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

Friday 23 May 2025 | Morning | 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	
8	
9–33	
TOTAL	

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Section A

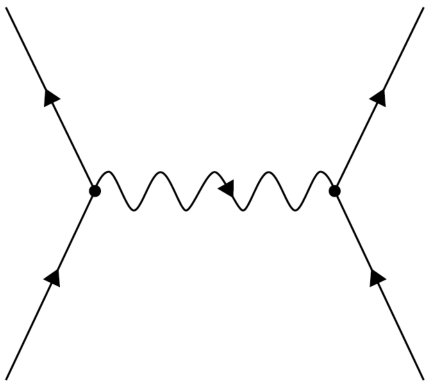
Answer **all** questions in this section.

0 1 This question is about an isotope of titanium that **only** decays by electron capture.

0 1 . 1 Complete **Figure 1** to show the quark change that occurs during electron capture. Label the incoming and outgoing particles and the exchange particle.

[3 marks]

Figure 1



0 1 . 2 In some circumstances, a nucleus of this isotope can exist with **no** orbiting electrons.

Explain why a neutral atom of this isotope is less stable than a nucleus that has no orbiting electrons.

[1 mark]

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0 1 . 3 A nucleus of this isotope of titanium has a proton number of 22 and a specific charge of $4.8 \times 10^{7}\ \mathrm{C\ kg^{-1}}$.

Determine the number of neutrons in this nucleus.

[2 marks]

number of neutrons = ____________________

6

Turn over for the next question

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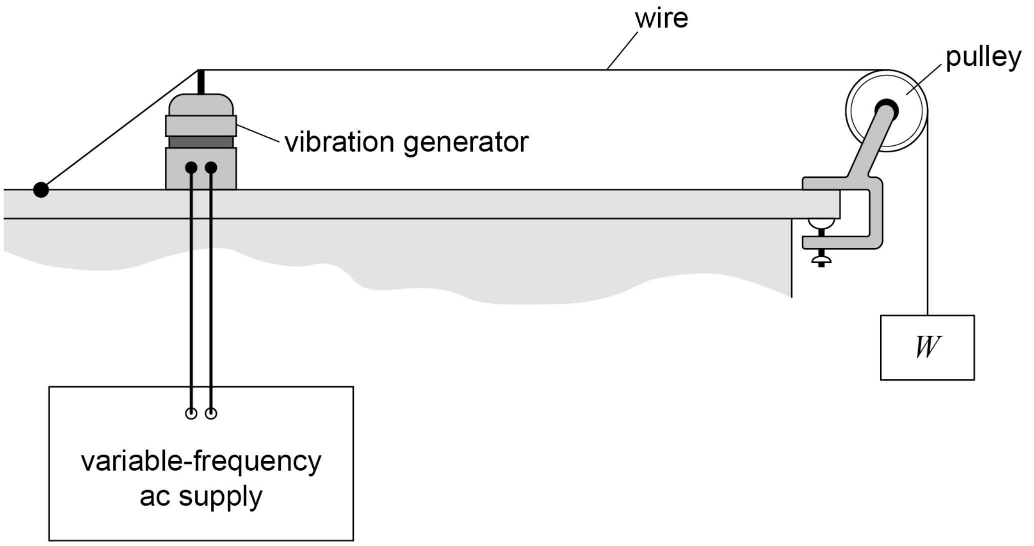
0 2 . 1 State what is meant by a transverse wave.

[2 marks]

Figure 2 shows apparatus that is used to investigate stationary waves on a stretched wire.

Figure 2



A block of weight W is used to keep the wire under tension.

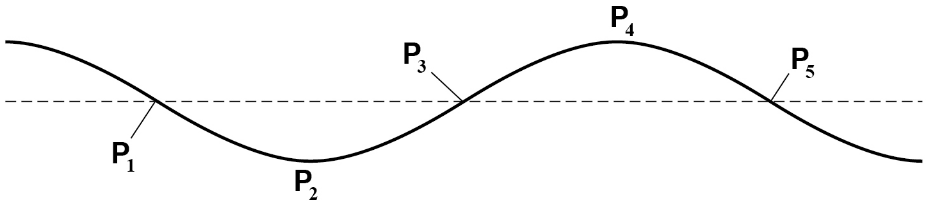
The frequency of the ac supply is varied until a stationary wave is produced on the wire.

0 2 . 2 Explain how a stationary wave is produced on the wire.

[1 mark]

0 2 . 3 **Figure 3** shows a small section of the wire at one instant.
Five points on the wire are labelled $\mathbf{P_1}$ to $\mathbf{P_5}$.
The dashed line represents the position of the wire when the ac supply is turned off.

Figure 3



Describe how the phase of the oscillating particles varies along the wire between $\mathbf{P_1}$ and $\mathbf{P_5}$.

[2 marks]

Question 2 continues on the next page

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0 2 . 4 A student investigates stationary waves on a wire using the apparatus in **Figure 2**. The investigation requires the student to produce the first five harmonics on the wire.

The student needs to choose **one** of two wires, **A** or **B**, for the investigation.

The mass of a $2.00\ \mathrm{m}$ length of wire **A** is $1.32\ \mathrm{g}$.
The mass of a $2.00\ \mathrm{m}$ length of wire **B** is $2.94\ \mathrm{g}$.

