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.

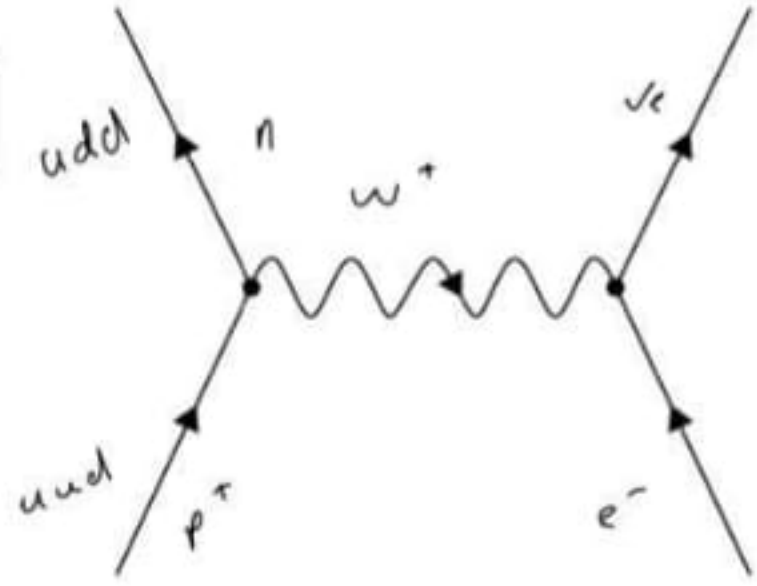
0 1 . 1 Complete **Figure 1** to show the quark change that occurs during electron capture. Label the incoming and outgoing particles and the exchange particle.

[3 marks]

Figure 1

$p^+ + e^- \rightarrow n + \nu_e$

In proton acts on the electron



LIGHT Q NGL

u → d

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]

A neutral atom is less stable as it has orbiting electrons to make it stable. Hence, electron capture can occur meaning the atom is unstable due to neutrons being produced

hence not considering electrons

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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 4.8×10^7 C kg^{-1}.

Determine the number of neutrons in this nucleus.

[2 marks]

A - total mass number = Z + N

Z - proton number

N - neutron number

m - mass of nucleus

$SC = \frac{Ze}{Am}$ $\quad \frac{Ze}{SCm} = 1$ $\quad \frac{Ze}{SCm} - Z = N$

$\frac{Ze}{Am} = Z + N$

$\frac{22(1.6\times10^{-19})}{4.8\times10^{7} \times 1.67\times10^{-27}} - 22 = N = 21.9$

↳ 22 neutrons

MORE AS🙃

number of neutrons = 22

6

Turn over for the next question

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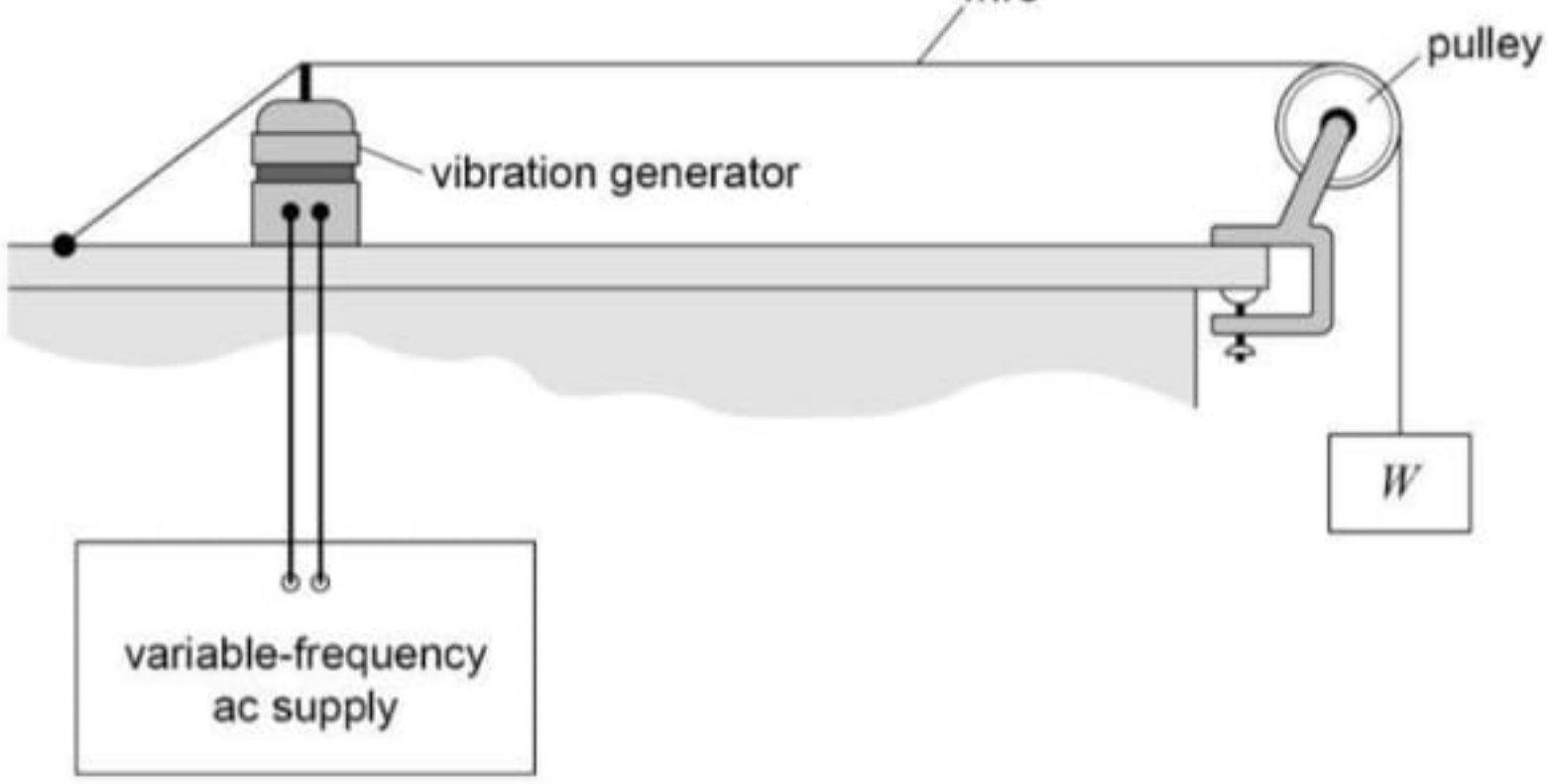
0 2 . 1 State what is meant by a transverse wave.

[2 marks]

A wave in which its energy propagation is perpendicular to the oscillations

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]

the wave reflects from the pulley/weight, these two waves with the same frequency and amplitude travel in opposite directions and superpose.

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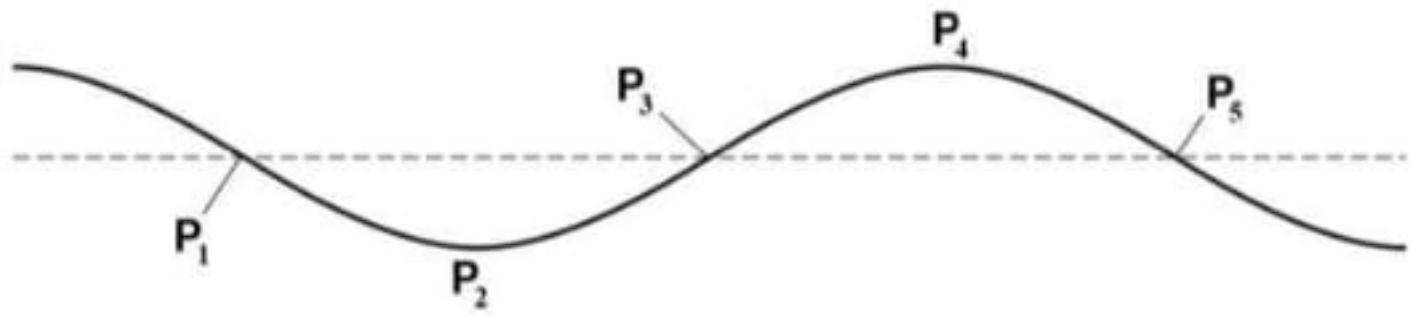
0 2 . 3 **Figure 3** shows a small section of the wire at one instant.
Five points on the wire are labelled P_1 to P_5. → Study room
The dashed line represents the position of the wire when the ac supply is turned off.

