AQA

Surname _____

Other Names _____

Centre Number _____

Candidate Number _____

Candidate Signature _____

I declare this is my own work.

A-level

PHYSICS

Paper 1

7408/1

Time allowed: 2 hours

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

[Turn over]

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

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 85.**

- **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

Cosmic rays are high-energy particles that come from space. Most of these particles are protons. There are other particles in cosmic rays, including atomic nuclei.

TABLE 1 gives the data for one particular nucleus X.

TABLE 1

Mass / kg	8.02×10^{-26}
Specific charge / C kg^{-1}	4.39×10^7
Kinetic energy / MeV	215

| 0 | 1 | . | 1 |

Determine the number of neutrons in nucleus X.
[3 marks]

number of neutrons = _____

[Turn over]

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REPEAT OF TABLE 1

Mass / kg	8.02×10^{-26}
Specific charge / C kg^{-1}	4.39×10^{7}
Kinetic energy / MeV	215

0 1 . 2

Calculate the speed of X.
Ignore relativistic effects. [3 marks]

speed = _____ m s^{-1}

[Turn over]

A pion (π^+) and a kaon (K^+) are produced when cosmic rays interact with the upper atmosphere.

| 0 | 1 | . | 3 |

The π^+ decays to produce a positron and an electron neutrino.

Show how the conservation laws apply to this decay.
[2 marks]

_____

_____

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0 1 . 4

The K^+ decays to produce an anti-muon and a muon neutrino.

Explain how strangeness applies in this decay.
[2 marks]

_____

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0 1 . 5

Write an equation for a K^+ decay that involves only hadrons. [2 marks]

_____

_____

[Turn over]

12

0 2

FIGURE 1 shows apparatus used to investigate the properties of microwaves. The microwaves from the transmitter T are vertically polarised and have a wavelength of about 3 cm.

The microwaves are detected at the receiver by a vertical metal rod R.

FIGURE 1
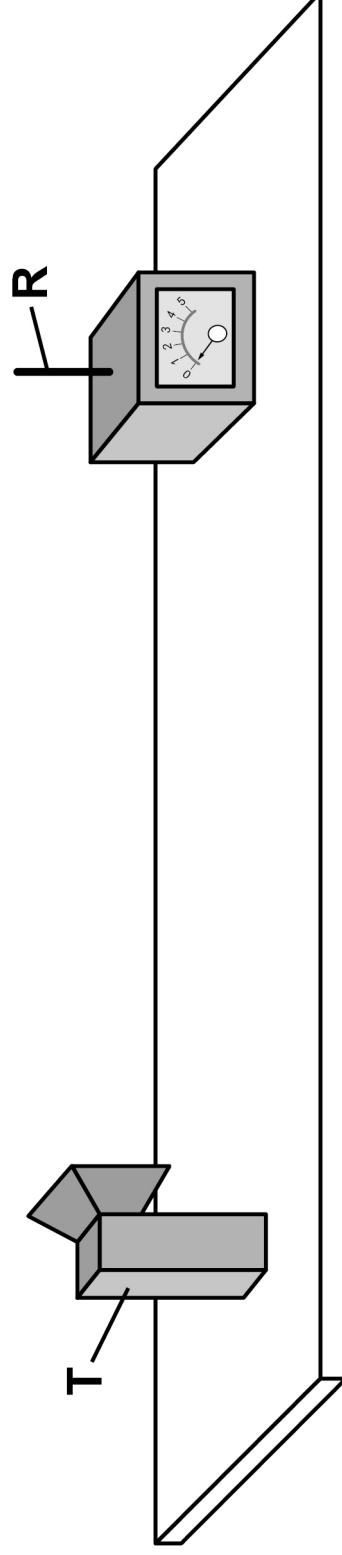
0 2 . 1

Explain how the apparatus can be used to demonstrate that the waves from T are vertically polarised. [3 marks]

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[Turn over]

FIGURES 2a and 2b show T and R and two different positions of a metal plate M that reflects microwaves. M is vertical and parallel to the direct transmission from T to R.

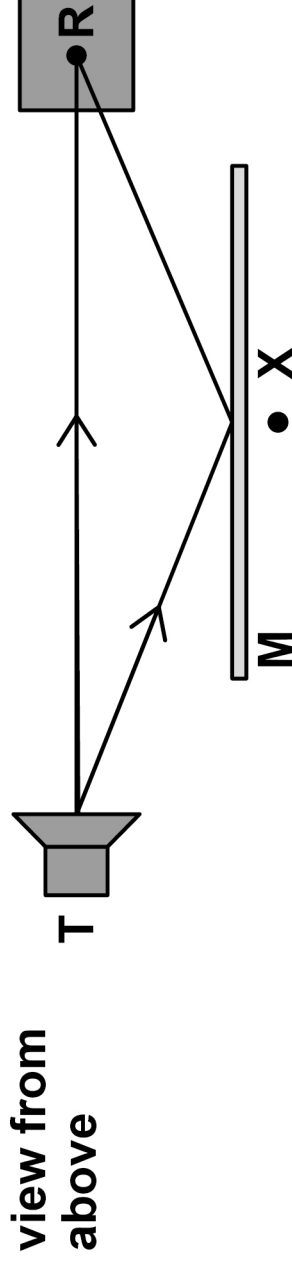FIGURES 2a and 2b are NOT drawn to scale.

FIGURE 2a

view from above

FIGURE 2b

view from above
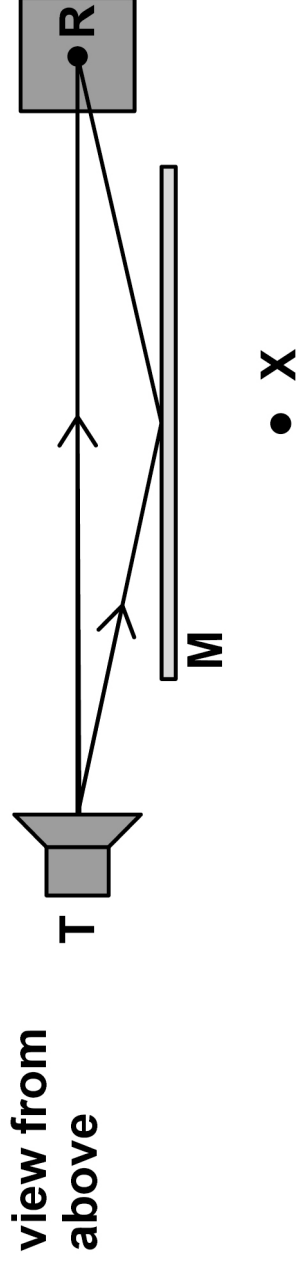
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[Turn over]

In an experiment, T and R are about two metres apart. M is moved slowly towards X.

FIGURE 2a shows the initial position of M.

FIGURE 2b shows M when it has been moved a few centimetres.

The arrowed lines show the path of waves that reach R directly and the path of waves that reach R by reflection from M.