The ac supply can produce signals in the range $1\ \mathrm{Hz}$ to $50\ \mathrm{Hz}$.
The length of the wire that vibrates between the vibration generator and the pulley is $1.50\ \mathrm{m}$.

The student needs to choose **one** value for weight W for the investigation.
W can be either $1.0\ \mathrm{N}$ or $5.0\ \mathrm{N}$.

Determine, in $\mathrm{kg\ m^{-1}}$, the mass per unit length of each wire.
Go on to suggest which wire and which value of W the student should use to produce the first five harmonics.

[5 marks]

mass per unit length of **A** = ______________________ $\mathrm{kg\ m^{-1}}$

mass per unit length of **B** = ______________________ $\mathrm{kg\ m^{-1}}$

wire = ______________________ W = ______________________ N

10

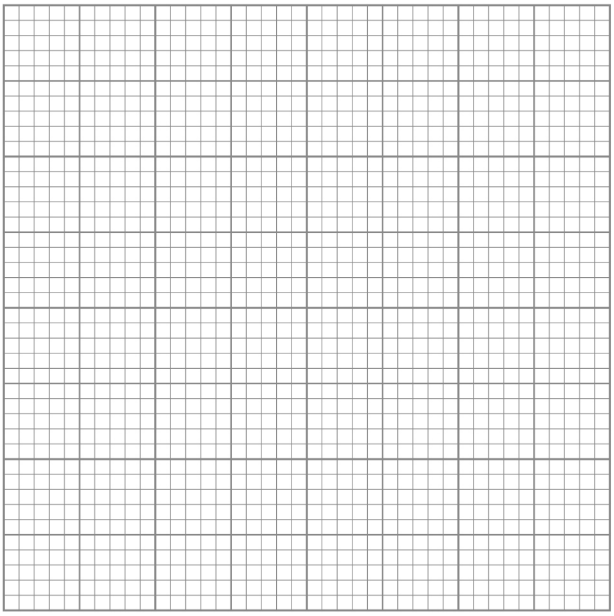
Do not write outside the box

0 3 A mass–spring system is undergoing simple harmonic motion (SHM).
The maximum velocity of the mass is $0.39\ \mathrm{m\ s^{-1}}$ and the period of oscillation is $0.81\ \mathrm{s}$.

0 3 . 1 Draw, on **Figure 4**, a graph of acceleration against displacement for the system.
Label each axis with a suitable unit and scale.

[4 marks]

Figure 4



0 3 . 2 Label, with a **P**, a point on your graph where the mass has 50% of its maximum kinetic energy.

[1 mark]

5

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0 4 . 1 Explain why the Young modulus and the breaking stress of a wire have the same SI unit.

[1 mark]

Table 1 contains data about four metal wires **W**, **X**, **Y** and **Z**.

Table 1

Wire	Length / m	Diameter / mm	Stiffness / $N\ m^{-1}$	Density / $kg\ m^{-3}$
W	3.10	1.7	4.90×10^4	2.71×10^3
X	2.17	1.4	5.25×10^4	1.93×10^4
Y	2.50	1.2	5.25×10^4	8.91×10^3
Z	2.50	1.2	3.08×10^4	2.71×10^3

0 4 . 2 The metal used to make wire **X** costs £75 per gram.

Calculate, in £, the cost of wire **X**.

[3 marks]

cost = £ ________________

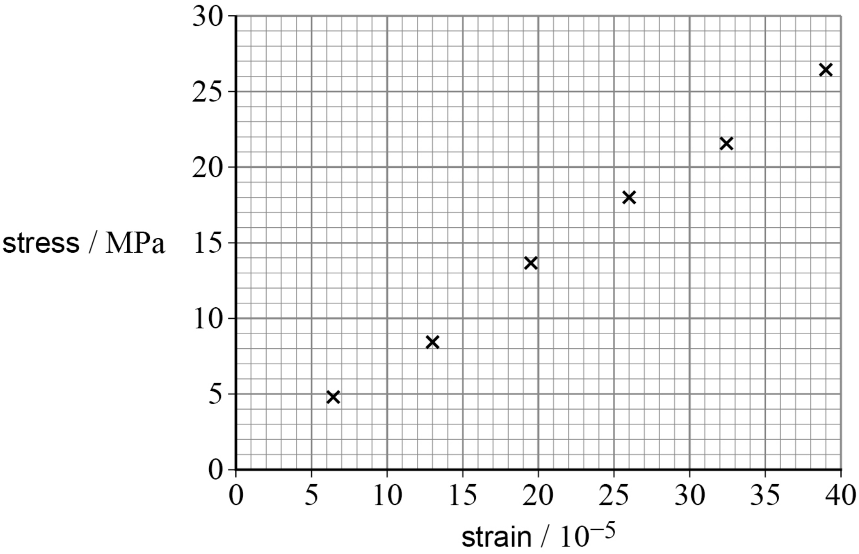
0 4 . 3 State and explain which of the wires in **Table 1** are made from the same material.

[1 mark]

Do not write outside the box

0 4 . 4 One of the wires in **Table 1** was used to obtain the stress–strain data shown in **Figure 5**.

Figure 5



Draw a line of best fit on **Figure 5**.
Go on to deduce, using your line of best fit and **Table 1**, whether wire **W** could have been used to produce **Figure 5**.

[4 marks]

9

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0 5 This question is about the batteries used to store energy in electric vehicles.
Each battery is a series of modules. Each module is an array of identical cells.

