Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2007
Advanced Subsidiary Examination

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

Friday 8 June 2007 9.00 am to 10.00 am

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 1(b) and 6(a)(i) 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			
6			
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.

Data Sheet

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 5.5×10^{-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 emf $= N\dfrac{\Delta\Phi}{\Delta t}$

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

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

Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

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

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

Nuclear Physics and Turning Points in Physics

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

force $= Bev$

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

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

work done $= eV$

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

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

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

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

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

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

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

$$E = mc^2 = \frac{m_0c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

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

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

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 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}

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Turn over for the first question

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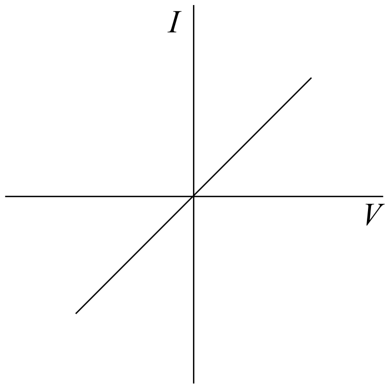
Answer **all** questions in the spaces provided.

1 (a) **Figure 1** shows the *I*-*V* characteristic for a component A which obeys Ohm's law. Component B also obeys Ohm's law, but has a greater resistance than component A. Draw the *I*-*V* characteristic for component B on the same axes, explaining your reasoning.

Figure 1



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(2 marks)

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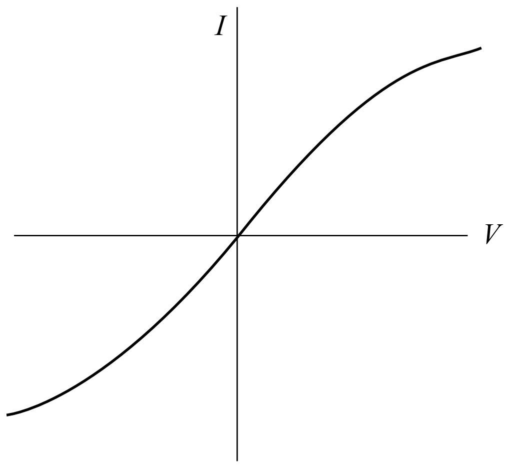
(b) **Figure 2** shows the *I-V* characteristic for a filament lamp. Explain the shape of this characteristic.

Figure 2



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

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(4 marks)

6

Turn over for the next question

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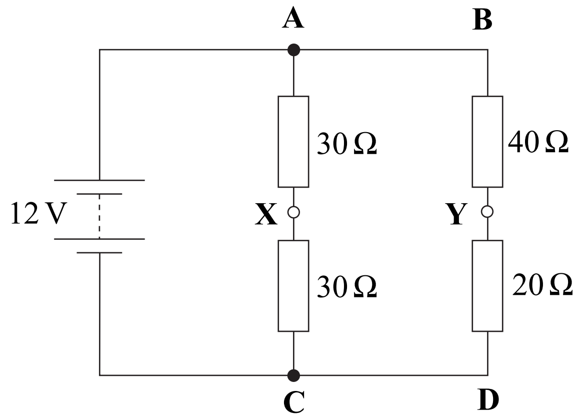
2 In the circuit shown in **Figure 3**, the battery, of negligible internal resistance, has an emf of 12 V.

Figure 3



(a) Show that the total resistance of the circuit is 30 Ω.

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(2 marks)

(b) (i) Calculate the current supplied by the battery.

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(ii) State why this current is divided equally between two arms (**AC** and **BD**) of the resistor network in **Figure 3**.

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(2 marks)

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(c) Calculate the potential difference

(i) between **X** and **C**,

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(ii) between **Y** and **D**.

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(2 marks)

(d) A high resistance voltmeter is connected between the points **X** and **Y**. What is the reading on the voltmeter?

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(1 mark)

7

Turn over for the next question

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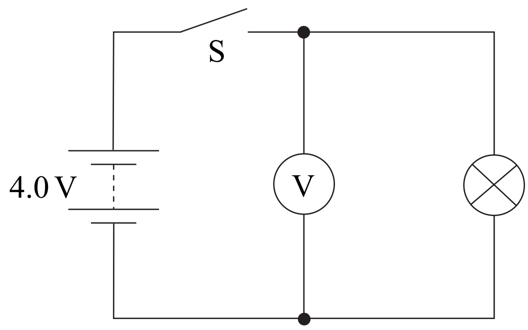
3 A battery of emf 4.0 V is connected to a lamp and a high resistance voltmeter as shown in **Figure 4**.

