Please write clearly in block capitals.

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

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________

I declare this is my own work.

AS PHYSICS

Paper 1

Wednesday 14 May 2025 Morning Time allowed: 1 hour 30 minutes

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 70.
- 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	
TOTAL	

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Answer **all** questions in the spaces provided.

0 1 Hydrogen has three naturally occurring isotopes. One of these isotopes is hydrogen-3 $\left({}^{3}_{1}\mathrm{H}\right)$.

0 1 . 1 Calculate the specific charge of a nucleus of hydrogen-3.

[2 marks]

1 proton → charge = + 1.6×10^{-19} C

2 neutrons → no charge.

mass number → 3

total mass ⇒ $3 \times 1.67 \times 10^{-27}$

$= 5.01 \times 10^{-27}$ kg

specific charge charge/mass

$= \dfrac{(1.6 \times 10^{-19})\,C}{5.01 \times 10^{-27}} = 3.19 \times 10^{7}\ \mathrm{C\,kg^{-1}}$

specific charge = 3×10^{7} $\mathrm{C\ kg^{-1}}$

0 1 . 2 The specific charge of the hydrogen-3 nucleus is less than the specific charges of the nuclei of the other two isotopes.

Suggest why.

[2 marks]

- The hydrogen-3 nucleus has more neutrons than the other isotopes.
- This increases the mass without increasing the charge (since charge comes only from protons) so the specific charge (charge/mass) is reduced.

Kaons (K) and pions (π) are produced when a beam of antiprotons is incident on a sample of hydrogen gas.

One reaction that occurs is

uud ūūd̄

$$p + \overline{p} \rightarrow K^- + \pi^+ + K^0$$

ūs ud̄ ?

0 1 . 3 Deduce, with reference to appropriate conservation laws, the quark structure of the K^0 produced in this reaction.

[3 marks]

K^0 should contain $\bar{s}$ to conserve strangeness

To cancel the extra $\bar{d}$ in π^+, the K^0 must have d in it

quark structure = $d\bar{s}$

0 1 . 4 One possible decay of a π^+ particle is

$$\pi^+ \rightarrow \mathbf{A} + \mathbf{B}$$

where **A** is a charged lepton.

Suggest, with reference to appropriate conservation laws, the name of **A** and the name of **B**.

[2 marks]

The π^+ is a meson composed of quarks (u and $\bar{d}$) and decays via the weak interaction.
To conserve charge, A must be +ively charged lepton: the μ^+ or e^+

name of **A** Muon (μ)

name of **B** Muon Neutrino (ν_μ)

To conserve lepton number, a corresponding neutrino must be produced.
∴ B must be the neutrino corresponding to the lepton.
μ^+ with muon neutrino
e^+ with electron neutrino

9

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0 2 An optical fibre consists of a glass core surrounded by cladding.

Monochromatic light enters the glass core of the optical fibre from air.

0 2 . 1 What happens to the frequency of the light as it enters the glass core?

Tick (✓) **one** box.

[1 mark]

It decreases.	☐
It is unchanged.	☒
It increases.	☐

frequency depends on the source
λ and speed changes, not frequency

The refractive index of the glass core is 1.51

0 2 . 2 The critical angle at the core–cladding boundary is 80.7°

Calculate the refractive index of the cladding.

[2 marks]

$n_{cladding} = n_{core} \cdot \sin(\theta_c)$

$= 1.51 \times \sin(80.7)$

$= 1.51 \times 0.985 = 1.49$

refractive index of cladding = 1.49

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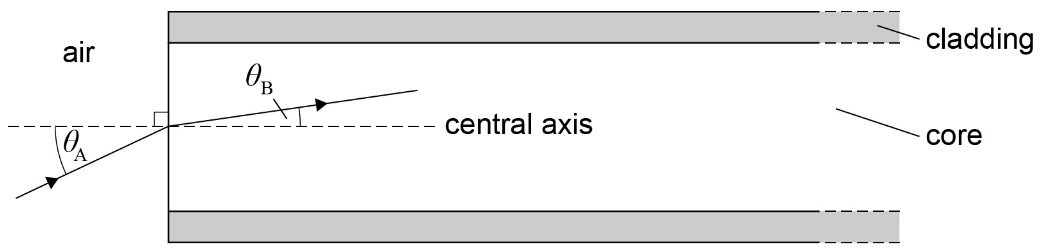
Figure 1 shows a ray of light that is incident on the centre of the core.
At the air–core boundary, the angle of incidence of this ray is θ_A and the angle of refraction is θ_B.