| 0 | 2 | . | 2 |

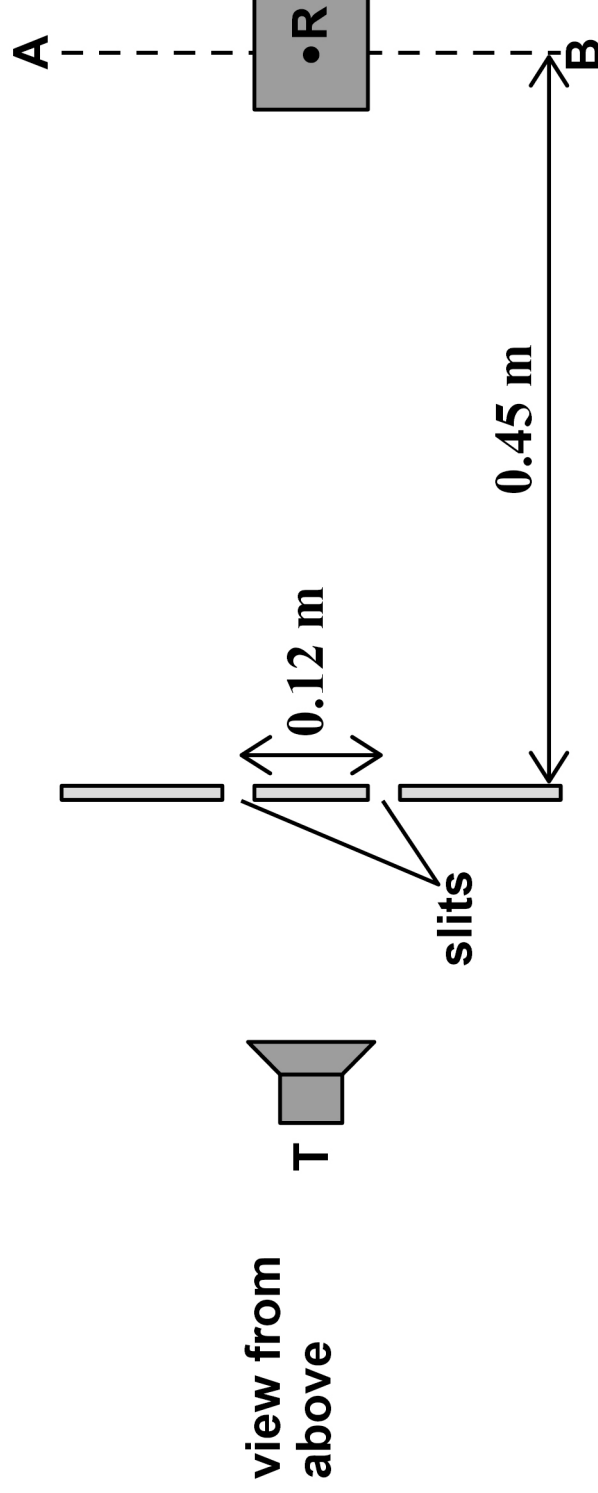Explain what happens to the signal detected by R as M is moved slowly towards X.
[4 marks]

FIGURE 3 shows an arrangement used in a different experiment to try to determine the wavelength of the microwaves.

FIGURE 3

view from above

T

slits

0.12 m

0.45 m

A

•R

B

A double-slit arrangement is placed between T and R.

The initial position of R is the same distance from each slit and is 0.45 m from the midpoint of the two slits.
AB is a line perpendicular to the line between T and the initial position of R.
R can be moved 0.25 m towards A and 0.25 m towards B along AB.

The two slits act as two coherent sources with a separation of 0.12 m.

| 0 | 2 | . | 3 |

Suggest why Young's double-slit equation should NOT be used to determine the wavelength. [1 mark]

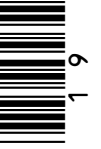_____

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0 2 . 4

The wavelength is known to be about 3 cm.

Deduce whether this practical arrangement is suitable for a determination of a value for the wavelength. [3 marks]

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0 3

FIGURE 4 shows a ray of monochromatic light incident at angle A from air onto the end of a straight optical fibre.

This ray undergoes total internal reflection at the core–cladding boundary. A ray that enters the optical fibre at an angle greater than A will only be partially reflected at the core–cladding boundary.

FIGURE 4
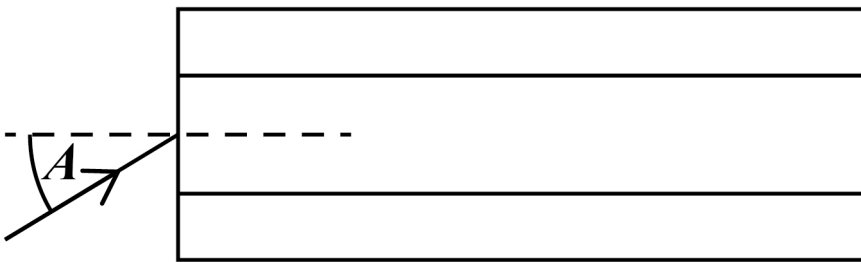
TABLE 2 shows some properties of the optical fibre.

TABLE 2

	Refractive index
cladding	1.41
core	1.47

0 3 . 1

Calculate the speed of the light ray in the optical fibre.
[1 mark]

speed = _____ **m s^{-1}**

[Turn over]

REPEAT OF FIGURE 4

| 0 | 3 | . | 2 |

Calculate A, in degrees, for the optical fibre shown in FIGURE 4. [3 marks]
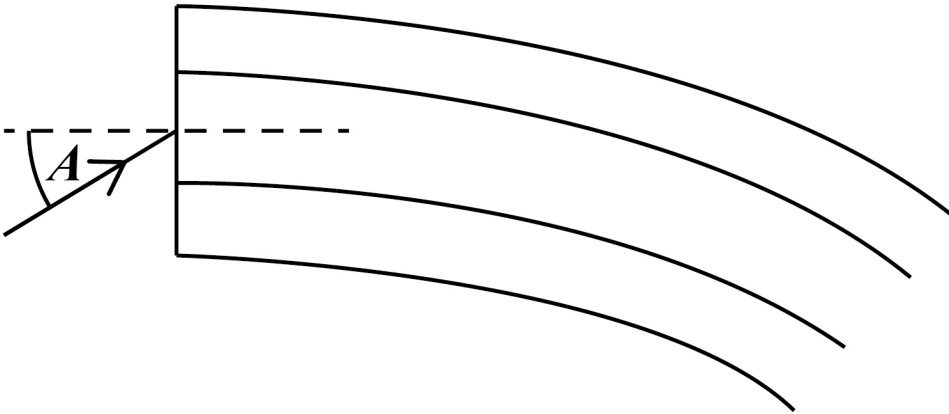
A = _____ **degrees**

[Turn over]

0 3 . 3

A ray is incident on the optical fibre at angle A. The optical fibre is now bent, as shown in FIGURE 5.

FIGURE 5

Draw, on FIGURE 5, what happens to the ray within the optical fibre.

Explain your answer. [3 marks]

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[Turn over]

7

0 4

FIGURE 6 shows a rotating spacecraft that is proposed to carry astronauts to Mars.

FIGURE 6
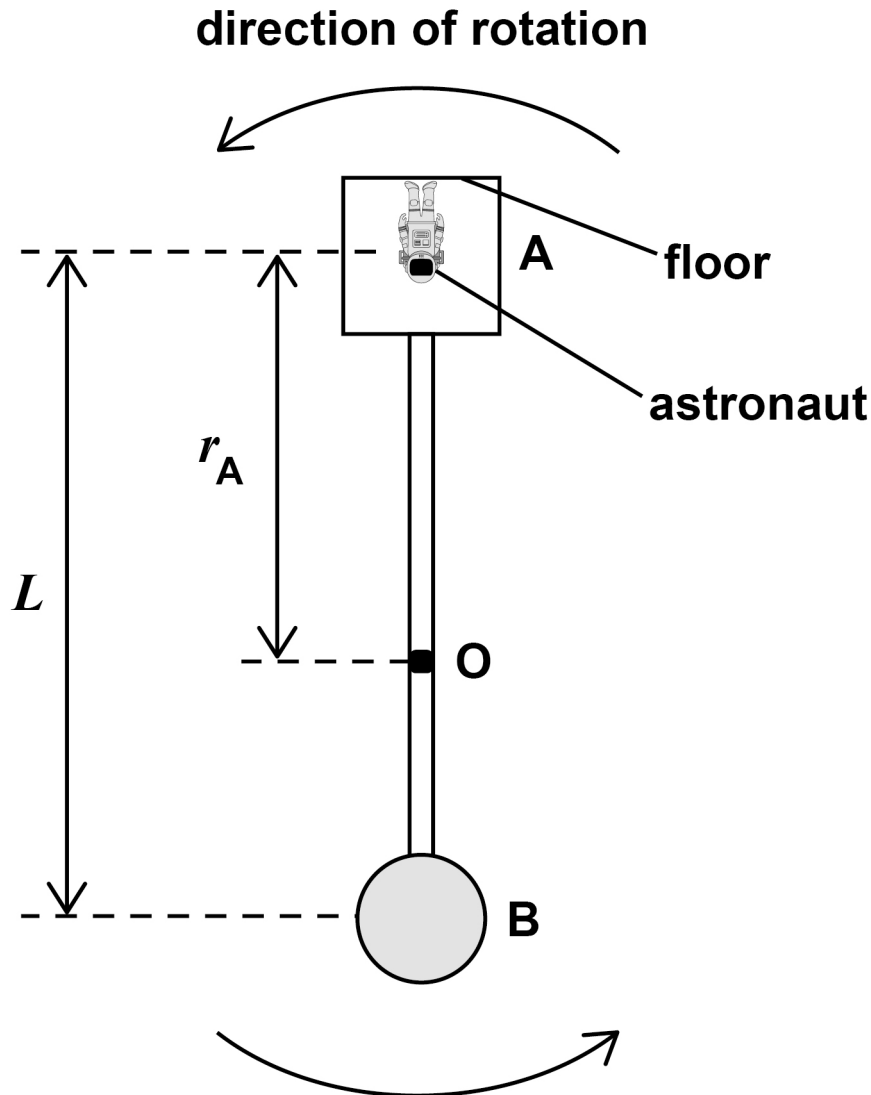
The spacecraft consists of two parts A and B connected by a rigid cylindrical rod. When the spacecraft is travelling, A and B rotate at a constant angular speed about their common centre of mass O.

