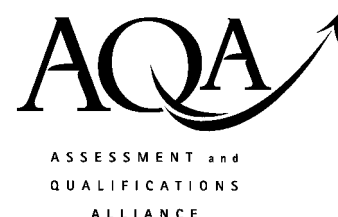


Surname						Other Names					
Centre Number						Candidate Number					
Candidate Signature											

For Examiner's Use

General Certificate of Education
January 2007
Advanced Subsidiary Examination



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

PHA3/W

Friday 12 January 2007 1.30 pm to 2.30 pm

For this paper you must have:

- 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.
- Answer the questions in the spaces provided.
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The maximum mark for this paper is 50.
- Two of these marks will be awarded for using good English, organising information clearly and using specialist vocabulary where appropriate.
- 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.
- Questions 2(b) and 5(b) should be answered in continuous prose. In these questions you will be marked on your ability to use good English, to organise information clearly and to use specialist vocabulary where appropriate.

For Examiner's Use			
Question	Mark	Question	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	α	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	$\omega_2 = \omega_1 + at$		$\theta \approx \frac{\lambda}{D}$
(equivalent to $5.5 \times 10^{-4} \text{u}$)				$\theta = \omega_1 t + \frac{1}{2} at^2$		${}_1n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}	$\omega_2^2 = \omega_1^2 + 2\alpha\theta$		${}_1n_2 = \frac{n_2}{n_1}$
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	$\Delta W = p\Delta V$		
(1u is equivalent to 931.3 MeV)				$pV^\gamma = \text{constant}$		
Fundamental particles				$\text{work done per cycle} = \text{area of loop}$		$\epsilon = \frac{E}{Q}$
Class	Name	Symbol	Rest energy /MeV	$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$		$\epsilon = I(R + r)$
photon	photon	γ	0	$\text{indicated power as (area of } p-V \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$		$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
lepton	neutrino	ν_e	0	$\text{friction power} = \text{indicated power} - \text{brake power}$		$R_T = R_1 + R_2 + R_3 + \dots$
		ν_μ	0	$\text{efficiency} = \frac{W}{Q_{\text{in}}} = \frac{Q_{\text{in}} - Q_{\text{out}}}{Q_{\text{in}}}$		$P = I^2 R$
	electron	$e^\pm$	0.510999	$\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$		$E = \frac{F}{Q} = \frac{V}{d}$
	muon	$\mu^\pm$	105.659			$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$
mesons	pion	$\pi^\pm$	139.576			$E = \frac{1}{2} QV$
		π^0	134.972			$F = BIl$
	kaon	$K^\pm$	493.821			$F = BQv$
		K^0	497.762			$Q = Q_0 e^{-t/RC}$
baryons	proton	p	938.257			$\Phi = BA$
	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 = $2\pi rh$						

$$\text{magnitude of induced emf} = N \frac{\Delta\Phi}{\Delta t}$$

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

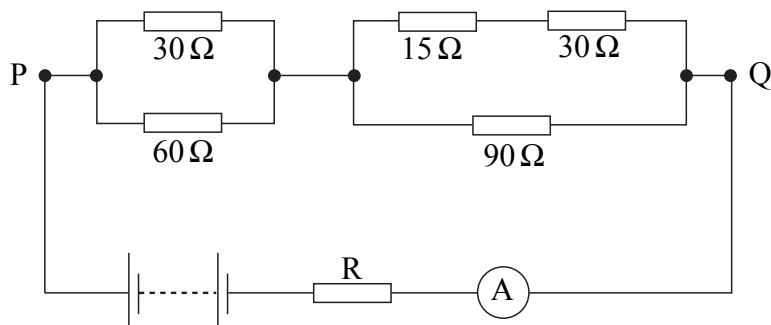
Turn over for the first question

Turn over ►

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

- 1 In the circuit shown in **Figure 1** the resistor network between the points P and Q is connected in series to a resistor R, an ammeter and a battery of negligible internal resistance.

Figure 1



- (a) Determine the equivalent resistance of the network between the points P and Q.

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(3 marks)

- (b) (i) If the current through the ammeter is 50 mA, calculate the total charge that flows through the resistor R in 4 minutes.

