Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

General Certificate of Education
January 2005
Advanced Subsidiary Examination

AQA

ASSESSMENT and
QUALIFICATIONS
ALLIANCE

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

Wednesday 12 January 2005   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.

PHA3/W

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}	$N\ m^2\ kg^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$J\ K^{-1}\ mol^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	$J\ K^{-1}$
the Stefan constant	σ	5.67×10^{-8}	$W\ m^{-2}\ K^{-4}$
the Wien constant	α	2.90×10^{-3}	$m\ K$
electron rest mass (equivalent to $5.5 \times 10^{-4} u$)	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 $1.00728 u$)	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 $1.00867 u$)	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

$$v = u + at$$

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

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

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

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

$$P = Fv$$

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

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

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

$$I = \sum mr^2$$

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

$$\omega_2 = \omega_1 + \alpha t$$

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

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

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

$$T = I\alpha$$

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 $= calorific$
$value \times fuel\ flow\ rate$

indicated power as (area of $p - V$
loop) $\times$ (no. of cycles/s) $\times$
(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

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

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

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

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

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

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

$$x = A \cos 2\pi ft$$

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

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

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

$$d \sin \theta = n\lambda$$

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

$$_1 n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$$

$$_1 n_2 = \frac{n_2}{n_1}$$

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

$$E = hf$$

$$hf = \phi + E_k$$

$$hf = E_1 - E_2$$

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

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

Electricity

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

$$\epsilon = I(R + r)$$

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

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

$$P = I^2 R$$

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

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

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

$$F = BIl$$

$$F = BQv$$

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

$$\Phi = BA$$

Turn over ▶

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

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

$$pV = \tfrac{1}{3}N m\overline{c^2}$$

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

Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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 = 1.50×10^{11} m

1 parsec = 206265 AU = 3.08×10^{16} m = 3.26 ly

1 light year = 9.45×10^{15} m

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

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

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

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

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

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

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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

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

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

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

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

1   In the circuit shown in **Figure 1**, the battery, of emf 6.0 V, has negligible internal resistance.
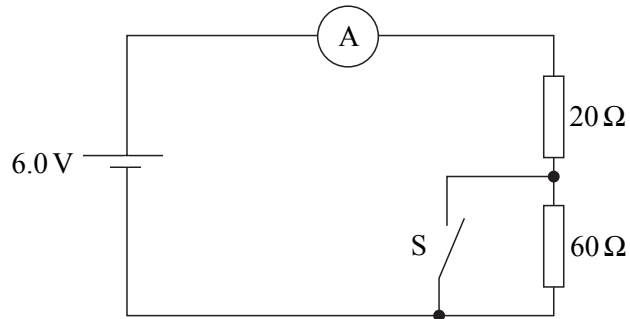
Figure 1

(a)   Calculate the current through the ammeter when the switch S is

   (i)   open,

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   ....

   (ii)   closed.

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   (3 marks)

(b)   The switch S is now replaced with a voltmeter of infinite resistance.
   Determine the reading on the voltmeter.

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   (2 marks)

2 (a) The graph in **Figure 2** shows the *I – V* characteristic for a semiconductor diode.
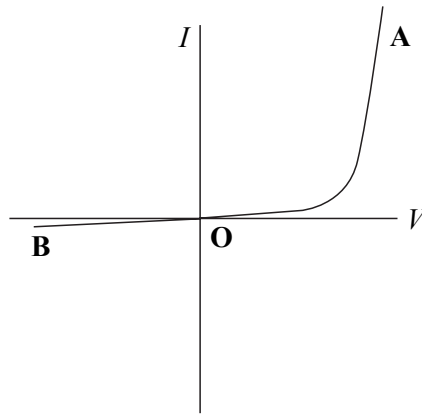
Figure 2

In order to produce this characteristic in the laboratory, a student is given suitable apparatus, including a data logger. The output of the data logger is connected to a computer to give a visual display.

