

Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
January 2006
Advanced Subsidiary Examination



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

Thursday 12 January 2006 9.00 am to 10.00 am

<p>For this paper you must have:</p> <ul style="list-style-type: none"> • a calculator • a pencil and a ruler
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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.
- Answer the questions in the spaces provided.
- Show all your working.
- Make and state any necessary assumptions.
- 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. This includes up to 2 marks for the Quality of Written Communication.
- The marks for questions are shown in brackets.
- 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 reminded of the need for good English and clear presentation in your answers. Questions indicated on the paper should be answered in continuous prose. Quality of Written Communication will be assessed in these answers.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
5			
Total (Column 1)		→	
Total (Column 2)		→	
Quality of Written Communication			
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				Mechanics and Applied Physics		Fields, Waves, Quantum Phenomena	
Quantity	Symbol	Value	Units				
speed of light in vacuo	c	3.00×10^8	m s^{-1}	$v = u + at$	$g = \frac{F}{m}$		
permeability of free space	μ_0	$4\pi \times 10^{-7}$	H m^{-1}	$s = \left(\frac{u+v}{2}\right)t$	$g = -\frac{GM}{r^2}$		
permittivity of free space	ϵ_0	8.85×10^{-12}	F m^{-1}	$s = ut + \frac{at^2}{2}$	$g = -\frac{\Delta V}{\Delta x}$		
charge of electron	e	1.60×10^{-19}	C	$v^2 = u^2 + 2as$	$V = -\frac{GM}{r}$		
the Planck constant	h	6.63×10^{-34}	J s	$F = \frac{\Delta(mv)}{\Delta t}$	$a = -(2\pi f)^2 x$		
gravitational constant	G	6.67×10^{-11}	$\text{N m}^2 \text{kg}^{-2}$	$P = Fv$	$v = \pm 2\pi f \sqrt{A^2 - x^2}$		
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}	$\text{efficiency} = \frac{\text{power output}}{\text{power input}}$	$x = A \cos 2\pi ft$		
molar gas constant	R	8.31	$\text{J K}^{-1} \text{mol}^{-1}$	$\omega = \frac{v}{r} = 2\pi f$	$T = 2\pi\sqrt{\frac{m}{k}}$		
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}	$a = \frac{v^2}{r} = r\omega^2$	$T = 2\pi\sqrt{\frac{l}{g}}$		
the Stefan constant	σ	5.67×10^{-8}	$\text{W m}^{-2} \text{K}^{-4}$	$I = \sum mr^2$	$\lambda = \frac{\omega s}{D}$		
the Wien constant	a	2.90×10^{-3}	m K	$E_k = \frac{1}{2} I\omega^2$	$d \sin \theta = n\lambda$		
electron rest mass	m_e	9.11×10^{-31}	kg	$\omega_2 = \omega_1 + \alpha t$	$\theta \approx \frac{\lambda}{D}$		
(equivalent to $5.5 \times 10^{-4}u$)				$\theta = \omega_1 t + \frac{1}{2} \alpha t^2$	$n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$		
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}	$\omega_2^2 = \omega_1^2 + 2\alpha\theta$	$n_2 = \frac{n_2}{n_1}$		
proton rest mass	m_p	1.67×10^{-27}	kg	$\theta = \frac{1}{2} (\omega_1 + \omega_2)t$	$\sin \theta_c = \frac{1}{n}$		
(equivalent to 1.00728u)				$T = I\alpha$	$E = hf$		
proton charge/mass ratio	e/m_p	9.58×10^7	C kg^{-1}	$\text{angular momentum} = I\omega$	$hf = \phi + E_k$		
neutron rest mass	m_n	1.67×10^{-27}	kg	$W = T\theta$	$hf = E_1 - E_2$		
(equivalent to 1.00867u)				$P = T\omega$	$\lambda = \frac{h}{p} = \frac{h}{mv}$		
gravitational field strength	g	9.81	N kg^{-1}	$\text{angular impulse} = \text{change of angular momentum} = Tt$	$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$		
acceleration due to gravity	g	9.81	m s^{-2}	$\Delta Q = \Delta U + \Delta W$	Electricity		
atomic mass unit	u	1.661×10^{-27}	kg	$\Delta W = p\Delta V$	$\epsilon = \frac{E}{Q}$		
(1u is equivalent to 931.3 MeV)				$pV^\gamma = \text{constant}$	$\epsilon = I(R + r)$		
Fundamental particles				$\text{work done per cycle} = \text{area of loop}$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$		
Class	Name	Symbol	Rest energy	$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$	$R_T = R_1 + R_2 + R_3 + \dots$		
			/MeV	$\text{indicated power as (area of } p-V \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$	$P = I^2 R$		
photon	photon	γ	0	$\text{friction power} = \text{indicated power} - \text{brake power}$	$E = \frac{F}{Q} = \frac{V}{d}$		
lepton	neutrino	ν_e	0	$\text{efficiency} = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$	$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$		
		ν_μ	0	$\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$	$E = \frac{1}{2} QV$		
	electron	e^\pm	0.510999		$F = BIl$		
	muon	μ^\pm	105.659		$F = BQv$		
mesons	pion	π^\pm	139.576		$Q = Q_0 e^{-t/RC}$		
		π^0	134.972		$\Phi = BA$		
	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 = πr^2							
area of cylinder = $2\pi rh$							
volume of cylinder = $\pi r^2 h$							
area of sphere = $4\pi r^2$							
volume of sphere = $\frac{4}{3}\pi r^3$							