Figure 3



Describe how the phase of the oscillating particles varies along the wire between P_1 and P_5.

[2 marks]

- P_1, P_3, P_5 are in phase with eachj (nodes)
- P_2 and P_4 are in antiphase

CHEEKY STANDING WAVE PHASE QS 😀

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 m length of wire **A** is 1.32 g.
The mass of a 2.00 m length of wire **B** is 2.94 g.

MISSED THE BOTTOM BIT IN THE ACTUAL EXAM FFS

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

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

Determine, in 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.

$\mu = \frac{\text{mass}}{\text{length}}$ **[5 marks]**

μ_A (kg m^{-1}) $= \frac{1.32 \times 10^{-3}}{2} = 6.6 \times 10^{-4}$

$\mu_B = \frac{2.94 \times 10^{-3}}{2} = 1.47 \times 10^{-3}$

mass per unit length of **A** = 6.6×10^{-4} kg m^{-1}

mass per unit length of **B** = 1.4×10^{-3} kg m^{-1}

1N or 5N

length = 1.5m

f = 1Hz - 50Hz → for up to 5th harmonic

$f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$ where n is the harmonic number

A

1N - $f_5 = \frac{5}{2(1.5)}\sqrt{\frac{1}{6.6 \times 10^{-4}}} = 64.87\,Hz$ x too high

5N - $f_5 = \frac{5}{2(1.5)}\sqrt{\frac{5}{6.6 \times 10^{-4}}} = 145.06$ x too high

DECENT QS THO

B

1N - $f_5 = \frac{5}{2(1.5)}\sqrt{\frac{1}{1.47 \times 10^{-3}}} = 43.47$ ✓

5N - $f_5 = \frac{5}{2(1.5)}\sqrt{\frac{5}{1.47 \times 10^{-3}}} = 97.2$ x too high

wire = B W = 1N 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 $0.39\ \text{m s}^{-1}$ and the period of oscillation is $0.81\ \text{s}$.

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]

$a = (-)\omega^2 x$ hence $a \propto (-)x$

↳ should be appropriate to ignore this

hence line 1 or line 2 is acceptable

$V_{max} = \omega A$

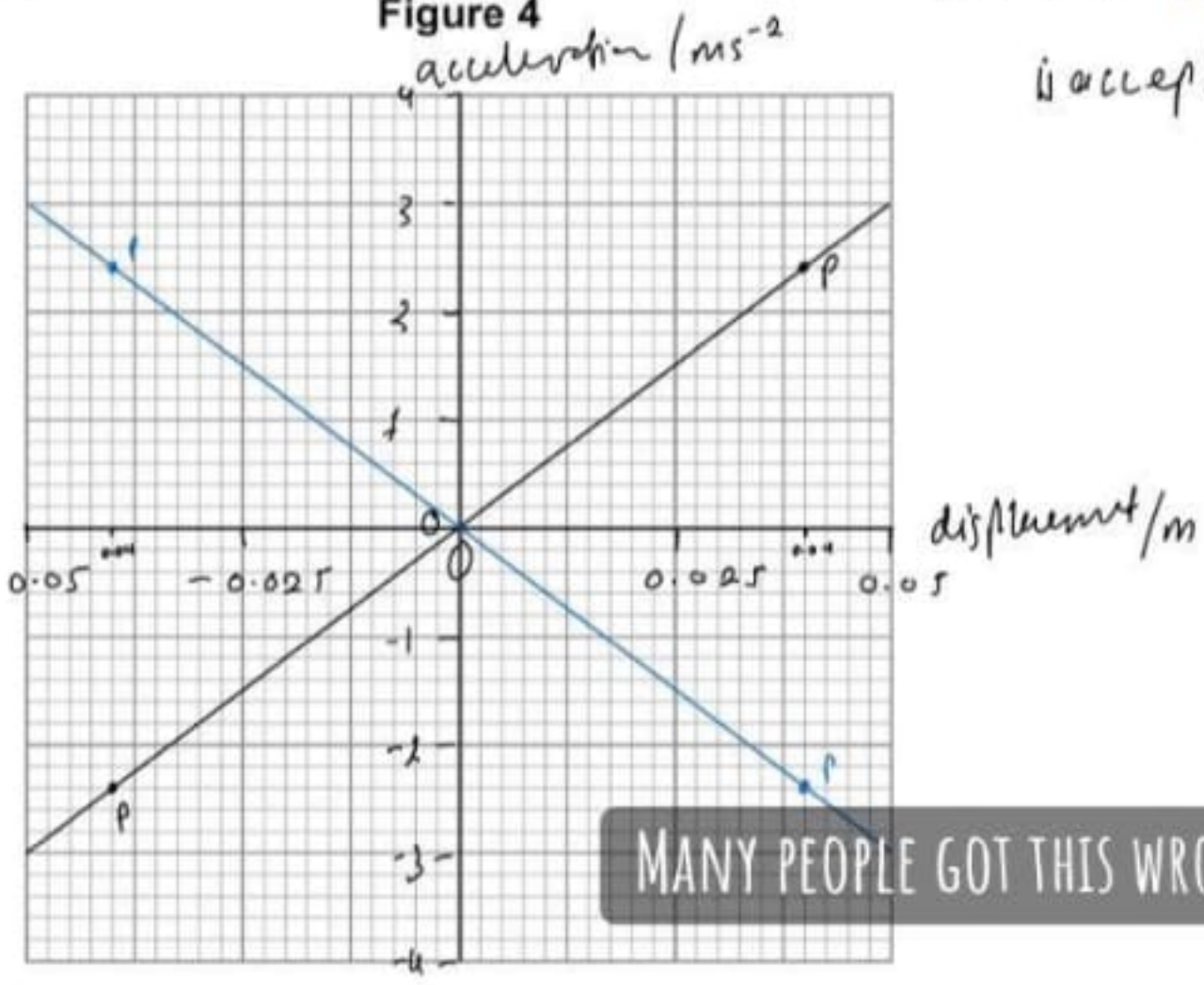
$\frac{0.39}{2\pi/0.81} = A = 0.05\text{m}$

$a_{max} = \omega^2 A$

$= \left(\frac{2\pi}{0.81}\right)^2 \cdot 0.05$

$= 3\text{ms}^{-2}$

Figure 4



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

(any three will be multiple)

[1 mark]

$V^2 = \omega^2(A^2 - x^2)$

$KE \propto (v)^2$

$0.5KE = (0.5v)^2$

$0.5ke = 0.25v^2$

$\sqrt{A^2 - \frac{0.25v^2}{\omega^2}} = x$

$= 0.05^2 - \frac{0.25 \cdot 0.39^2}{(2\pi/0.81)^2} = 0.04\text{m}$

5

Turn over ▶

Do not write outside the box

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

[1 mark]

$E = \frac{\text{stress}}{\text{strain}}$ strain has no units so E is with is the same as stress

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**. EXPENSIVE AHH WIRE 😭

[3 marks]

volume = Area × Length

$= \pi \left(\frac{1.4 \times 10^{-3}}{2} \right)^2 \times 2.17 = 3.34 \times 10^{-6} \text{ m}^3$

$\rho = \frac{\text{mass}}{\text{volume}}$ $\rho \cdot V = m = 3.34 \times 10^{-6} \times 1.93 \times 10^4$

$= 0.064 \text{ kg} = 64.47 \times 75 = £4835$

cost = £ 4835

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

[1 mark]

