AQA

Please write clearly in block capitals.

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

Surname _____

Forename(s) _____

Candidate signature _____

I declare this is my own work.

A-level PHYSICS

Paper 1

Time allowed: 2 hours

Materials

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.
- 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 85.
- 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	
6	
7–31	
TOTAL	

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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 = _____

0 1 . 2 Calculate the speed of **X**.
Ignore relativistic effects.

[3 marks]

speed = _____ m s^{-1}

Do not write outside the box

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]

0 1 . 4 The K^+ decays to produce an anti-muon and a muon neutrino.

Explain how strangeness applies in this decay.

[2 marks]

0 1 . 5 Write an equation for a K^+ decay that involves only hadrons.

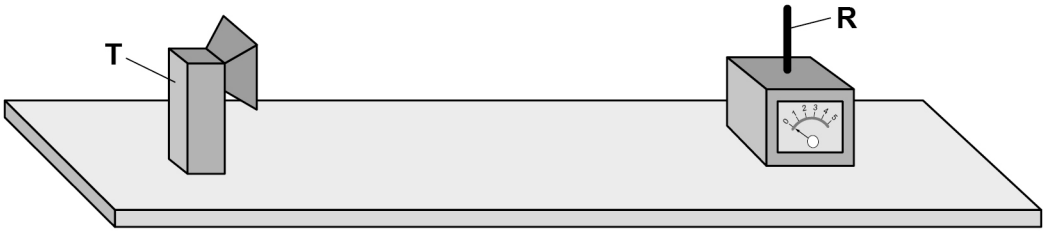
[2 marks]

12

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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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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**.

Figure 2a

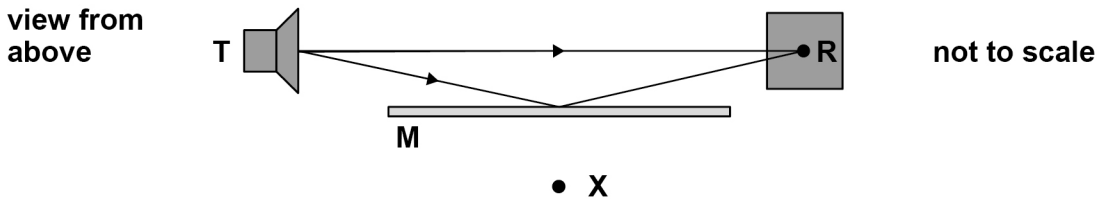
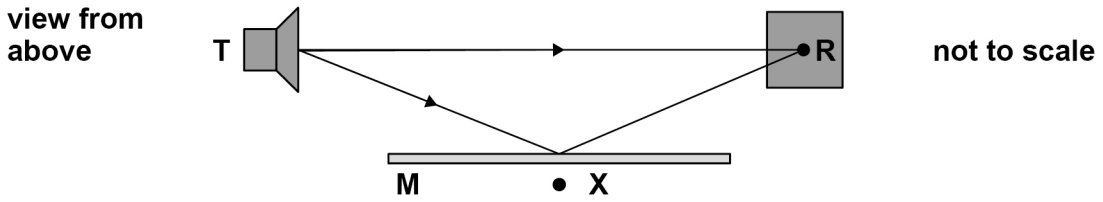


Figure 2b



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**.

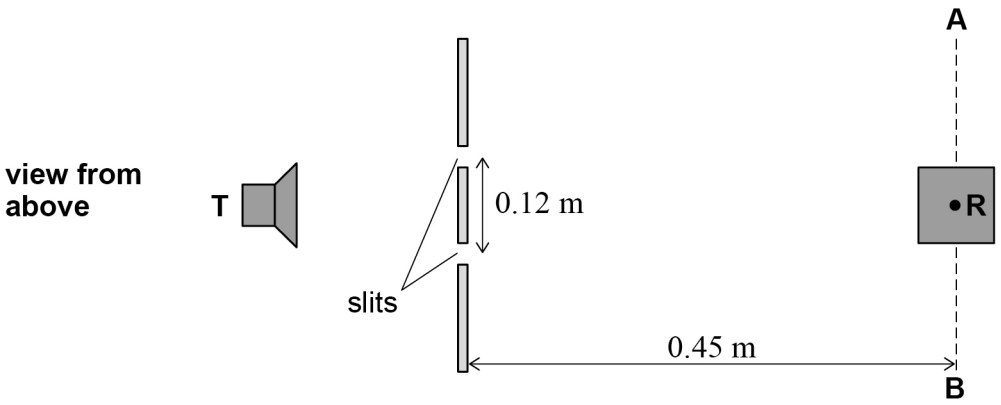
[4 marks]

Question 2 continues on the next page

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

Figure 3



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

The initial position of **R** is the same distance from each slit and is $0.45\ \text{m}$ 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 $0.25\ \text{m}$ towards **A** and $0.25\ \text{m}$ towards **B** along **AB**.

