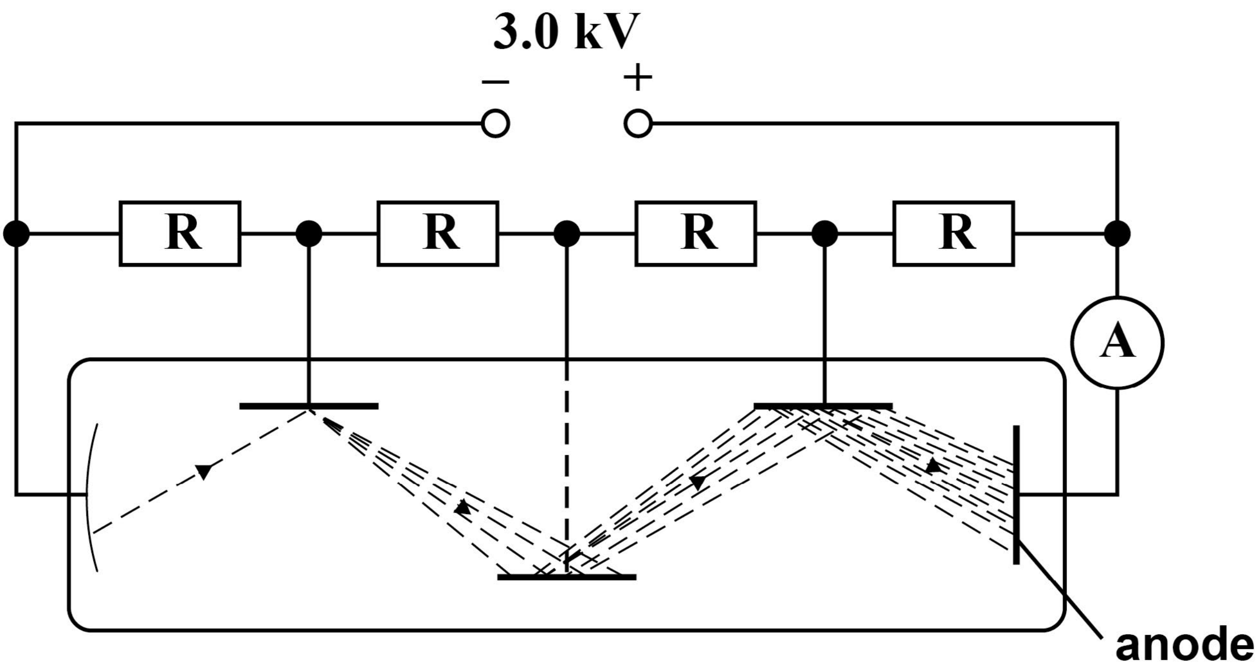
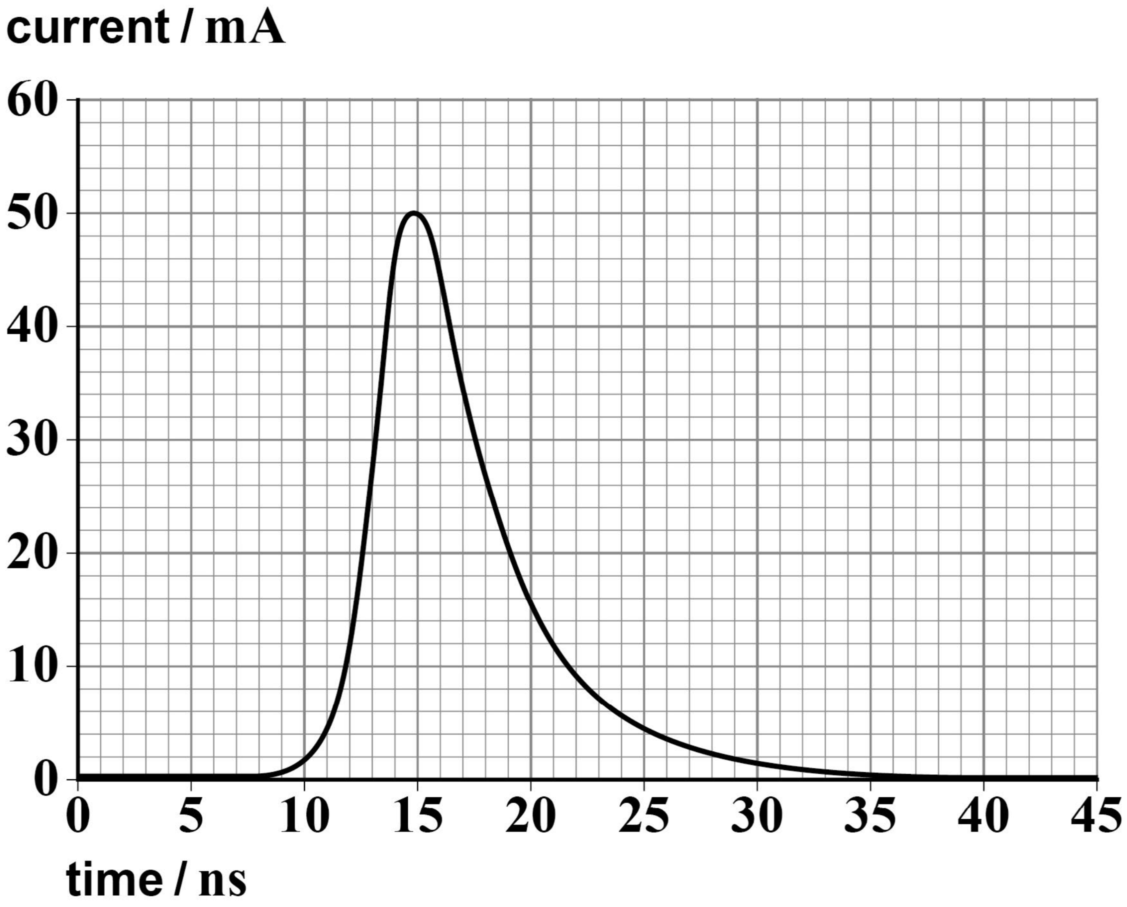