Table 2 shows the properties of one of these cells.

Table 2

emf	3.66 V
internal resistance	30.0 mΩ
maximum current	6.77 A

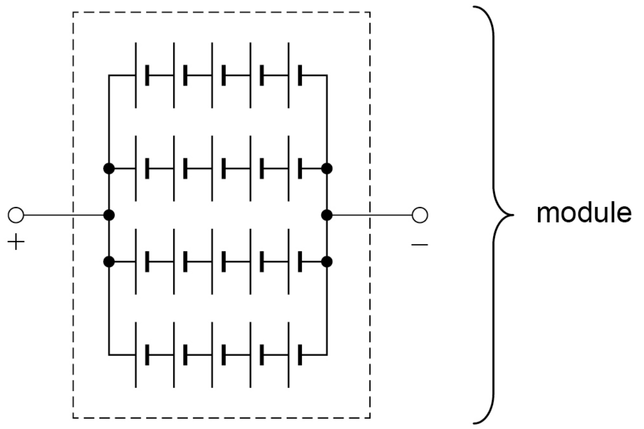
0 5 . 1 Calculate the terminal potential difference of the cell at its maximum current.

[1 mark]

terminal potential difference = ____________________ V

0 5 . 2 **Figure 6** shows an array of 20 of these cells connected to form a module.

Figure 6



Calculate the internal resistance of the module shown in **Figure 6**.

[2 marks]

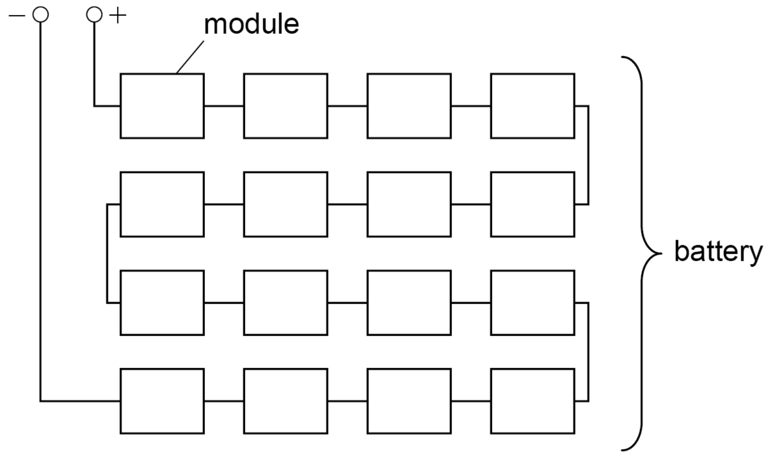
internal resistance = ____________________ Ω

Do not write outside the box

0 5 . 3 **Figure 7** shows the battery for an electric vehicle.
This battery has an emf of 352 V and gives a maximum current of 500 A.

The battery consists of a series of identical modules.
These modules are **different** from the module shown in **Figure 6**.

Figure 7



The individual cells used in each module have the properties shown in **Table 2**.

Deduce the number of cells in each module.

[3 marks]

number of cells = ____________________

6

Turn over ►

0 6 A person kicks a stationary football horizontally.

During the kick, the person gives an impulse of $6.55\ \mathrm{N\ s}$ to the ball during a contact time of $12.0\ \mathrm{ms}$.
The mass of the football is $410\ \mathrm{g}$.
Assume that friction forces are negligible.

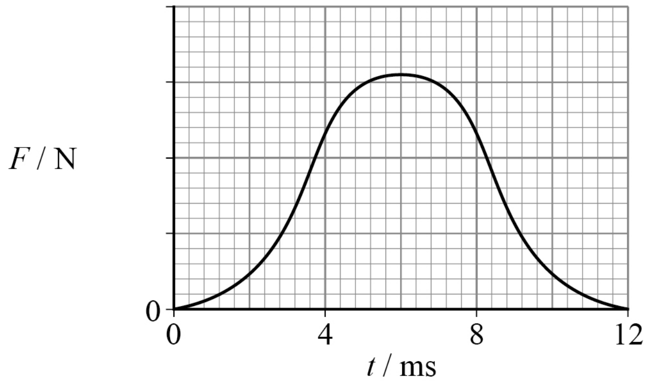
0 6 . 1 Calculate the kinetic energy transferred to the ball during the kick.

[2 marks]

kinetic energy = ______________________ J

0 6 . 2 **Figure 8** shows how the force F acting on the ball varies with time t.

Figure 8



Determine the scale for the F / N axis and add your scale to **Figure 8**.

