A

AQA

Surname ____________________

Other Names ____________________

Centre Number ____________________

Candidate Number ____________________

Candidate Signature ____________________

AS

PHYSICS

Paper 2

7407/2

Friday 17 May 2019 Morning

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

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 1 9 7 4 0 7 2 0 1

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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.**
- **Answer ALL questions.**
- **You must answer the questions in the spaces provided. Do NOT write on blank pages.**
- **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

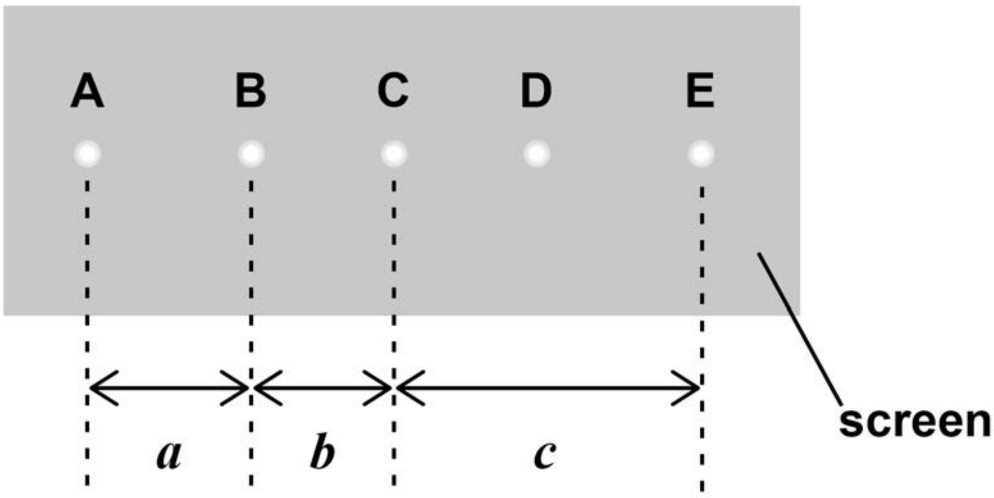
SECTION A

Answer ALL questions in this section.

0 1 This question is about the measurement of the wavelength of laser light.
The light is shone onto a diffraction grating at normal incidence.
The light transmitted by the diffraction grating produces five spots on a screen. These spots are labelled A to E in FIGURE 1.

FIGURE 1

The diagram is NOT drawn to scale.



A student uses a metre ruler with 1 mm divisions to take readings. He uses these readings to obtain measurements *a*, *b* and *c*, the distances between centres of the spots as shown in FIGURE 1.

TABLE 1 shows his measurements and his estimated uncertainties.

TABLE 1

Measurement	Distance / mm	Uncertainty / mm
a	289	2
b	255	2
c	544	2

[Turn over]

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0 1 . 1 **Explain why the student's estimated uncertainty in measurement *a* is greater than the smallest division on the metre ruler.**
You should refer to the readings taken by the student in obtaining this measurement.
[2 marks]

[Turn over]

0 1 . 2 **The distance between the centres of spots A and C and the distance between the centres of spots C and E are equal.**

That is:

$a + b = c$

Calculate the percentage uncertainty in the sum of a and b. [2 marks]

percentage uncertainty = ____________________

0 1 . 3 **Discuss why the experimental measurements lead to a different percentage uncertainty in c compared to that in $a + b$. [2 marks]**

[Turn over]

01.4 **Eye protection should be used to prevent eye damage when using a laser.**

Describe ONE other safety measure to minimise the risk of eye damage when using a laser in the laboratory. [1 mark]

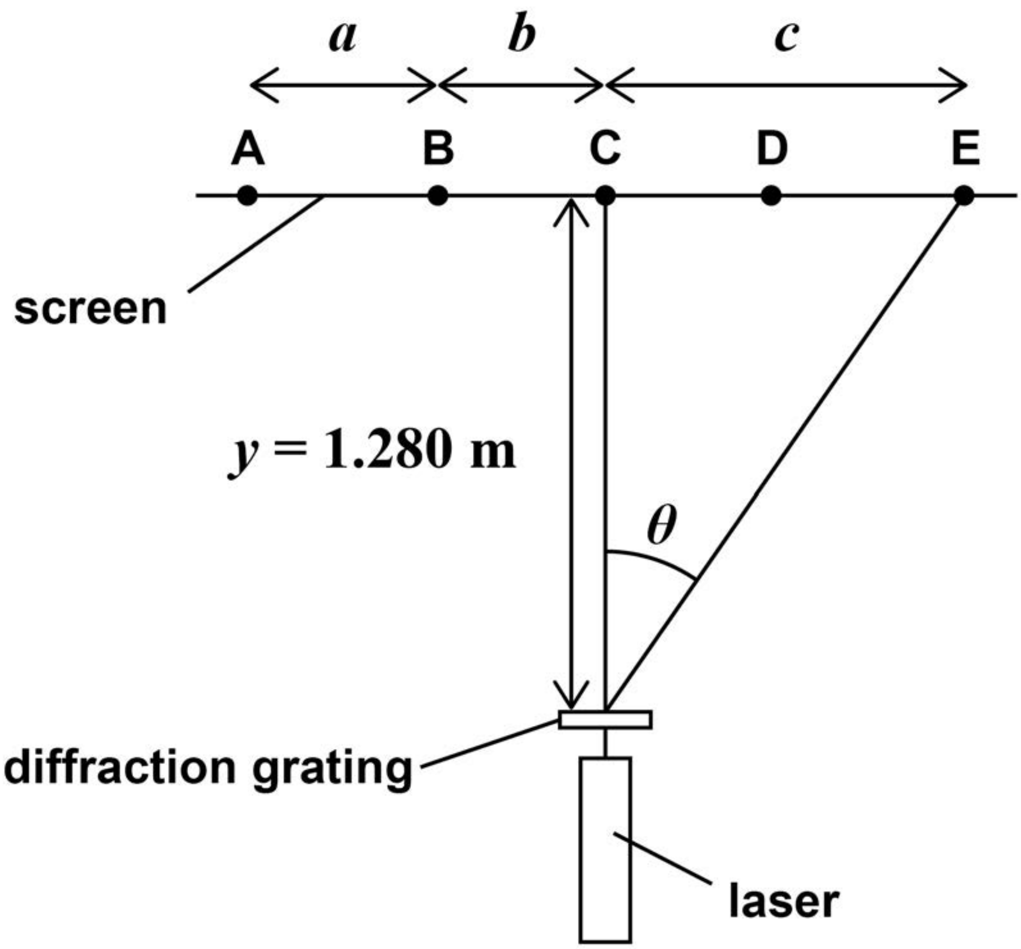
01.5 **FIGURE 2, on the opposite page, shows the experimental arrangement with y, the perpendicular distance between the diffraction grating and the screen, equal to 1.280 m.**

TABLE 2 shows some of the data from TABLE 1 on page 5.

TABLE 2

MEASUREMENT	DISTANCE / mm
a	289
b	255
c	544

FIGURE 2



Calculate the angle θ shown on FIGURE 2.
[1 mark]

θ = ____________________ **degrees**

[Turn over]

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0 1 . 6 **Spot E is the second-order maximum.**
The diffraction grating has 3.00×10^5 lines per metre.

Calculate the wavelength of the laser light.
[2 marks]

wavelength = ______________________ m

[Turn over]

0 1 . 7 **The student plans to repeat the experiment using the same diffraction grating and laser.**

State and explain ONE way the student can change the experimental arrangement to reduce the percentage uncertainty in the measurement of the wavelength.

Assume the percentage uncertainty in sin θ is the sum of the percentage uncertainties in y and c. [2 marks]

12

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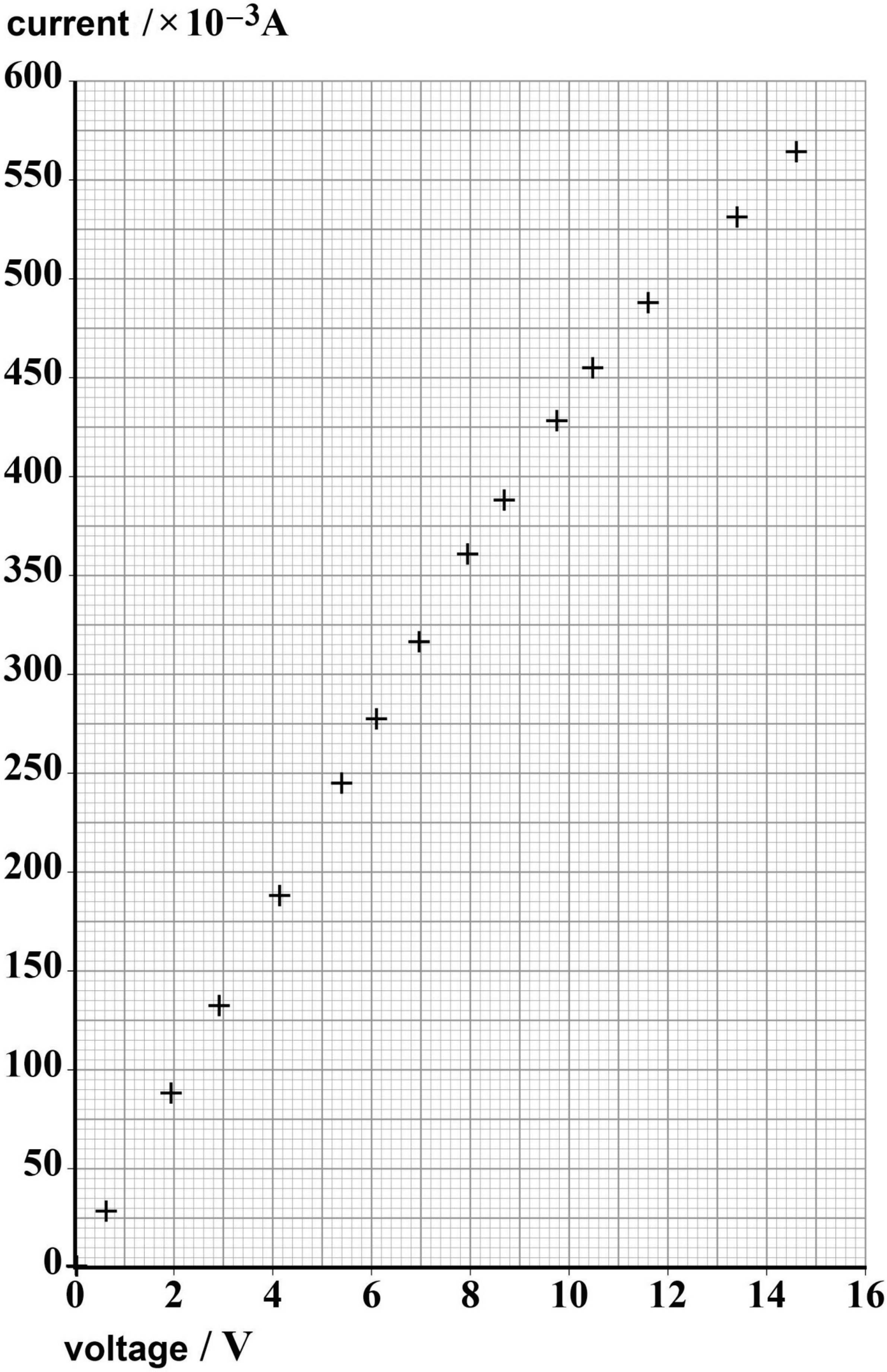
FIGURE 3