FIGURE 10, on the opposite page, shows the variation of current in the ammeter with time due to this pulse.

FIGURE 10



[Turn over]

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Determine the number of electrons that flow through the ammeter. [4 marks]

number of electrons = ____________________

SECTION C

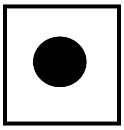
Each of Questions 05 to 34 is followed by four responses, A, B, C and D.

For each question select the best response.

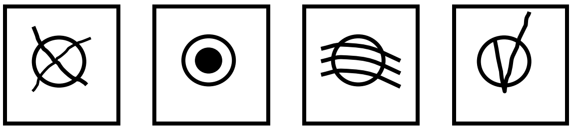
Only ONE answer per question is allowed.

For each question completely fill in the circle alongside the appropriate answer.

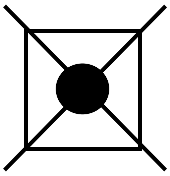
CORRECT METHOD



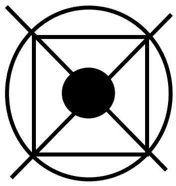
WRONG METHODS



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.

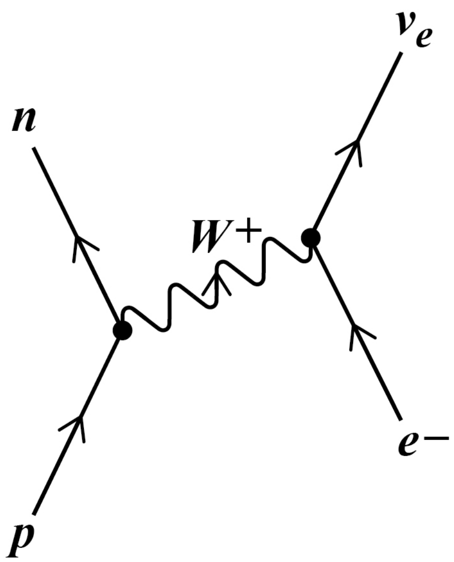
0 5 **Which row shows SI unit prefixes in order of smallest value to largest value? [1 mark]**

		SMALLEST			LARGEST
○	A	p	n	c	μ
○	B	p	n	μ	c
○	C	n	p	c	μ
○	D	n	p	μ	c

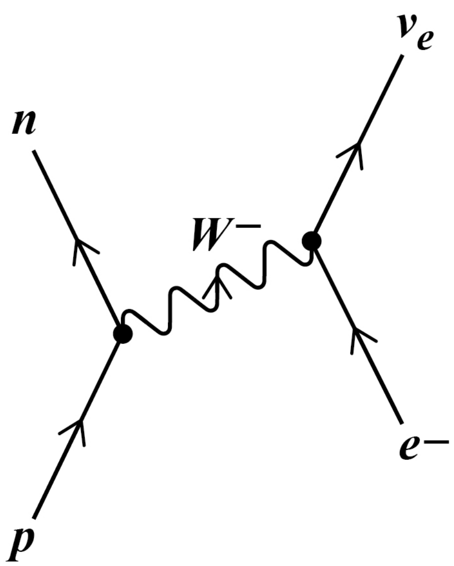
[Turn over]

0 6 **Which diagram represents electron capture?**
[1 mark]