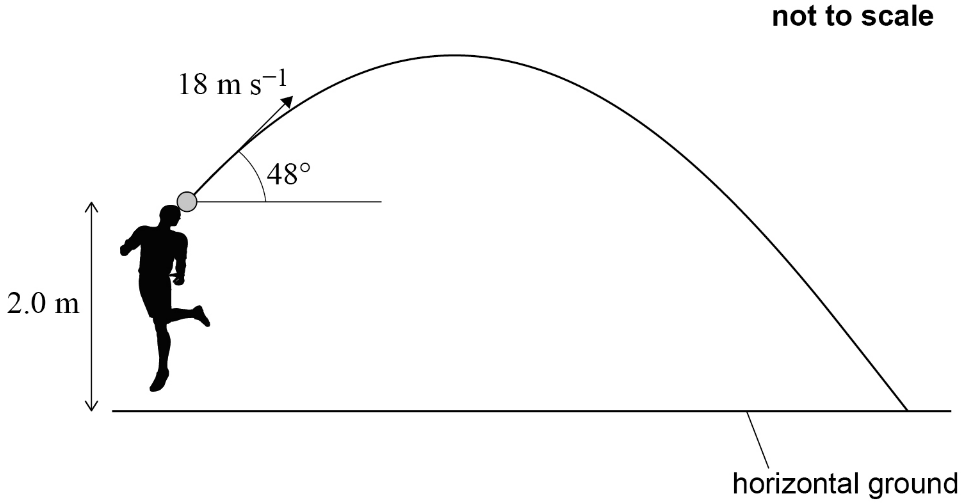
[3 marks]

Do not write outside the box

0 6 . 3 A player jumps up to head a football when it is 2.0 m above the ground. The initial velocity of the ball is 18 m s^{-1} at an angle of $48°$ to the horizontal.

Figure 9 shows the path of the ball above horizontal ground.

Figure 9



Determine the time that the ball takes to reach the ground from the instant it leaves the player's head.

Assume that the frictional forces acting on the ball are negligible.

[3 marks]

time = ______________________ s

8

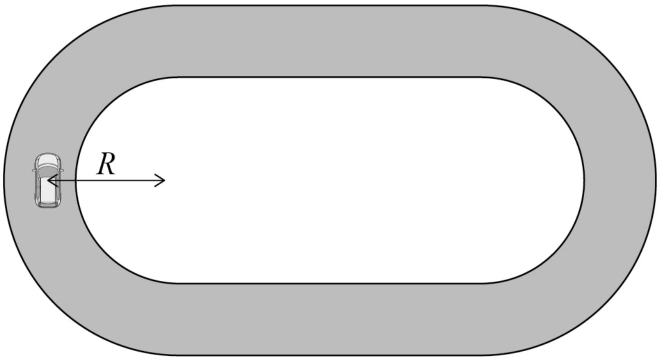
Turn over for the next question

0 7 A racing car of mass m travels around a horizontal oval track. The curved sections of the track are semicircles.

0 7 . 1 At the instant shown in **Figure 10** the car is moving with constant speed v in a circle of radius R.

Figure 10

not to scale



The car has kinetic energy E_k.

The resultant force acting on the car is F.

Show that $R = \frac{2E_k}{F}$

[2 marks]

The maximum centripetal force that can be produced between the car's tyres and the track is $24\ \text{kN}$.
The minimum value of R is $230\ \text{m}$.

$m = 1600\ \text{kg}$

0 7 . 2 The car just starts to slip when it travels on the track in a circular path of radius $230\ \text{m}$.

Deduce the speed of the car.

[1 mark]

speed = ______________________ m s^{-1}

0 7 . 3 The driver wishes to drive this car around the curved section of the track, without slipping, at a speed greater than your answer to Question **07.2**.

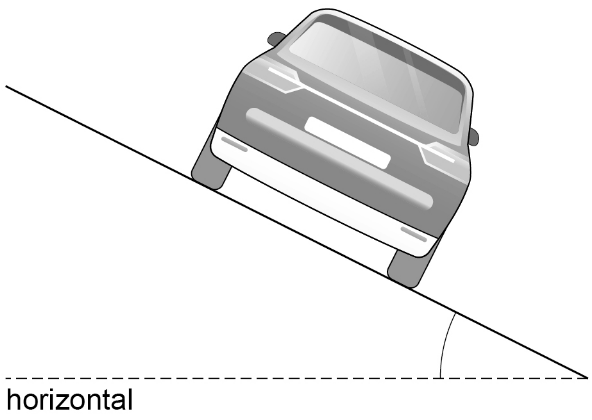
Suggest **one** way in which the driver can achieve this.

[1 mark]

Figure 11 shows the car on the curved section of a different oval track.
The curved section of this track is a slope. This means that cars can travel at greater speeds than on the track shown in **Figure 10**.

Figure 11

not to scale



0 7 . 4 The car in **Figure 11** stays at the same height on the curved section of the track. There is no tendency for the car to slip up or down the track and therefore there is no sideways friction on the tyres.

Draw and label, on **Figure 11**, arrows to show the direction of each force that acts on the car as it travels around the curved section of the track.

[2 marks]

Question 7 continues on the next page

Do not write outside the box

0 7 . 5 A car has a greater maximum speed on a sloped track than on a horizontal track of the same radius.

Explain why.

[2 marks]

8

Do not write outside the box

0 8 Electrons in a fluorescent tube are accelerated from rest by a potential difference of 130 V.

0 8 . 1 Calculate the maximum speed of an electron that is accelerated from rest by this potential difference.

[2 marks]

maximum speed = ______________________ $m\ s^{-1}$

0 8 . 2 Explain why the average speed of the electrons in the tube is much less than the maximum speed you calculated in Question **08.1**.