W and Z are by have the same density

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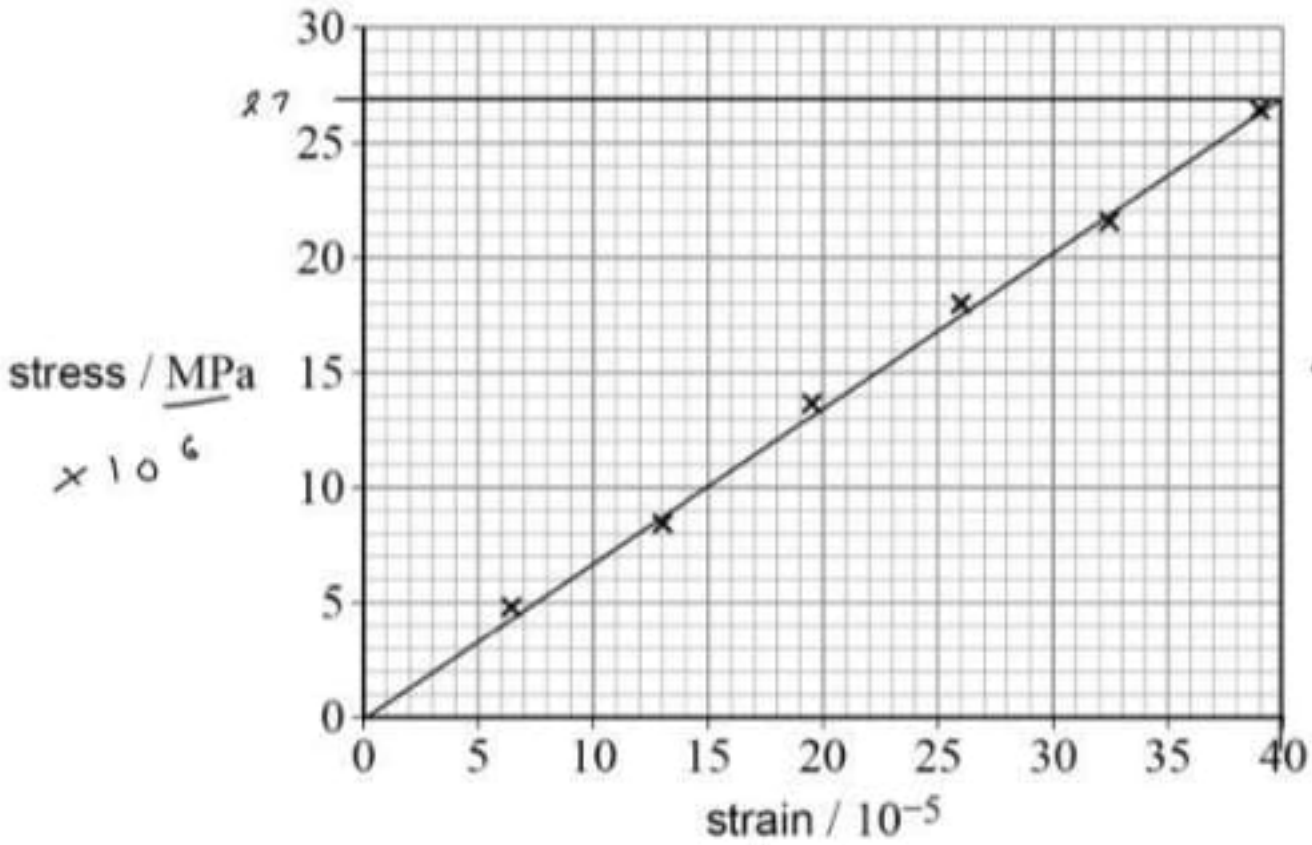
0 4 . 4 One of the wires in **Table 1** was used to obtain the stress–strain data shown in **Figure 5**.

→ has to go through origin

Figure 5



- make sure to draw triangle

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]

$$F = k\Delta L$$

$$\frac{\Delta\sigma}{\Delta\varepsilon} = \frac{F \cdot L}{A\Delta L} \qquad \frac{F}{\Delta L} = k$$

$$\frac{\Delta\sigma \cdot A}{\Delta\varepsilon \cdot L} = \frac{F}{\Delta L} = k = \frac{27\times10^{6}}{40\times10^{-5}} \times \frac{\pi\left(\frac{1.7\times10^{-3}}{2}\right)^2}{3.1}$$

$$= 4.9\times10^{4}\ Nm^{-1}$$

so yes wire W could have been used

VERY NICE

9

Do not write outside the box

The ion has a charge of $+3.20 \times 10^{-19}$ C and a mass of 5.31×10^{-26} kg.

0 6 . 3 The ion moves with a speed of 74.2 km s^{-1} in a circle of radius 4.22×10^{8} m.

Calculate the magnitude of the magnetic flux density required for this motion.
State, in fundamental (base) units, the unit for your answer.
Ignore any contribution from the gravitational field.

$Q = 3.2 \times 10^{-19}$ C

$m = 5.31 \times 10^{-26}$ kg

$r = 4.22 \times 10^{8}$ m

$v = 74.2 \times 10^{3}$ ms^{-1}

$F_{net} = BQv$

$\frac{mv^2}{r} = BQv$

$\frac{mv^2}{rQv} = B \longrightarrow \frac{mv}{rQ} = B$

$= \frac{5.31 \times 10^{-26} \times 74.2 \times 10^{3}}{4.22 \times 10^{8} \times 3.2 \times 10^{-19}}$

$= 2.9 \times 10^{-11}$

$F = BIL$ $= ma = kg\,ms^{-2}$

$B = \frac{F}{IL}$ $\frac{kg\,ms^{-2}}{Am} = kg\,s^{-2}A^{-1}$

magnetic flux density = 2.9×10^{-11} unit = $kg\,s^{-2}A^{-1}$

0 6 . 4 An electric field of strength 371 $\mu V\ m^{-1}$ can also accelerate the ion.

Calculate the acceleration of the ion due to this electric field.

[3 marks]

$F = EQ$ $a = \frac{F}{m} = \frac{EQ}{m}$

$\frac{371 \times 10^{-6} \cdot 3.2 \times 10^{-19}}{5.31 \times 10^{-26}} = 2235.8$

acceleration = 2236 $m\,s^{-2}$

Question 6 continues on the next page

Turn over ▶

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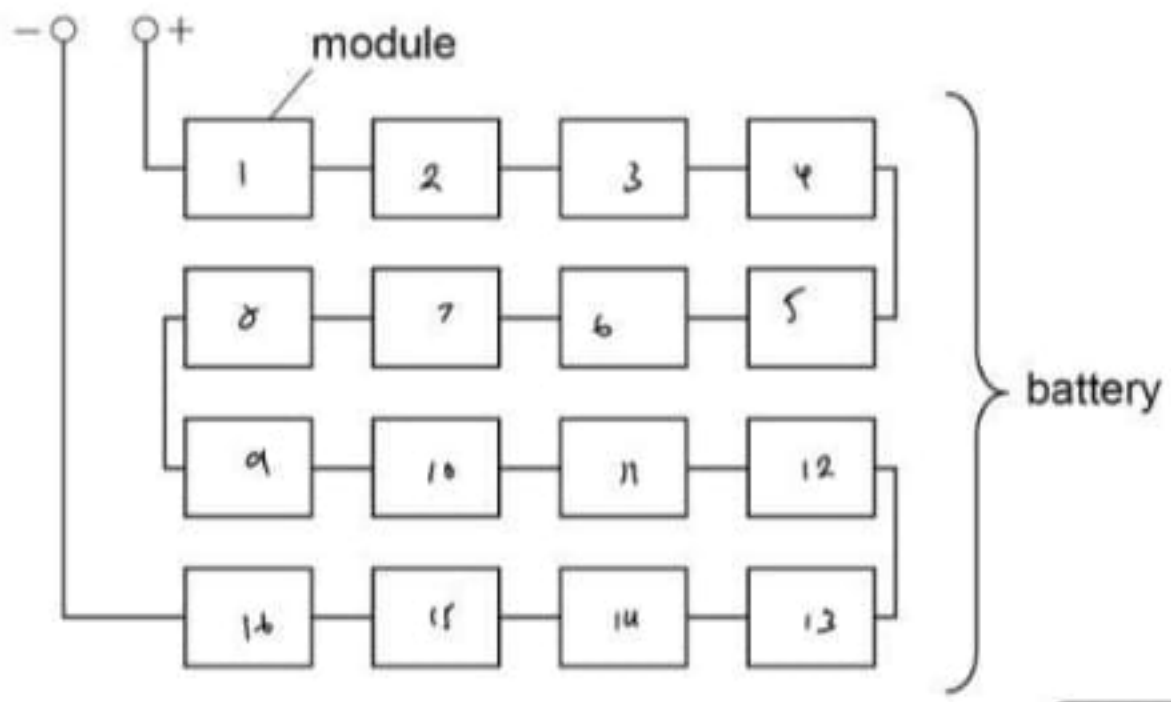
0 5 . 3 **Figure 7** shows the battery for an electric vehicle.
This battery has an emf of 352 V and gives a maximum current of 500 A.