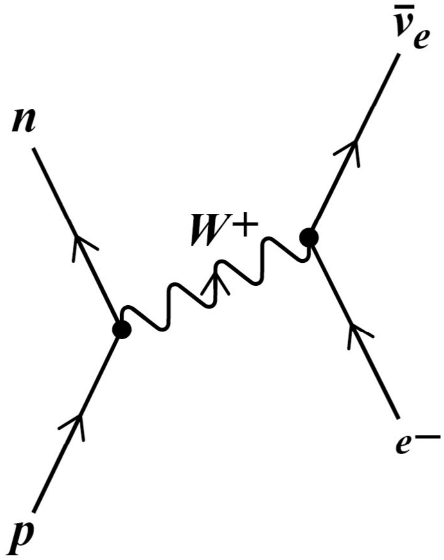
○ **A**



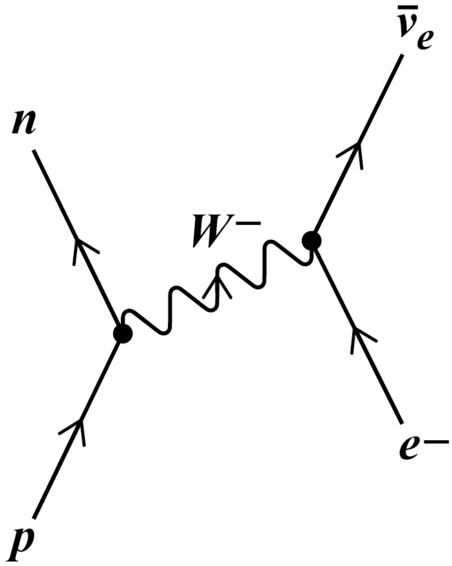
○ **B**



C



D



[Turn over]

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

[Turn over]

0 9 **Which decay of a positive kaon (K^+) particle is possible? [1 mark]**

- [ ] **A** $K^+ \longrightarrow \pi^0 + e^+ + \bar{\nu}_e$
- [ ] **B** $K^+ \longrightarrow p + \nu_\mu$
- [ ] **C** $K^+ \longrightarrow \pi^+ + \pi^+ + \pi^0$
- [ ] **D** $K^+ \longrightarrow \mu^+ + \nu_\mu$

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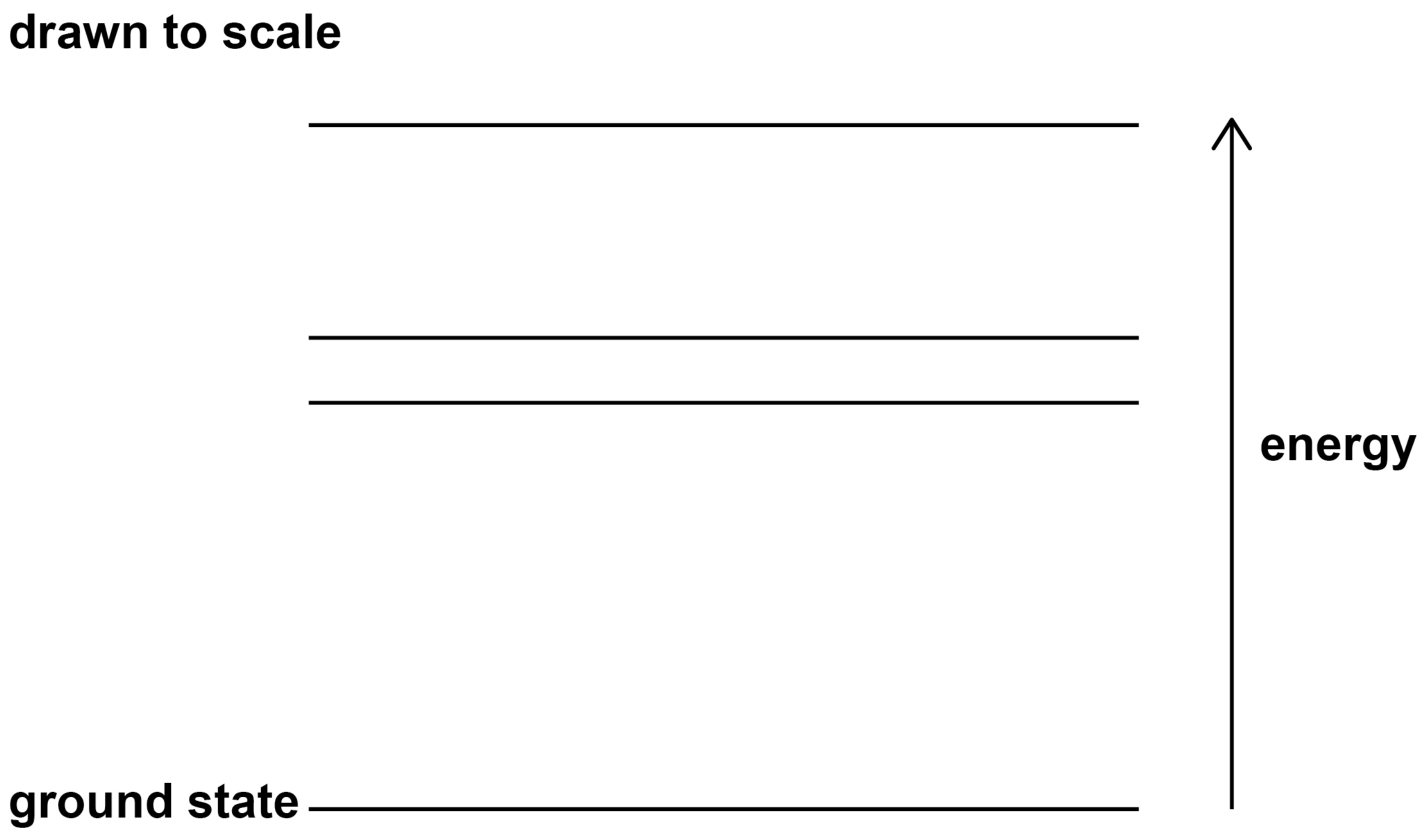
[Turn over]