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- (ii) If 18 J of energy are transferred to the resistor R in this time, calculate the potential difference across R.

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- (iii) Calculate the resistance of R.

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- (iv) Calculate the emf of the battery.

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(6 marks)

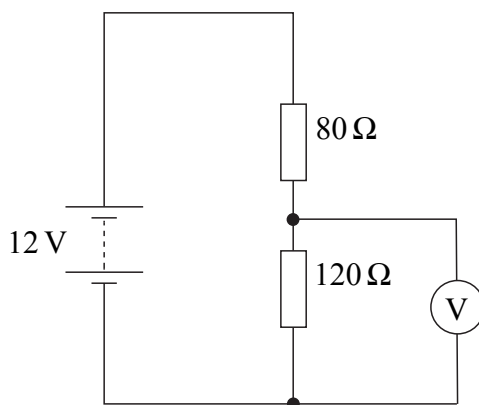
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Turn over for the next question

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- 2 (a) In the potential divider circuit shown in **Figure 2**, the battery has negligible internal resistance.

Figure 2



Calculate the reading on the voltmeter, stating the assumption made.

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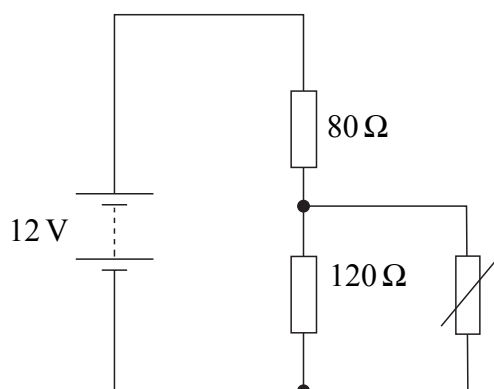
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(3 marks)

- (b) The voltmeter in **Figure 2** is replaced by a thermistor, giving the circuit shown in **Figure 3**.

Figure 3



The resistance of the thermistor at 0°C is $120\,\Omega$. As the temperature increases, its resistance decreases. Explain, without calculation, whether the current through the battery increases or decreases as the temperature of the thermistor is increased from 0°C .

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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(3 marks)

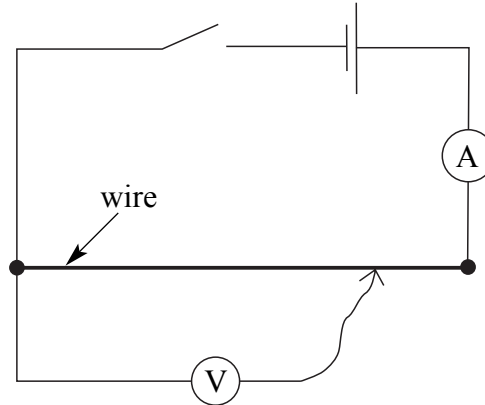
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6

Turn over ►

- 3 (a) A student is required to measure the resistivity of a material in the form of a uniform resistance wire, using the circuit shown in **Figure 4**. The cross-sectional area of the wire is known.

Figure 4



- (i) Describe the measurements the student should make in order to determine the resistivity by a graphical method.

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- (ii) Show how the value of the resistivity could be obtained from the measurements, using a suitable graph.

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(7 marks)

- (b) A square sheet of carbon-reinforced plastic, measuring $90\text{ mm} \times 90\text{ mm}$ and 1.1 mm thick, has its two large surfaces coated with a highly conducting metal film. When a pd of 210 V is applied between the metal films a current of 1.4 mA passes through the plastic sheet. Calculate the resistivity of the plastic.