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

Figure 7



ONLY 3 MARKS THO 😤

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

Deduce the number of cells in each module.

[3 marks]

$\mathcal{E} = 352\,V$

$I = 500\,A$

In series:- current is same
- $\mathcal{E}$ is shared

So 352 ÷ 16 = $\mathcal{E}$ in one module
= 22V

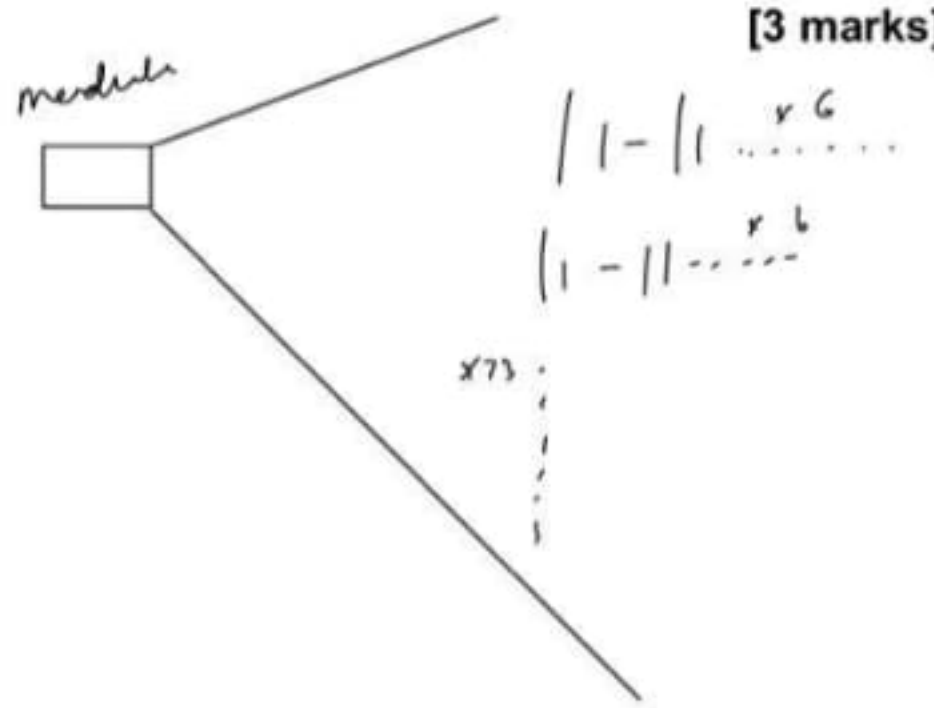
↳ $3.66x = 22V$
↑ number of cells in series of one branch

$x = 6$ cells

In parallel: - $\mathcal{E}$ same
- current added

$500A = 6.77x$
↑ ↳ number of parallel branches

$= 73.8$
↳ 73 branches



↳ most likely a range

(x73 · 438 cells

number of cells = 438

6

Turn over ▶

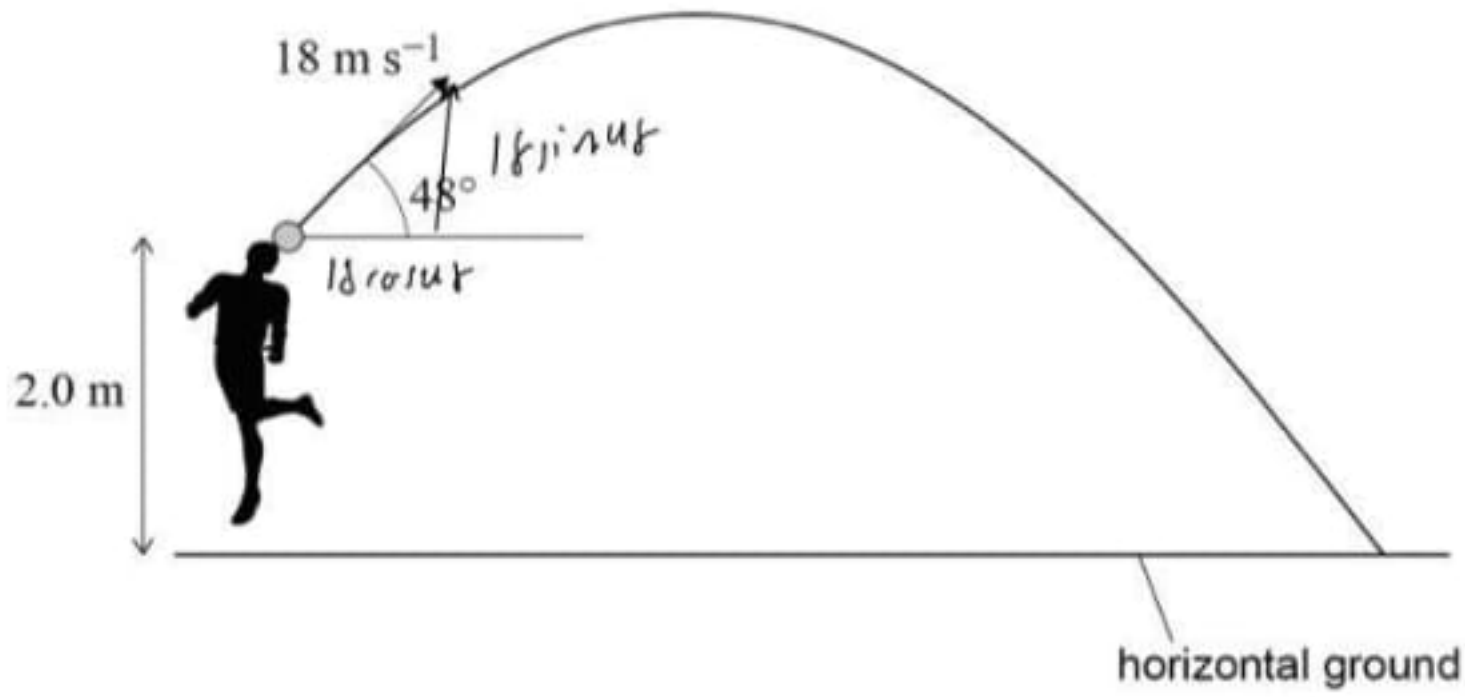
Do not write outside the box

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

not to scale



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]