[1 mark]

____

____

____

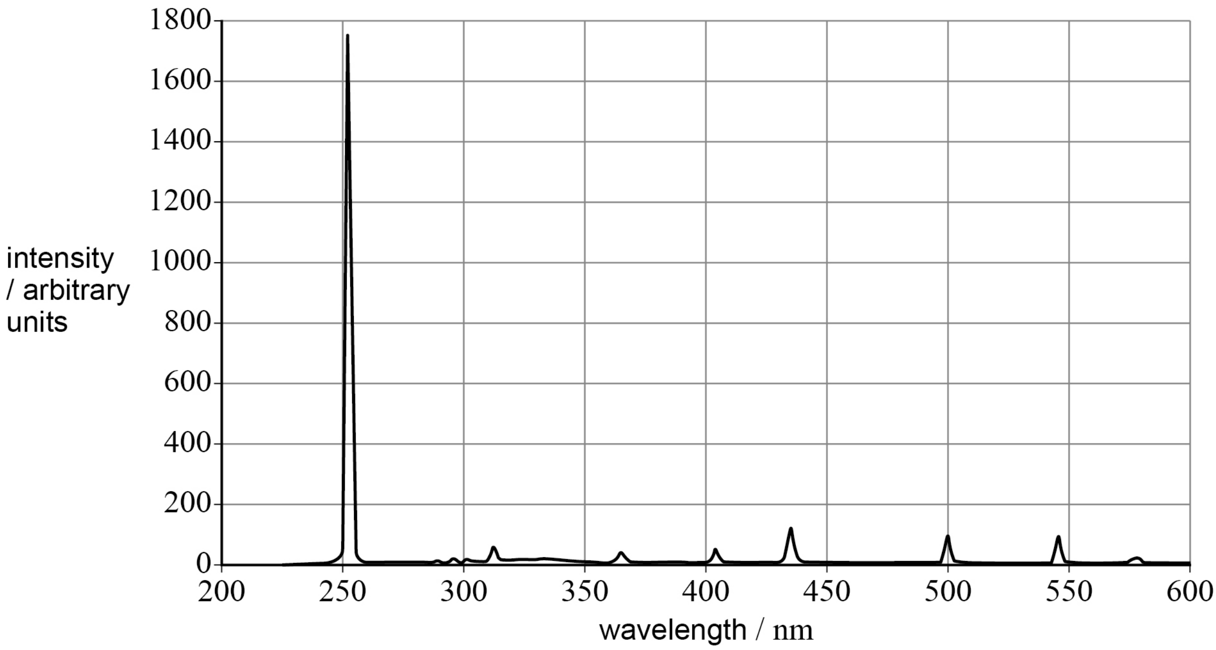
____

Question 8 continues on the next page

0 8 . 3 Scientists want to replace the mercury in fluorescent tubes with substance **X**.

Figure 12 is an emission spectrum for **X**.

Figure 12



White light consists of the whole range of visible wavelengths from 380 nm to 700 nm.

Explain, with reference to **Figure 12**, whether white light can be produced by a fluorescent tube that uses **X**.

[2 marks]

Do not write outside the box

0 8 . 4 **Figure 12** shows a maximum intensity peak that occurs at wavelength λ_{peak}.

Calculate, in eV, the energy change of an atom that produces a photon with a wavelength λ_{peak}.

[3 marks]

energy change = ____________________ eV

8

END OF SECTION A

Section B

Each of Questions **09** to **33** 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 9 The following equation represents a strong interaction between particle **X** and a proton.

$$\mathbf{X} + \mathrm{p} \rightarrow \mathrm{n} + \pi^0$$

What is the quark configuration of **X**?

[1 mark]

A $\bar{\mathrm{u}}\bar{\mathrm{u}}\bar{\mathrm{d}}$ ○

B $\mathrm{s}\bar{\mathrm{u}}$ ○

C $\mathrm{d}\bar{\mathrm{u}}$ ○

D $\mathrm{u}\bar{\mathrm{d}}$ ○

Do not write outside the box

1 0 In β^- decay:

[1 mark]

A energy is conserved.

B an up quark changes into a down quark.

C the interaction occurs outside the nucleus of an atom.

D momentum is not conserved.

1 1 A force F moves through a distance x in the direction of F.

In which row is the work done by the force 1 J?

[1 mark]

	F	x
A	1 mN	1 km
B	100 kN	100 μm
C	100 MN	100 nm
D	1 GN	1 fm

1 2 In a photoelectric effect experiment, monochromatic light is incident on a metal surface and the stopping potential is measured.

Which change results in a greater stopping potential?

[1 mark]

A using a metal that has a greater work function

B using a light source that emits more photons per second

C using a light source that emits light of a shorter wavelength

D using a metal surface that has a positive charge

Turn over ►

Do not write outside the box

1 3 Which row provides evidence for the particle nature of light and the wave nature of light?

[1 mark]

	Evidence for particle nature	Evidence for wave nature	
A	line spectra	photoelectric effect	⬭
B	diffraction	line spectra	⬭
C	photoelectric effect	diffraction	⬭
D	photoelectric effect	line spectra	⬭

1 4 In an investigation of stationary waves on different wires, the frequency f of the first harmonic is measured.

Which quantity produces a straight-line graph through the origin when plotted against f? In each case all other variables are kept constant.