current / × 10^{-3}A
600
550
500
450
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
16
voltage / V

0 2 This question is about an experiment to obtain current–voltage data for a resistor R. FIGURE 3, on page 16, shows a plot of current–voltage data for R.

0 2 . 1 Draw a best-fit line for the data on FIGURE 3. [1 mark]

0 2 . 2 Identify the data point with the greatest value of current and voltage at which R obeys Ohm's law.

Draw a circle around this data point on FIGURE 3. [1 mark]

[Turn over]

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0 2 . 3 **When R obeys Ohm's law it has a resistance of $22.2\ \Omega$.**

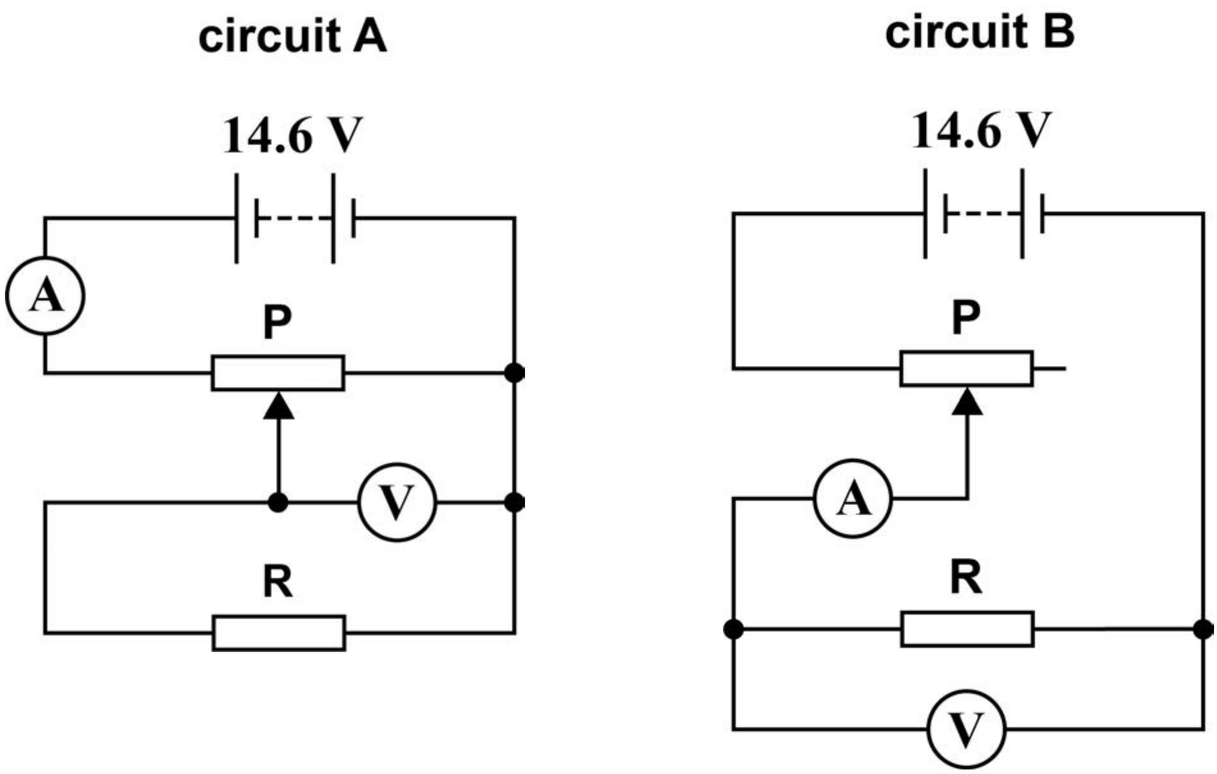
Determine the percentage increase in the resistance of R from its $22.2\ \Omega$ value to its value when the current is 550×10^{-3} A.
[2 marks]

percentage increase = ____________________

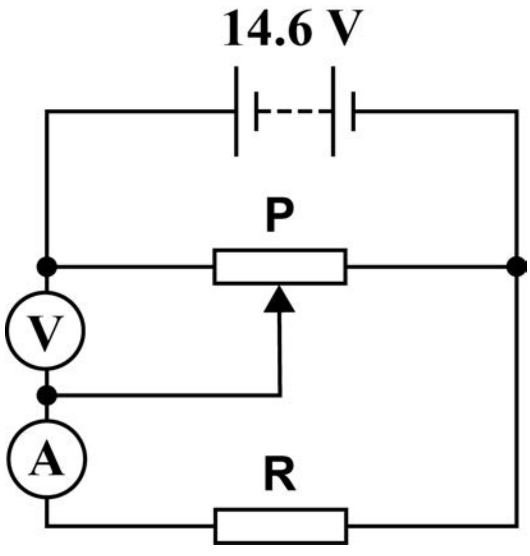
[Turn over]

0 2 . 4 One of the circuits A to D shown in FIGURE 4 was used to obtain the current–voltage data in FIGURE 3 on page 16. The maximum resistance of resistor P is twice the resistance of R. The battery has an emf of 14.6 V and negligible internal resistance.

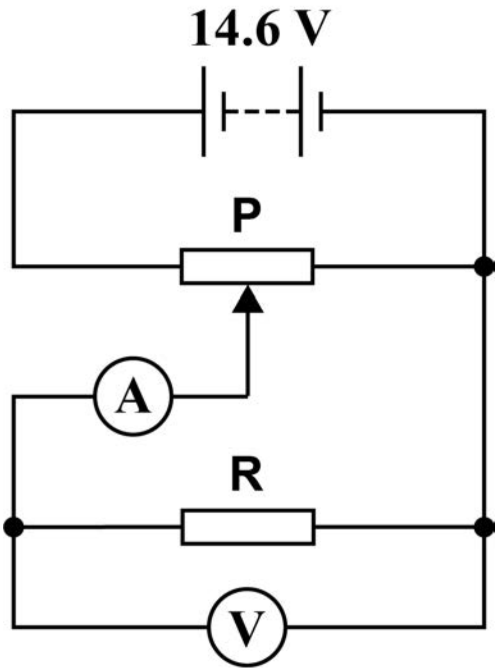
FIGURE 4



circuit C



circuit D



Deduce which ONE of these circuits was used to directly obtain the current–voltage data in FIGURE 3 on page 16.
You should include in your answer an explanation of why each of the other circuits is NOT suitable to obtain the data directly from the voltmeter and ammeter readings.
[4 marks]

[Turn over]

[Turn over]

8

SECTION B

Answer ALL questions in this section.

0 3 **This question is about two applications of photon energy and momentum: positron emission tomography (PET) and a solar sail.**

The momentum of a photon is

$$\frac{\text{photon energy}}{\text{speed of light in a vacuum}}$$

0 3 . 1 **In preparing for a PET scan of a patient's brain, a small sample of a substance containing unstable nuclei is injected into the patient.**
A positron is emitted when one of the unstable nuclei undergoes β^+ decay.