The two slits act as two coherent sources with a separation of $0.12\ \text{m}$.

0 2 . 3 Suggest why Young's double-slit equation should **not** be used to determine the wavelength.

[1 mark]

Do not write outside the box

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]

11

Turn over for the next question

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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

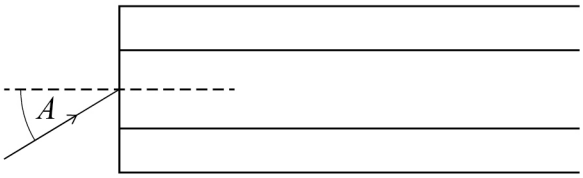


Table 2 shows some properties of the optical fibre.

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 = _____ $\mathrm{m\ s^{-1}}$

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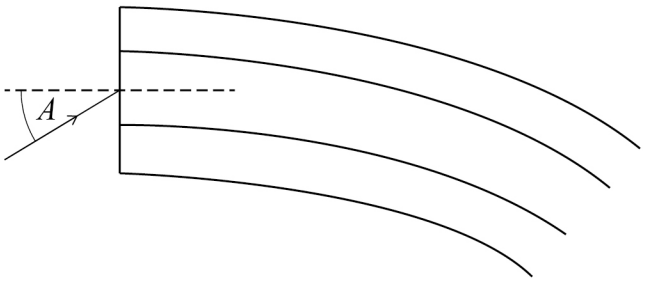
0 3 . 2 Calculate A, in degrees, for the optical fibre shown in **Figure 4**.

[3 marks]

$A =$ _____ degrees

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.

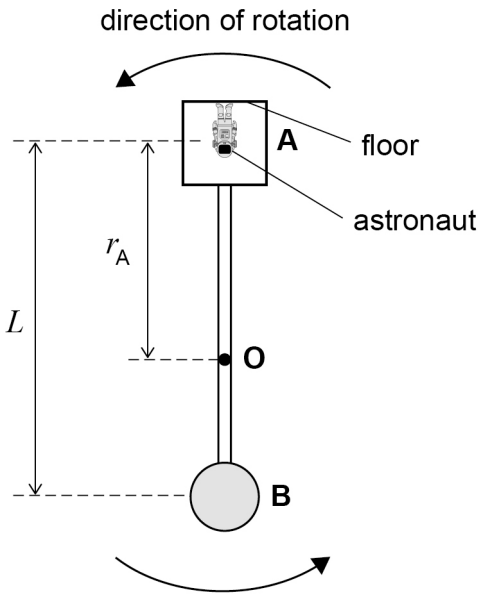
[3 marks]

7

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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]

Do not write outside the box

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]