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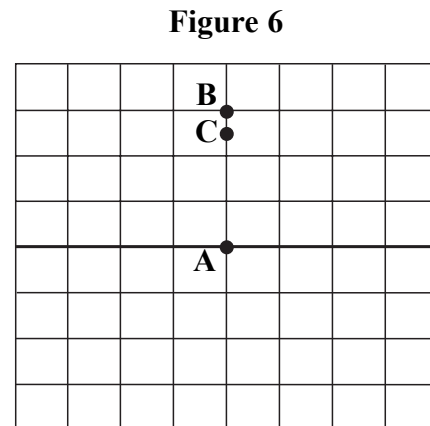
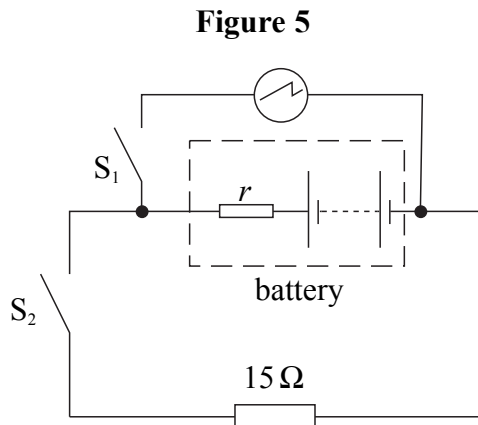
(3 marks)

10

Turn over for the next question

Turn over ►

- 4 (a) The circuit in **Figure 5** may be used to determine the internal resistance, r , of a battery. An oscilloscope is connected across the battery. **Figure 6** represents the screen of the oscilloscope.



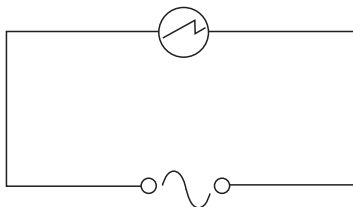
The vertical sensitivity of the oscilloscope is set at 2.0 V per division.
The time base of the oscilloscope is switched off throughout the experiment.
With both switches, S_1 and S_2 , open, the spot on the oscilloscope screen is at **A**.

- (i) Switch S_1 is closed with switch S_2 remaining open. The spot moves to **B**.
State what the deflection **AB** represents and determine its value.
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-
- (ii) With switch S_1 kept closed, switch S_2 is now also closed. The spot moves to **C**.
Explain why the voltage represented by **AC** is less than the voltage measured by the oscilloscope in part (i).
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-
- (iii) Calculate the current through the $15\ \Omega$ resistor with both switches closed.
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-
- (iv) Calculate the internal resistance, r , of the battery.
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(8 marks)

- (b) The oscilloscope is now connected to an alternating voltage source of rms value 5.3 V, as shown in **Figure 7**.

Figure 7



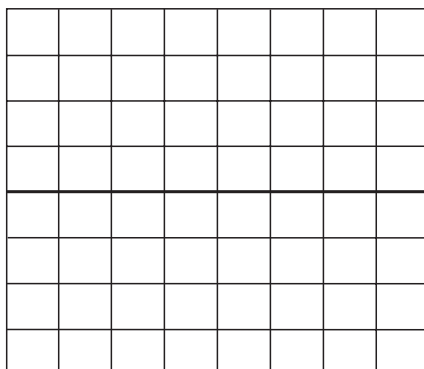
- (i) Calculate the peak value of the alternating voltage.

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- (ii) Draw on **Figure 8** what you would expect to see on the oscilloscope screen, if the time base remains switched off and the voltage sensitivity is changed to 5.0 V per division.

Figure 8



(3 marks)

- 5 A material in the form of a long wire is suspended from a support so that it hangs vertically with a mass holder attached to the lower end. Masses, up to a certain value, are added to the holder and then removed again, until only the mass holder remains. The extension of the wire is measured as each mass is added and again as they are removed. The table shows the extension of the wire as the masses are added and removed.

load/N	0	26	50	73	93	108	118	90	51	0
extension/mm	0	2.4	4.6	6.8	8.6	10.4	13.6	10.8	7.0	2.0

