Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
January 2004
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

PHYSICS (SPECIFICATION A) PHA3/W
Unit 3 Current Electricity and Elastic Properties of Solids

Monday 12 January 2004 Morning Session

In addition to this paper you will require:
- a calculator;
- a pencil and a ruler.

Time allowed: 1 hour

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions in the spaces provided. All working must be shown.
- Do all rough work in this book. Cross through any work you do not want marked.

Information
- The maximum mark for this paper is 50.
- Mark allocations are shown in brackets.
- The paper carries 25% of the total marks for Physics Advanced Subsidiary and carries $12\frac{1}{2}$% of the total marks for Physics Advanced.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- You are expected to use a calculator where appropriate.
- In questions requiring description and explanation you will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary where appropriate. The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
6			
Total (Column 1) →			
Total (Column 2) →			
TOTAL			
Examiner's Initials			

Data Sheet

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

Fundamental constants and values

Quantity	*Symbol*	*Value*	*Units*
speed of light in vacuo	c	3.00×10^{8}	m s^{-1}
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}
permittivity of free space	ε_0	8.85×10^{-12}	F m^{-1}
charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{ kg}^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$\text{J K}^{-1} \text{ mol}^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{ K}^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4}u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}
proton rest mass (equivalent to 1.00728u)	m_p	1.67×10^{-27}	kg
proton charge/mass ratio	e/m_p	9.58×10^{7}	C kg^{-1}
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-27}	kg
gravitational field strength	g	9.81	N kg^{-1}
acceleration due to gravity	g	9.81	m s^{-2}
atomic mass unit (1u is equivalent to 931.3 MeV)	u	1.661×10^{-27}	kg

Fundamental particles

Class	*Name*	*Symbol*	*Rest energy* /MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^{\pm}$	0.510999
	muon	$\mu^{\pm}$	105.659
mesons	pion	$\pi^{\pm}$	139.576
		π^{0}	134.972
	kaon	$K^{\pm}$	493.821
		K^{0}	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

Type	*Charge*	*Baryon number*	*Strangeness*
u	$+\frac{2}{3}$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}$	$+\frac{1}{3}$	–1

Geometrical equations

arc length $= r\theta$

circumference of circle $= 2\pi r$

area of circle $= \pi r^2$

area of cylinder $= 2\pi rh$

volume of cylinder $= \pi r^2 h$

area of sphere $= 4\pi r^2$

volume of sphere $= \frac{4}{3}\pi r^3$

Mechanics and Applied Physics

$v = u + at$

$s = \left(\frac{u+v}{2}\right) t$

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

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

$F = \frac{\Delta(mv)}{\Delta t}$

$P = Fv$

efficiency $= \frac{\textit{power output}}{\textit{power input}}$

$\omega = \frac{v}{r} = 2\pi f$

$a = \frac{v^2}{r} = r\omega^2$

$I = \sum mr^2$

$E_k = \frac{1}{2} I\omega^2$

$\omega_2 = \omega_1 + \alpha t$

$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$

$\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$

$T = I\alpha$

angular momentum $= I\omega$

$W = T\theta$

$P = T\omega$

angular impulse = change of angular momentum $= Tt$

$\Delta Q = \Delta U + \Delta W$

$\Delta W = p\Delta V$

$pV^{\gamma} =$ constant

work done per cycle = area of loop

input power = calorific value × fuel flow rate

indicated power as (area of p – V loop) × (no. of cycles/s) × (no. of cylinders)