Question 4 continues on the next page

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

When loaded,

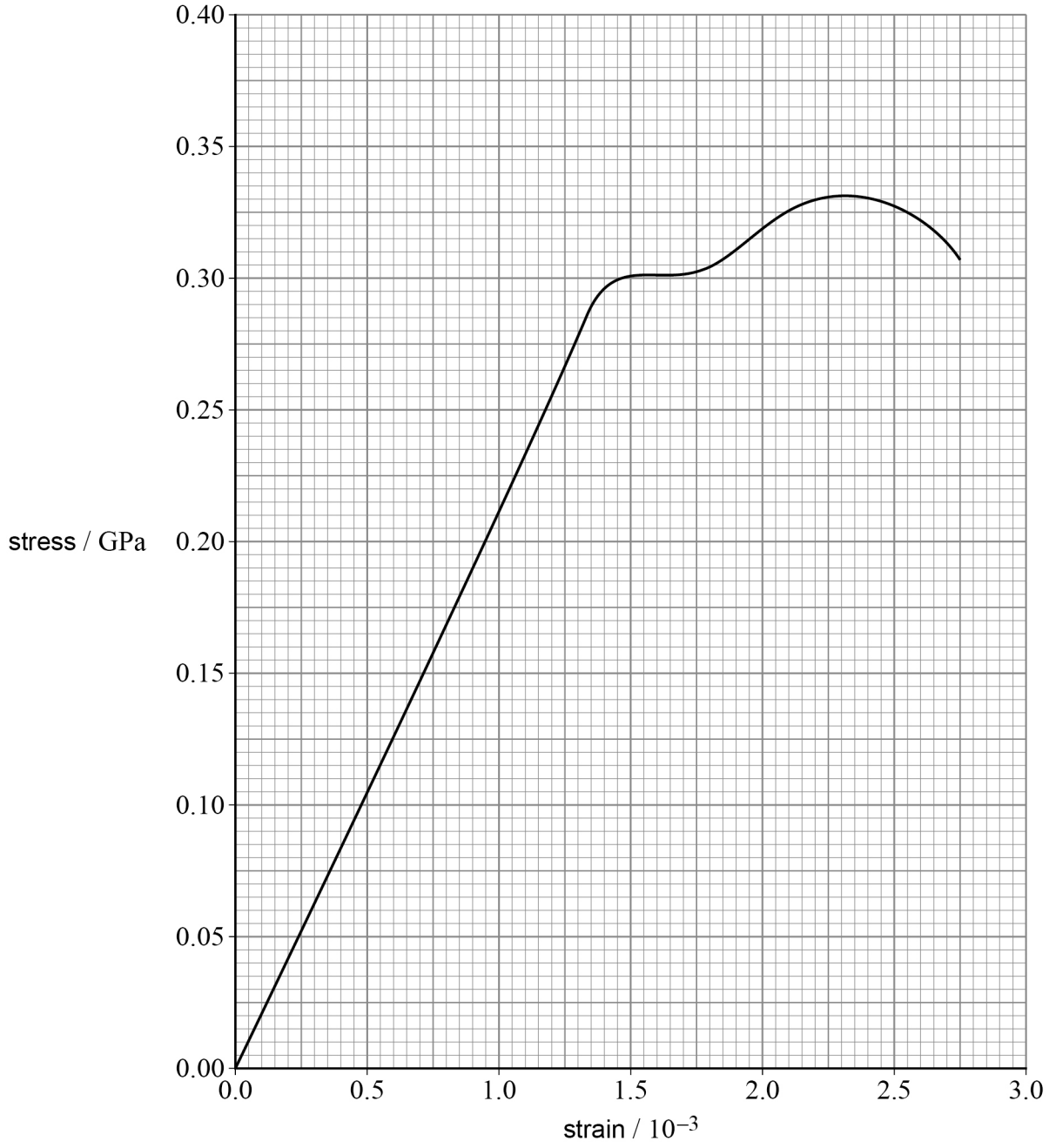
$m_A = 1.32 \times 10^6$ kg

$m_B = 3.30 \times 10^6$ kg.

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

Figure 7 shows a stress–strain curve for the metal used for the rigid rod.

Figure 7



Do not write outside the box

0 4 . 4 Suggest a suitable diameter for the rod.
Justify your answer.

[5 marks]

diameter = _____ m

11

Turn over ►

Do not write outside the box

0 5 **Figure 8** shows the H-shaped posts used in a game of rugby.

Figure 8

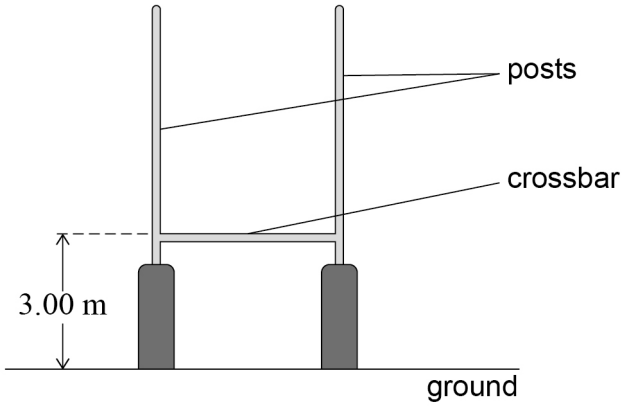
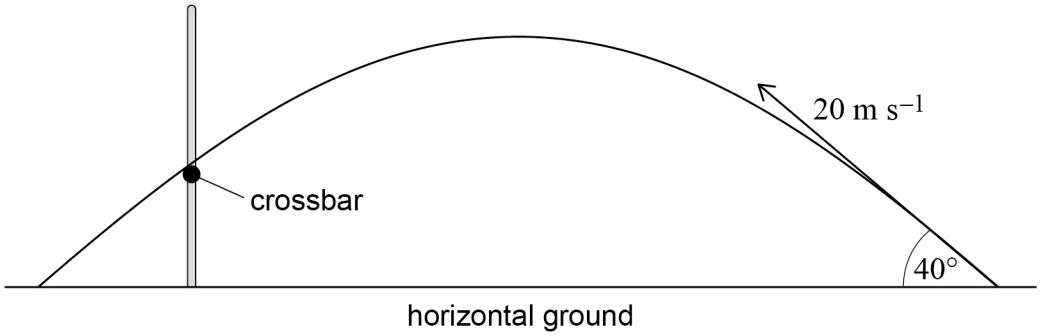