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

$$I_{\text{rms}} = \frac{I_0}{\sqrt{2}}$$

$$V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$$

Mechanical and Thermal Properties

$$\text{the Young modulus} = \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{F l}{A e}$$

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

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

$$\Delta Q = ml$$

$$pV = \frac{1}{3} Nmc^2$$

$$\frac{1}{2} mc^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$$

Nuclear Physics and Turning Points in Physics

$$\text{force} = \frac{eV_p}{d}$$

$$\text{force} = Bev$$

$$\text{radius of curvature} = \frac{mv}{Be}$$

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

$$\text{work done} = eV$$

$$F = 6\pi\eta rv$$

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\text{Hubble constant } (H) = 65 \text{ kms}^{-1} \text{ Mpc}^{-1}$$

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

Medical Physics

$$\text{power} = \frac{1}{f}$$

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

$$\text{intensity level} = 10 \log \frac{I}{I_0}$$

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

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

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

$$Z = \frac{V_{\text{rms}}}{I_{\text{rms}}}$$

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

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

$$X_C = \frac{1}{2\pi fC}$$

Alternating Currents

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

Operational amplifier

$$G = \frac{V_{\text{out}}}{V_{\text{in}}} \quad \text{voltage gain}$$

$$G = -\frac{R_f}{R_1} \quad \text{inverting}$$

$$G = 1 + \frac{R_f}{R_1} \quad \text{non-inverting}$$

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

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

- 1 (a) A steady current of 0.25 A passes through a torch bulb for 6 minutes. Calculate the charge which flows through the bulb in this time.

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(2 marks)

- (b) The torch bulb is now connected to a battery of negligible internal resistance. The battery supplies a steady current of 0.25 A for 20 hours. In this time the energy transferred in the bulb is 9.0×10^4 J. Calculate

- (i) the potential difference across the bulb,

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- (ii) the power of the bulb.

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(3 marks)

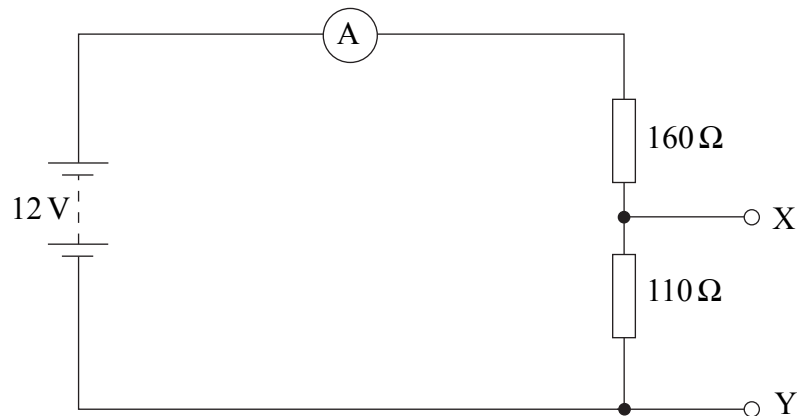
5

Turn over for the next question

Turn over ▶

- 2 In the circuit shown in **Figure 1**, the battery, of negligible internal resistance, is connected to two resistors which form a potential divider.

Figure 1



- (a) (i) Calculate the current through the ammeter.

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- (ii) A $20\ \Omega$ resistor is now connected between X and Y. State and explain, without further calculation, whether the current through the ammeter will increase or decrease.

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

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(4 marks)

- (b) The $20\ \Omega$ resistor is now removed and replaced with a voltmeter. Stating the assumption made, show that the reading on the voltmeter is $4.9\ \text{V}$.