Explain how the change in quark character in β^+ decay affects the number of neutrons and the number of protons in the unstable nucleus. [2 marks]

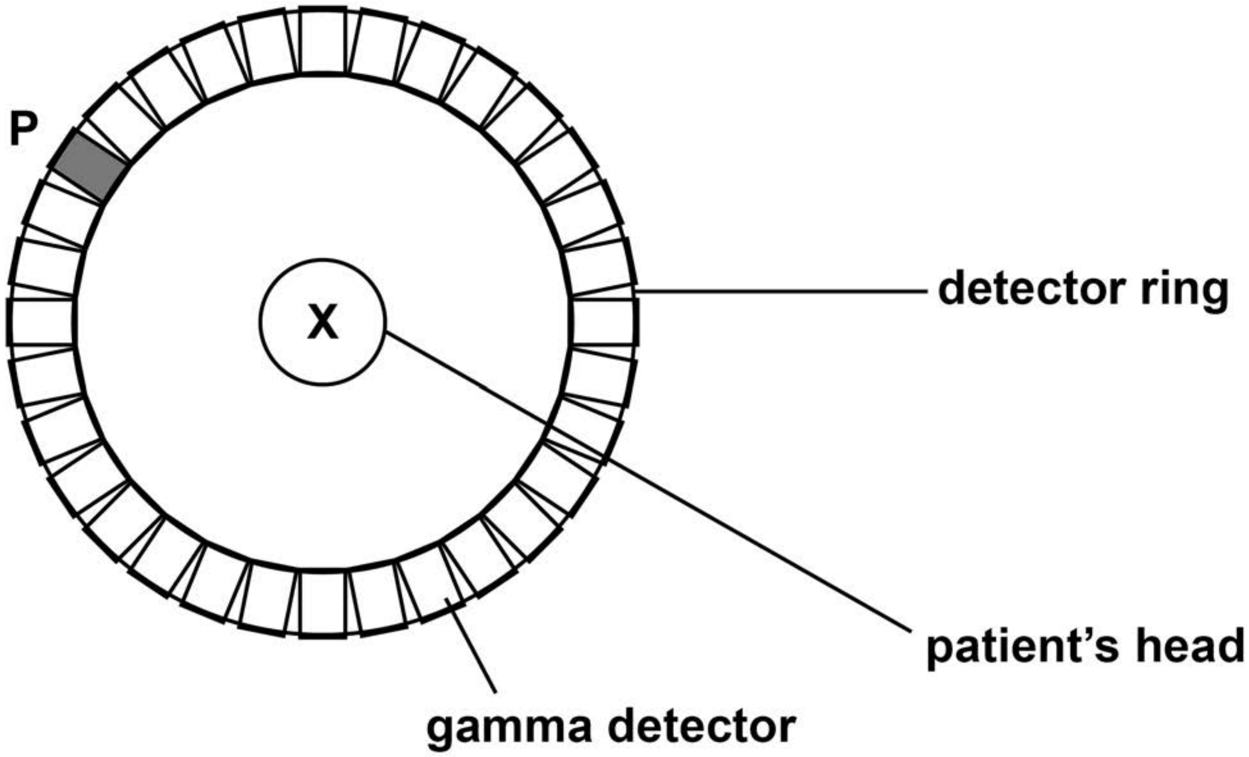
0 3 . 2 **The positron interacts with an electron, resulting in annihilation. As a result, gamma photons are produced.**
The energy of each gamma photon is $0.52\ \mathrm{MeV}$.

Calculate the momentum, in $\mathrm{N\,s}$, of one of the gamma photons produced in this annihilation.
[2 marks]

momentum = ____________________ $\mathrm{N\,s}$

0 3 . 3 **FIGURE 5 shows a cross-sectional view of the patient's head inside a ring of gamma detectors during the PET scan.**

FIGURE 5



A positron and an electron meet and annihilate at position X shown in FIGURE 5. Assume they have negligible kinetic energy when they meet.

Gamma photons are produced in this annihilation and are detected. The arrival of one gamma photon at detector P triggers a signal. Detector P has been shaded in FIGURE 5.

Identify by shading any other detectors that will be triggered by this annihilation. [1 mark]

03.4 **Explain your answer to question 03.3.**
[2 marks]

[Turn over]

0 3 . 5 **FIGURE 6 shows a stream of photons of light, emitted from the Sun, incident on a solar sail. A solar sail is an experimental spacecraft that uses photons of light to accelerate it.**

FIGURE 6

The diagram is NOT drawn to scale.

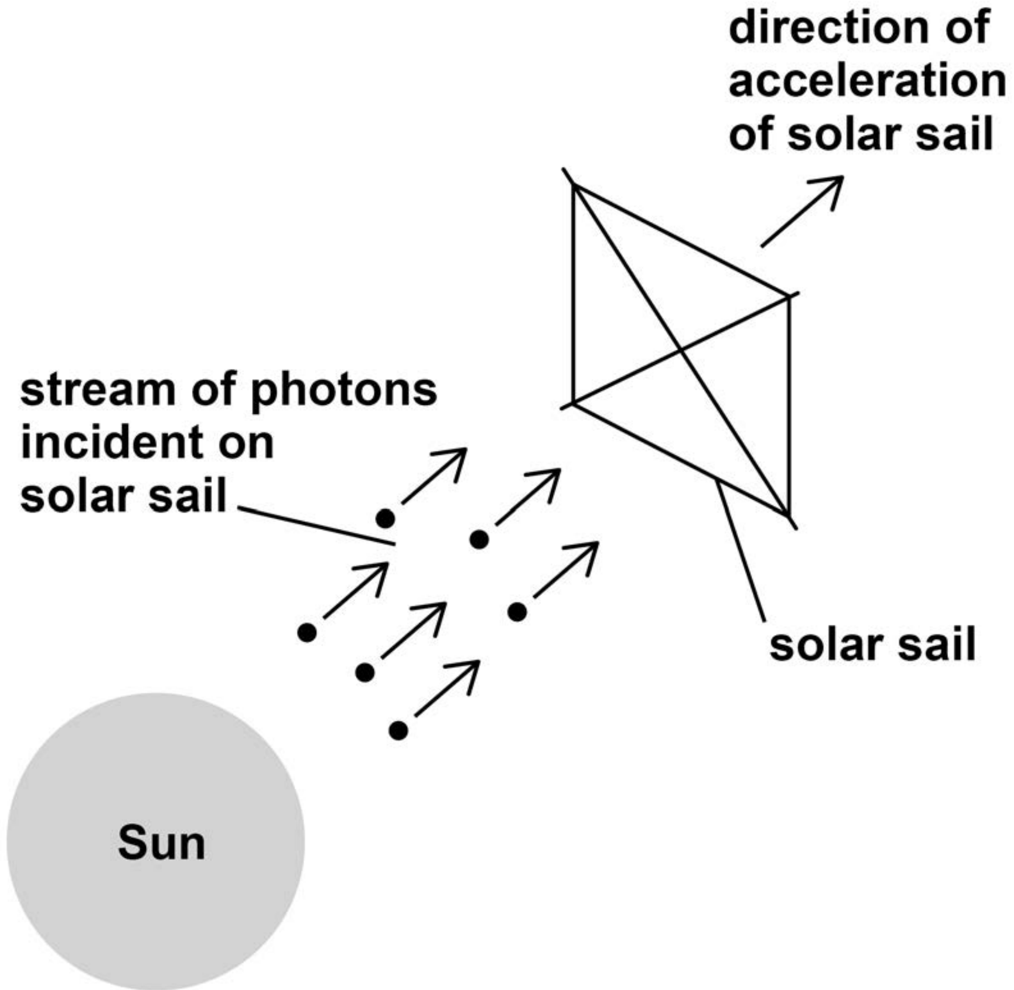
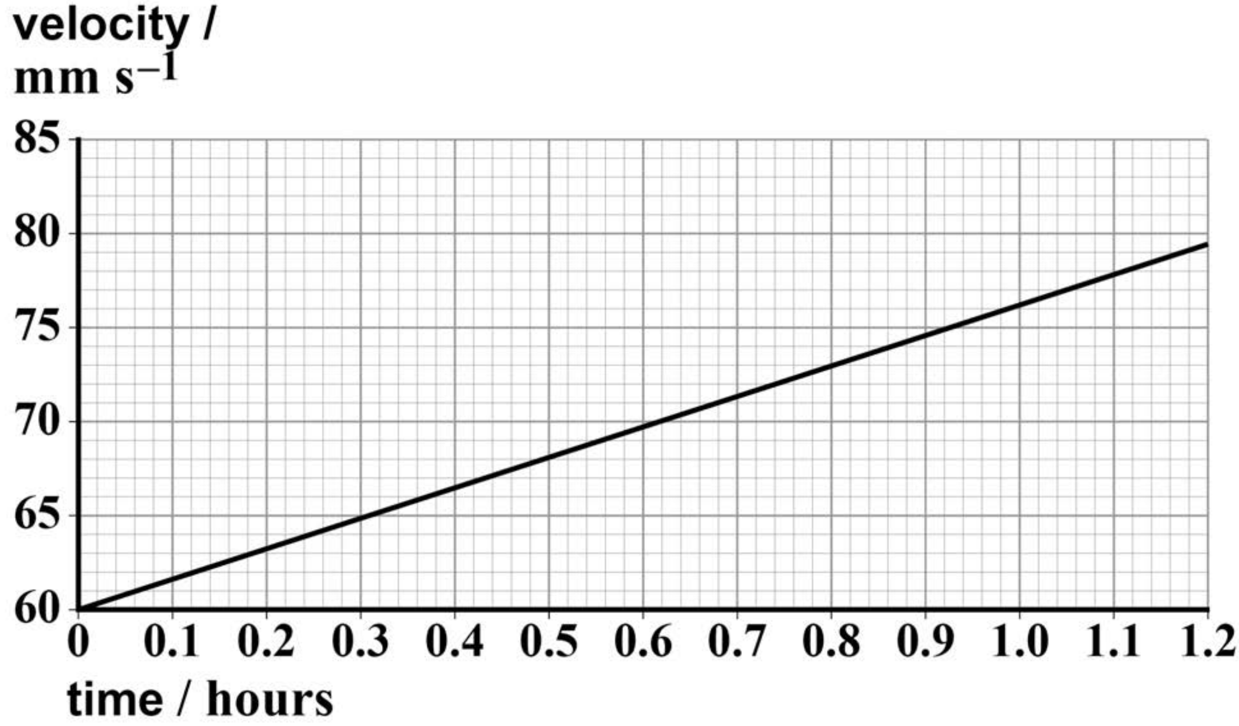


FIGURE 7, on the opposite page, shows the velocity–time graph for the solar sail.