L is the distance between the centre of mass of A and the centre of mass of B.

r_A is the distance from O to the centre of mass of A.

| 0 | 4 |.| 1 |

As the spacecraft rotates, a force that imitates the effect of gravity acts on an astronaut who is in contact with the floor.

Explain why. [2 marks]

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_____

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[Turn over]

0 4 . 2

The forces exerted on A and B by the connecting rod have the same magnitude.

m_A **is the mass of A**

m_B **is the mass of B**

Show, by considering the centripetal forces acting on A and B, that r_A is given by

$$r_A = \frac{m_B L}{m_A + m_B}$$

[2 marks]

0 4 . 3

In this spacecraft $m_A < m_B$.

Deduce whether the centre of mass of A or the centre of mass of B rotates with a greater linear speed. [2 marks]

_____

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[Turn over]

The astronauts live in A and the cargo is stored in B.

When loaded,

$m_A = 1.32 \times 10^6 \text{ kg}$

$m_B = 3.30 \times 10^6 \text{ kg}$.

The spacecraft imitates the gravity of Mars where $g = 3.7 \text{ m s}^{-2}$.

FIGURE 7, on the opposite page, shows a stress–strain curve for the metal used for the rigid rod.

FIGURE 7

stress / GPa

strain / 10^{-3}
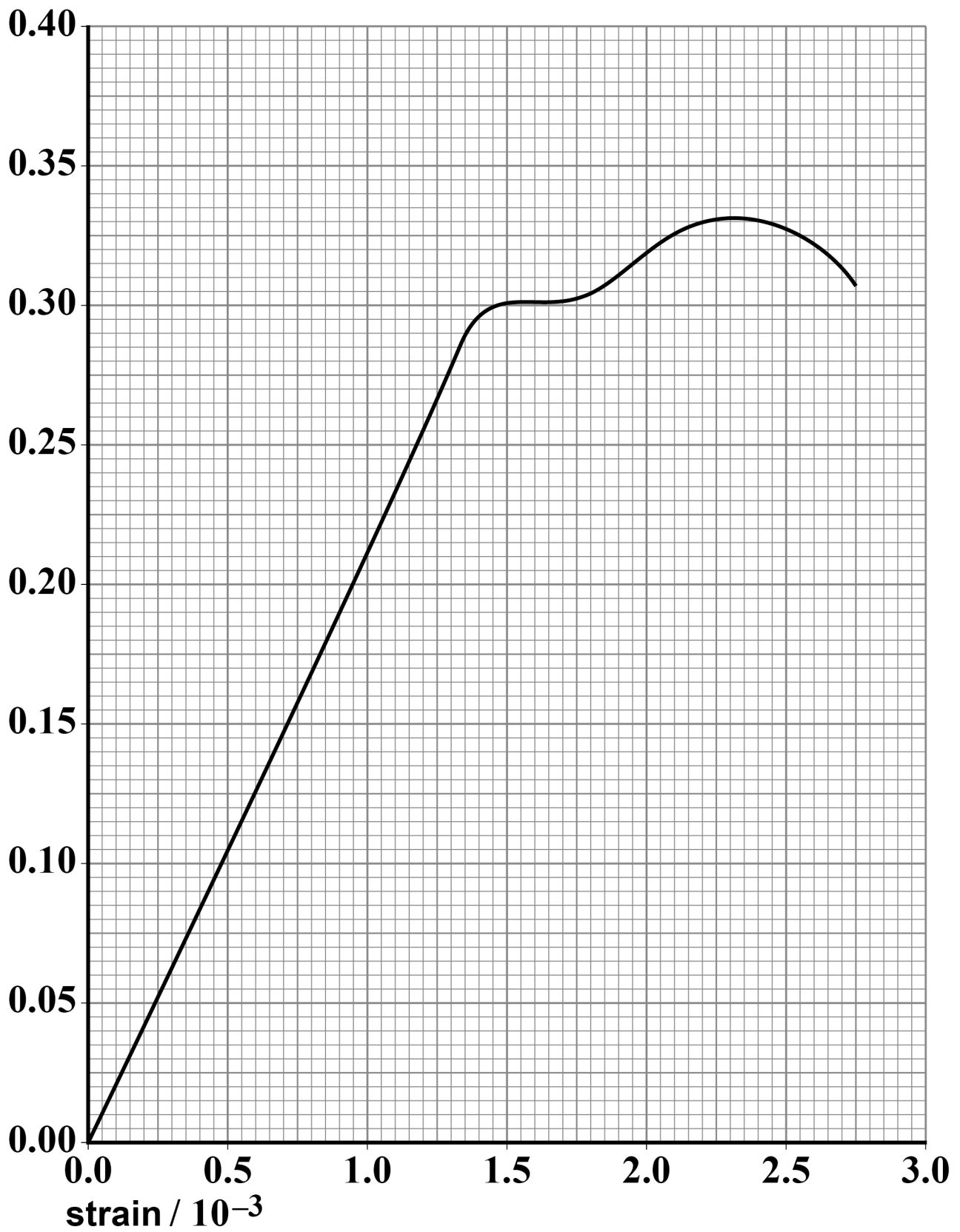
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| 0 | 4 | . | 4 |

Suggest a suitable diameter for the rod.
Justify your answer, on page 34. [5 marks]

diameter = _____ **m**

[Turn over]

$$\frac{\quad}{11}$$

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[Turn over]

0 5

FIGURE 8 shows the H-shaped posts used in a game of rugby.

FIGURE 8

posts

crossbar

3.00 m
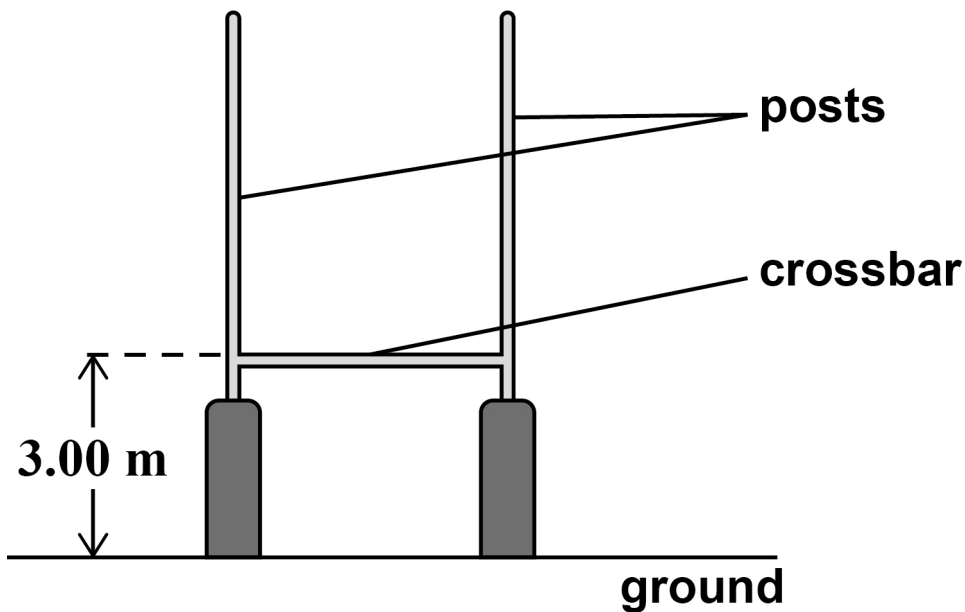
ground

FIGURE 9 shows the path of a ball that is kicked and just passes over the crossbar. The initial velocity of the ball is 20.0 m s^{-1} at an angle of $40.0°$ to the ground.

You should consider air resistance to be negligible and treat the ball as a simple projectile.