$s = -2m$

$u = 18\sin 48\ ms^{-1}$

$v =$

$a = -9.81\ ms^{-2}$

$t =$

↑ + ↓ $-9.81\ ms^{-2}$

$s = ut + \frac{1}{2}at^2$

$2 = 18\sin 48\ t + \frac{1}{2}(9.81)t^2$

$-4.905t^2 + 18\sin(48)t + 2 = 0$

$t = -0.142$ or 2.869

time = 2.87 s

8

Turn over for the next question

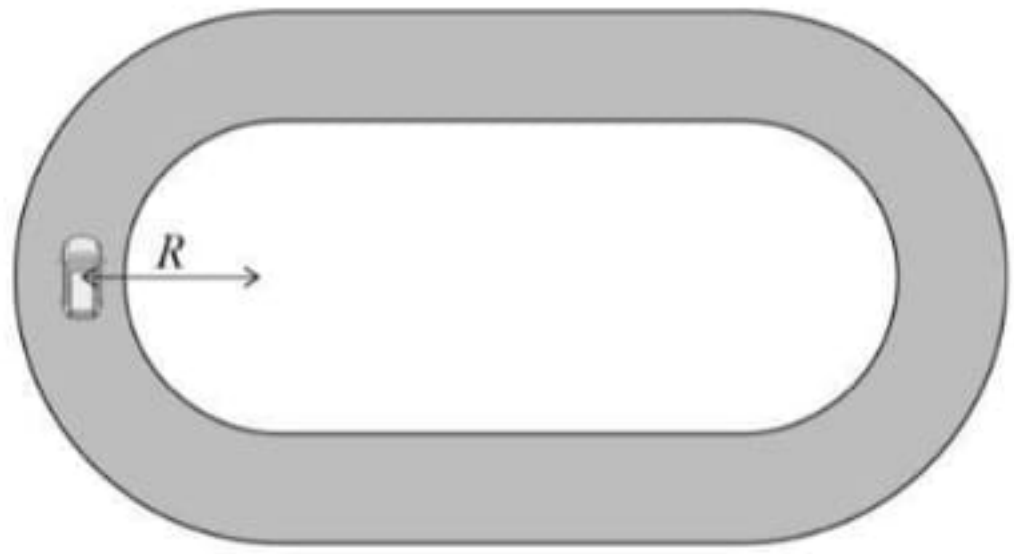
Do not write outside the box

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.

FINALLY A2

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

[2 marks]

$E_k = \frac{1}{2} mv^2$

$F = \frac{mv^2}{R}$

$2E_k = mv^2$

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

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

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

$m = 1600$ kg

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

Deduce the speed of the car.

[1 mark]

$\sqrt{\frac{FR}{m}} = v = \sqrt{\frac{24 \times 10^3 \times 230}{1600}} = 58.7$

speed = 58.7 $m\,s^{-1}$

Do not write outside the box

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**.

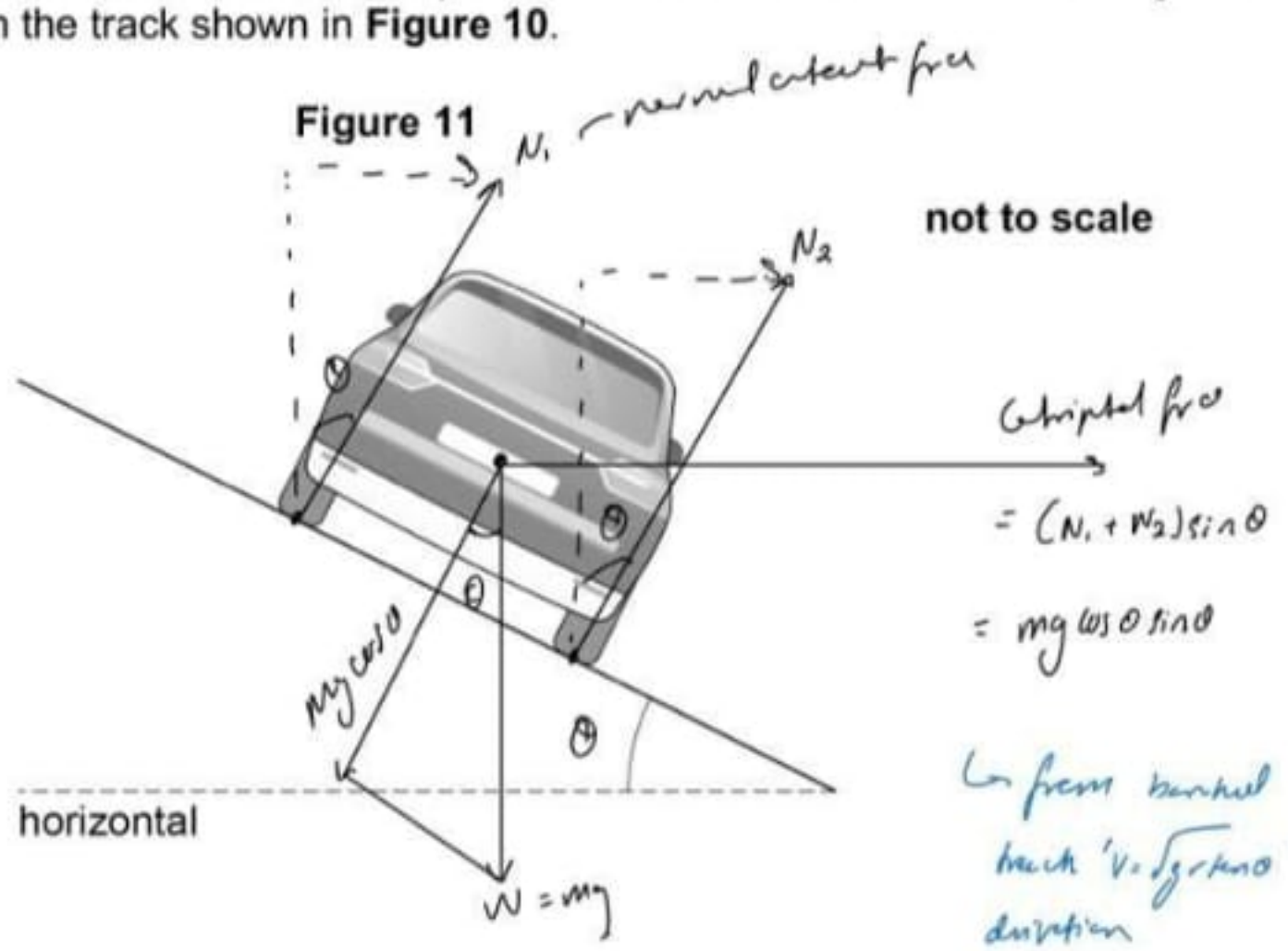
Suggest **one** way in which the driver can achieve this.

[1 mark]

drive along the outer edge of track

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



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]

On a sloped track the normal contact force has a horizontal component which provides the centripetal force. Hence allowing for a greater velocity as:

$V = \sqrt{\frac{FR}{m}} \rightarrow V \propto \sqrt{F}$

8

has a horizontal component but provides the centripetal force. Hence allowing for more velocity as: $V = \sqrt{\frac{FR}{m}} \rightarrow V \propto \sqrt{F}$

HEARD MANY GOT THIS WRONG SAW

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]

$E = QV$ $\quad \frac{1}{2}mv^2 = QV$

$v = \sqrt{\frac{2QV}{m}} = \sqrt{\frac{2(1.6\times10^{-19})(130}{9.11\times10^{-31}}} = 6.76\times10^{6}$

maximum speed = 6.8×10^{6} $\mathrm{m\,s^{-1}}$

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]

As there will be many atoms in the fluorescent tube but it collides with reducing its speed on average.