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(2 marks)

- (c) The voltmeter is now removed and the terminals X and Y joined together with a wire. Calculate the reading on the ammeter.

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(2 marks)

Turn over for the next question

8

Turn over ▶

3 (a) A student wishes to measure the resistivity of the material of a uniform resistance wire. The available apparatus includes a battery, a switch, a variable resistor, an ammeter and a voltmeter.

(i) Draw a circuit diagram which incorporates some or all of this apparatus and which enables the student to determine the resistivity of the material.

(ii) State the measurements which must be made to ensure that a reliable value of the resistivity is obtained.

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(iii) Explain how a value of the resistivity would be obtained from the measurements.

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(10 marks)

- (b) A wire made from tin with cross-sectional area $7.8 \times 10^{-9} \text{ m}^2$, has a pd of 2.0 V across it. Calculate the minimum length of wire needed so that the current through it does not exceed 4.0 A.

resistivity of tin = $1.1 \times 10^{-7} \Omega \text{ m}$

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(2 marks)

12

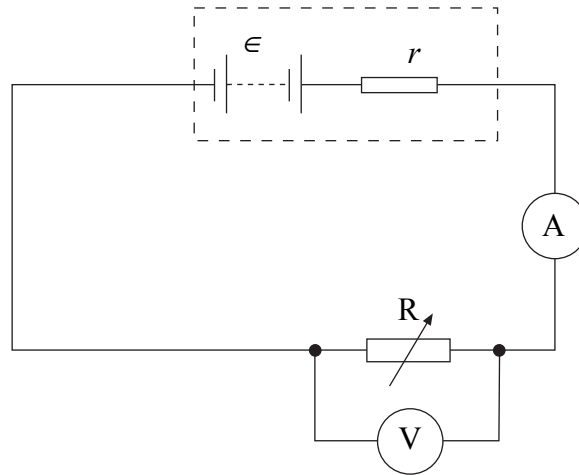
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- 4 A battery of emf ϵ and internal resistance r is connected in series to a variable resistor R and an ammeter of negligible resistance. A voltmeter is connected across R , as shown in **Figure 2**.

Figure 2



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

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- (ii) The reading on the voltmeter is less than the emf. Explain why this is so.

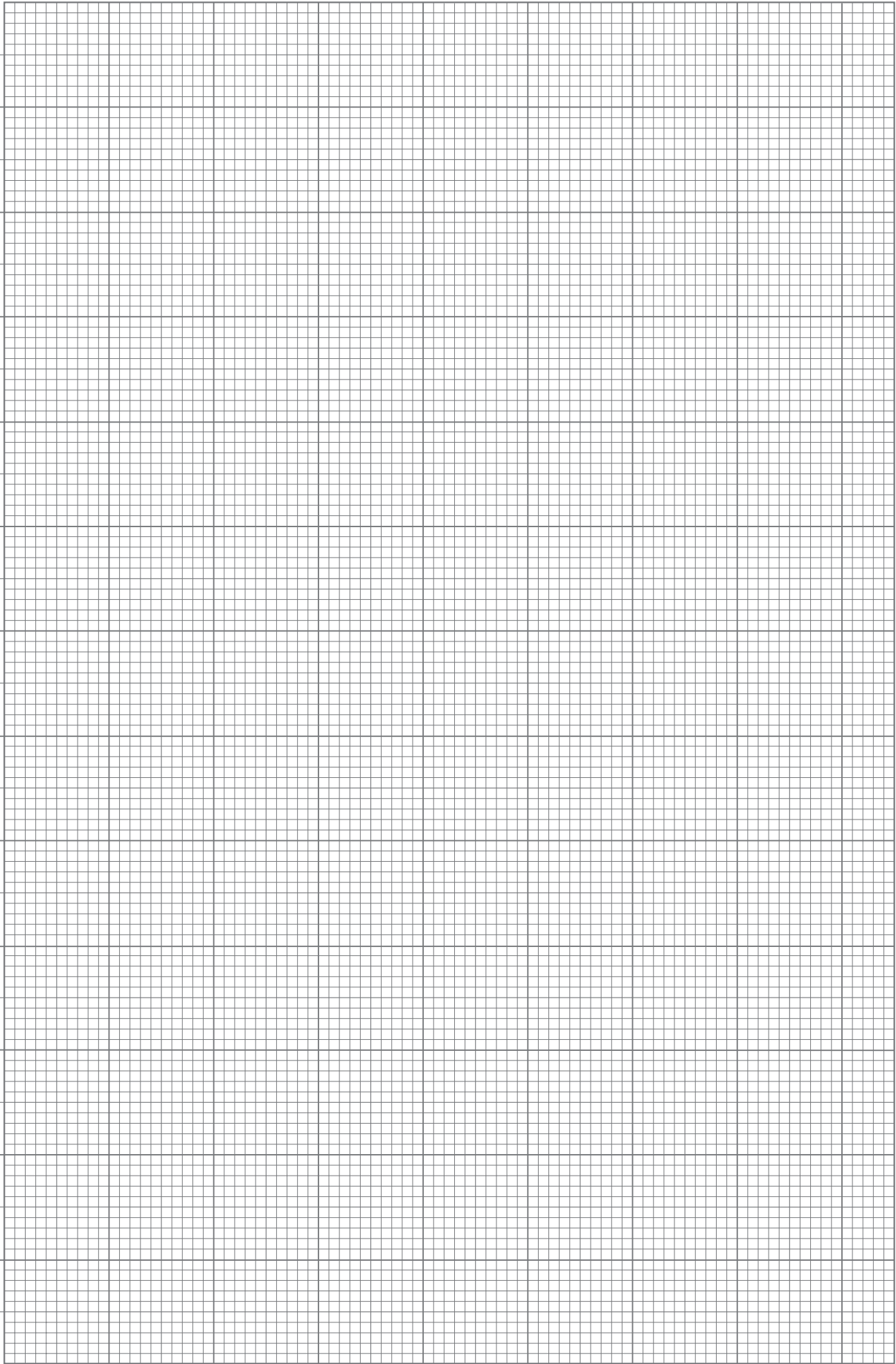
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(2 marks)