Figure 9 shows the path of a ball that is kicked and just passes over the crossbar. The initial velocity of the ball is $20.0\ \text{m s}^{-1}$ at an angle of $40.0°$ to the ground.

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

Figure 9



The top of the crossbar is $3.00\ \text{m}$ above the horizontal ground.

Do not write outside the box

0 5 . 1 Show that the minimum speed of the ball in flight is about $15\ \text{m s}^{-1}$.

Explain your answer.

[2 marks]

0 5 . 2 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]

Question 5 continues on the next page

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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

Do not write outside the box

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 $38\ \mathrm{m}$ from the posts.

Deduce whether the ball can pass over the crossbar.

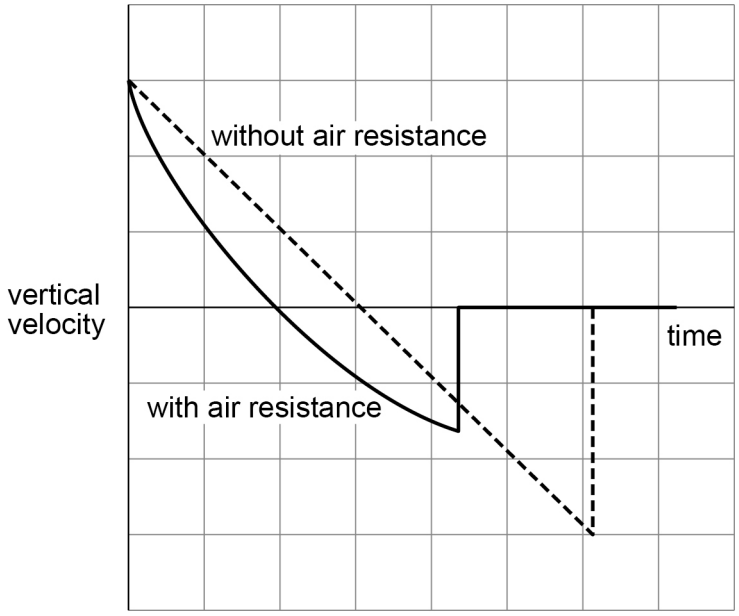
[1 mark]

Question 5 continues on the next page

Do not write outside the box

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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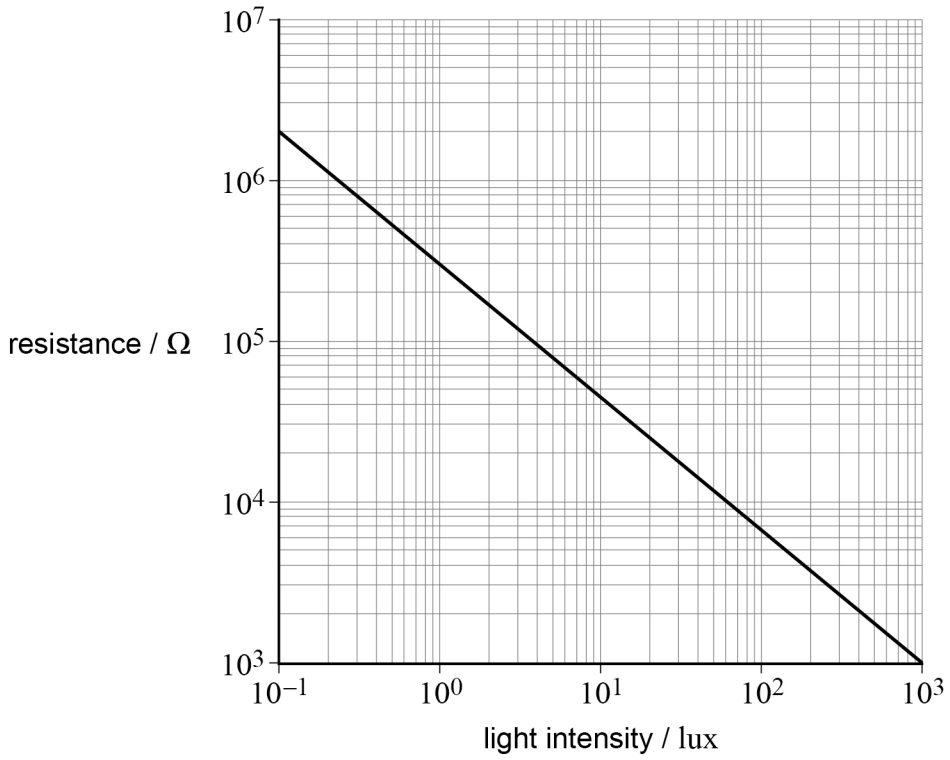
14