Figure 1

not to scale



When θ_B is greater than $9.3°$, the ray will **not** be transmitted through the optical fibre.

0 2 . 3 Calculate the maximum value of θ_A for the ray to be transmitted through the optical fibre.

[2 marks]

$n_{air} \cdot \sin(\theta_A) = n_{core} \cdot \sin(\theta_B)$

$1.00 \cdot \sin(\theta_A) = 1.51 \cdot \sin(9.3)$

$\sin(\theta_A) = 1.51 \cdot 0.161 \approx 0.243$

$\theta_A = \sin^{-1}(0.243) = 14.1°$

maximum value of θ_A = 14.1 °

Question 2 continues on the next page

Turn over ►

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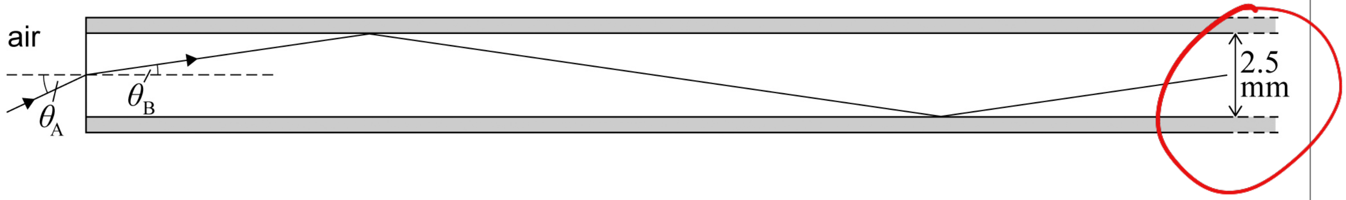
0 2 . 4 **Figure 2** shows the path of a ray of light that enters at the centre of the straight optical fibre at a smaller value of θ_A. Only the first two total internal reflections are shown.

Figure 2

not to scale



The core has a diameter of 2.5 mm.

θ_B is now 9.0°

3.1×10^4 total internal reflections occur before the light leaves the optical fibre.

Calculate the time for the light to travel through the optical fibre.

refractive index of glass core = 1.51

[3 marks]

Opposite side = core diameter $= 2.5 \times 10^{-3}$ m

Angle = 9.0°

From trigonometry: distance per reflection =

$$\frac{2.5 \times 10^{-3}}{\sin(9.0°)} \approx \frac{2.5 \times 10^{-3}}{0.1564} = 0.01598\text{m}$$

time = 2.49×10^{-6} s

8

Total distance $= 0.01548 \times 3.1 \times 10^4$

$= 495.4$ m

Speed of light in glass $\Rightarrow v = c/n$

$$= \frac{3 \times 10^8}{1.51} = 1.987 \times 10^8 \text{ m/s}$$

$$\text{time} = \frac{\text{distance}}{\text{speed}} = \frac{495.4}{1.987 \times 10^8} \approx 2.49 \times 10^{-6} \text{ s}$$

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0 3 A fluorescent tube contains a low-pressure gas consisting of mercury atoms.

Figure 3 shows the four lowest energy levels of a mercury atom.

Figure 3

$n = 4$	-2.56×10^{-19} J
$n = 3$	-5.92×10^{-19} J
$n = 2$	-8.80×10^{-19} J
$n = 1$	-16.64×10^{-19} J

A mercury atom inside the fluorescent tube is in its ground state $n = 1$

An electron is travelling inside the tube. The electron has a kinetic energy of 13.10×10^{-19} J when it collides with the mercury atom.

As a result of the collision, the mercury atom is excited to its $n = 3$ energy level. Immediately after the collision, the electron is moving with a speed that is smaller than before the collision.
Assume that the kinetic energy of the mercury atom does not change.