10 The diagram shows four energy levels of an atom drawn to scale.

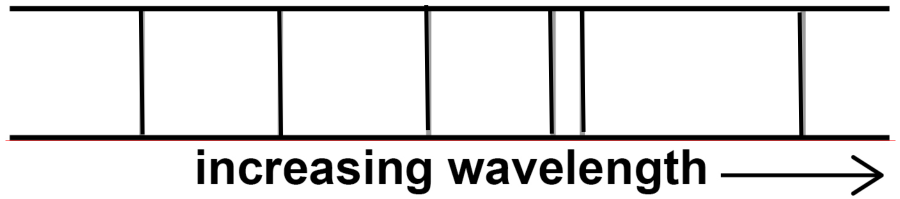
These energy levels give rise to part of an emission spectrum.



Which pattern of lines will be observed from these energy levels? [1 mark]

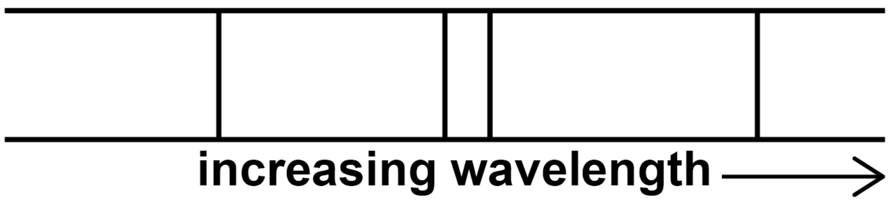
○ A

○ B



○ C

○ D



[Turn over]

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1 1 **A particle has a kinetic energy of E_{k} and a de Broglie wavelength of λ.**

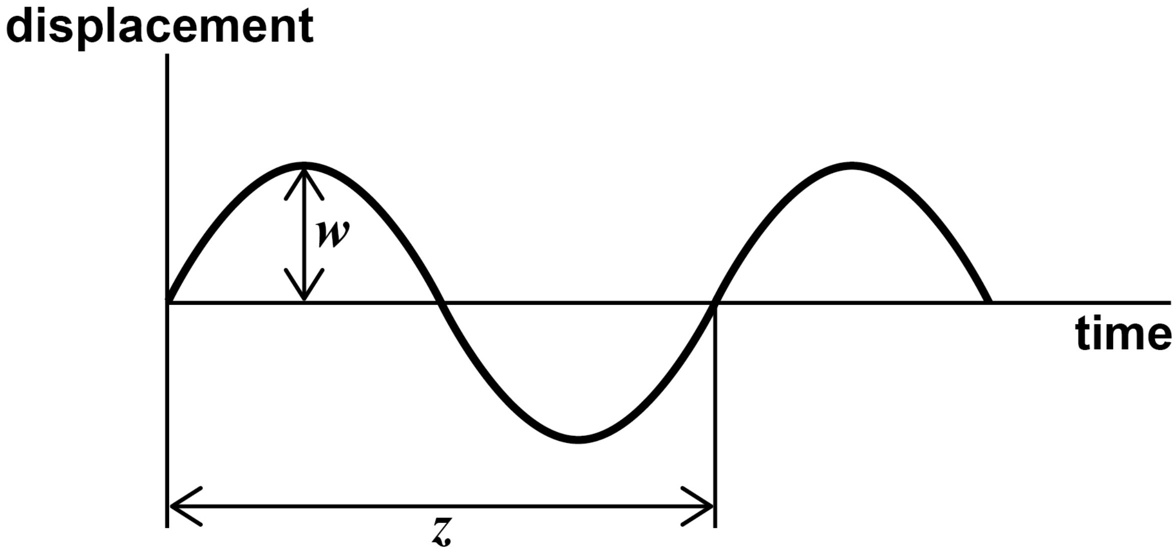
What is the de Broglie wavelength when the particle has a kinetic energy of $4E_{\mathrm{k}}$? [1 mark]