FIGURE 7



Calculate the acceleration, in m s^{-2}, of the solar sail.
[2 marks]

acceleration = ____________________________ m s^{-2}

[Turn over]

0 3 . 6 **The reflectance of a surface is proportional to the percentage of incident photons that are reflected off the surface.**

Explain the effect of increasing the reflectance of the solar sail on the acceleration. Assume gravity has negligible effect on the solar sail. [2 marks]

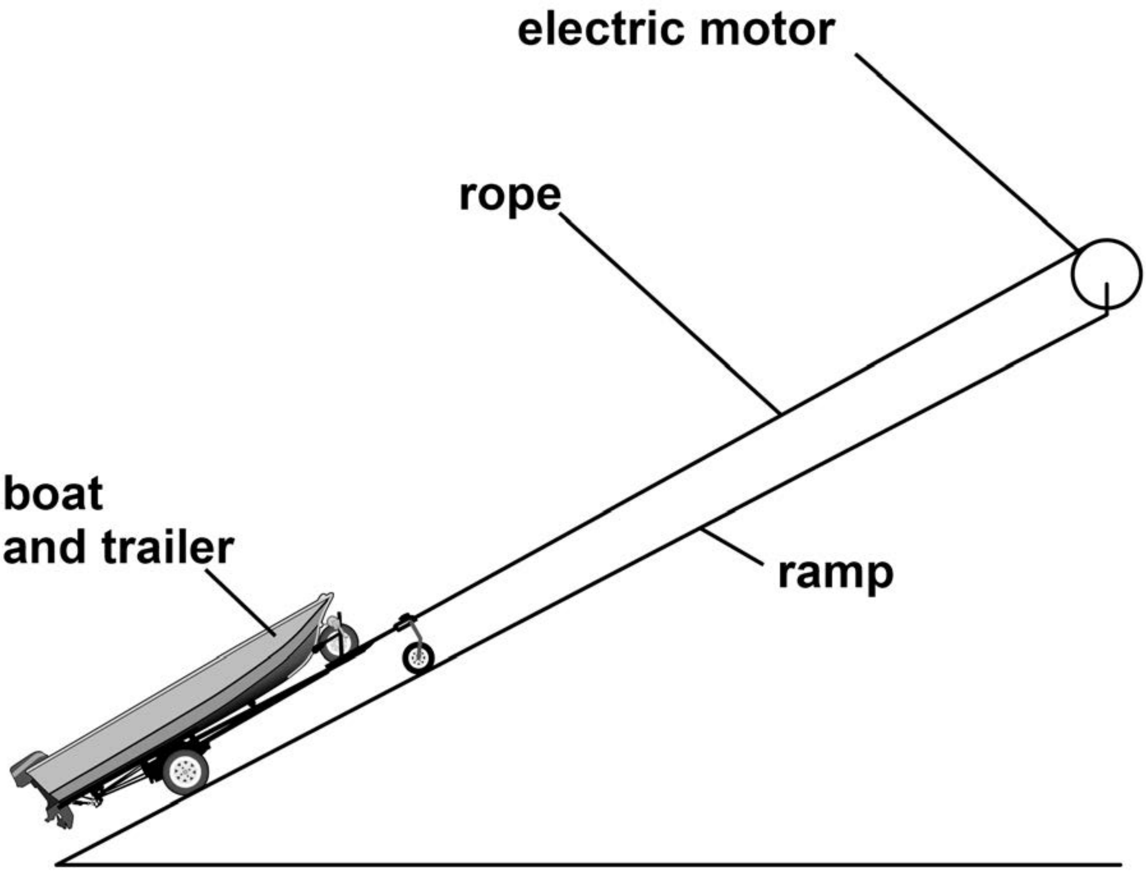
11

[Turn over]

0 4 This question is about the initial motion of a boat and trailer when pulled up a ramp as shown in FIGURE 8.

FIGURE 8

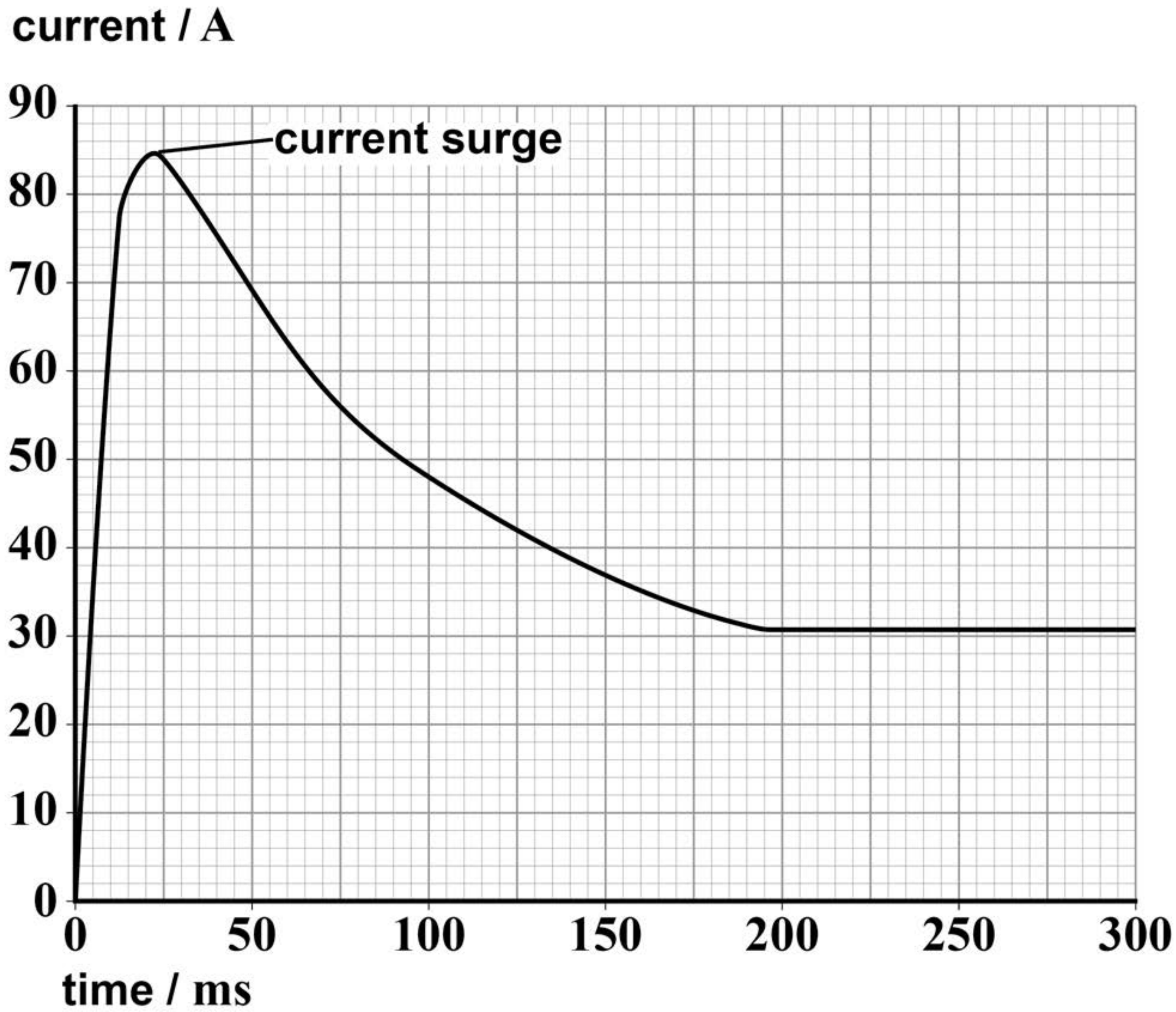
The diagram is NOT drawn to scale.



The boat and trailer are pulled by a motor which is connected to a 24 V battery of negligible internal resistance.

The motor is switched on at time $t = 0$
FIGURE 9 shows how the current in the motor's circuit varies with time.

FIGURE 9



[Turn over]

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0 4 . 1 **Determine the total energy input by the 24 V battery to the motor in the first 200 ms.**
[3 marks]

total energy input = ____________________ J

[Turn over]

0 4 . 2 **The boat and trailer are initially at rest. In the first $200\ \mathrm{ms}$ the boat and trailer are raised through a vertical height of $3.3 \times 10^{-2}\ \mathrm{m}$ and the speed increases to $0.85\ \mathrm{m\,s^{-1}}$.**

Assume that all the useful energy output by the motor is transferred into kinetic energy and gravitational potential energy of the boat and trailer.
The boat and trailer have a total mass of $180\ \mathrm{kg}$.

Determine the average efficiency of the motor during these first $200\ \mathrm{ms}$. [3 marks]

average efficiency = ______________________

[Turn over]

0 4 . 3 Either of the circuits shown in FIGURE 10a and FIGURE 10b could be used to reduce the initial current surge.

FIGURE 10a

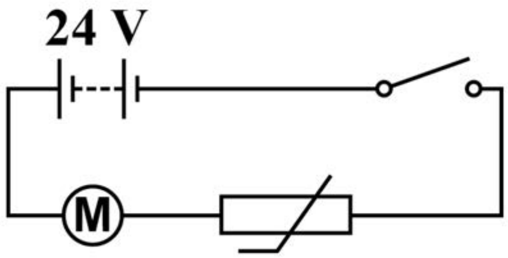
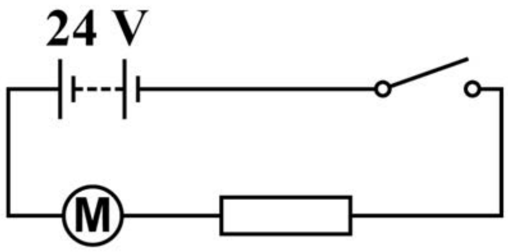


FIGURE 10b



The thermistor and the fixed resistor have the same resistance when they are at the temperature of the surroundings.
When the surge has ended, the boat and trailer continue to move at a constant speed to the top of the ramp.