0 3 . 1 Calculate the de Broglie wavelength of this electron immediately after the collision.

[4 marks]

(1) $n=1$ to $n=3$

$\Delta E = -5.92 \times 10^{-19} - (-16.64 \times 10^{-19})$

$\Delta E = 10.72 \times 10^{-19}$ J

(2) Remaining kinetic energy electron:

$E_k = 13.10 \times 10^{-19} - (10.72 \times 10^{-19})$

$= 2.38 \times 10^{-19}$ J

(3) $p = \sqrt{2 m_e E_k} = \sqrt{2 \times 9.11 \times 10^{-31} \times 2.38 \times 10^{-19}}$

$\approx 2.09 \times 10^{-24}$

(4) De Broglie eqn:

$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{2.09 \times 10^{-24}} = \boxed{3.17 \times 10^{-10}}$

de Broglie wavelength = 3.17×10^{-10} m

Question 3 continues on the next page

Turn over ▶

The excited mercury atoms inside the fluorescent tube can emit photons of ultraviolet light, each of energy 7.83×10^{-19} J.

0 3 . 2 Calculate, in nm, the wavelength of a photon with this energy.

[2 marks]

$E = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E}$

$\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{7.38 \times 10^{-19}}$

$= 2.54 \times 10^{-7}\,m = \boxed{254\,nm}$

wavelength = 254 nm

0 3 . 3 The fluorescent tube has an input power of 18 W.

82% of the input power is converted into ultraviolet photons, each of energy 7.83×10^{-19} J.

Calculate the number of these photons emitted in one second.

[2 marks]

Useful power output:

$P = 0.28 \times 18 = 14.76\,W$

Number of photons per second:

Number $= \frac{P}{E} = \frac{14.76}{7.38 \times 10^{-19}}$ 1.89×10^{19}

number of photons = 1.89×10^{19}

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0 3 . 4 Explain how the coating of the fluorescent tube emits white light.

In your answer you should:

- describe the processes that take place in the coating
- suggest why there are many more visible photons than ultraviolet photons emitted by the tube.

[4 marks]

UV photons are absorbed by the atoms in the coating.

Electrons in the coating atoms are excited to higher energy levels.

These electrons de-excite in multiple steps, emitting photons of various visible wavelengths

Each UV photon can produce multiple visible photons.

The mixture of differ visible wavelengths appears as white light

12

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0 4 . 1 State the principle of moments.

[2 marks]

When a body is in equillibrium, The sum of The clockwise moments about any point is equal to The sum of The anticlockwise moments about The same point

Question 4 continues on the next page

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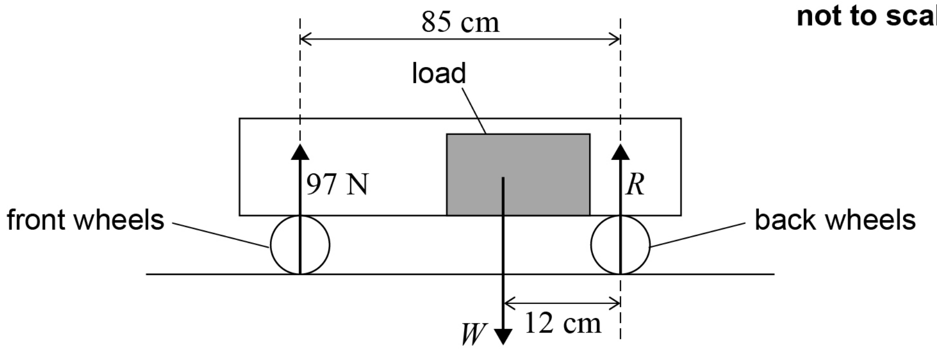
0 4 . 2 **Figure 4** shows a trolley at rest on a horizontal surface. A load is fixed to the base of the trolley.

Figure 4

not to scale



Assume that the forces in **Figure 4** are coplanar.

The distance between the centre of the front wheels and the centre of the back wheels is 85 cm.