friction power = indicated power – brake power

efficiency $= \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$

maximum possible efficiency $= \frac{T_H - T_C}{T_H}$

Fields, Waves, Quantum Phenomena

$g = \frac{F}{m}$

$g = -\frac{GM}{r^2}$

$g = -\frac{\Delta V}{\Delta x}$

$V = -\frac{GM}{r}$

$a = -(2\pi f)^2 x$

$v = \pm 2\pi f\sqrt{A^2 - x^2}$

$x = A\cos 2\pi ft$

$T = 2\pi\sqrt{\frac{m}{k}}$

$T = 2\pi\sqrt{\frac{l}{g}}$

$\lambda = \frac{\omega s}{D}$

$d\sin\theta = n\lambda$

$\theta \approx \frac{\lambda}{D}$

${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$

${}_1n_2 = \frac{n_2}{n_1}$

$\sin\theta_c = \frac{1}{n}$

$E = hf$

$hf = \phi + E_k$

$hf = E_1 - E_2$

$\lambda = \frac{h}{p} = \frac{h}{mv}$

$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Electricity

$\epsilon = \frac{E}{Q}$

$\epsilon = I(R + r)$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

$R_T = R_1 + R_2 + R_3 + \cdots$

$P = I^2 R$

$E = \frac{F}{Q} = \frac{V}{d}$

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

$E = \frac{1}{2}QV$

$F = BIl$

$F = BQv$

$Q = Q_0 e^{-t/RC}$

$\Phi = BA$

Turn over ▶

magnitude of induced e.m.f. $= N\dfrac{\Delta\Phi}{\Delta t}$

$I_{rms} = \dfrac{I_0}{\sqrt{2}}$

$V_{rms} = \dfrac{V_0}{\sqrt{2}}$

Mechanical and Thermal Properties

the Young modulus $= \dfrac{\textit{tensile stress}}{\textit{tensile strain}} = \dfrac{F}{A}\dfrac{l}{e}$

energy stored $= \frac{1}{2} Fe$

$\Delta Q = mc\,\Delta\theta$

$\Delta Q = ml$

$pV = \frac{1}{3} Nm\overline{c^2}$

$\frac{1}{2} m\overline{c^2} = \frac{3}{2} kT = \dfrac{3RT}{2N_A}$

Nuclear Physics and Turning Points in Physics

force $= \dfrac{eV_p}{d}$

force $= Bev$

radius of curvature $= \dfrac{mv}{Be}$

$\dfrac{eV}{d} = mg$

work done $= eV$

$F = 6\pi\eta rv$

$I = k\dfrac{I_0}{x^2}$

$\dfrac{\Delta N}{\Delta t} = -\lambda N$

$\lambda = \dfrac{h}{\sqrt{2meV}}$

$N = N_0 e^{-\lambda t}$

$T_{\frac{1}{2}} = \dfrac{\ln 2}{\lambda}$

$R = r_0 A^{\frac{1}{3}}$

$E = mc^2 = \dfrac{m_0 c^2}{\left(1 - \dfrac{v^2}{c^2}\right)^{\frac{1}{2}}}$

$l = l_0\left(1 - \dfrac{v^2}{c^2}\right)^{\frac{1}{2}}$

$t = \dfrac{t_0}{\left(1 - \dfrac{v^2}{c^2}\right)^{\frac{1}{2}}}$

Astrophysics and Medical Physics

Body	*Mass*/kg	*Mean radius*/m
Sun	2.00×10^{30}	7.00×10^{8}
Earth	6.00×10^{24}	6.40×10^{6}

1 astronomical unit $= 1.50 \times 10^{11}$ m

1 parsec = 206265 AU $= 3.08 \times 10^{16}$ m = 3.26 ly

1 light year $= 9.45 \times 10^{15}$ m

Hubble constant (H) = 65 km s^{-1} Mpc^{-1}

$M = \dfrac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$

$M = \dfrac{f_o}{f_e}$

$m - M = 5 \log \dfrac{d}{10}$

$\lambda_{max} T$ = constant = 0.0029 m K

$v = Hd$

$P = \sigma A T^4$

$\dfrac{\Delta f}{f} = \dfrac{v}{c}$

$\dfrac{\Delta\lambda}{\lambda} = -\dfrac{v}{c}$

$R_s \approx \dfrac{2GM}{c^2}$

Medical Physics

power $= \dfrac{1}{f}$

$\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$ and $m = \dfrac{v}{u}$

intensity level $= 10 \log \dfrac{I}{I_0}$

$I = I_0 e^{-\mu x}$

$\mu_m = \dfrac{\mu}{\rho}$

Electronics

Resistors

Preferred values for resistors (E24)
Series: 1.0 1.1 1.2 1.3 1.5 1.6 1.8 2.0 2.2 2.4 2.7 3.0 3.3 3.6 3.9 4.3 4.7 5.1 5.6 6.2 6.8 7.5 8.2 9.1 ohms
and multiples that are ten times greater

$Z = \dfrac{V_{rms}}{I_{rms}}$

$\dfrac{1}{C_T} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3} + \cdots$

$C_T = C_1 + C_2 + C_3 + \cdots$

$X_C = \dfrac{1}{2\pi f C}$

Alternating Currents

$f = \dfrac{1}{T}$

Operational amplifier

$G = \dfrac{V_{out}}{V_{in}}$ voltage gain

$G = -\dfrac{R_f}{R_1}$ inverting

$G = 1 + \dfrac{R_f}{R_1}$ non-inverting

$V_{out} = -R_f\left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2} + \dfrac{V_3}{R_3}\right)$ summing

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

1 (a) In the circuit in **Figure 1**, the battery, of emf 15 V and negligible internal resistance, is connected in series with two lamps and a resistor. The three components each have a resistance of 12 Ω.