FIGURE 9

crossbar

20 m s^{-1}

$40°$

horizontal ground

3 6
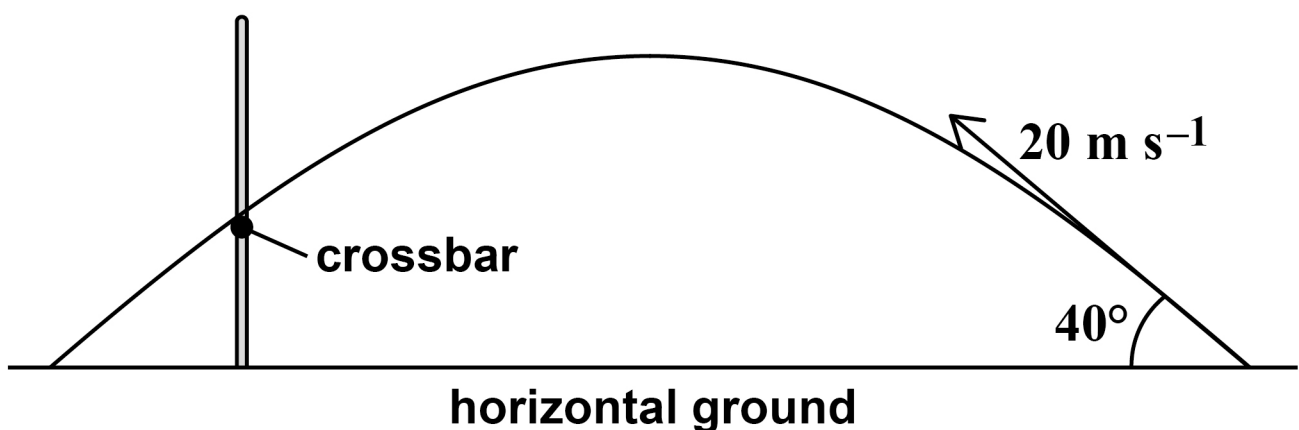
The top of the crossbar is 3.00 m above the horizontal ground.

| 0 | 5 | . | 1 |

Show that the minimum speed of the ball in flight is about 15 m s^{-1}.

Explain your answer. [2 marks]

_____

_____

_____

_____

[Turn over]

The ball just passes over the crossbar at a time t after it is kicked.

Show that t must satisfy the following equation:

$$4.91t^2 - 12.9t + 3.00 = 0$$

[2 marks]

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[Turn over]

0 5 . 3

There are two solutions to the equation

$$4.91t^2 - 12.9t + 3.00 = 0$$

Discuss which of the two solutions is the time taken for the ball to pass over the crossbar from when it is kicked.

In your answer you should

- **state the value for t given by each solution**

- **explain the physical significance of the other solution.**

[4 marks]

solution 1 = _____ s

solution 2 = _____ s

_____

_____

_____

_____

_____

_____

_____

[Turn over]

| 0 | 5 | . | 4 |

Another attempt is made to kick the ball over the crossbar. The initial velocity of the ball is the same as in the first attempt.
This kick is made from a horizontal distance of 38 m from the posts.

Deduce whether the ball can pass over the crossbar.
[1 mark]

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[Turn over]

0 5 . 5

FIGURE 10 shows the variations with time of the vertical velocity of a ball with and without air resistance.

FIGURE 10
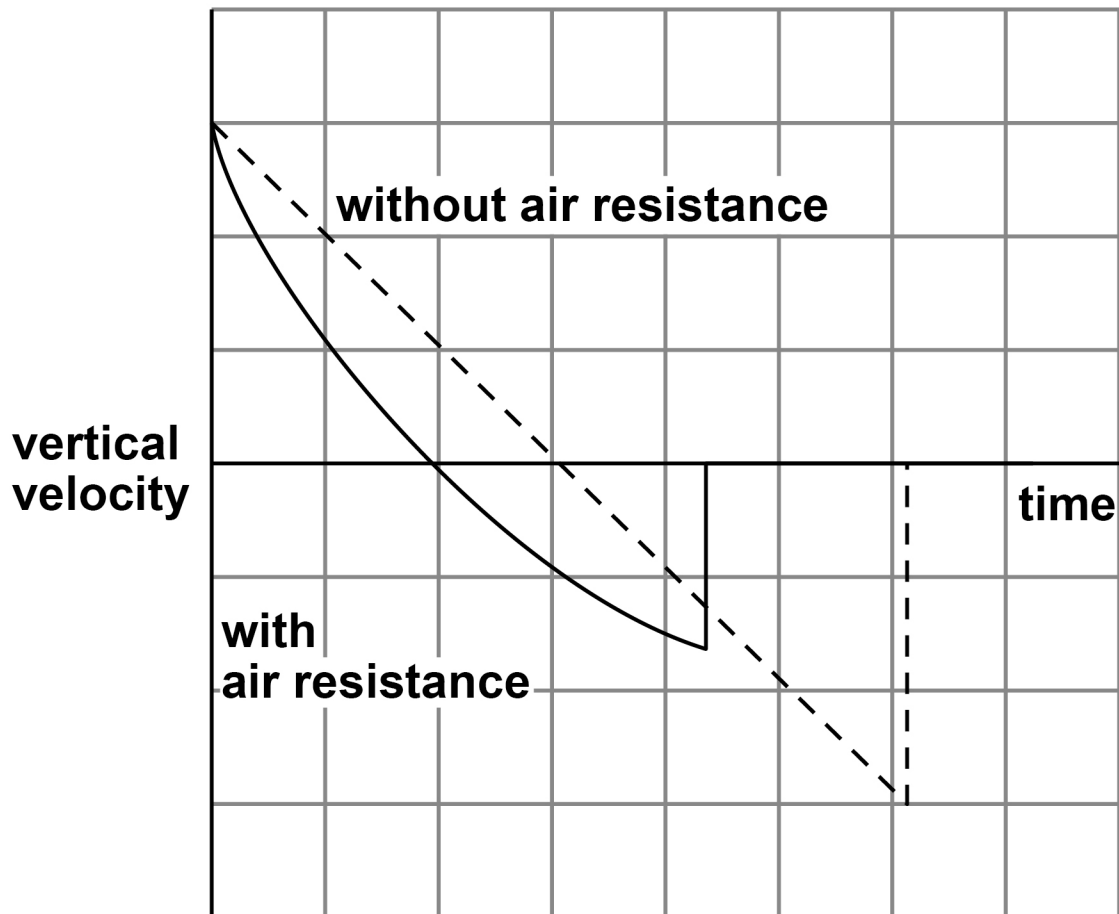
Discuss the features of the motion of the ball shown by the two graphs.

In your answer you should refer to

- **the gradients of the graphs**

- **the area between each line and the time axis.**

[5 marks]

_____

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[Turn over]

14

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[Turn over]

0	6

FIGURE 11 shows how the resistance of an LDR varies with light intensity.