The total reaction force at the front wheels is 97 N and the total reaction force at the back wheels is R.

The trolley and load have a total weight W.

The perpendicular distance between the lines of action of the forces W and R is 12 cm.

Calculate R.

[3 marks]

principle of moments about the back wheels:

↻ moments : $97 \times 85 = 8245$ Ncm

↺ moment : $W \times 12$

Since moments balance:

$W \times 12 = 8245 \Rightarrow W = \frac{8245}{12}$

$W = 687.08$

$W = 97 + R \Rightarrow R = W - 97 = \boxed{590}$

$R =$ 590 N

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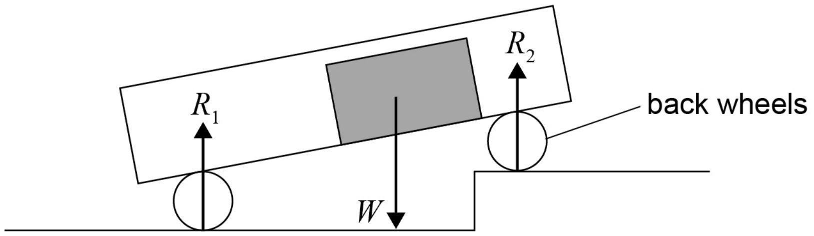
Figure 5 shows the trolley after its back wheels have been lifted onto a step.
The trolley is stationary.

Figure 5



0 4 . 3 When the back wheels are on the step, the moment of W about the centre of the back wheels is less than that in **Figure 4**.

Explain why.

[1 mark]

The perpendicular distance from the line of action of W to the backwheels is smaller, because the trolley is tilted, reducing the moment arm.

0 4 . 4 Deduce how the magnitude of R_1 in **Figure 5** compares with the value of $97\ \mathrm{N}$ in **Figure 4**.

[3 marks]

The total downward force has not changed. The moment of W about the backwheel is reduced. Therefore, less upward force is needed from the backwheels. This means the front wheels must provide more upward force to balance the reduced moment

So R_1 is greater than 97.

9

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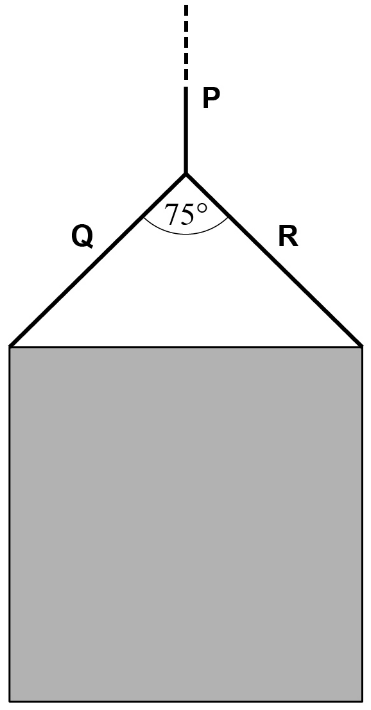
0 5 **Figure 6** shows a stationary lift suspended using three steel cables **P**, **Q** and **R**.
The centre of mass of the lift is vertically below cable **P**.

Figure 6



The mass of the lift is 850 kg.
The angle between **Q** and **R** is 75°
Q and **R** each have an unstretched length of 2.0 m.
The cross-sectional area of each cable is 1.4×10^{-4} m^2.
The Young modulus of the steel is 2.1×10^{11} Pa.

0 5 . 1 Determine the extension of **Q**.

[4 marks]

$W = mg = 850 \times 9.81 = 8338.5\ N.$

$2T\cos(37.5°) = 8338.5 \Rightarrow T = \frac{8338.5}{2\cos(37.5)}$

$T = 5242.3\ N.$

Young's modulus $= \frac{FL}{AE} \Rightarrow$ Extension $= \frac{5242.3 \times 2.0}{1.4 \times 10^{-4} \times 2.1 \times 10^{11}}$