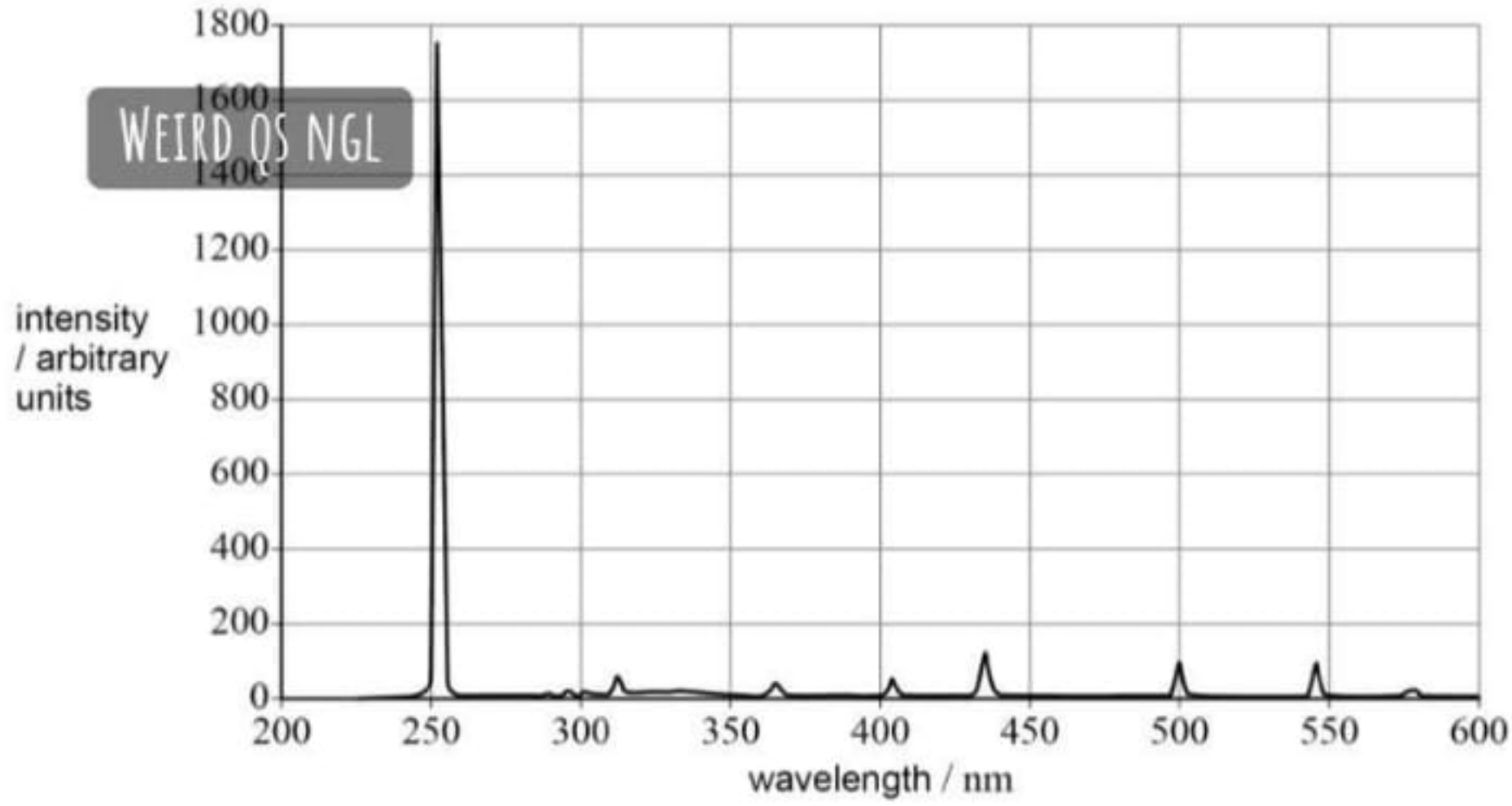
Question 8 continues on the next page

Do not write outside the box

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



WEIRD QS NGL

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]

No, as X does not produce all wavelengths from 380-700 (nm). It only has a few peaks with the main one big at 255 nm, hence no mix of colours and no white light

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]

$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{255 \times 10^{-9}}$

$= \frac{7.8 \times 10^{-19}}{1.6 \times 10^{-19}} = 4.875$

energy change = 4.88 eV

8

END OF SECTION A

Do not write outside the box

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.

MCQS WERE LIGHT

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.

↳ no lifetime

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

$\pi^0 = u\bar{u}$ or $d\bar{d}$ or $s\bar{s}$

↳ but strong interaction

What is the quark configuration of **X**? **[1 mark]**

A $\bar{u}\bar{u}\bar{d}$ ⬭

B $s\bar{u}$ ⬭

C $d\bar{u}$ ⬭

D $u\bar{d}$ ⬭

$X + p u d \rightarrow p d d + u\bar{u}$

B: $0 + 1 \rightarrow 1 + 0$

Q: $-1 + 1 \rightarrow 0 + 0$

S: $0 + 0 \rightarrow 0 + 0$

$\bar{u}\bar{d} + u u d \rightarrow u d d + u\bar{u}$

↳ $\bar{u}d$

Do not write outside the box

1 0 In β^- decay:

$n \rightarrow p^+ + e^- + \nu_e$

$ddd \rightarrow uud$

$d \rightarrow u$

[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]

$W = Fd$

	F	x	
A	1 mN	1 km $= 1$ J	✓
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?

$E = \phi + E_{kmax}$

$V_s = E_{kmax}$

[1 mark]

A using a metal that has a greater work function ✗ → $V_s = hf - \phi$

B using a light source that emits more photons per second ✗

C using a light source that emits light of a shorter wavelength ✓ → $V_s = \frac{hc}{\lambda} - \phi$; $\lambda \downarrow : \frac{hc}{\lambda} \uparrow = V_s \uparrow$

D using a metal surface that has a positive charge

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 ✗	⬭

↳ evidence for particle nature

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]

$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

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

$f - \frac{1}{\mu}$ ✗ **B** (mass per unit length of the wire)^2 ⬭

$f - \frac{1}{L}$ ✗ **C** length of the wire ⬭

$f - T$ **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. ✗ ⬭

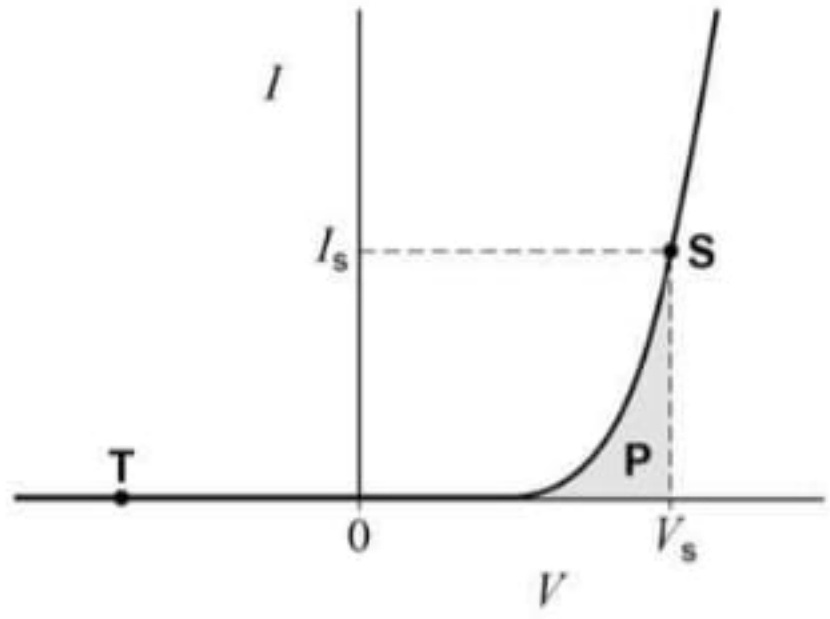
B d is the number of slits per unit length. ✗ ⬭

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 $\frac{1}{\text{gradient}}$ $\times \frac{dV}{dI} \neq R$