FIGURE 11

resistance / Ω

light intensity / lux
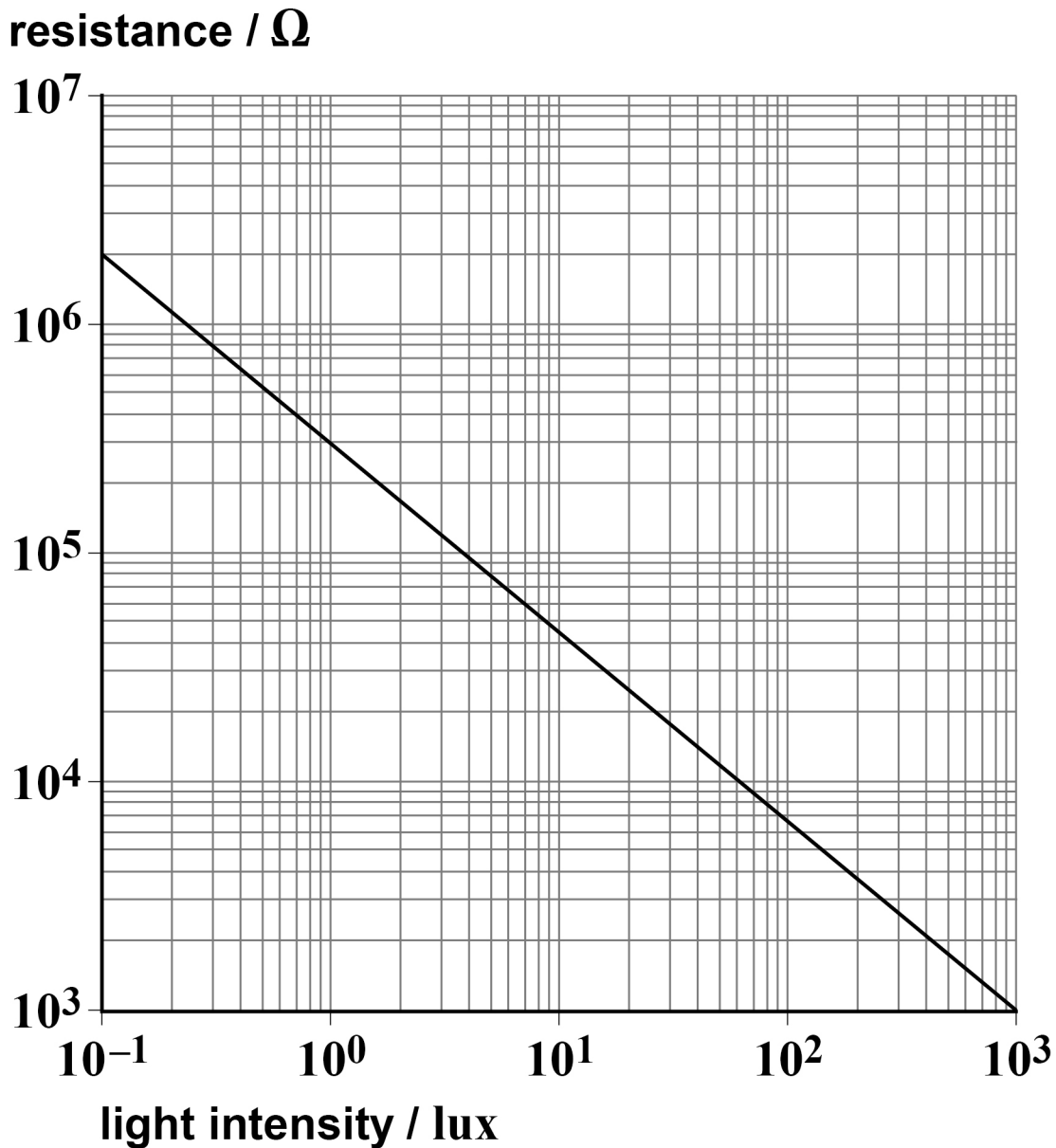
The LDR is used as part of an alarm system in a dim room. FIGURE 12, on the opposite page, shows one proposal for a sensor circuit for this system.

FIGURE 12
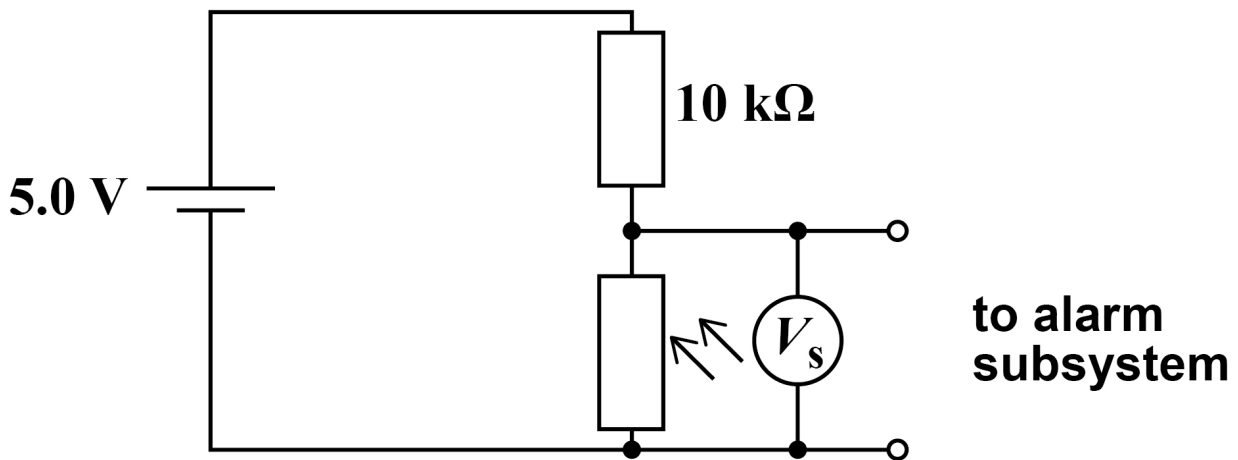
The power supply to the sensor has an emf of 5.0 V and a negligible internal resistance. A negligible current is drawn from the sensor circuit by the alarm subsystem.

A light beam illuminates the LDR. When the light beam is broken the LDR is not illuminated by the light beam. This causes the alarm to sound.

[Turn over]

TABLE 3 shows how the light intensity at the LDR changes.

TABLE 3

	Light intensity / lux
LDR illuminated by light beam	4.0
LDR not illuminated by light beam	1.0

| 0 | 6 | . | 1 |

Show that the current in the sensor circuit when the LDR is NOT illuminated by the light beam is approximately $16\ \mu A$. [2 marks]

0 6 . 2

The alarm sounds when the potential difference V_S across the LDR changes by more than 25% of the power supply emf.

Discuss whether the circuit shown in FIGURE 12, on page 49, is suitable.

Support your answer with a calculation. [3 marks]

_____

_____

_____

[Turn over]

5

SECTION B

Each of Questions 07 to 31 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
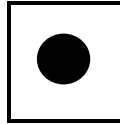
WRONG METHODS
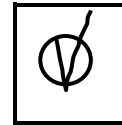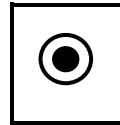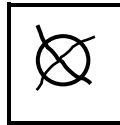
If you want to change your answer you must cross out your original answer as shown.
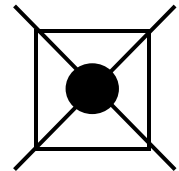
If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.
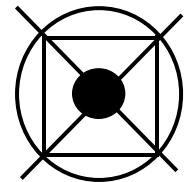
You may do your working in the blank space around each question but this will not be marked.

Do NOT use additional sheets for this working.

0 7

Which is approximately equal to 3 kW h? [1 mark]

◯ **A** 3×10^3 J

◯ **B** 1×10^4 J

◯ **C** 2×10^5 J

◯ **D** 1×10^7 J

[Turn over]

5 3

0 8

Which is the shortest distance? [1 mark]

○ **A** 10^{-19} Gm

○ **B** 10^{-14} km

○ **C** 10^{-4} μm

○ **D** 10^7 fm

0 9

The gravitational force is one of the four fundamental forces.
The ticks in the table match particles with the other fundamental forces.

In which row is the particle matched to the only other fundamental forces it experiences? **[1 mark]**

	Particle	Electromagnetic force	Weak nuclear force	Strong nuclear force
○ A	μ^+	✓	✓	
○ B	$\bar{p}$	✓		✓
○ C	π^0	✓	✓	✓
○ D	ν_e		✓	✓

[Turn over]

1	0

The proton number of uranium is 92 and the proton number of radon is 88

Which series of decays turns a uranium nucleus into a radon nucleus? [1 mark]

○   **A** $\alpha + \beta^- + \beta^- + \alpha + \alpha$

○   **B** $\beta^- + \beta^- + \alpha + \beta^- + \alpha$

○   **C** $\alpha + \alpha + \alpha + \alpha + \beta^-$

○   **D** $\beta^- + \beta^- + \beta^- + \beta^- + \alpha$

1 1

The diagram represents a particle interaction.
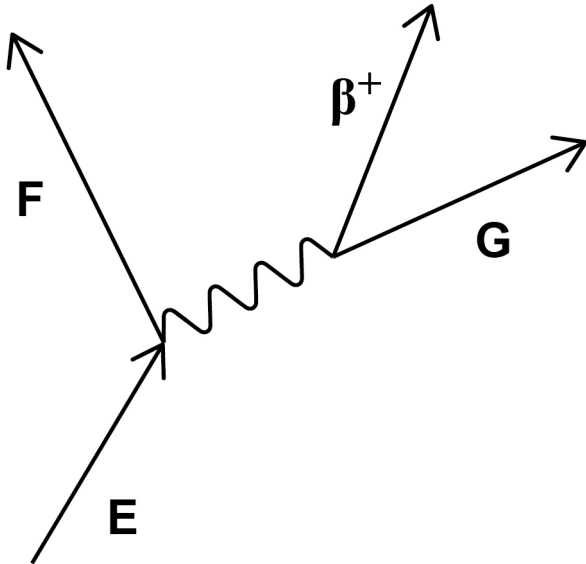
Which row identifies particles E, F and G? [1 mark]

		E	F	G
○	A	up quark	down quark	neutrino
○	B	down quark	up quark	neutrino
○	C	up quark	down quark	antineutrino
○	D	down quark	up quark	antineutrino

[Turn over]

12

The quark combination of a particle is sū.