- ○ **A** $\frac{\lambda}{2}$
- ○ **B** $\frac{\lambda}{\sqrt{2}}$
- ○ **C** $\sqrt{2}\lambda$
- ○ **D** 2λ

[Turn over]

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**

[Turn over]

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** $148°$

14 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	$2s$	$2D$

[Turn over]

15 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

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

[Turn over]

17 **Which row describes charge and impulse?**
[1 mark]

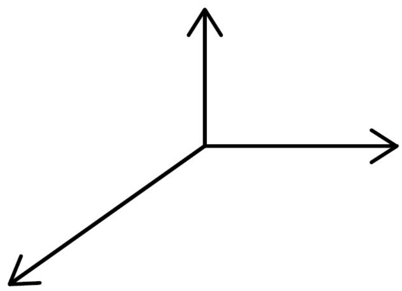
		Charge	Impulse
○	A	scalar	scalar
○	B	scalar	vector
○	C	vector	scalar
○	D	vector	vector

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

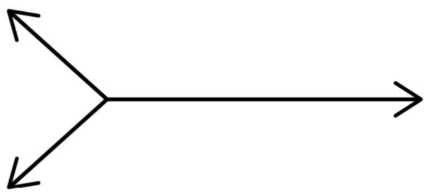
Which free-body diagram is correct?

Each diagram is drawn to scale. [1 mark]

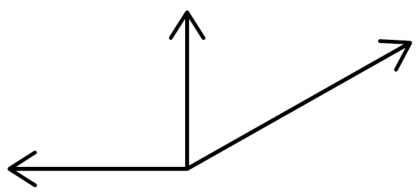
○ **A**



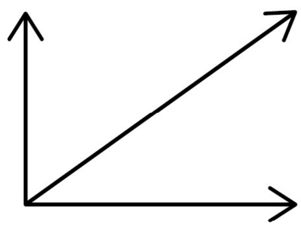
○ **B**



○ **C**



○ **D**



[Turn over]

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

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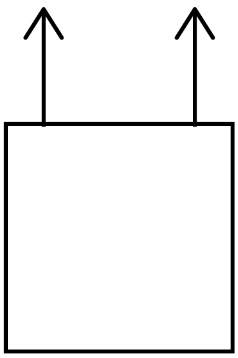
[Turn over]

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

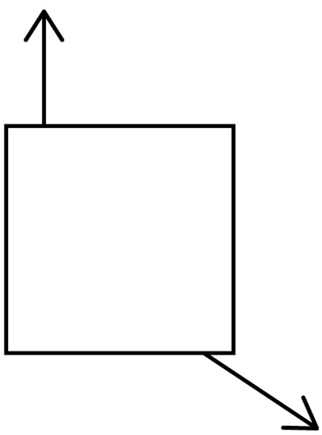
All the forces have the same magnitude.

Which system produces a couple about any point inside the object? [1 mark]