(i) Draw a labelled circuit diagram of the apparatus that would be used to obtain the characteristic from **O** to **A** in **Figure 2**.

(ii) Describe how the apparatus would be used.

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

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(iii)   What change would have to be made to the circuit in order to obtain the characteristic from **O** to **B** in **Figure 2**?

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(6 marks)

(b)   On the axes in **Figure 3** draw the characteristic for a filament lamp.

I

0 V
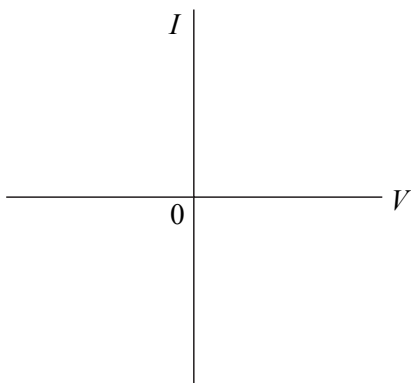
Figure 3

Explain why the $I - V$ characteristic has the shape you have drawn.

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

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(5 marks)

11

Turn over ▶

3 The graph shows how the resistance, R_R, of a metal resistor and the resistance, R_{Th}, of a thermistor change with temperature.
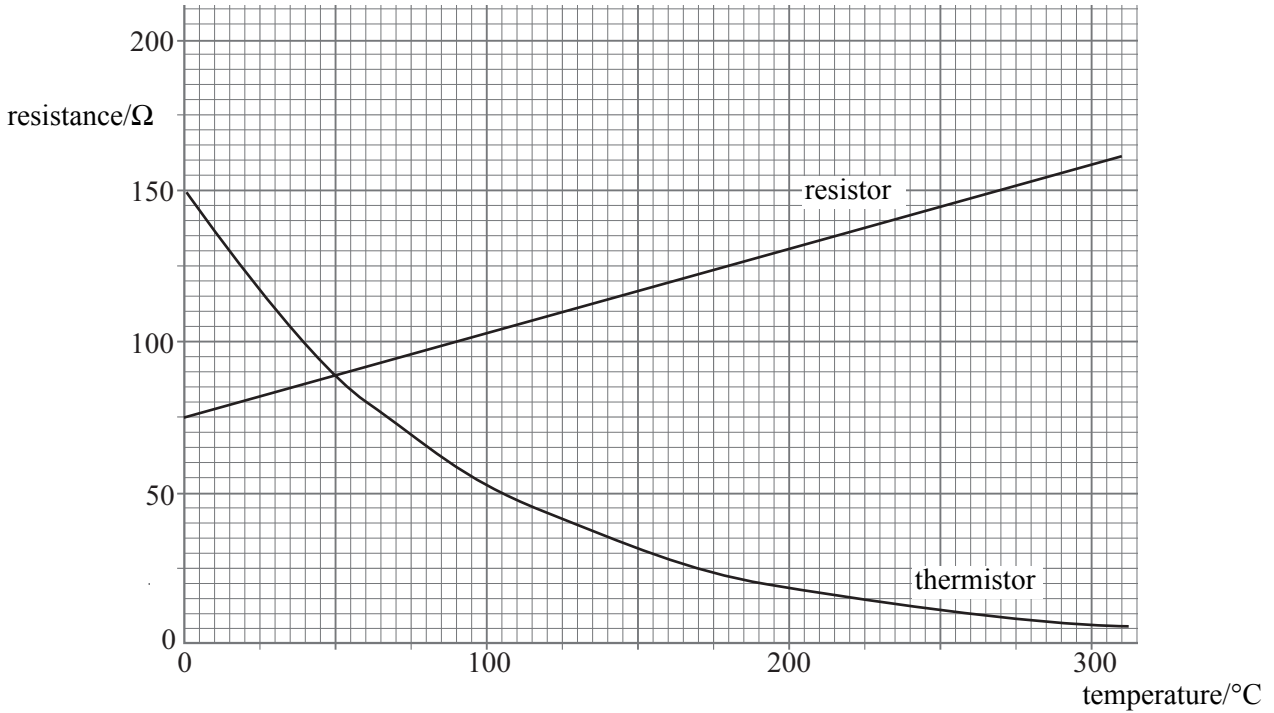
(a) Give the values of the resistance R_R and R_{Th} at a temperature of 200°C.