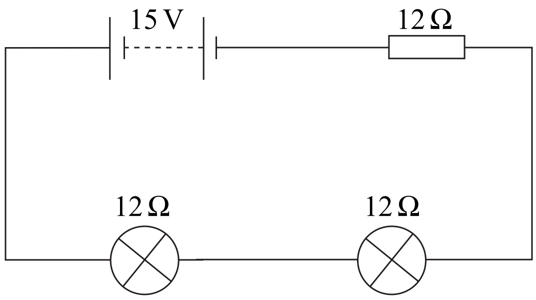


Figure 1

(i) What is the voltage across each lamp?

....

(ii) Calculate the current through the lamps.

....

....

(3 marks)

(b) The two lamps are now disconnected and reconnected in parallel as shown in **Figure 2**.

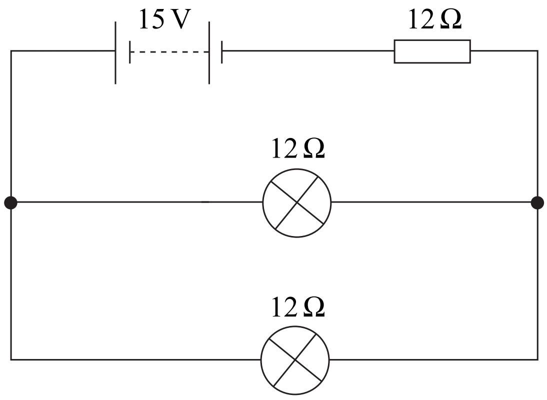


Figure 2

(i) Show that the current supplied by the battery is 0.83 A.

....

....

....

....

(ii) Hence show that the current in each lamp is the same as the current in the lamps in the circuit in **Figure 1**.

....

....

....

....

(3 marks)

(c) How does the brightness of the lamps in the circuit in **Figure 1** compare with the brightness of the lamps in the circuit in **Figure 2**?

Explain your answer.

....

....

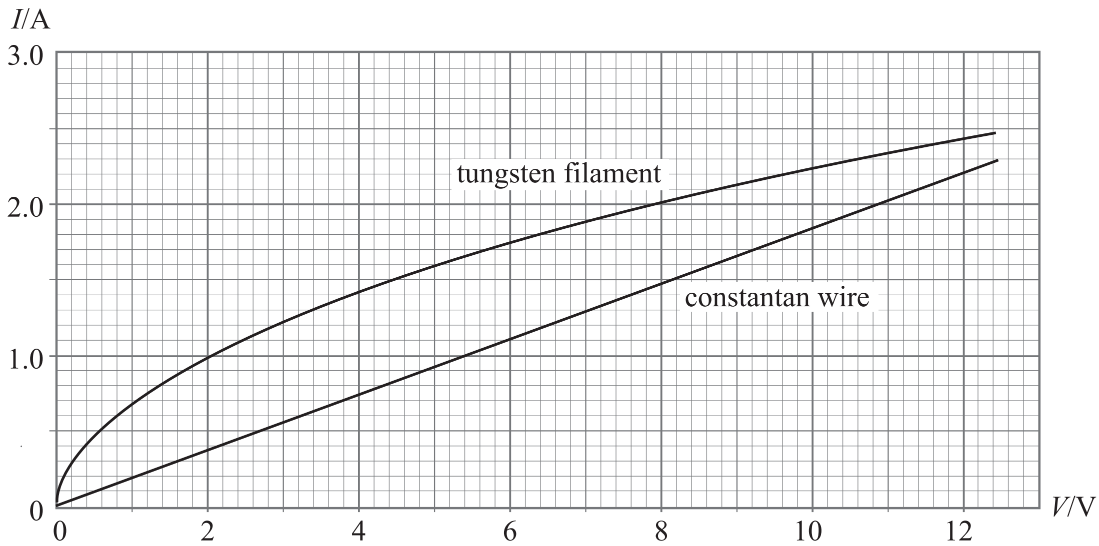
....