Explain, with reference to the properties of the thermistor and the fixed resistor, why using the thermistor is preferable to using the fixed resistor. [3 marks]

[Turn over]

9

SECTION C

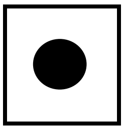
Each of Questions 5 to 34 is followed by four responses, A, B, C and D.

For each question select the best response.

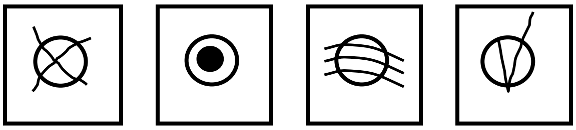
Only ONE answer per question is allowed.

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

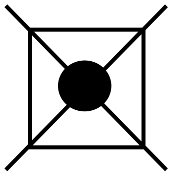
CORRECT METHOD



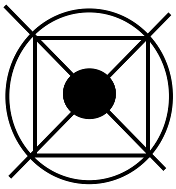
WRONG METHODS



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 quantities can be written in the fundamental units $\mathrm{kg\ m^{-1}\ s^{-2}}$? [1 mark]**

○ **A** **Tensile stress and kinetic energy**

○ **B** **The moment of a force and kinetic energy**

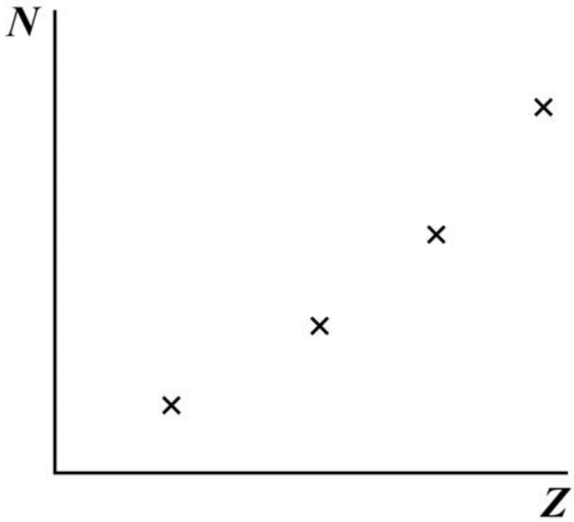
○ **C** **Young modulus and the moment of a force**

○ **D** **Young modulus and tensile stress**

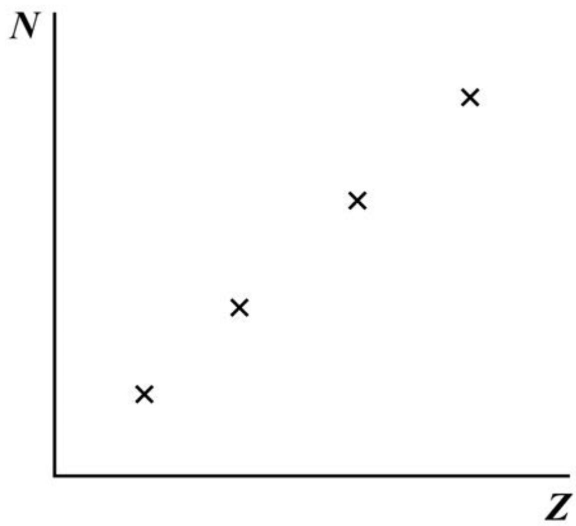
[Turn over]

0 6 **Which is a graph of neutron number N plotted against proton number Z for the isotopes of a given element? [1 mark]**

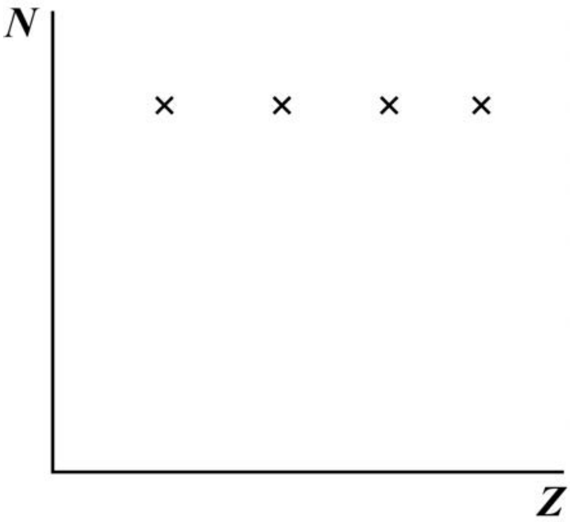
○ **A**



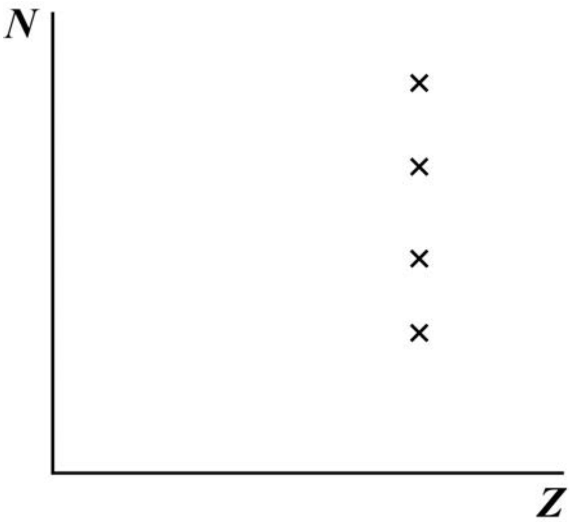
○ **B**



C



D



[Turn over]

0 7 Unstable nuclide P decays to nuclide T through a series of alpha (α) and beta-minus (β^-) decays.

$$P \xrightarrow{\alpha} Q \xrightarrow{\beta^-} R \xrightarrow{\beta^-} S \xrightarrow{\alpha} T$$

Which statement is correct? [1 mark]

- ○ **A** P and S are isotopes.
- ○ **B** Q and T have different proton numbers.
- ○ **C** Q and S have different nucleon numbers.
- ○ **D** R has a greater proton number than P.

0 8 **Which row gives a particle with its quark combination and category? [1 mark]**

	Particle	Quark combination	Category
A	Negative pion	$d\bar{u}$	baryon
B	Positive pion	$u\bar{d}$	hadron
C	Negative pion	$u\bar{d}$	meson
D	Positive pion	$d\bar{u}$	hadron

[Turn over]

0 9 **Which row gives the numbers of baryons and leptons in an atom of $^{12}_{6}\mathrm{C}$? [1 mark]**

		Number of baryons	Number of leptons
○	A	6	6
○	B	12	6
○	C	6	12
○	D	18	0

1 0 **A muon [1 mark]**

- ○ **A** is subject to the strong interaction.
- ○ **B** can decay into an electron only.
- ○ **C** is a stable particle.
- ○ **D** is subject to the weak interaction.

[Turn over]

11 **Photons of energy 1.0×10^{-18} J are incident on a metal surface and cause the emission of electrons from the metal surface.**

Which statement about the emitted electrons is correct? [1 mark]

- ○ **A** **They each have a kinetic energy of 1.0×10^{-18} J.**
- ○ **B** **They each have a kinetic energy that is a multiple of 1.0×10^{-18} J.**
- ○ **C** **Their mean kinetic energy is 1.0×10^{-18} J.**
- ○ **D** **The kinetic energy of each must be less than 1.0×10^{-18} J.**

12 Evidence of the wave-like properties of electrons is [1 mark]

- **A** the emission of electrons when short-wavelength light falls on a metal surface.
- **B** the movement of electrons in an electric current.
- **C** the diffraction of electrons by a metal crystal.
- **D** the annihilation of an electron with a positron.

[Turn over]

1 3 **What is the approximate average kinetic energy of a cyclist in a race? [1 mark]**

- ○ **A** 10 J
- ○ **B** 10 kJ
- ○ **C** 10 MJ
- ○ **D** 10 TJ

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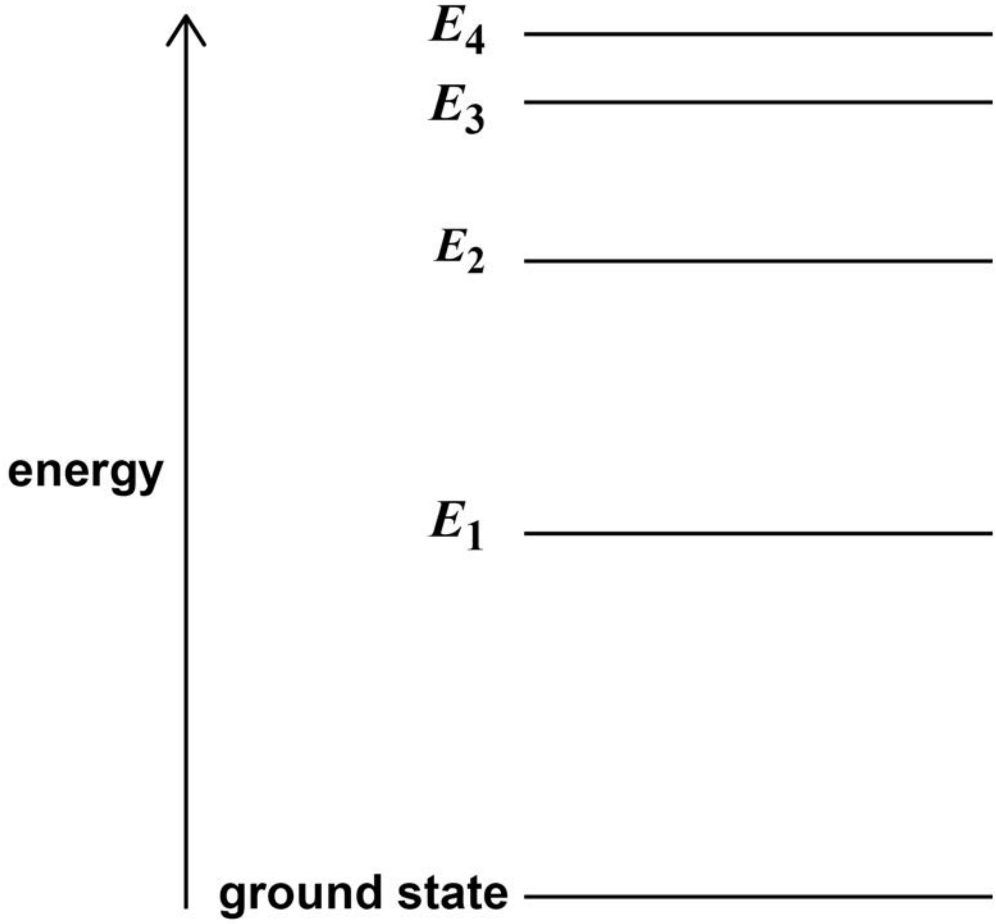
[Turn over]