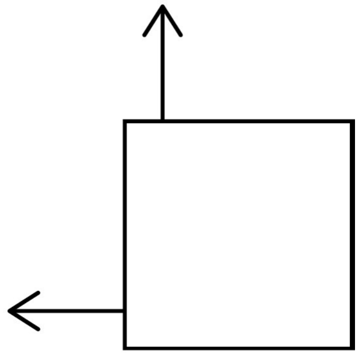
A



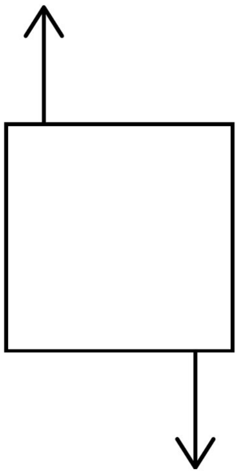
B



C



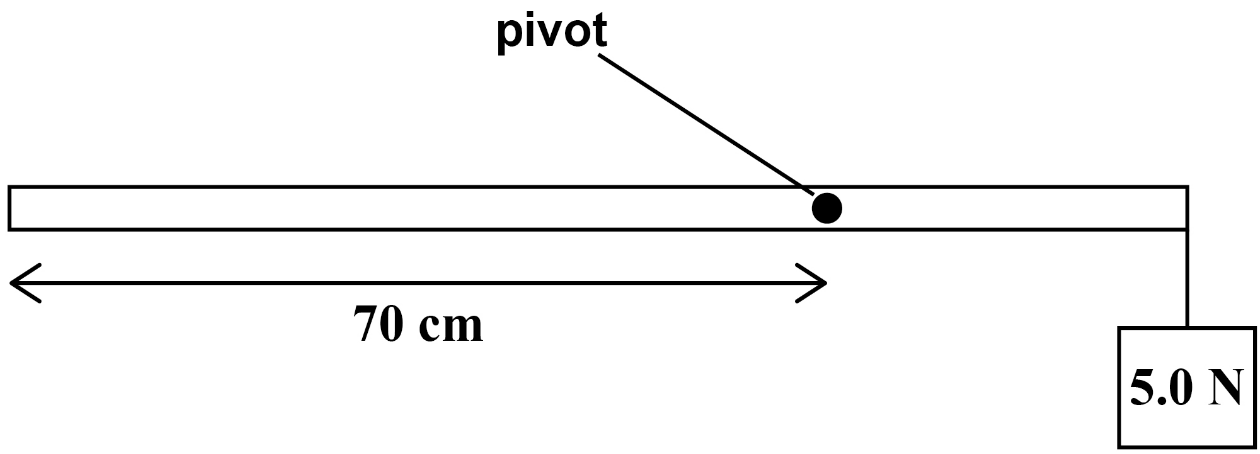
D



[Turn over]

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

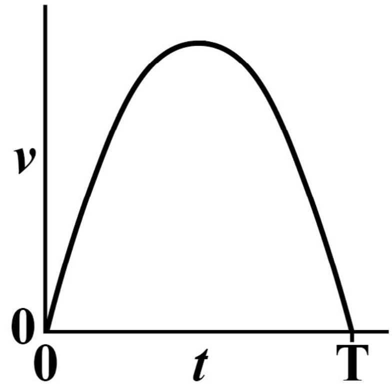
○ **B** 0.19 N m

○ **C** 1.1 N m

○ **D** 1.9 N m

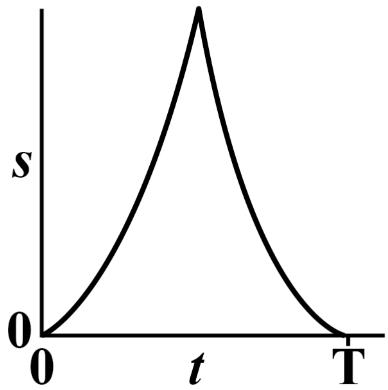
[Turn over]

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

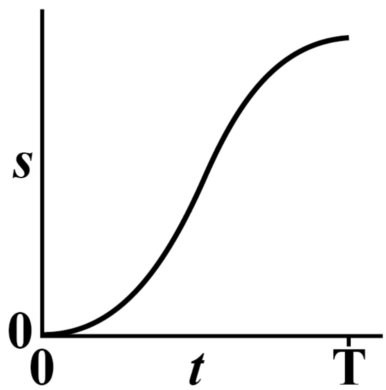


Which graph shows the variation of distance s with t for the object? [1 mark]

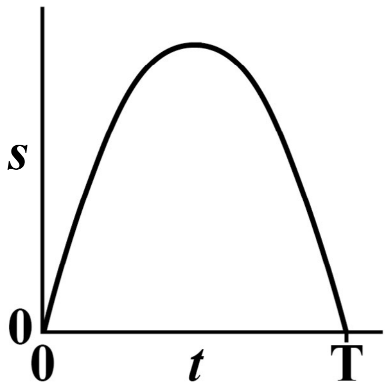
○ **A**



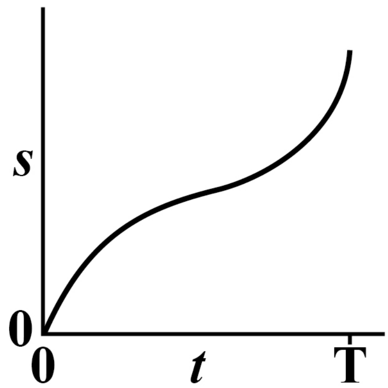
○ **B**



C



D



[Turn over]

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.