(2 marks)

8

Turn over

2 The graph shows the I - V characteristics for two conductors, the tungsten filament of a lamp and a length of constantan wire.



(a) State, with a reason, which conductor obeys Ohm's law across the full voltage range.

conductor: ....

reason: ....

(2 marks)

(b) (i) Calculate the resistance of the tungsten filament when $V = 1\text{ V}$ and $V = 10\text{ V}$.

$V = 1\text{ V}$: ....

....

$V = 10\text{ V}$: ....

....

(ii) Explain why the values of resistance, calculated in part (b)(i), differ from each other.

You may be awarded marks for the quality of written communication in your answer.

....

....

....

....

(4 marks)

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(c) Use the graph to determine the resistivity of constantan, given that the wire is 0.80 m long with a uniform cross-sectional area of $6.8 \times 10^{-8}\,m^2$.

....

....

....

....

....

....

....

(3 marks)

(d) A student is required to obtain the *I – V* characteristic for a filament lamp using a datalogger, so that the data can be fed into a computer to give a visual display of the characteristic.

Draw a labelled circuit diagram for such an experiment.
(An account of the experiment is not required).

TURN OVER FOR THE NEXT QUESTION

(3 marks)

12

3 An oscilloscope is connected to a sinusoidal ac source as shown in **Figure 3**.
The frequency and the voltage output of the ac source can be varied.

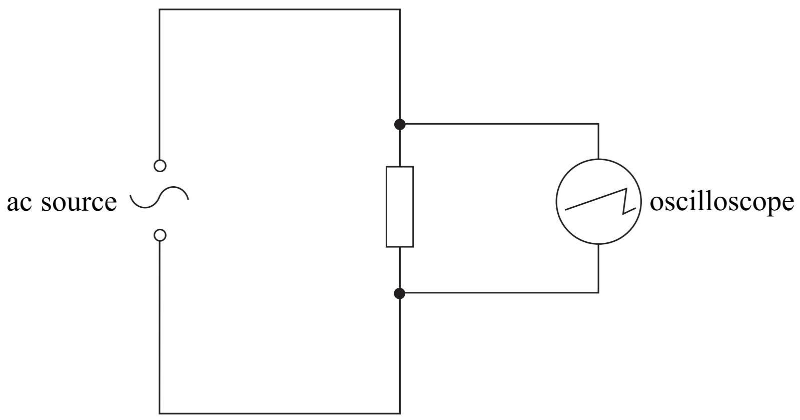

Figure 3

At a certain frequency the ac signal has an rms output of 7.1 V. **Figure 4** shows the trace obtained on the screen of the oscilloscope when one horizontal division corresponded to a time of 5.0 ms.

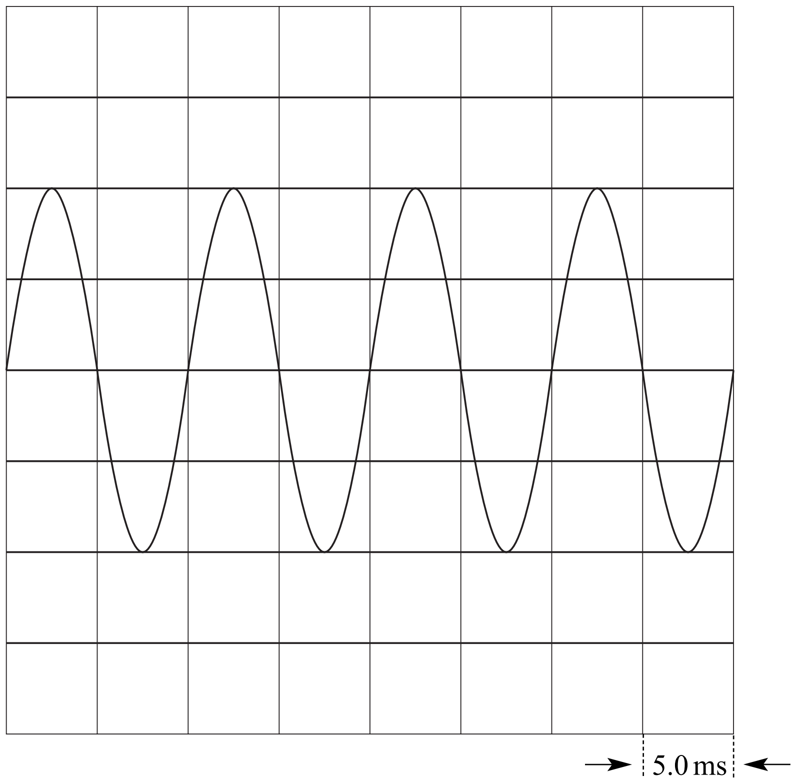

Figure 4

(a) Calculate, for the signal shown in **Figure 4**,

(i) the peak voltage,

....