14 **The diagram shows the energy levels in an atom drawn to scale. A transition from E_4 to E_2 causes the emission of a photon of green light.**



Which transition could cause the emission of a photon of red light? [1 mark]

A E_2 to E_1

B E_3 to E_1

C E_3 to E_2

D E_4 to E_1

[Turn over]

15 A sonar transmitter on a ship produces pulses of sound waves.

Each pulse of sound waves contains 12 complete oscillations.

The frequency of these waves is 8.0 kHz and the speed of sound in seawater is $1.5 \times 10^3 \text{ m s}^{-1}$.

What is the length of one pulse in seawater? [1 mark]

○ **A** 0.188 m

○ **B** 2.25 m

○ **C** $2.25 \times 10^3 \text{ m}$

○ **D** $1.44 \times 10^5 \text{ m}$

16 Which gives the regions of the electromagnetic spectrum in order of increasing wavelength? [1 mark]

- ○ **A** X-rays, ultraviolet, infrared, radio waves
- ○ **B** X-rays, microwaves, ultraviolet, infrared
- ○ **C** infrared, radio waves, microwaves, X-rays
- ○ **D** microwaves, infrared, ultraviolet, X-rays

[Turn over]

17 The frequency of the first harmonic of a wire fixed at both ends is $300\ \text{Hz}$.
The tension in the wire is now doubled.

What is the frequency of the first harmonic after this change? [1 mark]

- ○ **A** $150\ \text{Hz}$
- ○ **B** $210\ \text{Hz}$
- ○ **C** $420\ \text{Hz}$
- ○ **D** $600\ \text{Hz}$

18 In a Young's double-slit experiment, the spacing of the double slits is s and the distance between the slits and the screen on which fringes are formed is D. When monochromatic light of wavelength λ is incident on the slits the distance between adjacent fringes on the screen is w.

Which row shows another arrangement that produces a fringe spacing of w? [1 mark]

		Spacing of double slits	Distance between the slits and the screen	Wavelength of the light
○	A	$4s$	$2D$	2λ
○	B	$2s$	$4D$	2λ
○	C	$2s$	$2D$	4λ
○	D	$2s$	$2D$	2λ

[Turn over]

19 **Monochromatic electromagnetic radiation of wavelength 5.8×10^{-7} m is incident normally on a diffraction grating with 3.0×10^{5} lines per metre.**

What is the highest order maximum produced? [1 mark]

- ○ **A** 5
- ○ **B** 6
- ○ **C** 10
- ○ **D** 13

2 0 **Which characteristics of monochromatic light change when the light passes from air into glass? [1 mark]**

- ○ **A** **Speed, wavelength and frequency.**
- ○ **B** **Speed and frequency only.**
- ○ **C** **Speed and wavelength only.**
- ○ **D** **Wavelength and frequency only.**

[Turn over]

2 1 **Which is a description of the pattern produced when monochromatic light passes through a very narrow slit? [1 mark]**

- ○ **A** **A series of equally-spaced light and dark fringes.**
- ○ **B** **A narrow central maximum with wider side fringes.**
- ○ **C** **A few bright fringes that are widely spaced.**
- ○ **D** **A wide central maximum with narrower side fringes.**

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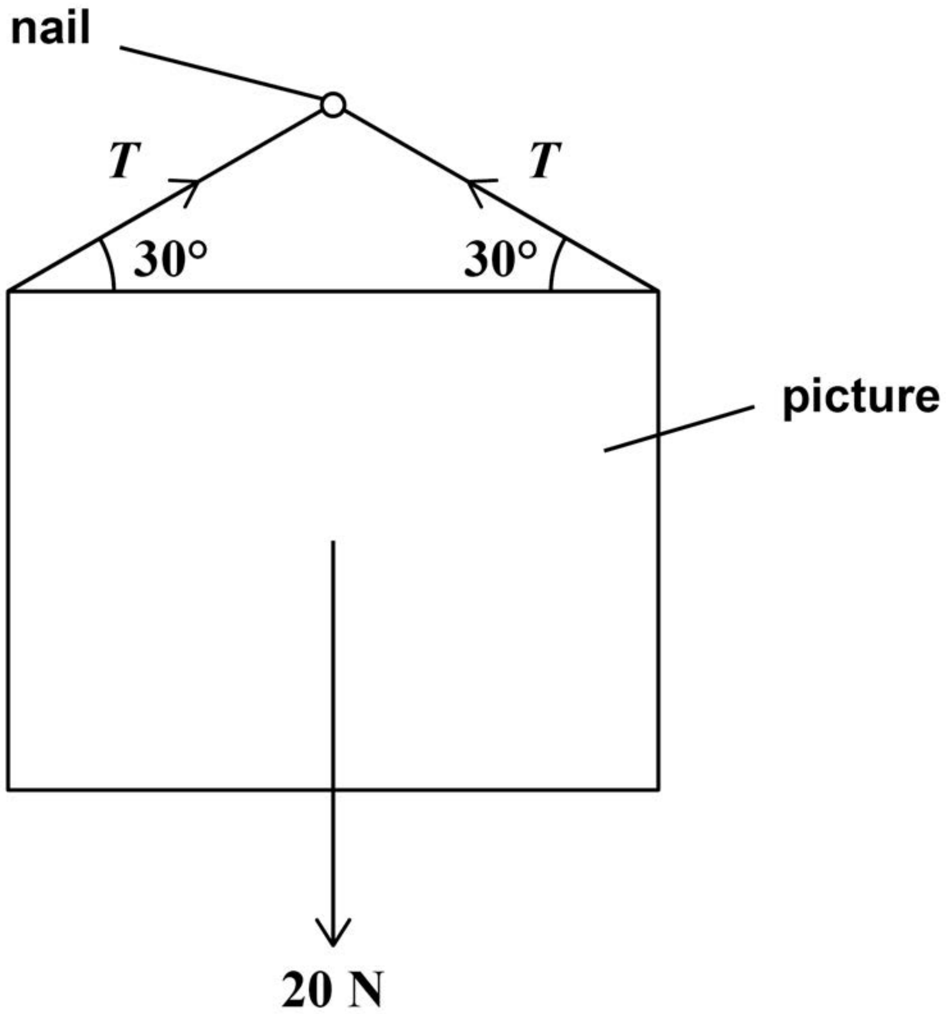
[Turn over]

2 2 **A uniform picture is suspended from a string which passes over a smooth nail. The tension in the string is T and the weight of the picture is 20 N.**



What is T ? [1 mark]

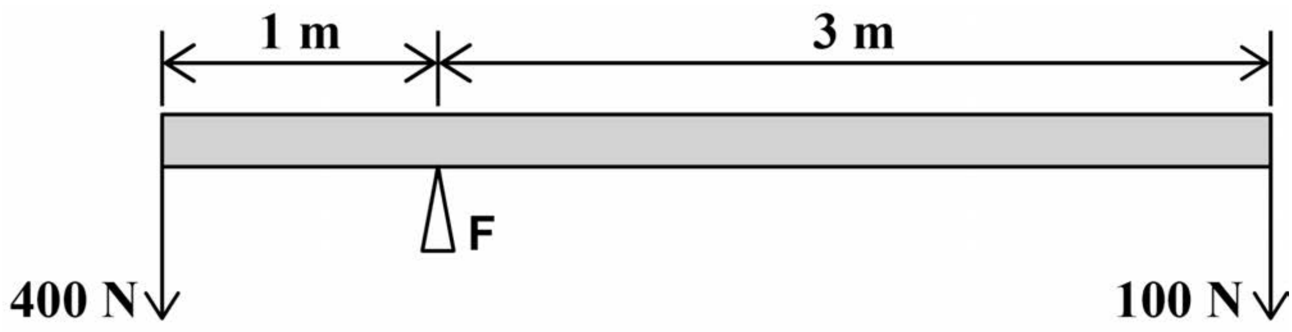
- ○ **A** 10 N
- ○ **B** 12 N
- ○ **C** 20 N
- ○ **D** 40 N

[Turn over]

2 3 **Which row contains vector quantities only?**
[1 mark]

○	**A**	**acceleration**	**mass**
○	**B**	**displacement**	**momentum**
○	**C**	**energy**	**force**
○	**D**	**distance**	**speed**

24 A uniform rod is balanced horizontally about a support F. Forces of 400 N and 100 N act at the ends of the rod, as shown.