Turn over for the next question

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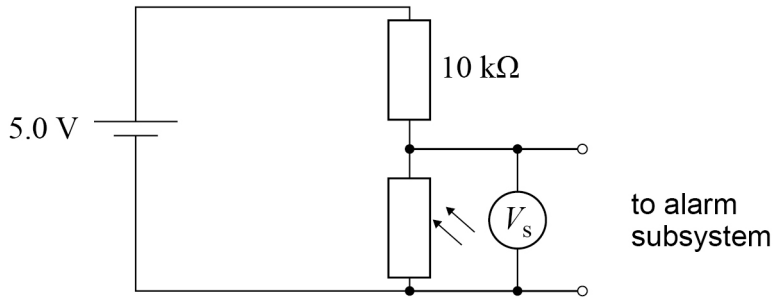
0 6 **Figure 11** shows how the resistance of an LDR varies with light intensity.

Figure 11



The LDR is used as part of an alarm system in a dim room. **Figure 12** 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.

Do not write outside the box

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** is suitable.
Support your answer with a calculation.

[3 marks]

5

END OF SECTION A

Turn over ►

Do not write outside the box

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 $3\ \text{kW h}$?

[1 mark]

A $3 \times 10^3\ \text{J}$ ⬭

B $1 \times 10^4\ \text{J}$ ⬭

C $2 \times 10^5\ \text{J}$ ⬭

D $1 \times 10^7\ \text{J}$ ⬭

0 8 Which is the shortest distance?

[1 mark]

A $10^{-19}\ \text{Gm}$ ⬭

B $10^{-14}\ \text{km}$ ⬭

C $10^{-4}\ \mu\text{m}$ ⬭

D $10^7\ \text{fm}$ ⬭

Do not write outside the box

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	$\overline{p}$	✓		✓	⬭
C	π^0	✓	✓	✓	⬭
D	ν_e		✓	✓	⬭

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 $\alpha + \beta^- + \beta^- + \alpha + \alpha$ ⬭

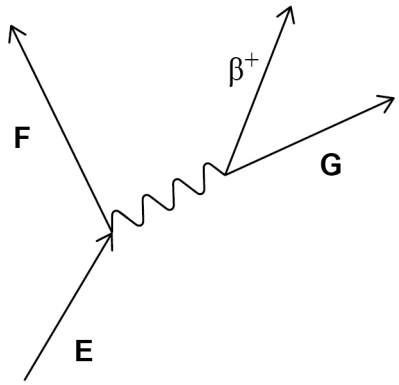
B $\beta^- + \beta^- + \alpha + \beta^- + \alpha$ ⬭

C $\alpha + \alpha + \alpha + \alpha + \beta^-$ ⬭

D $\beta^- + \beta^- + \beta^- + \beta^- + \alpha$ ⬭

Do not write outside the box

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	⬭

1 2 The quark combination of a particle is $s\bar{u}$.