- (a) On the grid opposite, plot a graph of load against extension for both increasing and decreasing loads. (5 marks)
- (b) With reference to the graph, describe the behaviour of the wire as the load is increased and then decreased.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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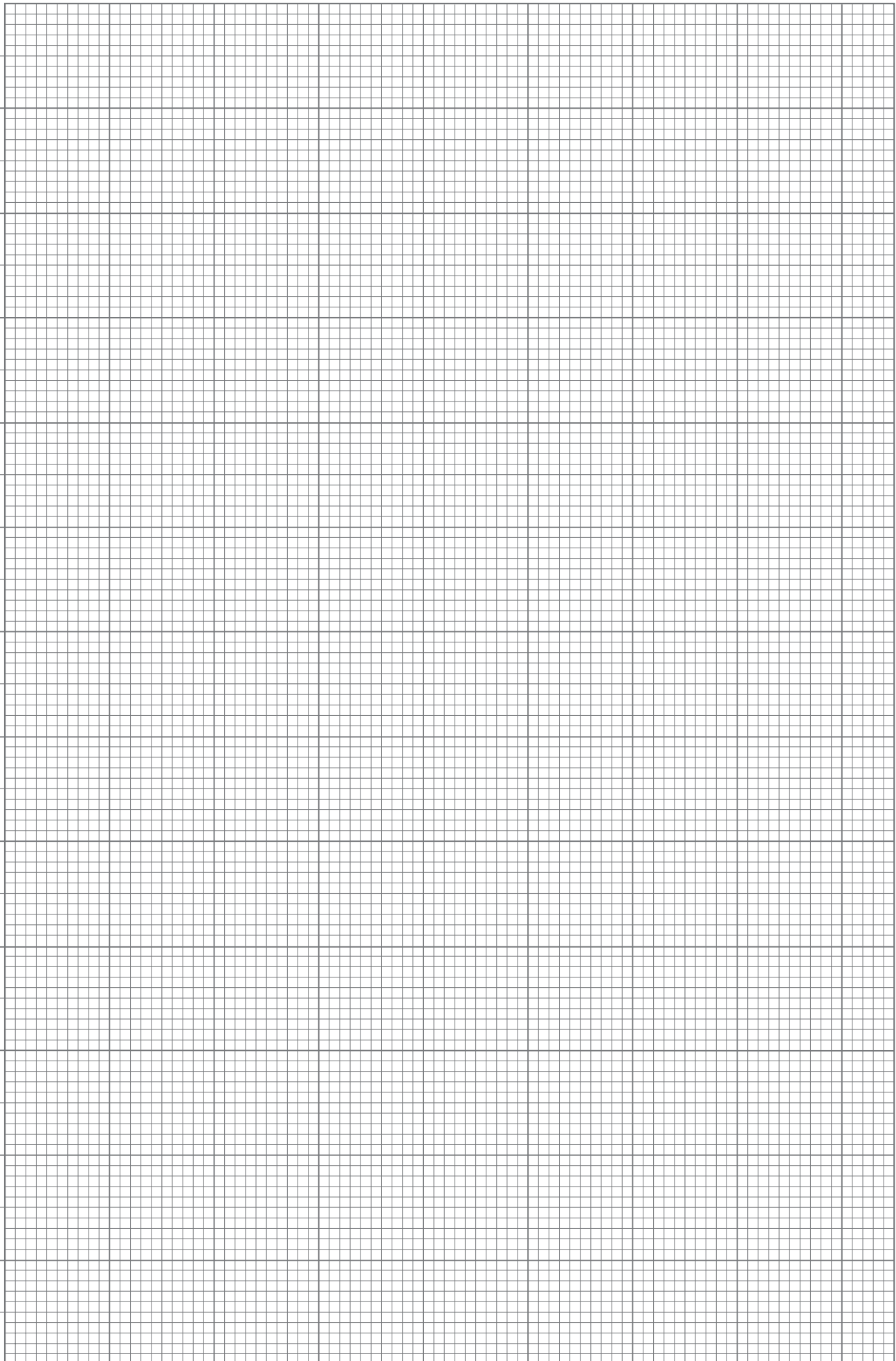
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(3 marks)

**Question 5 continues on the next page****Turn over ►**

- (c) The wire described in the first paragraph of the question has an original length of 2.5 m and a cross-sectional area of $2.8 \times 10^{-7} \text{ m}^2$. At an extension corresponding to a load of 82 N (when the load is being increased), calculate for the wire,

- (i) the tensile stress,

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- (ii) the tensile strain,

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- (iii) the Young modulus for the material of the wire,

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- (iv) the energy stored in the wire.

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(4 marks)

12

Quality of Written Communication (2 marks)

2

END OF QUESTIONS