24 **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]

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

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

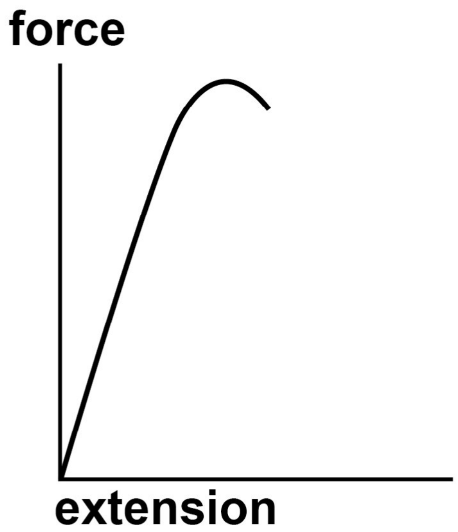
C $\frac{F_1+F_2}{2} \times (x_2-x_1)$

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

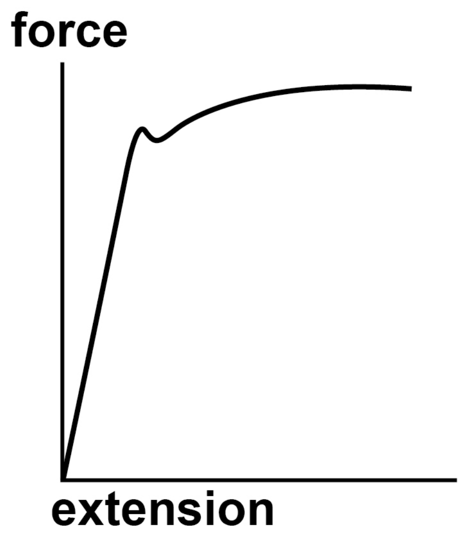
[Turn over]

2 7 **Which is a force–extension graph for a brittle material? [1 mark]**

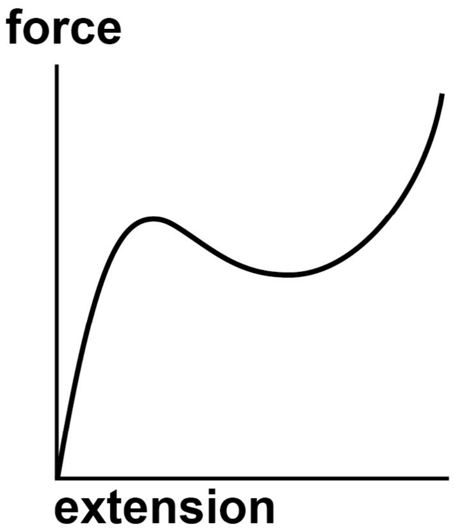
○ **A**



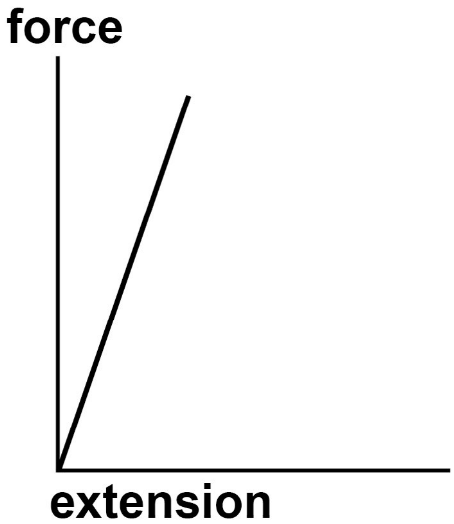
○ **B**



○ C



○ D



[Turn over]

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**

[Turn over]

29 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

30 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** $24\ MJ$

[Turn over]

31 A filament lamp with resistance $12\ \Omega$ is operated at a power of $36\ \text{W}$.

How much charge flows through the filament lamp during 15 minutes? [1 mark]

- ○ **A** $26\ \text{C}$
- ○ **B** $1.6\ \text{kC}$
- ○ **C** $2.7\ \text{kC}$
- ○ **D** $6.5\ \text{kC}$

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** $\sqrt{\dfrac{2\rho R}{\pi L}}$