$\approx \frac{10484.6}{2.94 \times 10^{7}} \approx 3.57 \times 10^{-4}$

extension = 3.57×10^{-4} m

Question 5 continues on the next page

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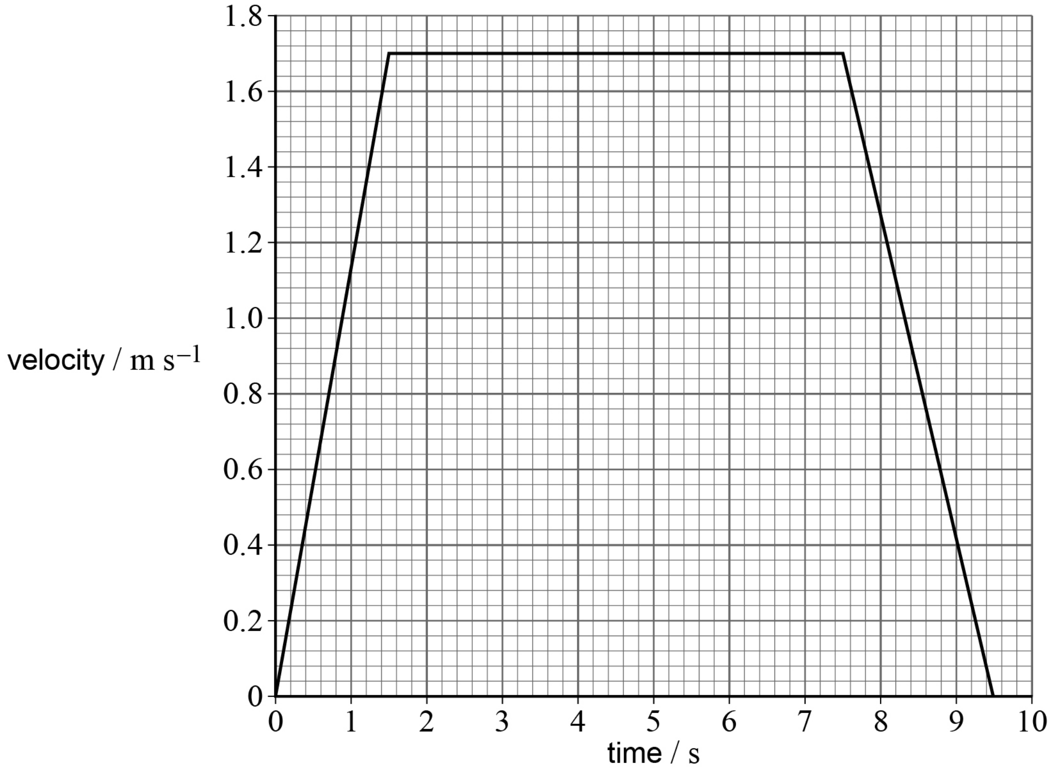
Figure 7 is a velocity–time graph for the lift as it travels upwards from ground level.

Figure 7



0 5 . 2 Determine the gravitational potential energy gained by the lift during the first 1.5 s of the motion.

[3 marks]

A with base 1.5 s and height 1.7 m/s

distance = ½ × 1.5 × 1.7

= 1.275

G.P.E = m.g.h = 850 × 9.81 × 1.275 = 1.06 × 10⁴ J

gravitational potential energy = 1.06×10^4 J

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0 5 . 3 **Q** and **R** are connected to **P** as shown in **Figure 6**.

Determine the tension in **P** during the last 2.0 s of the motion.

[3 marks]

$a = \frac{v-u}{t} = \frac{0 - 1.7}{2.0} = -0.85 \text{ m/s}^2$

$T - W = ma \Rightarrow T = ma + mg$

$= m(a + g)$

$= 880(9.81 - 0.85) = 7616$

tension = 7616 N

Question 5 continues on the next page

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After $4.0\ \mathrm{s}$ of the motion, the lift is moving at a constant velocity and has travelled $5.5\ \mathrm{m}$ from ground level. An object becomes detached from the underside of the lift.

0 5 . 4 Determine the velocity of the object when it reaches ground level.