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 $-\frac{1}{3}$ ⬭

Do not write outside the box

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 ⬭

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. ⬭

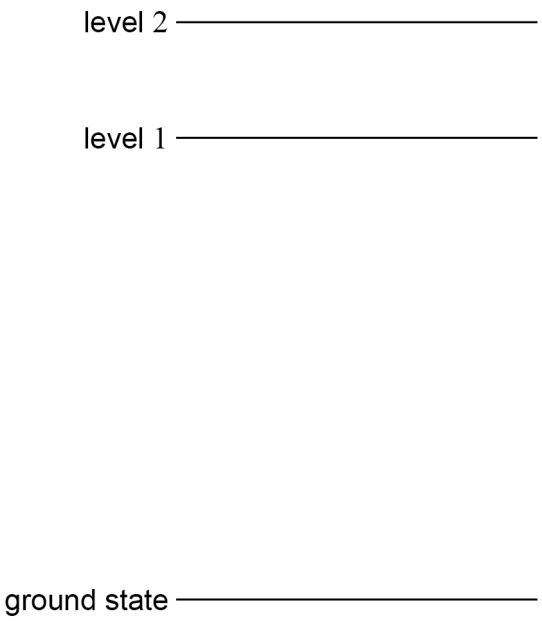
C It emits photons of visible light following ionisation or excitation. ⬭

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

Turn over for the next question

Do not write outside the box

1 5 The diagram shows the three lowest energy levels for an atom.
The energy levels have been drawn to scale.



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 ⬭

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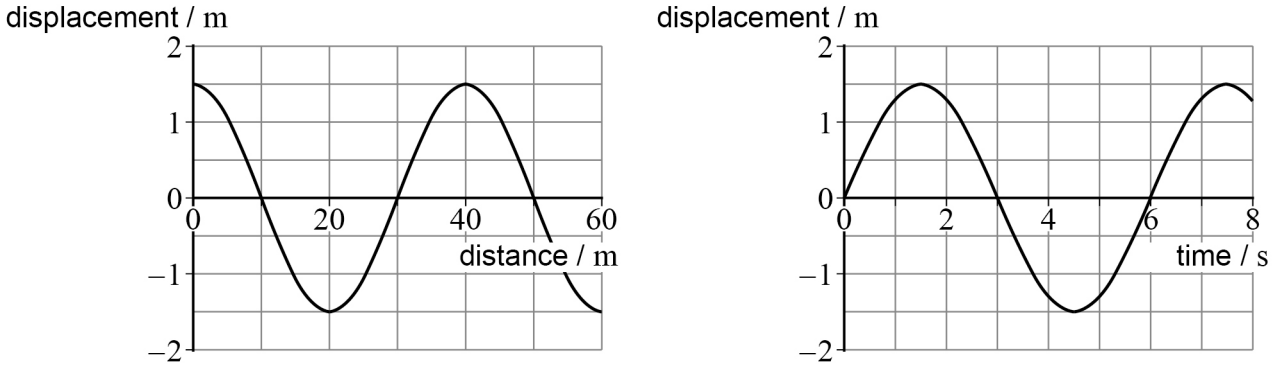
1 6 A muon and an electron are travelling at the same speed.

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	⬭

1 7 The diagrams show the displacement–distance graph for a wave and the displacement–time graph for a point in the wave.



Which is correct for this wave?

[1 mark]

A The amplitude is $3.0\ \text{m}$. ⬭

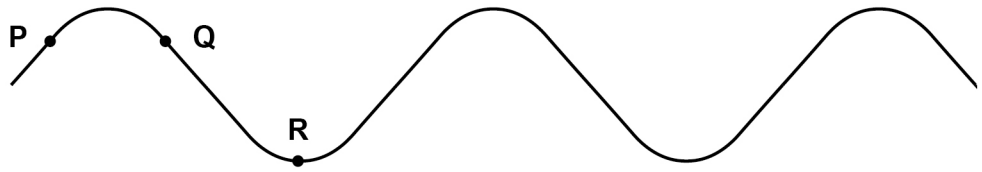
B The wavelength is $6\ \text{m}$. ⬭

C The speed is $8.3\ \text{m s}^{-1}$. ⬭

D The frequency is $0.17\ \text{Hz}$. ⬭

Do not write outside the box

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 $650\ \text{nm}$ occurs at the same angle as the third-order maximum for light of wavelength λ.

What is λ?