R_R ....R_{Th} ....

(1 mark)

(b) The resistor and thermistor are connected in series to a 12 V battery of negligible internal resistance, as shown in **Figure 4**.
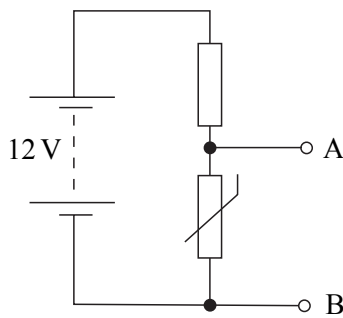
Figure 4

(i) Calculate the voltage across the terminals AB when both the resistor and thermistor are at 200 °C.

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(ii) Assuming that the temperature of the resistor always equals the temperature of the thermistor, deduce the temperature when the voltage across the resistor equals the voltage across the thermistor.

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(4 marks)

(c) A lamp and a switch are now connected across the terminals AB, as shown in **Figure 5**. The temperature of the thermistor does not change from that obtained in part (b)(ii).
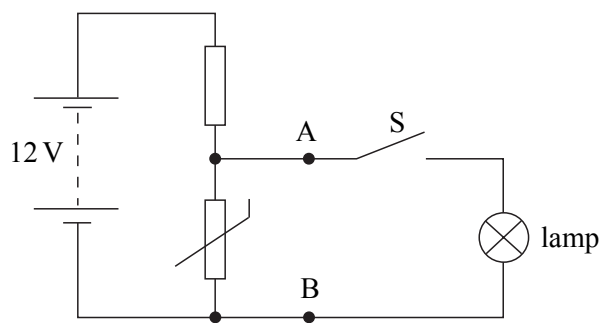
Figure 5

(i) The lamp is rated at 2.0 W at a voltage of 6.0 V. Calculate the resistance of the lamp at this rating.

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(ii) The switch S is now closed. Explain, without calculation, why the voltage across the thermistor will fall from the value in part (b)(ii).

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(4 marks)

Turn over ▶

4 (a) For a conductor in the form of a wire of uniform cross-sectional area, give an equation which relates its resistance to the resistivity of the material of the conductor. Define the symbols used in the equation.

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(2 marks)

(b) (i) An electrical heating element, made from uniform nichrome wire, is required to dissipate 500 W when connected to the 230 V mains supply. The cross-sectional area of the wire is $8.0 \times 10^{-8}\,\text{m}^2$. Calculate the length of nichrome wire required.

resistivity of nichrome $= 1.1 \times 10^{-6}\,\Omega\,\text{m}$

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(ii) Two heating elements, each rated at 230 V, 500 W are connected to the 230 mains supply

(A) in series,
(B) in parallel.

Explain why only one of the circuits will provide an output of 1 kW.

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(6 marks)

8

5 A sinusoidal alternating voltage source of frequency 500 Hz is connected to a resistor of resistance 2.0 kΩ and an oscilloscope, as shown in **Figure 6**.

Figure 6
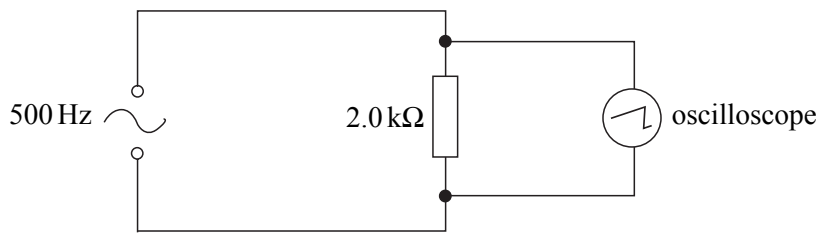
(a) The rms current through the resistor is 5.3 mA. Calculate the peak voltage across the resistor.