[1 mark]

A $\dfrac{1}{\text{diameter of the wire}}$ ⬭

B (mass per unit length of the wire)^2 ⬭

C length of the wire ⬭

D (tension in the wire)^2 ⬭

1 5 A student derives the equation $n\lambda = d\sin\theta$ for the production of a diffraction pattern on a screen.
This derivation requires that:

[1 mark]

A the diffraction angle θ is a small angle. ⬭

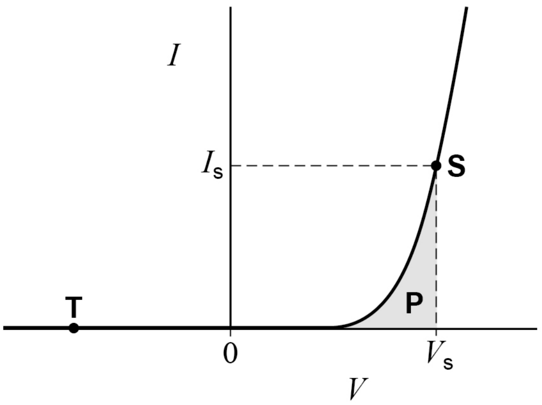
B d is the number of slits per unit length. ⬭

C light from adjacent slits arrives at the screen in phase. ⬭

D $n\lambda$ is greater than or equal to d, where n is a whole number. ⬭

Do not write outside the box

1 6 The graph shows the I–V characteristic for a semiconductor diode.



Which is true for this graph?

[1 mark]

A The resistance of the diode decreases as V increases for $V > V_s$. ⬭

B The resistance at **S** is equal to $\frac{1}{\text{gradient}}$ ⬭

C The resistance at **T** is equal to zero. ⬭

D At $I = I_s$, the power dissipated in the diode is equal to area **P**. ⬭

1 7 Monochromatic light of wavelength λ is used in a double-slit experiment.
The slits are vertical and have a separation s.
A narrow screen of width Y is placed a distance D from the slits.

Which gives the number of fringes observed on the screen?

[1 mark]

A $\frac{\lambda D}{sY}$ ⬭

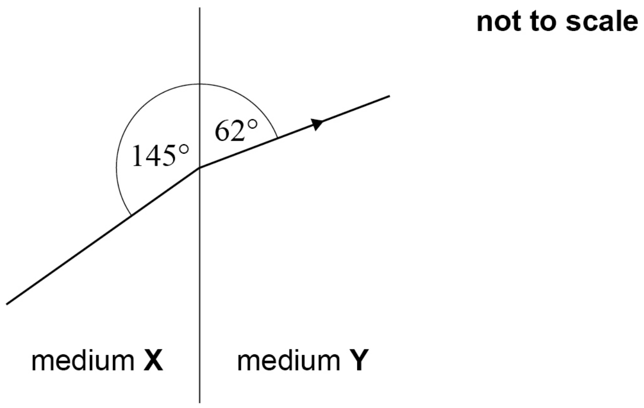
B $\frac{\lambda s}{DY}$ ⬭

C $\frac{DY}{s\lambda}$ ⬭

D $\frac{Ys}{\lambda D}$ ⬭

Do not write outside the box

1 8 A light ray passes from medium **X** to medium **Y**.



The refractive index of **X** is 1.33

What is the refractive index of **Y**?

[1 mark]

A 0.86

B 1.22

C 1.74

D 2.32

1 9 The critical angle at a boundary between two media is 53°.
The speed of light in one medium is 2.6×10^{8} m s^{-1}.

What is the speed of light in the other medium?

[1 mark]

A 1.6×10^{8} m s^{-1}

B 2.1×10^{8} m s^{-1}

C 3.0×10^{8} m s^{-1}

D 3.2×10^{8} m s^{-1}

2 0 Monochromatic light of wavelength $420\ \text{nm}$ is incident normally on a plane transmission diffraction grating that has a slit separation of $3.6\ \mu\text{m}$.

What is the total number of maxima produced by the grating?

[1 mark]

A 8

B 9

C 16

D 17

2 1 A skydiver is falling at a terminal velocity v_1.
When she is at a height h_1 she opens her parachute.
When she is at a height h_2 she reaches a new terminal velocity v_2.

Which is true?

[1 mark]

A The increased air resistance when her height is h_1 causes her initially to move upwards.

B The drag force when her velocity is v_2 is equal to the drag force when her velocity is v_1.

C At v_1, her weight and the drag force are an action–reaction pair according to Newton's third law.

D Between h_1 and h_2, the work done by the drag force is equal to the change in the kinetic energy of the parachute and skydiver.

Turn over for the next question

Do not write outside the box

2 2 The work function of a metal is ϕ.

A photon with an energy of 3.8×10^{-19} J is incident on the metal surface.

Electrons are emitted from the surface with a maximum speed of 2.5×10^{5} m s^{-1}.

What is ϕ?

[1 mark]

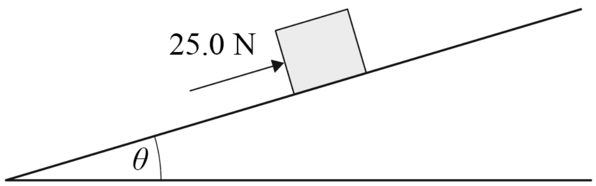
A 0.29×10^{-19} J

B 3.5×10^{-19} J

C 3.8×10^{-19} J

D 4.1×10^{-19} J

2 3 A ramp is inclined at an angle θ to the horizontal.
A block of weight 240 N is pushed up the ramp by a 25.0 N force. This force acts parallel to the ramp.
The block experiences a frictional force of 3.0 N.
The block moves at a constant speed.



What is θ?