[1 mark]

A $217\ \text{nm}$ ⬭

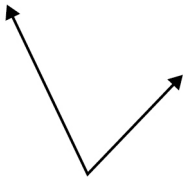
B $325\ \text{nm}$ ⬭

C $433\ \text{nm}$ ⬭

D $975\ \text{nm}$ ⬭

Do not write outside the box

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 ⬭

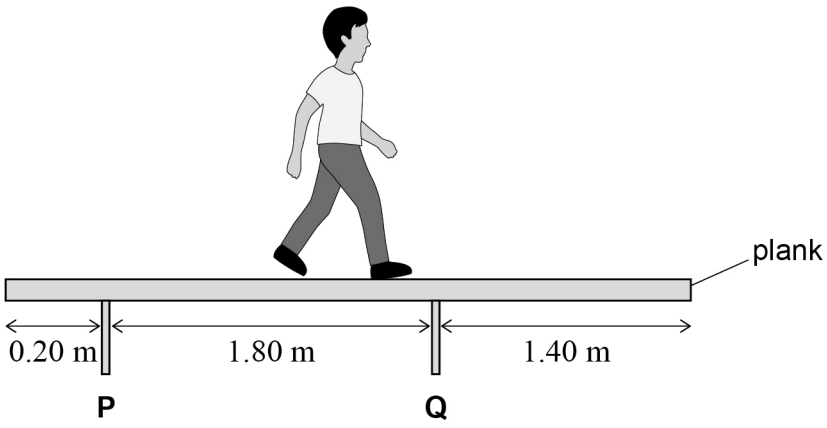
C 8.6 N ⬭

D 9.6 N ⬭

Turn over for the next question

Do not write outside the box

2 1 A uniform plank weighs $1200\ \text{N}$ and rests on two pillars **P** and **Q**.
P and **Q** are $1.80\ \text{m}$ apart.
P is $0.20\ \text{m}$ from one end of the plank. **Q** is $1.40\ \text{m}$ from the other end of the plank.
A man weighs $800\ \text{N}$ and walks along the plank away from pillar **P**.



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 $0.45\ \text{m}$ ⬭

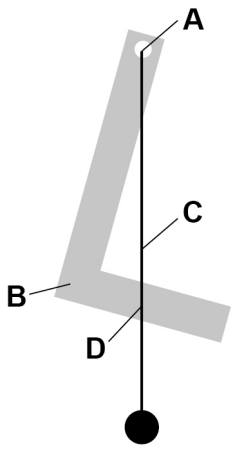
B $2.25\ \text{m}$ ⬭

C $2.45\ \text{m}$ ⬭

D $3.15\ \text{m}$ ⬭

Do not write outside the box

2 2 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 ⬭

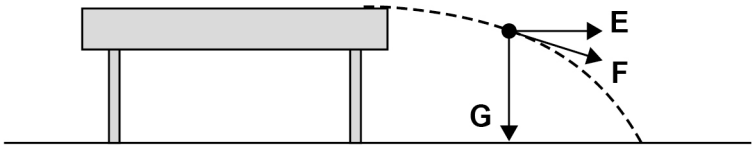
C ⬭

D ⬭

Turn over for the next question

Do not write outside the box

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. ⬭

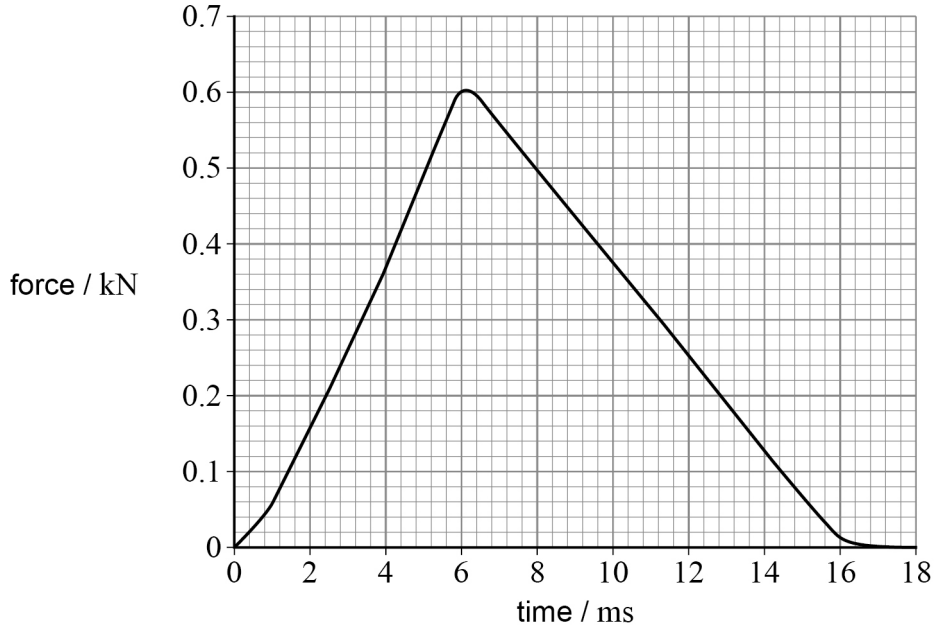
B the drag forces on the car decrease. ⬭

C the maximum speed of the car increases. ⬭

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

Do not write outside the box

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.