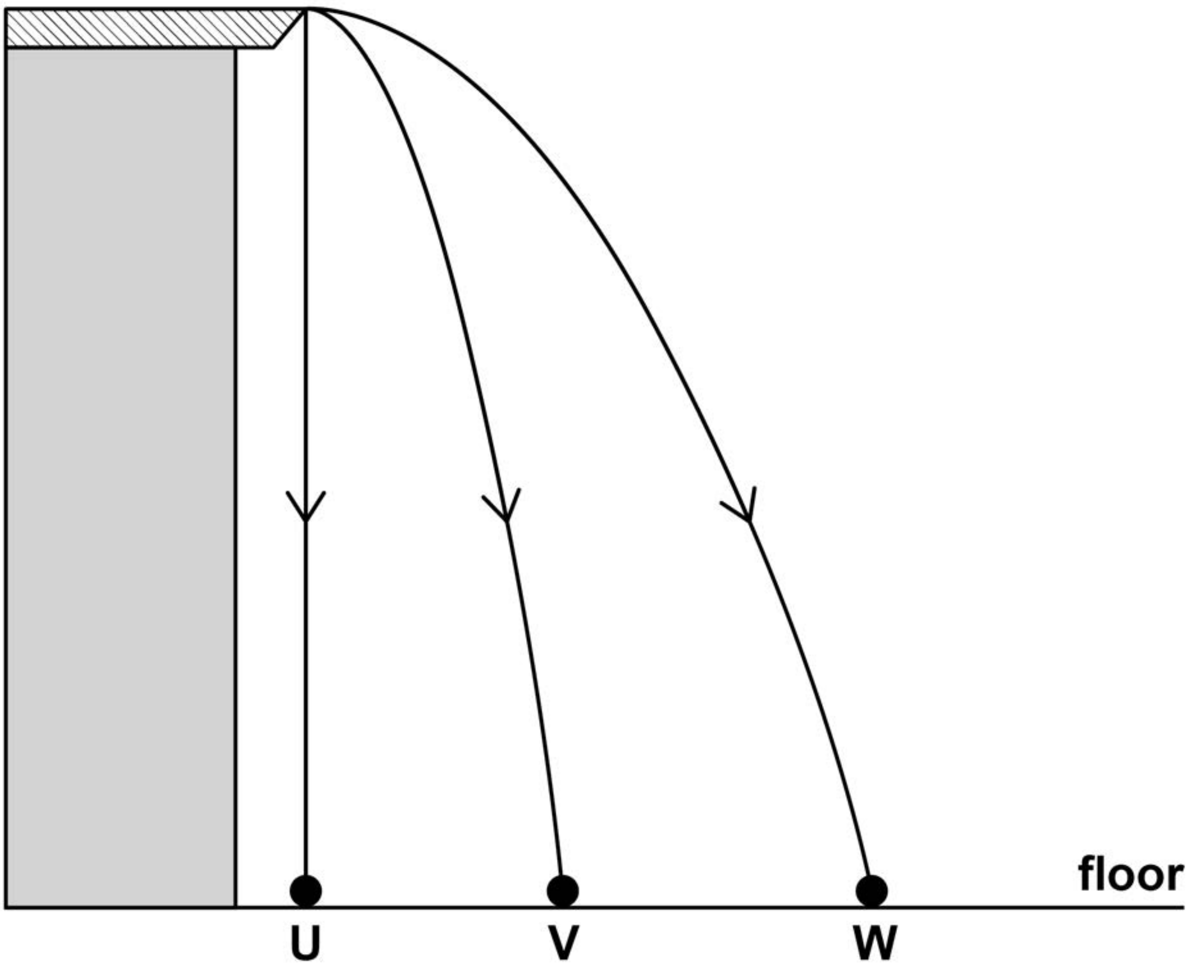
What is the reaction force acting on the rod at support F? [1 mark]

- A 100 N
- B 500 N
- C 550 N
- D 600 N

[Turn over]

2 5 **Three objects U, V and W leave the edge of a bench at the same time.**
The objects fall in the same vertical plane with negligible air resistance.
U is released from rest so that it falls vertically.
V and W are projected horizontally.

The paths of the three objects are shown.



Which statement is correct? [1 mark]

- ◯ **A** **U hits the floor before V and W.**
- ◯ **B** **W hits the floor before V.**
- ◯ **C** **W hits the floor with the greatest speed.**
- ◯ **D** **U hits the floor with the greatest speed.**

[Turn over]

2 6 A railway truck of mass $2000\ \mathrm{kg}$ travelling horizontally at $1.5\ \mathrm{m\,s^{-1}}$ collides with a stationary truck of mass $3000\ \mathrm{kg}$.
After the collision they move together.

Which row is correct? [1 mark]

		Speed of the trucks immediately after collision / $\mathrm{m\,s^{-1}}$	Effect of collision on total kinetic energy
○	A	0.6	no change
○	B	0.6	decrease
○	C	1.0	no change
○	D	1.0	decrease

27 **A car of mass $1000\ \mathrm{kg}$ accelerates uniformly from rest to a speed of $25.0\ \mathrm{m\,s^{-1}}$ in $50.0\ \mathrm{s}$. The car is travelling along a horizontal road.**

What is the average useful power output of the car over this period? [1 mark]

○ **A** $0.50\ \mathrm{kW}$

○ **B** $2.00\ \mathrm{kW}$

○ **C** $6.25\ \mathrm{kW}$

○ **D** $12.5\ \mathrm{kW}$

[Turn over]

28 A tensile force produces an extension ΔL in a steel wire of initial length L and diameter d.

The same steel is used to make a second wire of initial length $2L$ and diameter $\frac{d}{2}$.

What is the extension when the same force is applied to the second wire? [1 mark]

- A $\frac{\Delta L}{2}$
- B $2\Delta L$
- C $4\Delta L$
- D $8\Delta L$

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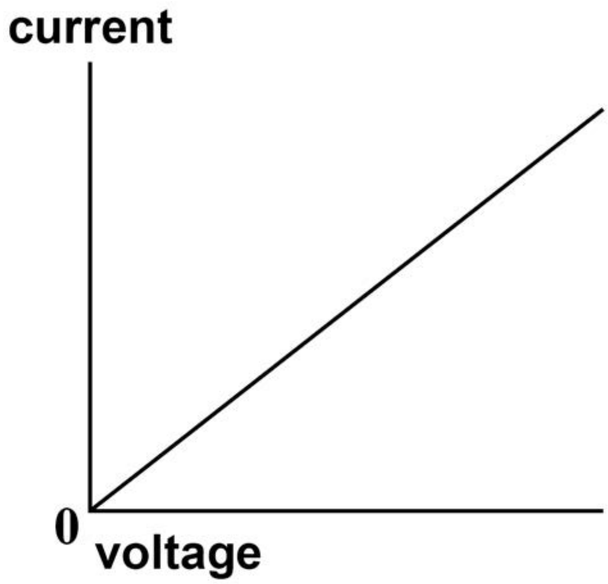
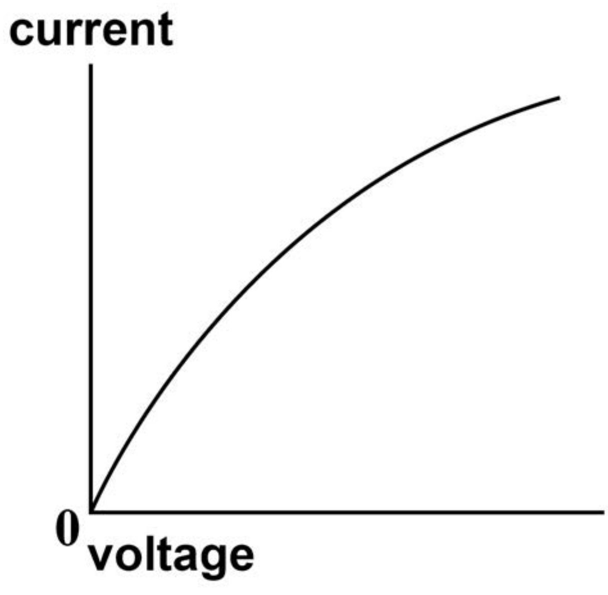
[Turn over]

29 **Which is the current–voltage characteristic graph for a filament lamp up to its working voltage? [1 mark]**