Question 4 continues on page 13

Turn over ▶



- (b) A student wishes to measure ϵ and r . Using the circuit shown in **Figure 2** the value of R is decreased in steps and at each step the readings V and I on the voltmeter and ammeter respectively are recorded. These are shown in the table.

reading on voltmeter/V	reading on ammeter/A
8.3	0.07
6.8	0.17
4.6	0.33
2.9	0.44
0.3	0.63

- (i) Give an expression relating V , I , ϵ and r .

.....

- (ii) Using the grid on **page 12** of this booklet, draw a graph of V (on the y -axis) against I (on the x -axis).

- (iii) Determine the values of ϵ and r from the graph, explaining your method.

ϵ :

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r :

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(8 marks)

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,

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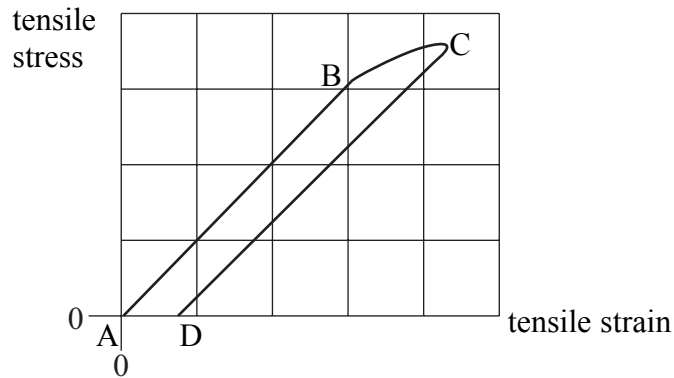
tensile strain.

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(2 marks)

(b) A long, thin metal wire is suspended from a fixed support and hangs vertically. Masses are suspended from its lower end.

As the load on the lower end is increased from zero to a certain value, and then decreased again to zero, the variation of the resulting tensile strain with the applied tensile stress is shown in the graph.



(i) Describe the behaviour of the wire during this process. Refer to the points A, B, C and D in your answer. You may be awarded marks for the quality of written communication in your answer.

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- (ii) State, with a reason, whether the material of the wire is ductile or brittle.

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- (iii) What does AD represent?

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- (iv) State how the Young modulus for the material may be obtained from the graph.

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- (v) State how the energy per unit volume stored in the wire during the loading process may be estimated from the graph.

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(9 marks)

- (c) The wire described in part (b) has an unstretched length of 3.0 m and cross-sectional area $2.8 \times 10^{-7} \text{ m}^2$. At a certain stage between the points A and B on the graph, the wire supports a load of 75 N. Calculate the extension produced in the wire by this load.

the Young modulus for the material of the wire = $2.1 \times 10^{11} \text{ Pa}$

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(2 marks)

13

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

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