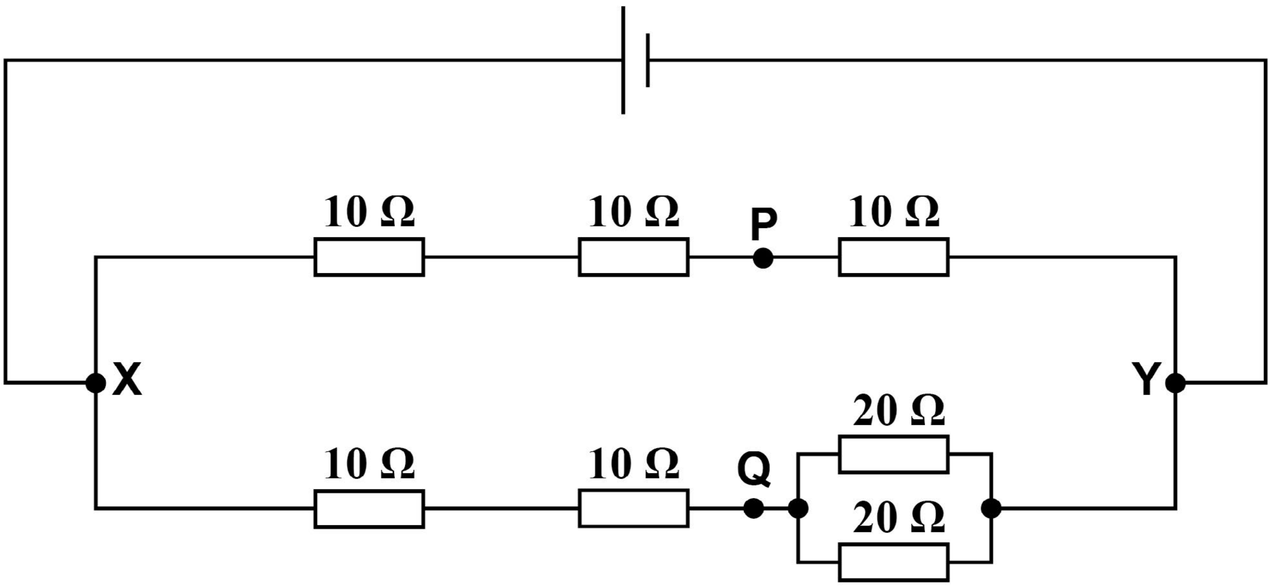
○ **B** $\sqrt{\dfrac{2\rho L}{\pi R}}$

○ **C** $2\sqrt{\dfrac{\rho L}{\pi R}}$

○ **D** $2\sqrt{\dfrac{\rho R}{\pi L}}$

[Turn over]

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

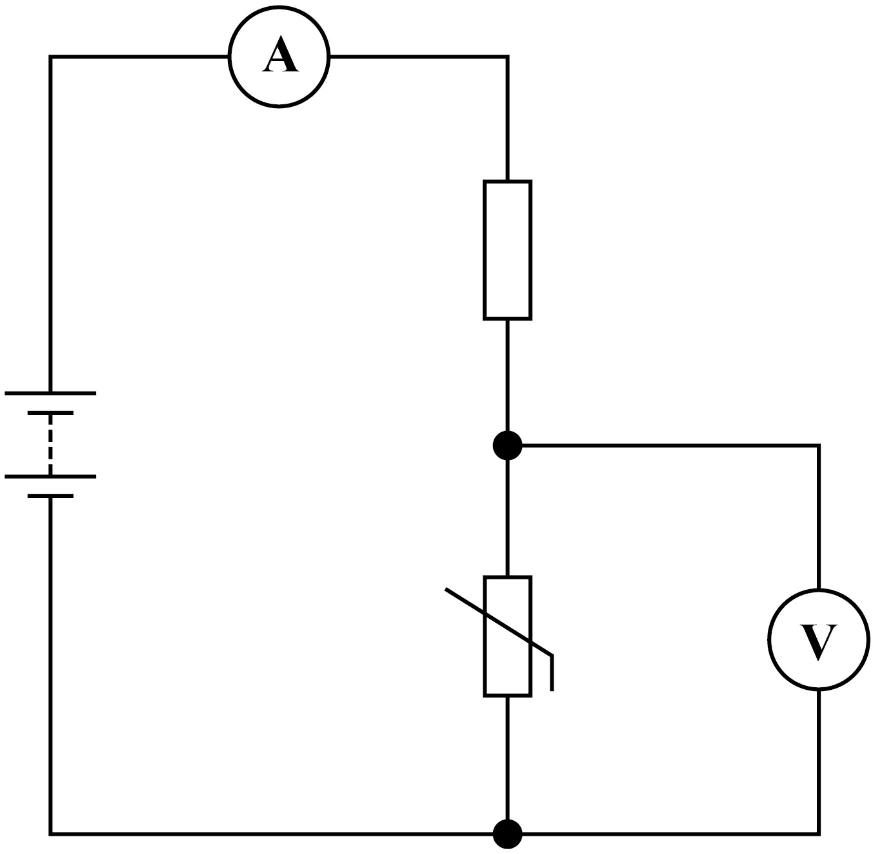


What is the potential difference between P and Q? [1 mark]

- ◯ **A** zero
- ◯ **B** $\frac{V}{3}$
- ◯ **C** $\frac{V}{2}$
- ◯ **D** $\frac{2V}{3}$

[Turn over]

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

END OF QUESTIONS

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