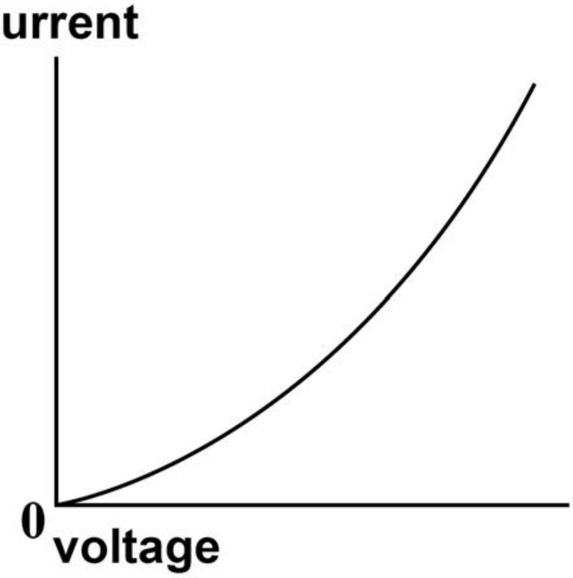
○ **A**



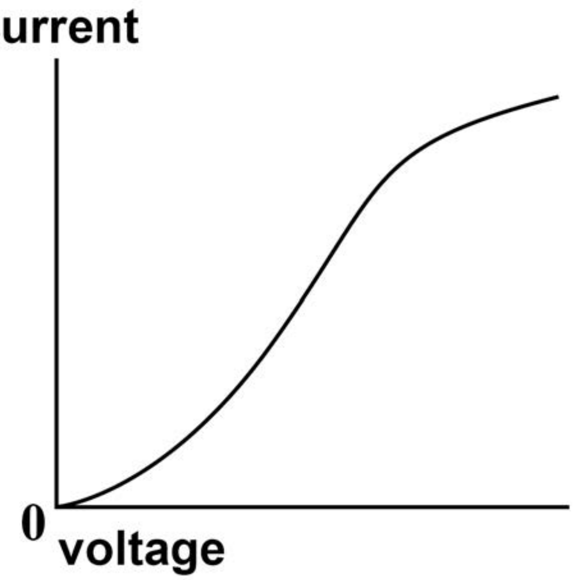
○ **B**



○ **C**

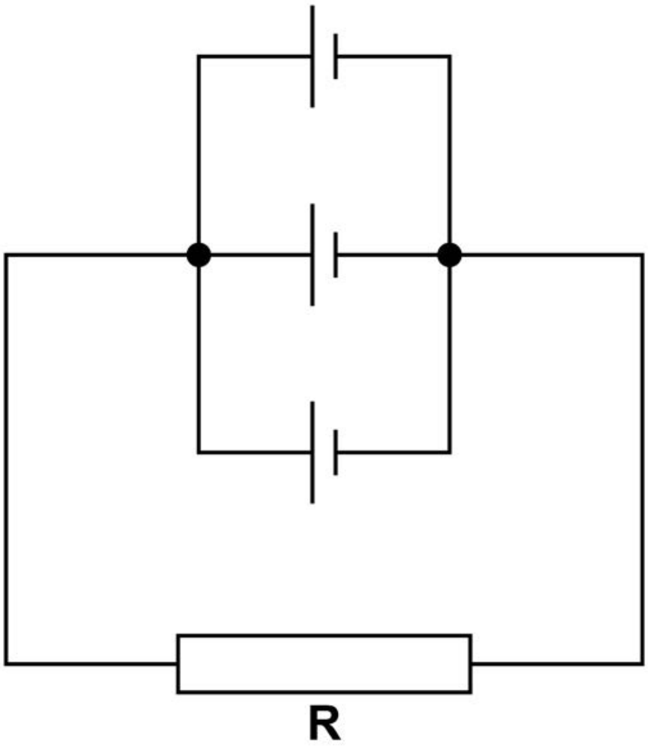


○ **D**



[Turn over]

3 0 Three identical cells, each of emf $1.5\ \mathrm{V}$ and internal resistance $6.0\ \Omega$, are connected to resistor R. The resistance of R is $6.0\ \Omega$.



What is the current in R? [1 mark]

- ○ **A** $0.19\ \mathrm{A}$
- ○ **B** $0.25\ \mathrm{A}$
- ○ **C** $0.56\ \mathrm{A}$
- ○ **D** $0.75\ \mathrm{A}$

31 A power of $100\ \mathrm{kW}$ at a potential difference of $10\ \mathrm{kV}$ is transmitted to a load resistor through cables of total resistance $5.0\ \Omega$.

What is the power loss in the cables? [1 mark]

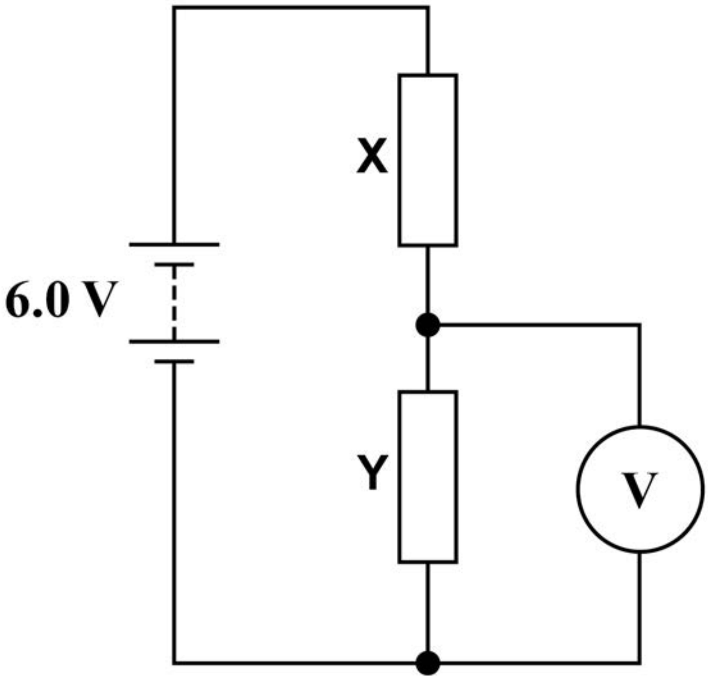
- ○ A $50\ \mathrm{W}$
- ○ B $0.5\ \mathrm{kW}$
- ○ C $100\ \mathrm{kW}$
- ○ D $20\ \mathrm{MW}$

[Turn over]

3 2 Resistors X and Y are connected in series with a $6.0\ \mathrm{V}$ battery of negligible internal resistance.

X has resistance R and Y has resistance $\frac{R}{2}$.

A voltmeter of resistance R is connected across Y.

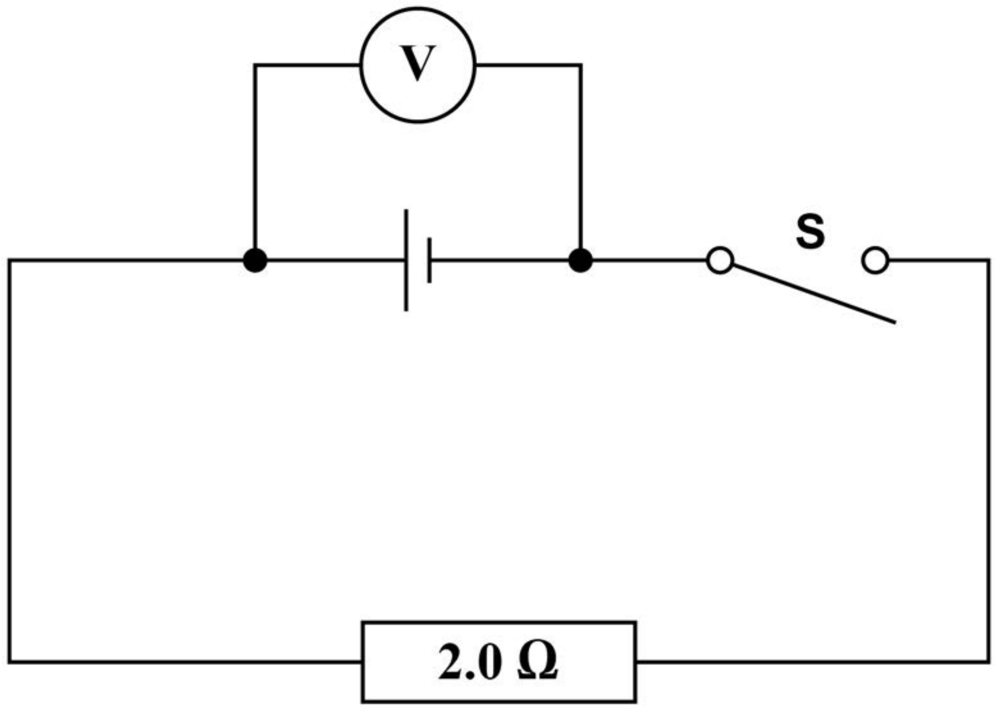


What is the reading on the voltmeter? [1 mark]

- ○ **A** 0.0 V
- ○ **B** 1.5 V
- ○ **C** 3.0 V
- ○ **D** 4.5 V

[Turn over]

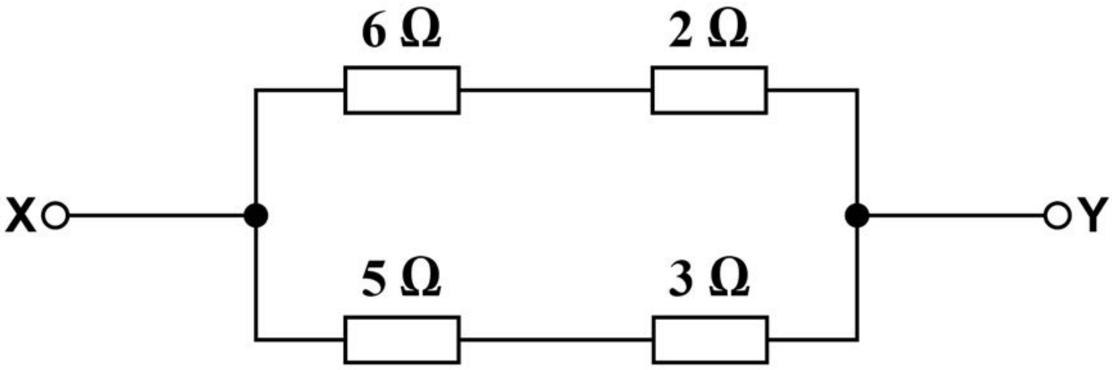
33 **The reading on the voltmeter halves when switch S is closed.**



What is the internal resistance of the cell?
[1 mark]

- ○ **A** 0.50 Ω
- ○ **B** 1.0 Ω
- ○ **C** 2.0 Ω
- ○ **D** 4.0 Ω

3 4 **In the circuit shown, a potential difference of $3.0\ \mathrm{V}$ is applied across XY.**



What is the current in the $5\ \Omega$ resistor?
[1 mark]

A $0.38\ \mathrm{A}$

B $0.60\ \mathrm{A}$

C $0.75\ \mathrm{A}$

D $2.7\ \mathrm{A}$

END OF QUESTIONS

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

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1 9 6 A 7 4 0 7 / 2