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** ✗

↳ Pwr at $I = I_s = I_s \times V_s$

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 $\frac{DY}{s\lambda}$

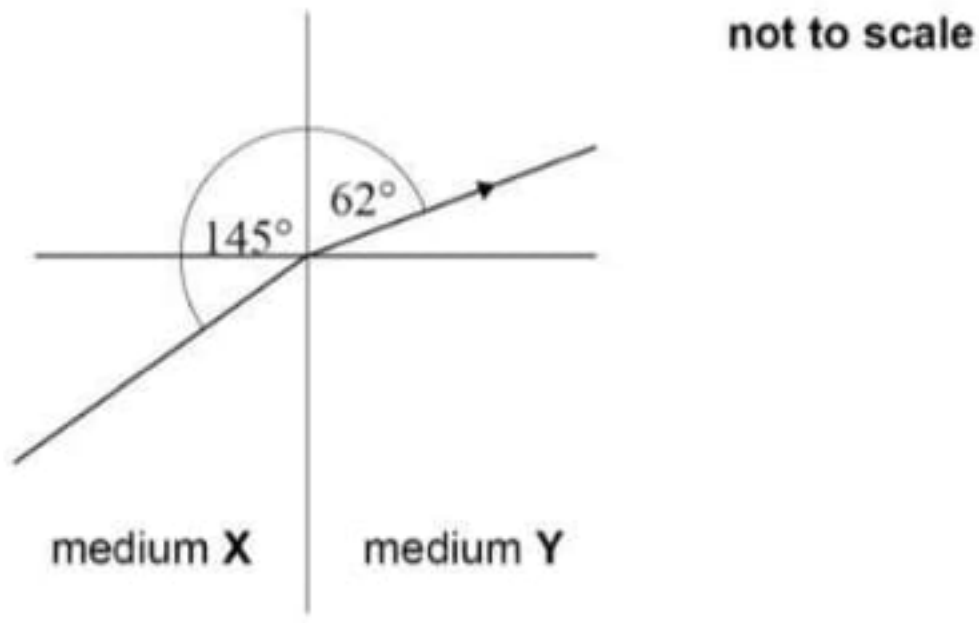
D $\frac{Ys}{\lambda D}$

$w = \frac{\lambda D}{s}$ $\quad \frac{Y}{w} = n$ ← number of fringes

$\frac{Y}{\lambda n / s} = \frac{Ys}{\lambda D}$

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]

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\frac{n_1 \sin\theta_1}{\sin\theta_2} = n_2 = \frac{1.33 \sin(145-90)}{\sin(90-62)} = 2.32$

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 $2.6 \times 10^8\ \text{m s}^{-1}$.

What is the speed of light in the other medium?

[1 mark]

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

A $1.6 \times 10^8\ \text{m s}^{-1}$

B $2.1 \times 10^8\ \text{m s}^{-1}$

C $3.0 \times 10^8\ \text{m s}^{-1}$

D $3.2 \times 10^8\ \text{m s}^{-1}$

$\frac{c}{c_{s_1}} \sin\theta_c = \frac{c}{c_{s_2}} \sin 90 \quad (=1)$

$\frac{\sin\theta_c}{c_{s_1}} = \frac{1}{c_{s_2}}$

TS WAS A BIT WEIRD.
WHY AQA MAKING THE ANSWER FASTER THEN SPEED OF LIGHT???

$\frac{c_{s_2}}{\sin\theta_c} = c_{s_2} = \frac{2.6 \times 10^8}{\sin 53} = 3.2 \times 10^8$

Do not write outside the box

2 0 Monochromatic light of wavelength 420 nm is incident normally on a plane transmission diffraction grating that has a slit separation of 3.6 μm.

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

[1 mark]

$d\sin\theta = n\lambda$

θ for max orders

$\frac{3.6\times10^{-6}}{420\times10^{-9}} = 8$ for either side

$8 \times 2 = 16$ + orbital maxima

$= 17$

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. ✗ → just accelerates upwards to v_t. $F=ma$ ○

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?

$E = \phi + E_{kmax}$

$3.8 \times 10^{-19} - \frac{1}{2} \cdot 9.11 \times 10^{-31} \cdot (2.5 \times 10^{5})^2$

$= 3.52 \times 10^{-19}$

[1 mark]

A 0.29×10^{-19} J ○

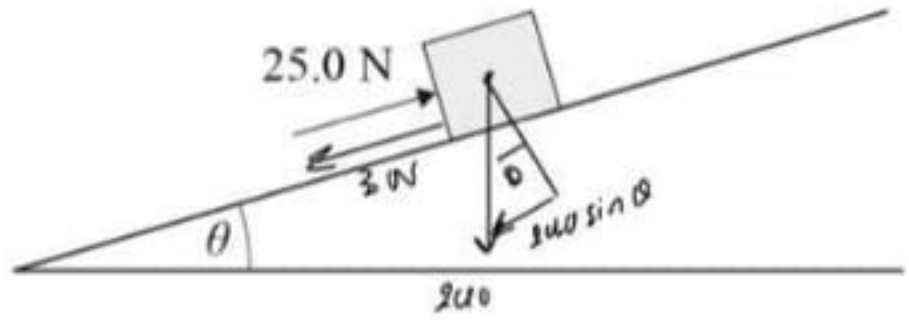
B 3.5×10^{-19} J ✓

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.

→ no resultant F



What is θ?

[1 mark]

$240 \sin\theta + 3 - 25 = 0$

$\sin\theta = \frac{22}{240}$

$\theta = 5.26$

A 0.12° ○

B 5.3° ✓

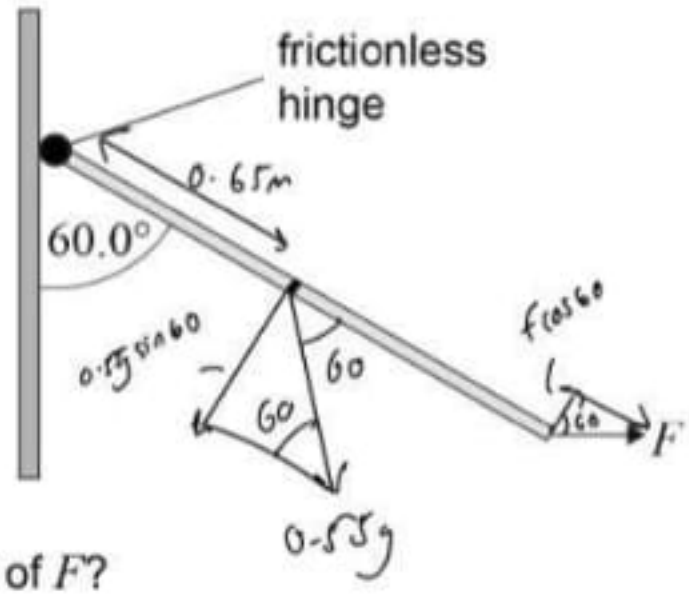
C 6.0° ○

D 6.7° ○

Do not write outside the box

2 4 A uniform wooden rod of mass $0.55\ \text{kg}$ and length $1.3\ \text{m}$ 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 N ⬭

B 1.6 N ⬭

C 2.7 N ⬭

D 4.7 N ⬭

$0.55g \sin 60 \cdot 0.65 = 1.3 F \cos 60$

$\frac{0.55 \cdot 0.65 \cdot 9.81}{1.3} \cdot \tan 60 = F$

$= 4.67$

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?

↳ at equilibrium when $a = 0 \rightarrow v =$ max

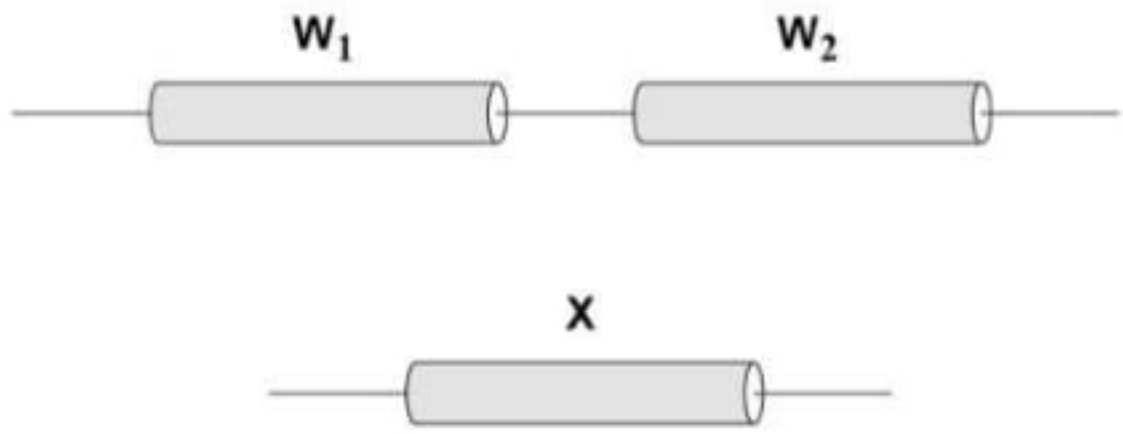
$p = mv$

[1 mark]

	Momentum	GPE	
A	zero	maximum	⬭
B	maximum	minimum	⬭
C	maximum	maximum	⬭
D	zero	minimum	⬭

Do not write outside the box

2 6 Two thin metal rods $\mathbf{W_1}$ and $\mathbf{W_2}$, each of length L and diameter d, are connected in series.