Which is true for this particle? [1 mark]

○ **A It has a baryon number of 1**

○ **B It has a charge of −1.6 × 10^{-19} C.**

○ **C It is a pion.**

○ **D It has a strangeness of $-\dfrac{1}{3}$**

1 3

Monochromatic light with a photon energy of 4.1×10^{-19} J is incident on a metal surface. The maximum speed of the photoelectrons released is 4.2×10^5 m s^{-1}.

What is the work function of the metal? [1 mark]

○   A 2.5×10^{-19} J

○   B 3.3×10^{-19} J

○   C 4.1×10^{-19} J

○   D 4.9×10^{-19} J

[Turn over]

1 4

What is the role of the mercury vapour in a fluorescent tube? [1 mark]

○ **A It absorbs photons of UV light and emits visible light.**

○ **B It absorbs photons of visible light and emits UV light.**

○ **C It emits photons of visible light following ionisation or excitation.**

○ **D It emits photons of UV light following ionisation or excitation.**

BLANK PAGE

[Turn over]

1 5

The diagram shows the three lowest energy levels for an atom.
The energy levels have been drawn to scale.

level 2 ————————————————

level 1 ————————————————

ground state ————————————————

Transitions of electrons between these energy levels produce photons of the following frequencies:

4.56×10^{14} **Hz**

2.46×10^{15} **Hz**

2.92×10^{15} **Hz.**

What is the difference in energy between the ground state and energy level 1? [1 mark]

○   **A** 0.3×10^{-18} **J**

○   **B** 1.3×10^{-18} **J**

○   **C** 1.6×10^{-18} **J**

○   **D** 1.9×10^{-18} **J**

[Turn over]

1 6

A muon and an electron are travelling at the same speed.

Which row gives the particle with the greater kinetic energy and the particle with the longer de Broglie wavelength? [1 mark]

		Greater kinetic energy	Longer de Broglie wavelength
○	A	muon	muon
○	B	muon	electron
○	C	electron	muon
○	D	electron	electron

BLANK PAGE

[Turn over]

1 7

The diagrams show the displacement–distance graph for a wave and the displacement–time graph for a point in the wave.

displacement / m
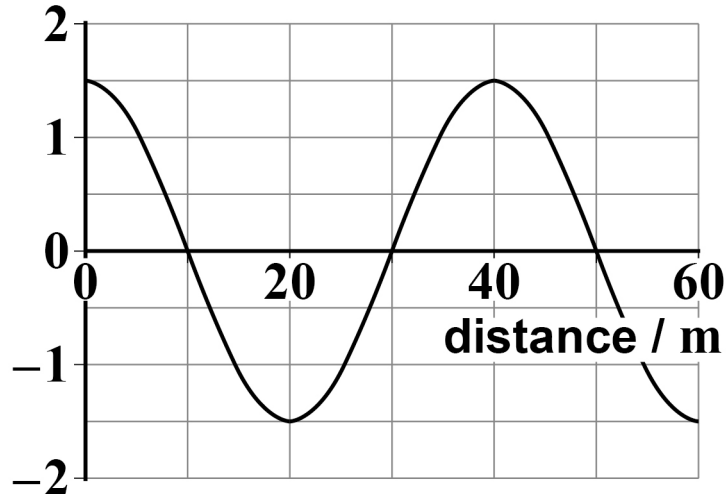
displacement / m
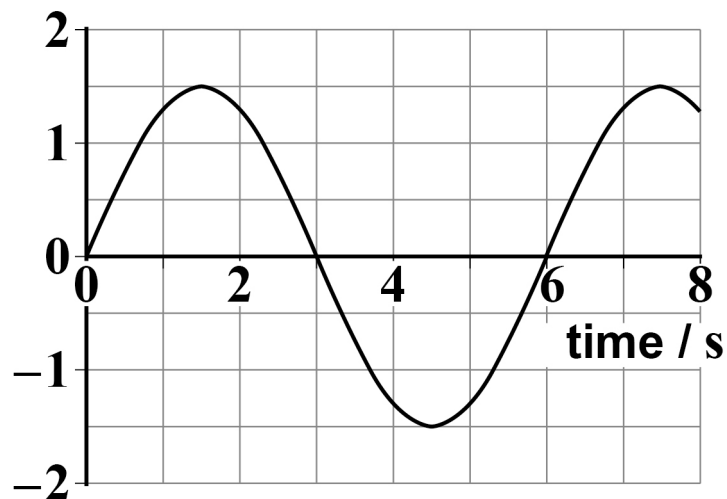
Which is correct for this wave? **[1 mark]**

○ **A** The amplitude is 3.0 m.

○ **B** The wavelength is 6 m.

○ **C** The speed is 8.3 m s^{-1}.

○ **D** The frequency is 0.17 Hz.

[Turn over]

1 8

The diagram shows a stationary wave on a string at one instant in time.
P, Q and R are three points on the string.
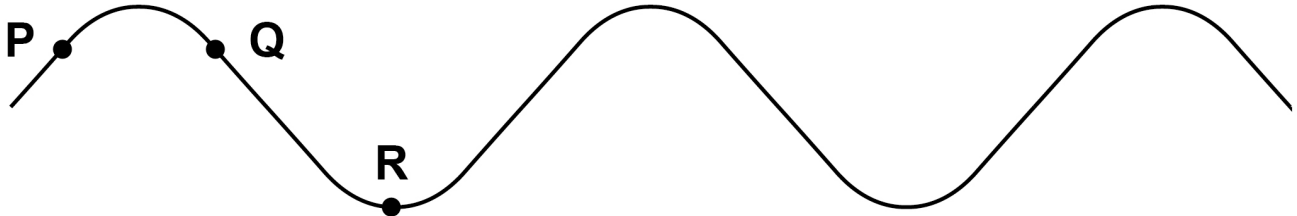
Which row is correct? [1 mark]

○	A	P is in antiphase with R	P has the same amplitude as Q
○	B	P is out of phase with R	P has the same amplitude as R
○	C	P is in phase with Q	P has the same amplitude as R
○	D	P is out of phase with Q	P has a smaller amplitude than R

1 9

A diffraction grating is illuminated normally.

The second-order maximum for light of wavelength 650 nm occurs at the same angle as the third-order maximum for light of wavelength λ.

What is λ? [1 mark]

○   **A 217 nm**

○   **B 325 nm**

○   **C 433 nm**

○   **D 975 nm**

[Turn over]

6 9

70 70

2 0

The diagram shows a vector diagram of two forces acting on an object.
The diagram is drawn to scale.
The magnitude of the smaller force is 5.0 N.
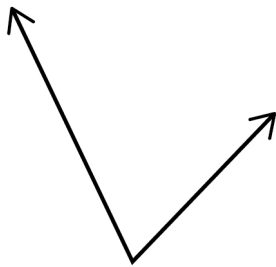
What is the magnitude of the resultant force on the object? [1 mark]

A 3.2 N

B 7.5 N

C 8.6 N

D 9.6 N

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[Turn over]

2 1

A uniform plank weighs 1200 N and rests on two pillars P and Q.

P and Q are 1.80 m apart.

P is 0.20 m from one end of the plank. Q is 1.40 m from the other end of the plank.