Figure 4



(a) (i) When the switch S is closed, the lamp lights and the reading on the voltmeter is 3.8 V. Explain why this reading is less than the emf of the battery.

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(ii) With the switch closed the lamp is operating at its rated power of 1.6 W. Calculate the internal resistance, r, of the battery.

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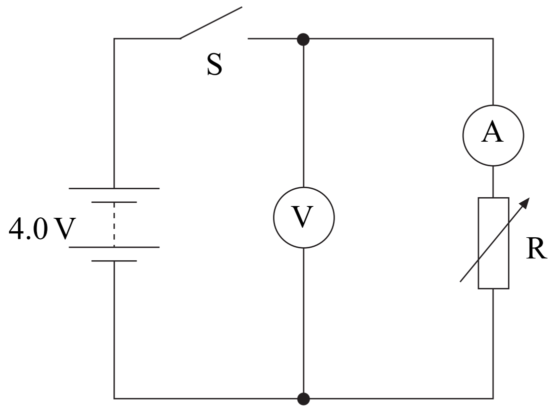
(b) The lamp is replaced by an ammeter and a variable resistor R, as shown in **Figure 5**.

Figure 5



Describe an experiment, using the circuit in **Figure 5**, which would enable the emf and the internal resistance of the battery to be determined by a graphical method.

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(5 marks)

9

Turn over for the next question

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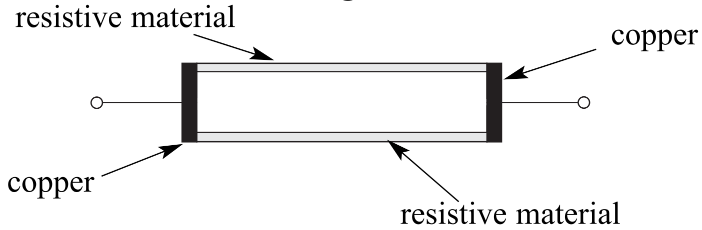
4 A heating element consists of two strips of resistive material, joined by pieces of copper of negligible resistance, as shown in **Figure 6**.

Figure 6



(a) The resistance of each strip of resistive material is 12 Ω. The element is connected to a battery of emf 12 V and negligible internal resistance.
Show that heat is generated in the element at a rate of 24 W.

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(2 marks)

(b) The heating system of the rear window of a car consists of two of the elements described in **Figure 6**. The two elements can be connected in parallel or in series, as shown in **Figure 7** and **Figure 8** respectively.

Figure 7

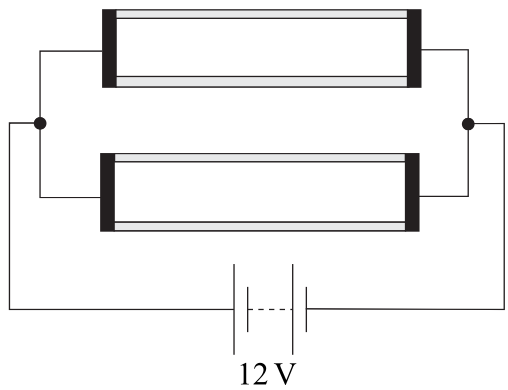
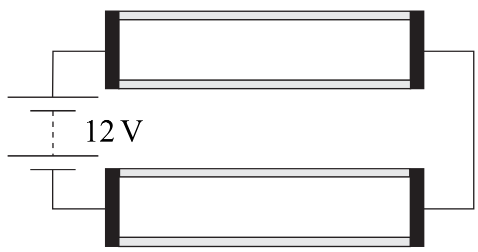


Figure 8



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Determine, by calculation, which configuration of the two elements would have the greater heating effect.

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(4 marks)

(c) If each of the strips of resistive material in the element is 2.5 mm wide and 1.2 mm thick, determine the length of each strip.

resistivity of the material = $4.3 \times 10^{-5}\ \Omega\,\text{m}$

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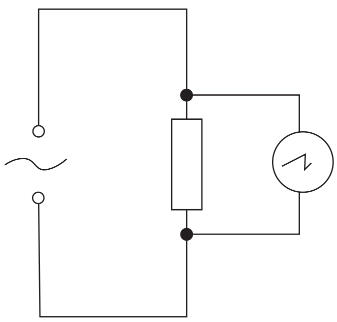
(2 marks)