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(2 marks)

(b) The settings on the oscilloscope are

timebase: 250 μs per division,
voltage sensitivity: 5.0 V per division.

Draw on the grid, which represents the screen of the oscilloscope, the trace that would be seen.

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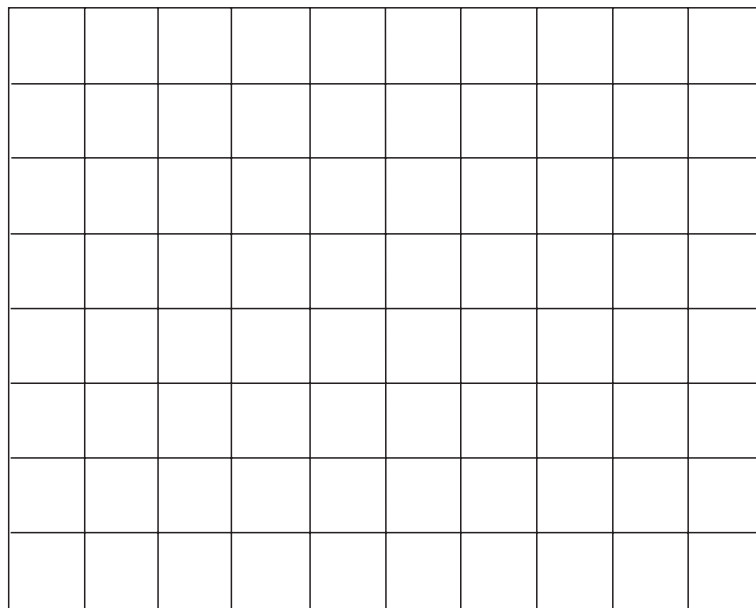
(4 marks)

6

Turn over ▶

6 (a) When determining the Young modulus for the material of a wire, a *tensile stress* is applied to the wire and the *tensile strain* is measured.

    (i) State the meaning of

       tensile stress..

       ....

       tensile strain..

       ....

    (ii) Define the Young modulus...

       ....

(3 marks)

(b) **Figure 7** shows two wires, one made of steel and the other of brass, firmly clamped together at their ends. The wires have the same unstretched length and the same cross-sectional area.
One of the clamped ends is fixed to a horizontal support and a mass M is suspended from the other end, so that the wires hang vertically.
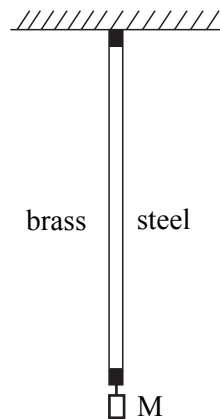

Figure 7

(i) Since the wires are clamped together the extension of each wire will be the same. If E_S is the Young modulus for steel and E_B the Young modulus for brass, show that

$$\frac{E_S}{E_B} = \frac{F_S}{F_B} \ ,$$

where F_S and F_B are the respective forces in the steel and brass wire.

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(ii) The mass M produces a total force of 15 N. Show that the magnitude of the force F_S = 10 N.

the Young modulus for steel $= 2.0 \times 10^{11}$ Pa
the Young modulus for brass $= 1.0 \times 10^{11}$ Pa

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(iii) The cross-sectional area of each wire is 1.4×10^{-6} m^2 and the unstretched length is 1.5 m. Determine the extension produced in either wire.

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(6 marks)

$\overline{9}$

QUALITY OF WRITTEN COMMUNICATION *(2 marks)*

$\overline{2}$

END OF QUESTIONS