A man weighs 800 N and walks along the plank away from pillar P.

plank

0.20 m | 1.80 m | 1.40 m
P | Q
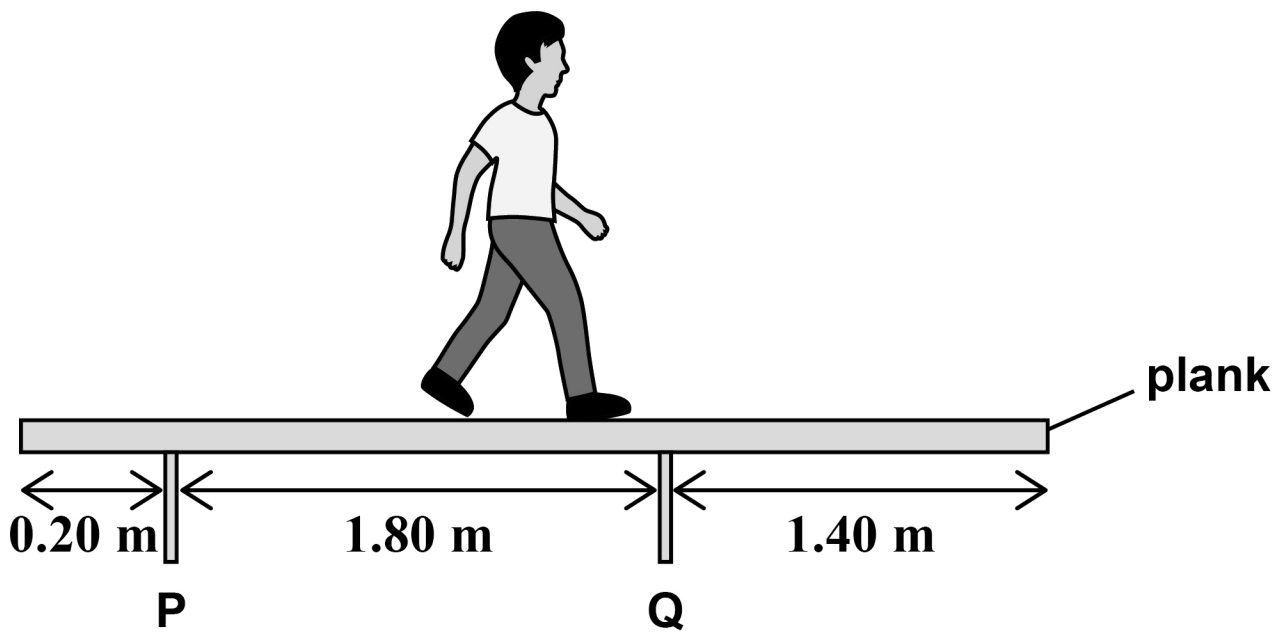
What is the horizontal distance between pillar P and the centre of mass of the man when the plank starts to tip? [1 mark]

○ **A 0.45 m**

○ **B 2.25 m**
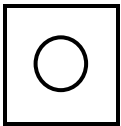
○ **C 2.45 m**

○ **D 3.15 m**

[Turn over]

22

A uniform piece of card in the shape of the letter L is suspended freely from a horizontal pin.
A plumb line is also suspended from the pin.
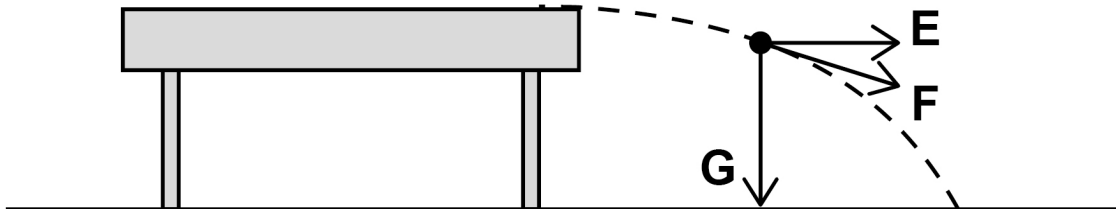**The diagram shows the card in its equilibrium position.**
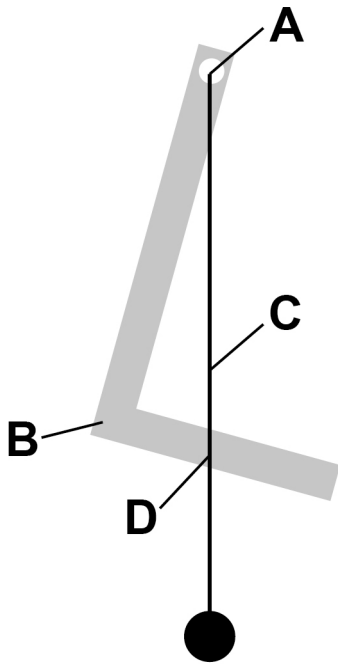
What is the position of the centre of mass of the piece of card? [1 mark]
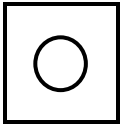
○ **A**
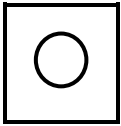
○ **B**
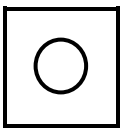
○ **C**

○ **D**

[Turn over]

2 3

**A coin is projected horizontally from the top of a desk.
The diagram shows the coin at one point in its path.
The air resistance is negligible.**

The arrows E, F and G represent different directions.

**Which row gives the direction of the acceleration and
the direction of the momentum of the coin at this point?
[1 mark]**

		Acceleration	Momentum
◯	A	F	F
◯	B	F	E
◯	C	G	F
◯	D	G	E

2	4

A Formula 1 racing car uses up its fuel during the race, causing its lap times to decrease.

The lap times decrease because

[1 mark]

○ A the acceleration of the car increases.

○ B the drag forces on the car decrease.
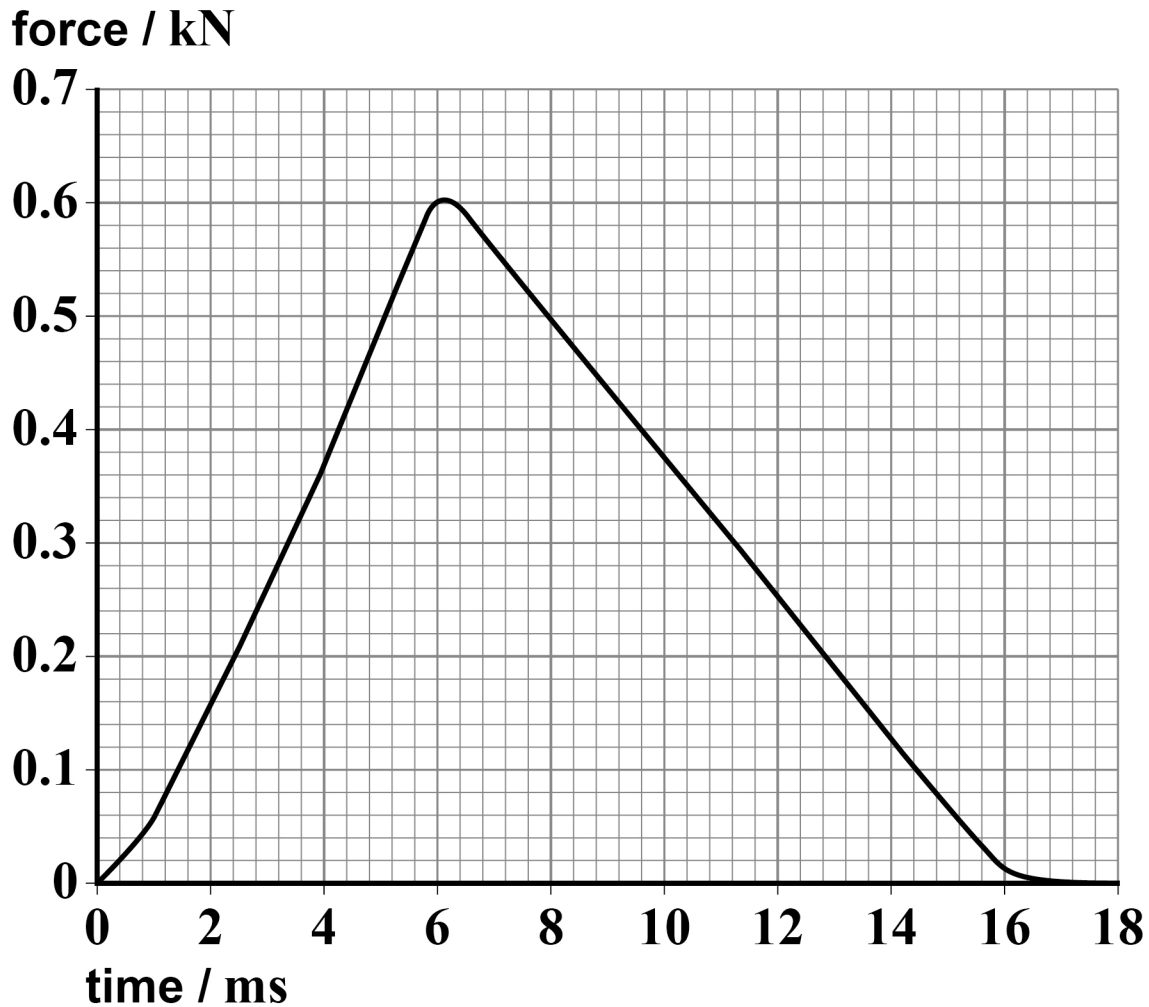
○ C the maximum speed of the car increases.