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 for the next question

Do not write outside the box

2 6 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 $2d$.

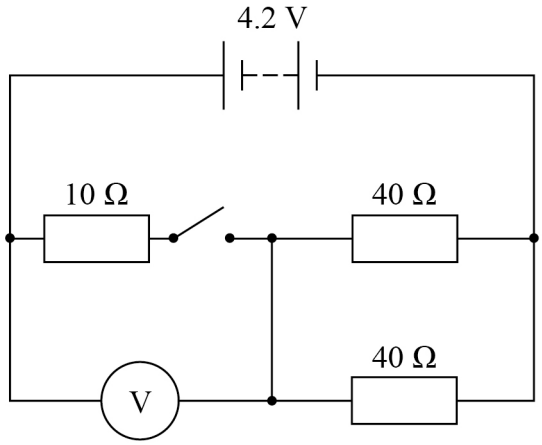
What are the density and the Young modulus of the metal from which **Y** is made?

[1 mark]

	Density	Young modulus	
A	$\frac{\rho}{2}$	$\frac{E}{4}$	⬭
B	$\frac{\rho}{2}$	$4E$	⬭
C	$\frac{\rho}{4}$	$\frac{E}{4}$	⬭
D	$\frac{\rho}{4}$	$4E$	⬭

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2 7 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)?

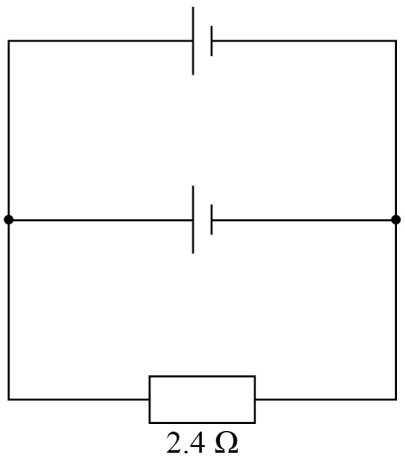
[1 mark]

	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 for the next question

Do not write outside the box

2 8 Two identical batteries each of emf $1.5\ \text{V}$ and internal resistance $1.6\ \Omega$ are connected in parallel. A $2.4\ \Omega$ resistor is connected in parallel with this combination.



What is the current in the $2.4\ \Omega$ resistor?

[1 mark]

A $0.38\ \text{A}$ ⬭

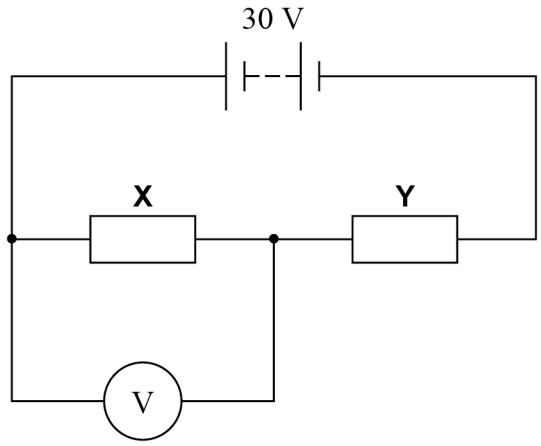
B $0.47\ \text{A}$ ⬭

C $0.75\ \text{A}$ ⬭

D $0.94\ \text{A}$ ⬭

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2 9 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 $10\ \text{V}$ ⬭

B $15\ \text{V}$ ⬭

C $20\ \text{V}$ ⬭

D $24\ \text{V}$ ⬭

Turn over for the next question

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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 $\frac{mA^2}{2T^2}$ ⬭

B $\frac{\pi^2 mA^2}{2T^2}$ ⬭

C $\frac{2mA^2}{T^2}$ ⬭

D $\frac{2\pi^2 mA^2}{T^2}$ ⬭

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