[3 marks]

$v^2 = u^2 + 2as$

$v^2 = (1.7)^2 + (2 \times 9.81 \times 5.5)$

$= 110.80$

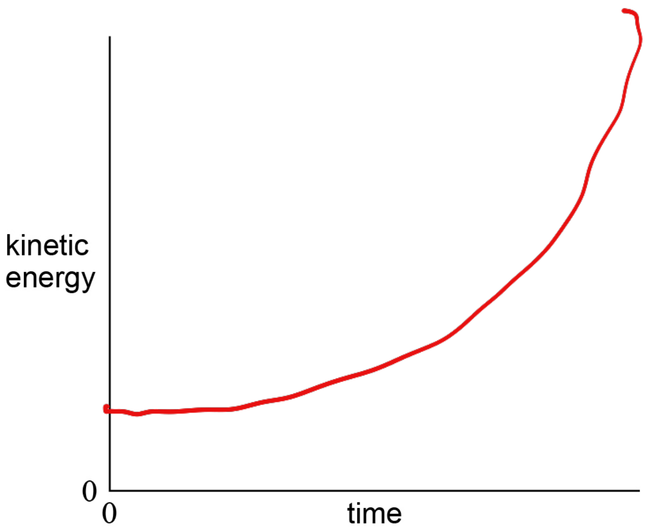
$v = \sqrt{110.80} = 10.5$

velocity = 10.5 $\mathrm{m\ s^{-1}}$

0 5 . 5 Sketch on **Figure 8** the variation with time of the kinetic energy of the object from when it becomes detached until it hits the ground.
No calculations are required.

[2 marks]

Figure 8



15

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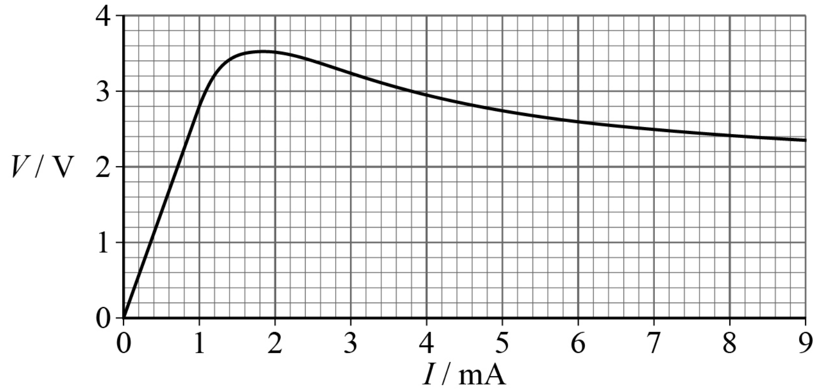
0 6 **Figure 9** shows the variation of potential difference V with current I for a thermistor **T**.

Figure 9



0 6 . 1 Discuss, for the range 0 to 9 mA, the characteristic of **T** shown by **Figure 9**.

In your answer you should:

- 1 describe how to produce a characteristic experimentally
- 2 describe, in terms of resistance, the behaviour of **T**
- 3 explain, with reference to temperature, the behaviour of **T**.

[6 marks]

1 How to produce the characteristic experimentally
- connect a thermistor T in series with an ammeter and variable power supply,
- connect a voltmeter in parallel across T
- Gradually increase the supply voltage to increase current

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- Record readings of voltage (V) and current (I)
- Plot a graph of V against I.

② Description in terms of resistance
- At low currents (0-3mA) both V and I increase indicating that resistance is increasing.
- At peak (around 3.5mA), V reaches a maximum.
- Beyond this point, V decreases while I increases: resistance decreases.
- Therefore, T shows non-ohmic behaviour

③ Explanation with reference to temp:
- Thermistor is a negative temperature coefficient device.
- As current increases, more power is dissipated → Thermistor heats up
- As temp increases, resistance decreases, due to more charge carriers being released.
- Hence the curve bends downwards after a certain current due to thermal runaway effect

Question 6 continues on the next page

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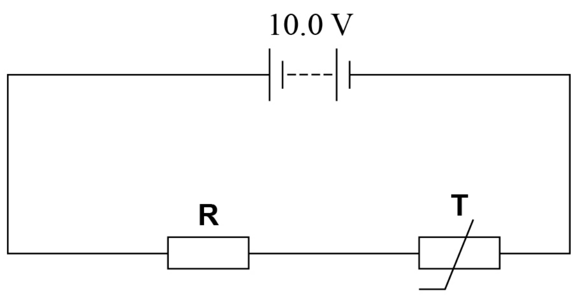
0 6 . 2 **Figure 10** shows thermistor **T** in series with a fixed resistor **R** and a battery.