[1 mark]

A 0.12°

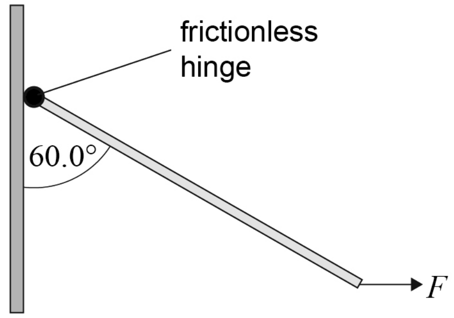
B 5.3°

C 6.0°

D 6.7°

2 4 A uniform wooden rod of mass $0.55\ \mathrm{kg}$ and length $1.3\ \mathrm{m}$ is attached to a wall by a light frictionless hinge.

A horizontal force F acts so that the rod hangs at an angle of $60.0°$ to the vertical.



What is the magnitude of F?

[1 mark]

A $0.95\ \mathrm{N}$ ○

B $1.6\ \mathrm{N}$ ○

C $2.7\ \mathrm{N}$ ○

D $4.7\ \mathrm{N}$ ○

2 5 A pendulum is oscillating with simple harmonic motion.

Which row gives the momentum of the pendulum bob and its gravitational potential energy (GPE) when the acceleration of the pendulum bob is zero?

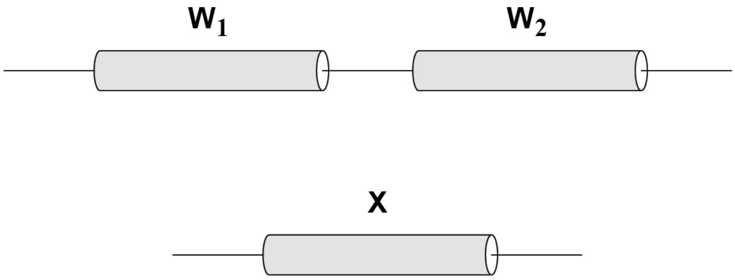
[1 mark]

	Momentum	**GPE**	
A	zero	maximum	○
B	maximum	minimum	○
C	maximum	maximum	○
D	zero	minimum	○

Turn over ►

Do not write outside the box

2 6 Two thin metal rods **W_1** and **W_2**, each of length L and diameter d, are connected in series.



The resistivity of **W_1** is ρ_1 and the resistivity of **W_2** is ρ_2.

A single metal rod **X**, also of length L and diameter d, has the same resistance as the series combination of **W_1** and **W_2**.

What is the resistivity of **X**?

[1 mark]

A $\rho_1 + \rho_2$

B $\dfrac{\rho_1 + \rho_2}{2}$

C $\dfrac{\rho_1 + \rho_2}{\rho_1 \rho_2}$

D $\dfrac{\rho_1 \rho_2}{\rho_1 + \rho_2}$

2 7 An alpha particle has a speed of 4.5×10^5 m s^{-1}.

What is the de Broglie wavelength of the alpha particle?

[1 mark]

A 2.2×10^{-13} m

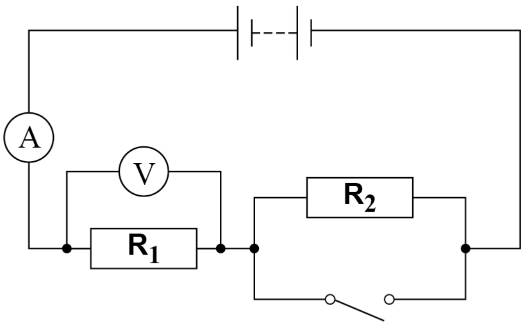
B 4.4×10^{-13} m

C 8.8×10^{-13} m

D 3.9×10^{-12} m

Do not write outside the box

2 8 In a circuit, the resistance of resistor $\mathbf{R_1}$ is double the resistance of resistor $\mathbf{R_2}$.
The internal resistance of the battery is negligible.



When the switch is open, the voltmeter reads $12\ \mathrm{V}$ and the ammeter reads $12\ \mathrm{mA}$.

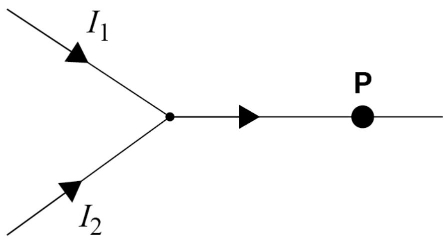
What are the readings on the voltmeter and ammeter when the switch is closed?

[1 mark]

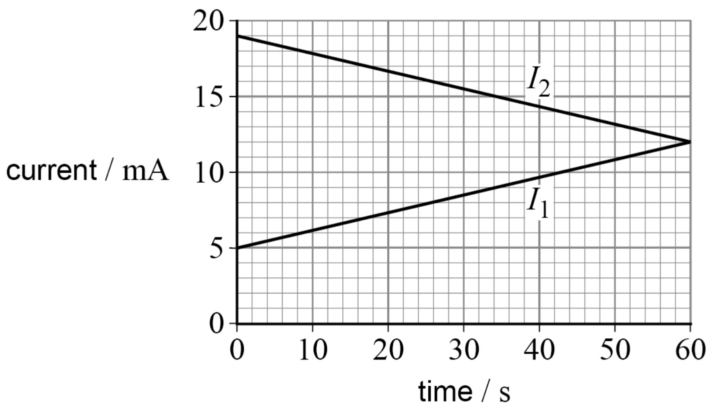
	Voltmeter reading / V	Ammeter reading / mA	
A	4	12	⬭
B	18	12	⬭
C	18	18	⬭
D	24	24	⬭

Turn over for the next question

2 9 The diagram shows part of a circuit.