(ii) the frequency.

....

....

(3 marks)

(b) The voltage output and frequency of the signal are now changed so that the peak voltage is 80 V and the frequency is 200 Hz.

State which **two** controls on the oscilloscope have to be altered so that **four** full cycles again appear on the screen but the peak to peak distance occupies the **full** screen.

Determine the values at which these two controls have to be set.

control 1: ....

value of the setting: ....

....

....

control 2: ....

value of the setting: ....

....

....

(5 marks)

8

TURN OVER FOR THE NEXT QUESTION

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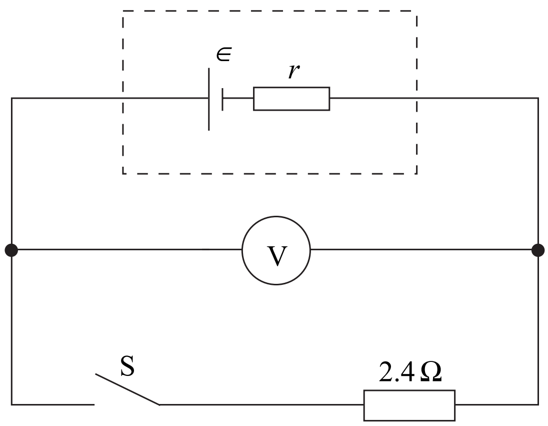
4 In the circuit shown the battery has emf $\in$ and internal resistance r.



(a) (i) State what is meant by the emf of a battery.

....

....

(ii) When the switch S is open, the voltmeter, which has infinite resistance, reads 8.0 V. When the switch is closed, the voltmeter reads 6.0 V.
Determine the current in the circuit when the switch is closed.

....

....

....

(iii) Show that $r = 0.80\,\Omega$.

....

....

(4 marks)

(b) The switch S remains closed. Calculate

(i) the power dissipated in the 2.4 Ω resistor,

....

(ii) the total power dissipated in the circuit,

....

....

(iii) the energy wasted in the battery in 2 minutes.

....

(4 marks)

8

LEAVE MARGIN BLANK

5 (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire. State the meaning of

tensile stress, ...

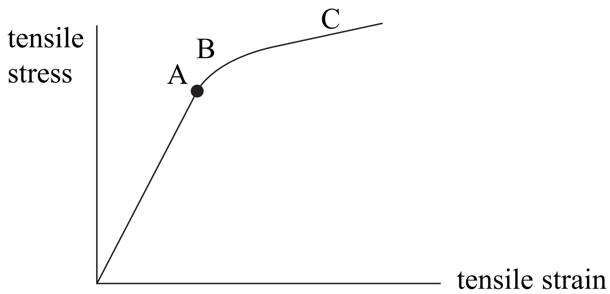
....

tensile strain. ....

....

(2 marks)

(b) A long thin metallic wire is suspended from a fixed support and hangs vertically. Weights are added to increase the load on the free end of the wire until the wire breaks. The graph below shows how the tensile strain in the wire increases as the tensile stress increases.



With reference to the graph, describe the behaviour of the wire as the load on the free end is increased. To assist with your answer refer to the point A, and regions B and C.

You may be awarded marks for the quality of written communication in your answer.

....

....

....

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....

....

(5 marks)

7

TURN OVER FOR THE NEXT QUESTION

LEAVE MARGIN BLANK

6 (a) Define the *density* of a material.

....

....

(1 mark)

(b) Brass, an alloy of copper and zinc, consists of 70% **by volume** of copper and 30% **by volume** of zinc.

density of copper $= 8.9 \times 10^{3}\,\mathrm{kg\,m^{-3}}$
density of zinc $= 7.1 \times 10^{3}\,\mathrm{kg\,m^{-3}}$

(i) Determine the mass of copper and the mass of zinc required to make a rod of brass of volume $0.80 \times 10^{-3}\,\mathrm{m^{3}}$.

....

....

....

....

(ii) Calculate the density of brass.

....

....

(4 marks)

—
5

QUALITY OF WRITTEN COMMUNICATION *(2 marks)*

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2

END OF QUESTIONS