The variation of V with I shown in **Figure 9** applies to **T** in this circuit.

Figure 10



The battery has an emf of $10.0\ \text{V}$ and negligible internal resistance.

The current in **T** is $1.0\ \text{mA}$.

Determine the resistance of **R**.

[3 marks]

$V_R = 10.0 - 2.8 = 7.2\text{V}$

$R = \dfrac{V_R}{I} = \dfrac{7.2}{1.0 \times 10^{-3}} = 7200$

resistance = 7200 Ω

9

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0 7 . 1 State what is meant by the threshold frequency of radiation in the photoelectric effect.

[2 marks]

The threshold frequency is the minimum frequency of incident electromagnetic radiation that can cause photoelectrons to be emitted from the surface of a material

When magnesium is illuminated with monochromatic electromagnetic radiation, photoelectrons are emitted.
For this radiation, the maximum kinetic energy of the photoelectrons is 5.47×10^{-19} J and the stopping potential is V_s.

0 7 . 2 Calculate V_s.

[1 mark]

$E_k = eV_s \Rightarrow V_s = \frac{E_k}{E}$

$= \frac{5.47 \times 10^{-19}}{1.60 \times 10^{-19}} =$ $V_s =$ 3.42 V

0 7 . 3 The radiation incident on the magnesium has a frequency of 1710 THz.

Calculate the work function of the magnesium.

[2 marks]

$hf = \phi + E_k \quad \phi = hf - E_k$

$\phi = (6.63 \times 10^{-34} \times 1.71 \times 10^{15}) - (5.47 \times 10^{-19})$

work function = 5.87×10^{-19} J

Question 7 continues on the next page

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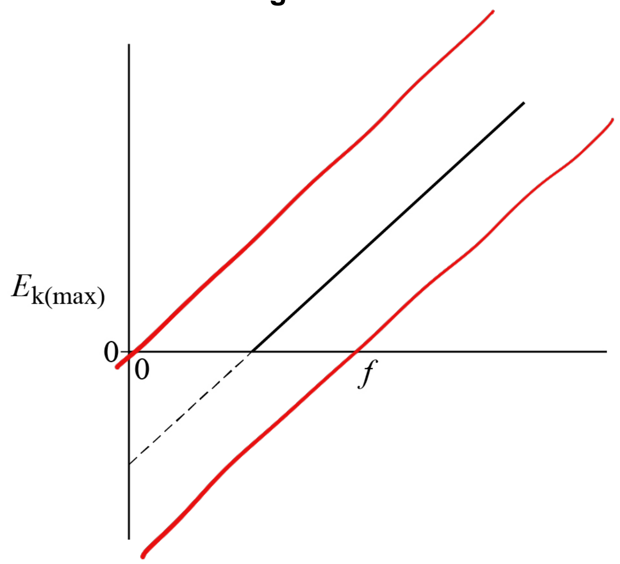
0 7 . 4 The frequency f of the electromagnetic radiation is varied.

Figure 11 shows the variation of $E_{k(max)}$ with f for magnesium.

Figure 11



Metal **X** and metal **Y** are illuminated by radiation with the same range of frequencies as used for the magnesium.

Sketch, on **Figure 11**, graphs to show how $E_{k(max)}$ varies with f for **X** and for **Y**.
Label your graphs **X** and **Y**.
Go on to explain your reasoning.

work function of **X** > work function of magnesium > work function of **Y**

[3 marks]

Slope of each line is h, so gradient is the same for all metals.
The x intercept corresponds to threshold frequency.
A higher work function means a higher threshold frequency, so metal X has the largest threshold frequency, and Y the smallest.

8

END OF QUESTIONS

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