The resistivity of $\mathbf{W_1}$ is ρ_1 and the resistivity of $\mathbf{W_2}$ is ρ_2.

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

What is the resistivity of **X**?

[1 mark]

A $\rho_1 + \rho_2$ ✓

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

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

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

$R_T = R_1 + R_2$ LONG AHH QS

$= \frac{\rho_1 L}{A} + \frac{\rho_2 L}{A} = \frac{L}{A}(\rho_1 + \rho_2)$

X also has $L = L$ and $A = A$

hence $R_X = \frac{L}{A}(\rho_1 + \rho_2)$

$\rho_X = \frac{R_X A}{L}$

$= \frac{A}{L} \cdot \frac{L}{A}(\rho_1 + \rho_2)$

$= \rho_1 + \rho_2$

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

What is the de Broglie wavelength of the alpha particle?

[1 mark]

A $2.2 \times 10^{-13}\ \mathrm{m}$ ✓

B $4.4 \times 10^{-13}\ \mathrm{m}$

C $8.8 \times 10^{-13}\ \mathrm{m}$

D $3.9 \times 10^{-12}\ \mathrm{m}$

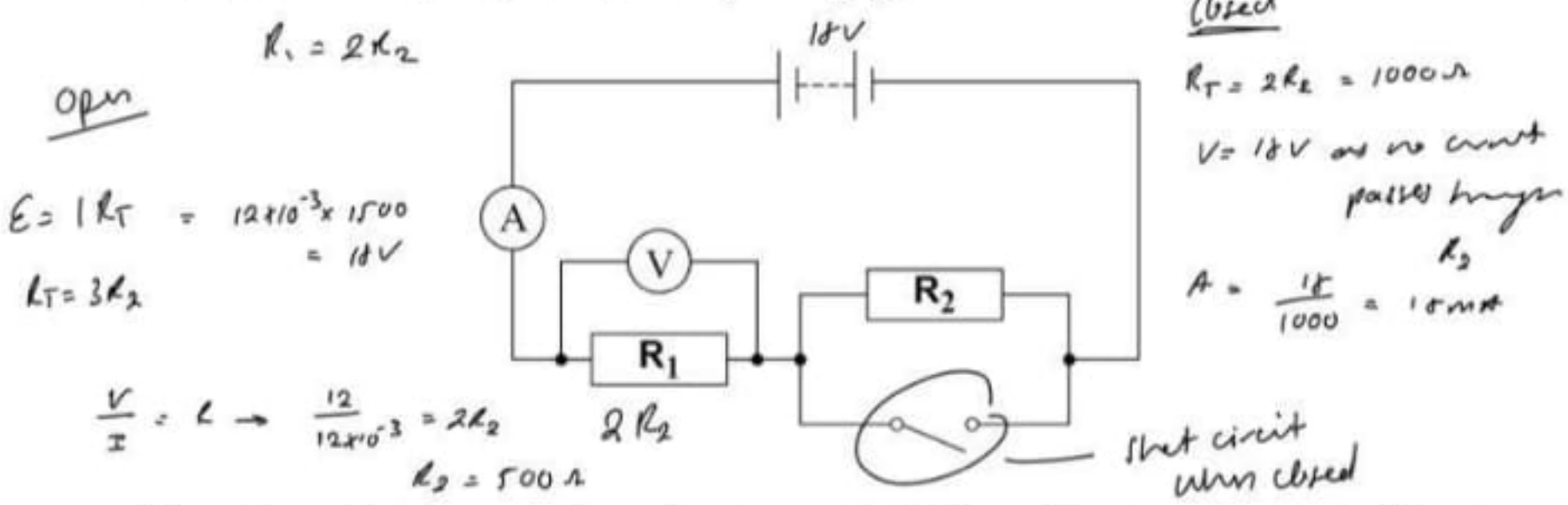
$\frac{h}{mv} = \frac{6.63 \times 10^{-34}}{4 \cdot 1.67 \times 10^{-27} \cdot 6.5 \times 10^5}$

$= 2.2 \times 10^{-13}$

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 V and the ammeter reads 12 mA.

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

[1 mark]

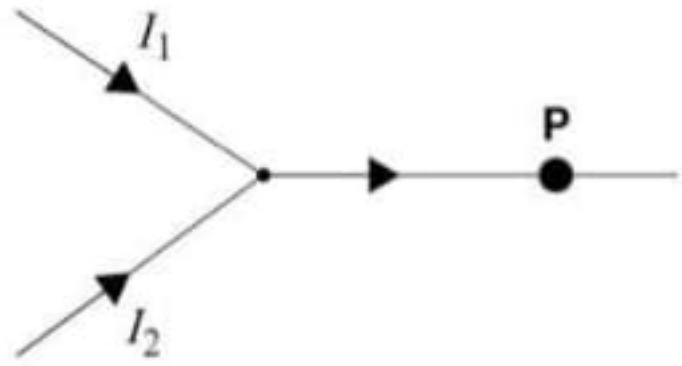
LOVELY STUFF 😍

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

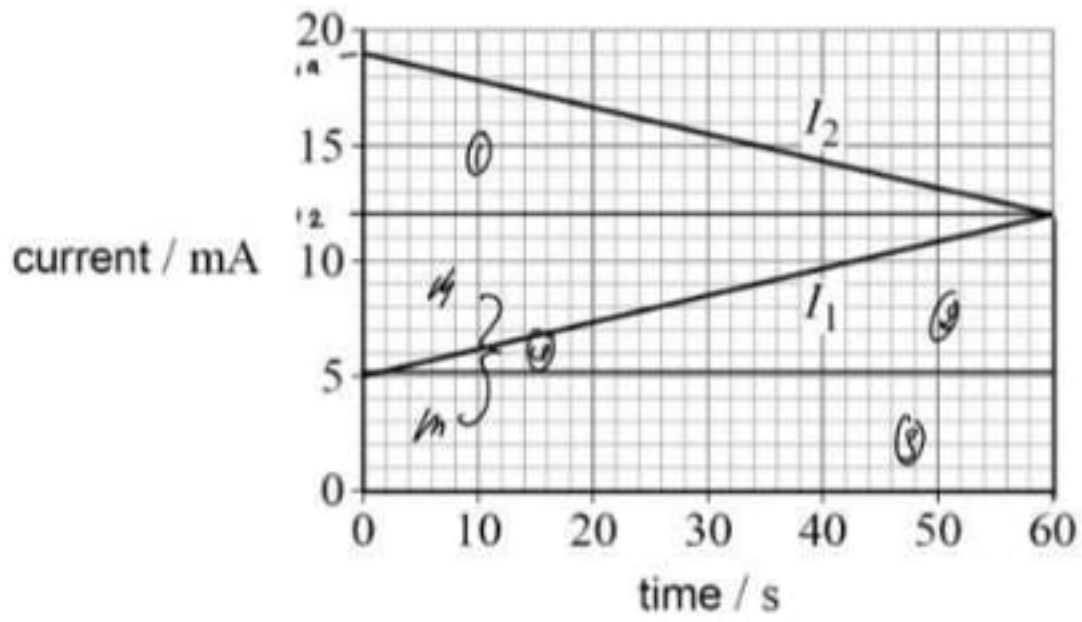
Turn over for the next question

Do not write outside the box

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

$Q = It$

$Q_1 = ② + ③ = \frac{(12-5)\times10^{-3}}{2} \times 60 + 60 \times 5\times10^{-3} = 0.51$

$Q_2 = ① + ④ = \frac{(19-12)\times10^{-3}}{2} \times 60 + 12\times10^{-3} \times 60 = 0.93$

$Q_1 + Q_2 =$

HATED THIS

$0.51 + 0.93 = 1.44$