8

Turn over for the next question

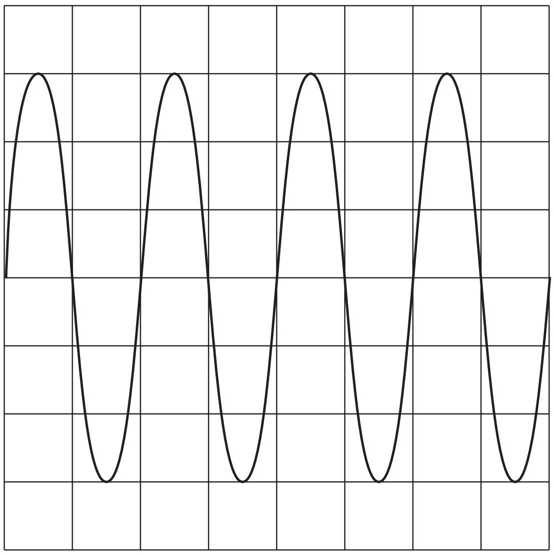
5 A signal generator supplying a sinusoidal alternating voltage is connected to a resistor and an oscilloscope as shown in **Figure 9**. The frequency and output voltage of the signal generator may be varied.

Figure 9



(a) At a certain frequency the trace shown in **Figure 10** is obtained on the screen of the oscilloscope when the time base is set to 2.5 ms div^{-1} and the voltage sensitivity to 5.0 V div^{-1}.

Figure 10



Calculate, for the source,

(i) the rms output voltage,

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(ii) the frequency.

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(4 marks)

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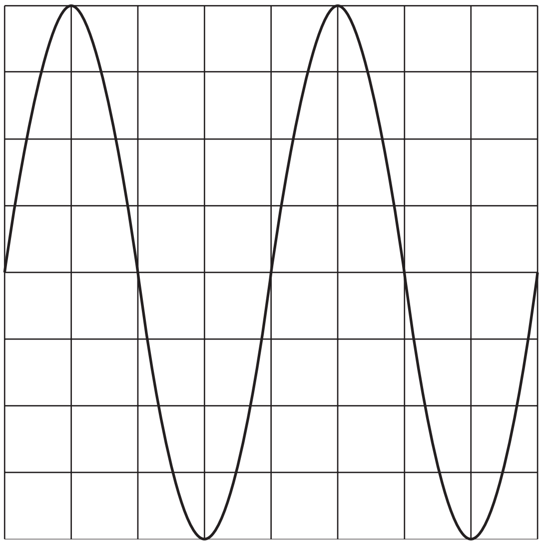
(b) The frequency is changed to 2500 Hz and the voltage output is changed so that the rms voltage is 42.4 V. The time base and the voltage sensitivity of the oscilloscope are altered until the trace seen is that shown in **Figure 11**.

Figure 11



Determine

(i) the new time base setting,

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(ii) the new voltage sensitivity setting.

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(2 marks)

6

Turn over for the next question

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6 (a) (i) Describe an experiment a student would carry out to determine the Young modulus of the material of a long uniform wire of known cross-sectional area. You may draw a diagram of the apparatus, if necessary.

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

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(ii) Explain how the value of the Young modulus could be determined from the measurements made using a suitable graph.

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(8 marks)

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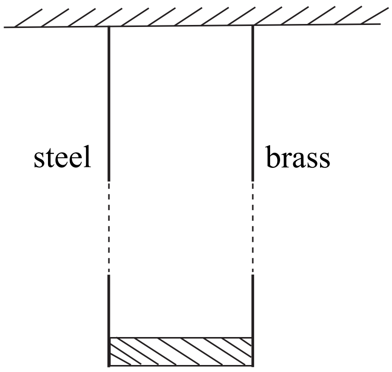
(b) A uniform heavy metal bar is suspended by two vertical wires, supported at their upper ends from a horizontal surface, as shown in **Figure 12**. One of the wires is brass and the other steel. Each wire has the same original length and both extend by the same amount, thus making the metal bar horizontal.

Figure 12



the Young modulus for brass = 1.0×10^{11} Pa
the Young modulus for steel = 2.0×10^{11} Pa

(i) Explain why the brass wire has the greater cross-sectional area.

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(ii) The unstretched length of each wire is 2.5 m and the extension produced is 4.8×10^{-3} m. If the cross-sectional area of the steel wire is 1.6×10^{-7} m^2, calculate the tension in the steel wire.

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(4 marks)

12

Quality of Written Communication *(2 marks)*

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END OF QUESTIONS

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