○ D the tyres become worn, reducing the friction with the road.

[Turn over]

2 5

A golf ball has a mass of 46 g and is initially stationary.
The diagram shows the variation with time of the force
acting on the golf ball as it is hit with a golf club.

force / kN

time / ms

What is an estimate of the kinetic energy of the golf ball immediately after it is hit? [1 mark]

A 5 J

B 50 J

C 250 J

D 500 J

[Turn over]

26

Two wires X and Y have the same extension for the same load.

X has a diameter d and is made of a metal of density ρ and Young modulus E.

Y has the same mass and length as X but its diameter is $2d$.

What are the density and the Young modulus of the metal from which Y is made? [1 mark]

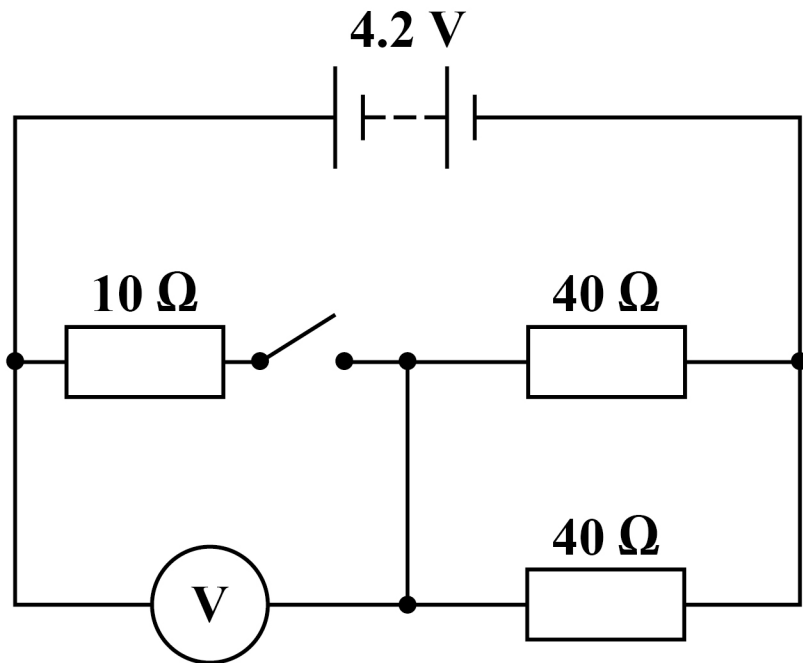|		Density	Young modulus
○	A	$\dfrac{\rho}{2}$	$\dfrac{E}{4}$
○	B	$\dfrac{\rho}{2}$	$4E$
○	C	$\dfrac{\rho}{4}$	$\dfrac{E}{4}$
○	D	$\dfrac{\rho}{4}$	$4E$

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[Turn over]

27

The battery in this circuit has an emf of 4.2 V and negligible internal resistance.

What are the readings on the voltmeter when the switch is open (off) and when the switch is closed (on)?
[1 mark]

		Open	Closed
○	A	0 V	2.1 V
○	B	4.2 V	2.1 V
○	C	0 V	1.4 V
○	D	4.2 V	1.4 V

[Turn over]

2 8

Two identical batteries each of emf 1.5 V and internal resistance $1.6 \, \Omega$ are connected in parallel. A $2.4 \, \Omega$ resistor is connected in parallel with this combination.

2.4 Ω
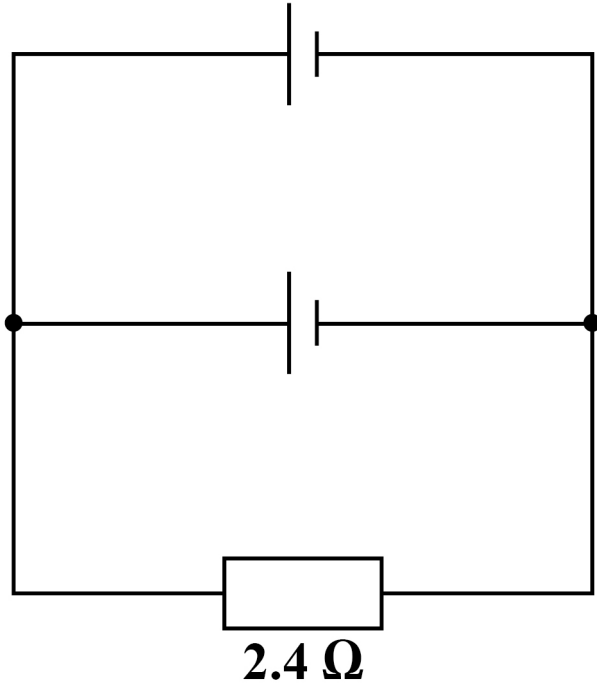
What is the current in the $2.4 \, \Omega$ resistor? [1 mark]

A 0.38 A

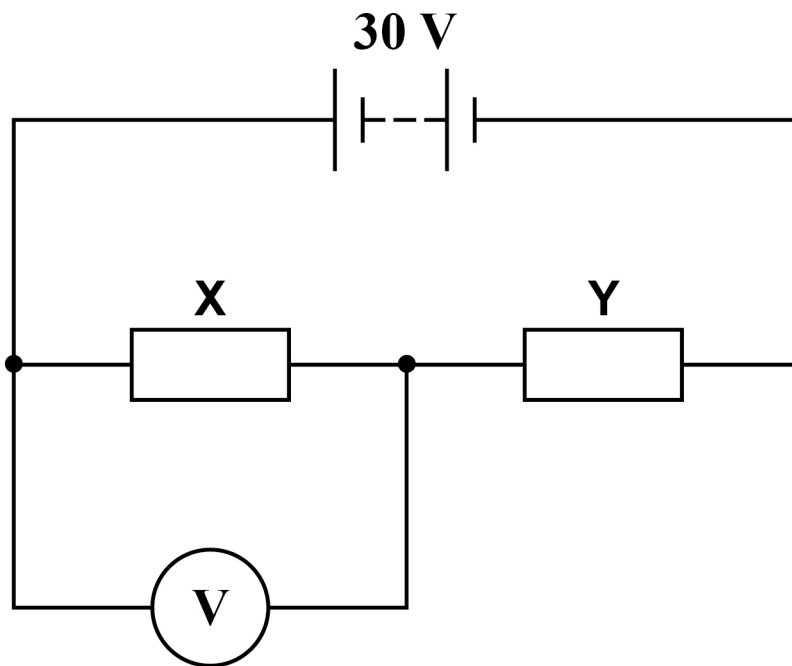B 0.47 A

C 0.75 A

D 0.94 A

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[Turn over]

29

Two resistors X and Y are connected in series with a power supply of emf $30\ \text{V}$ and negligible internal resistance.

The resistors are made from wire of the same material. The wires have the same length.

X uses wire of diameter d and Y uses wire of diameter $2d$.

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

◯ **A 10 V**

◯ **B 15 V**

◯ **C 20 V**

◯ **D 24 V**

[Turn over]

3 0

A simple pendulum and a mass−spring system each have a time period T on the Earth.
They are taken to the surface of a planet where the acceleration due to gravity is $\frac{g}{4}$.

What are the time periods of the pendulum and the mass−spring system on this planet? [1 mark]

		Simple pendulum	Mass−spring system
○	A	$\frac{T}{2}$	T
○	B	$2T$	T
○	C	$\frac{T}{2}$	$2T$
○	D	$2T$	$2T$

3	1

A particle of mass m is oscillating with simple harmonic motion.
The period of the oscillation is T and the amplitude is A.

What is the maximum kinetic energy of the particle?
[1 mark]

○   **A** $\dfrac{mA^2}{2T^2}$

○   **B** $\dfrac{\pi^2 mA^2}{2T^2}$

○   **C** $\dfrac{2mA^2}{T^2}$

○   **D** $\dfrac{2\pi^2 mA^2}{T^2}$

END OF QUESTIONS

25

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Write the question numbers in the left-hand margin.

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