The graph shows how the two currents I_1 and I_2 vary with time.



What is the total charge that flows through point **P** in 60 s?

[1 mark]

A 1.44 C ⬭

B 0.93 C ⬭

C 0.72 C ⬭

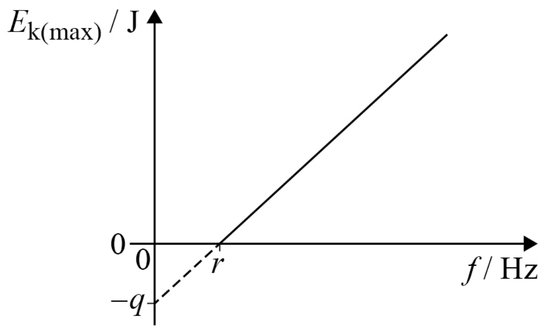
D 0.42 C ⬭

Do not write outside the box

3 0 In a photoelectric experiment, the maximum kinetic energy $E_{k(max)}$ of the emitted electrons and the frequency f of the incident radiation are measured.

A graph of the variation of $E_{k(max)}$ with f has:

- a gradient p
- an intercept $-q$ on the $E_{k(max)}$ axis
- an intercept r on the f axis.



What is the value of the Planck constant?

[1 mark]

A $\dfrac{p}{r}$ ⬭

B $\dfrac{r}{p}$ ⬭

C $\dfrac{r}{q}$ ⬭

D $\dfrac{q}{r}$ ⬭

Turn over for the next question

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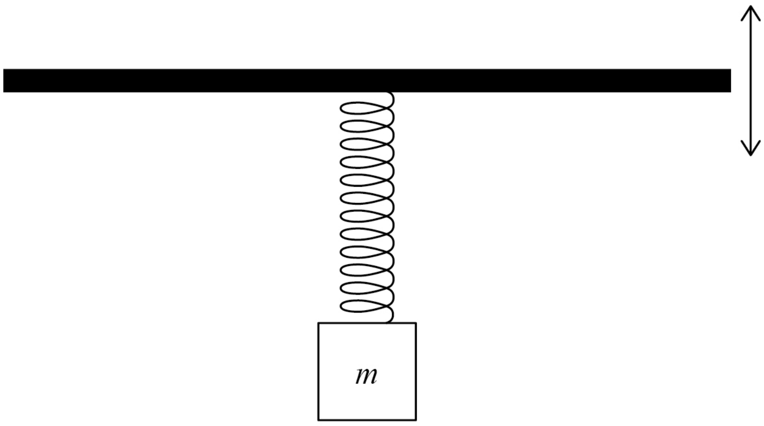
3 1 A spring with a spring constant of 50 N m^{-1} is attached to a rigid horizontal bar.
An object of mass m is attached to the bottom of the spring.

When the bar is made to move vertically up and down with a frequency of 2.6 Hz, the mass–spring system undergoes resonance.
Ignore the effects of damping.



What is m?

[1 mark]

A 190 g

B 370 g

C 490 g

D 590 g

3 2 A simple pendulum of length 8.0 cm oscillates on Earth with a frequency f_1.
An identical pendulum on the Moon oscillates with a frequency f_2.
The acceleration due to gravity is 1.6 m s^{-2} on the surface of the Moon.

What is $f_1 - f_2$?

[1 mark]

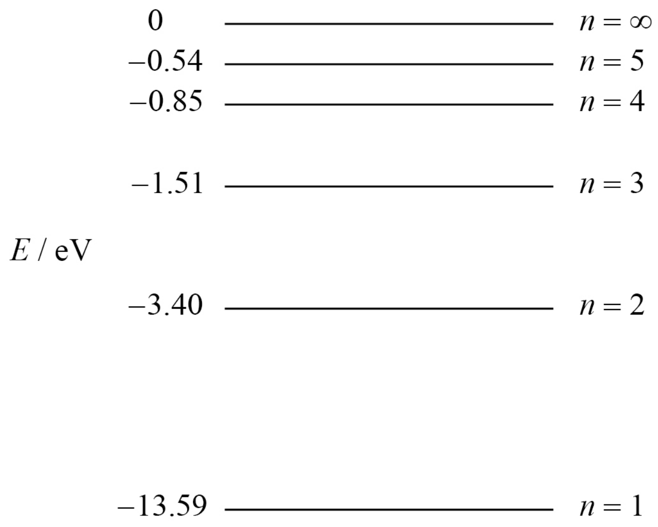
A 1.8 Hz

B 1.1 Hz

C 0.85 Hz

D 0.35 Hz

3 3 The diagram shows some of the energy levels for a hydrogen atom.



Photons of energy $12.74\ \text{eV}$ excite hydrogen atoms that are all initially in the ground state ($n = 1$).

How many different photon frequencies are emitted as the atoms return to their ground state?

[1 mark]

A 3 ⬭

B 5 ⬭

C 6 ⬭

D 9 ⬭

25

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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Question number	**Additional page, if required. Write the question numbers in the left-hand margin.**

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