

1

- (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

- (ii) Explain what is meant by the elastic limit of the wire.

- (iii) Define the Young modulus of a material and state the unit in which it is measured.

(5)

- (b) A student is required to carry out an experiment and draw a suitable graph in order to obtain a value for the Young modulus of a material in the form of a wire.
A long, uniform wire is suspended vertically and a weight, sufficient to make the wire taut, is fixed to the free end. The student increases the load gradually by adding known weights. As each weight is added, the extension of the wire is measured accurately.

- (i) What other quantities must be measured before the value of the Young modulus can be obtained?

- (ii) Explain how the student may obtain a value of the Young modulus.

- (iii) How would a value for the elastic energy stored in the wire be found from the results?

(6)

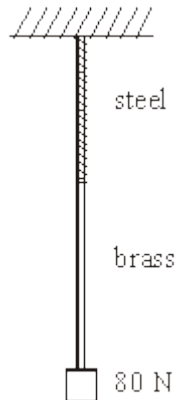
(Total 11 marks)

2

- (a) State *Hooke's law* for a material in the form of a wire and state the conditions under which this law applies.

(2)

- (b) A length of steel wire and a length of brass wire are joined together. This combination is suspended from a fixed support and a force of 80 N is applied at the bottom end, as shown in the figure below.



Each wire has a cross-sectional area of $2.4 \times 10^{-6} \text{ m}^2$.

length of the steel wire = 0.80 m

length of the brass wire = 1.40 m

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

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

- (i) Calculate the total extension produced when the force of 80 N is applied.

(ii) Show that the mass of the combination wire = 4.4×10^{-2} kg.

density of steel = $7.9 \times 10^3 \text{ kg m}^{-3}$

density of brass = $8.5 \times 10^3 \text{ kg m}^{-3}$

(7)

(c) A single brass wire has the same mass and the same cross-sectional area as the combination wire described in part (b). Calculate its length.

(2)

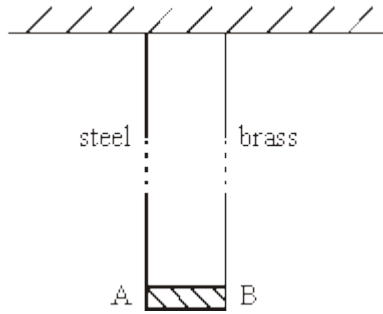
(Total 11 marks)

3

(a) State *Hooke's law* for a material in the form of a wire.

(2)

- (b) A rigid bar AB of negligible mass, is suspended horizontally from two long, vertical wires as shown in the diagram. One wire is made of steel and the other of brass. The wires are fixed at their upper end to a rigid horizontal surface. Each wire is 2.5 m long but they have different cross-sectional areas.



When a mass of 16 kg is suspended from the centre of AB, the bar remains horizontal.

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

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

- (i) What is the tension in each wire?

- (ii) If the cross-sectional area of the steel wire is $2.8 \times 10^{-7} \text{ m}^2$, calculate the extension of the steel wire.

- (iii) Calculate the cross-sectional area of the brass wire.

- (iv) Calculate the energy stored in the steel wire.

(7)

- (c) The brass wire is replaced by a steel wire of the same dimensions as the brass wire. The same mass is suspended from the midpoint of AB.

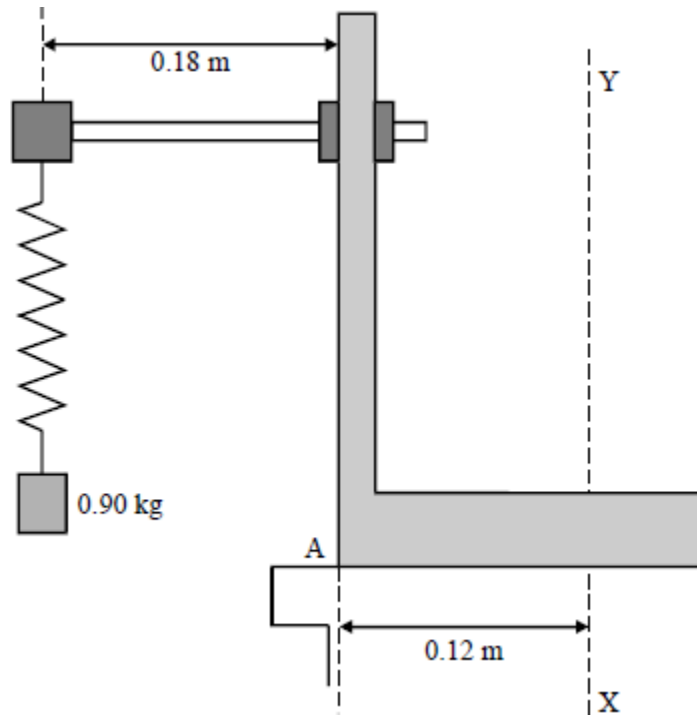
- (i) Which end of the bar is lower?

- (ii) Calculate the vertical distance between the ends of the bar.

(2)

(Total 11 marks)

4



The mass of a retort stand and clamp is 1.6 kg and their combined centre of mass lies along the line XY. A spring which has a negligible mass is attached to the clamp and supports a mass of 0.90 kg, as shown in the diagram. The spring requires a force of 6.0 N to stretch it 100 mm.

- (a) Calculate the extension of the spring.

(2)

- (b) Show that this arrangement will not tip (i.e. will not rotate about A) when the 0.90 kg mass is at rest in its equilibrium position.

(2)

- (c) If the mass is lifted up and released, it will vibrate about the equilibrium position. Explain, without calculation, why the stand will tip if the amplitude exceeds a certain value.

(3)

(Total 7 marks)

Mark schemes

1

- (a) (i) the extension produced (by a force) in a wire is directly proportional to the force applied **(1)**
applies up to the limit of proportionality **(1)**
- (ii) elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length (when the force is removed) **(1)**
[or correct use of permanent deformation]
- (iii) the Young modulus: ratio of tensile stress to tensile strain **(1)**
unit: Pa or Nm^{-2} **(1)**

5

- (b) (i) length of wire **(1)**
diameter (of wire) **(1)**
- (ii) graph of force vs extension **(1)**
reference to gradient **(1)**

$$\text{gradient} = E \frac{A}{l} \quad \textbf{(1)}$$

[or graph of stress vs strain, with both defined
reference to gradient
gradient = E]

area under the line of F vs ΔL **(1)**
[or energy per unit volume = area under graph of stress vs strain]

6

[11]

2

- (a) Hooke's law: the extension is proportional to the force applied **(1)**
up to the limit of proportionality or elastic limit
[or for small extensions] **(1)**

2

(b) (i) (use of $E = \frac{F}{A} \frac{l}{\Delta L}$ gives) $\Delta L_s = \frac{80 \times 0.8}{2.0 \times 10^{11} \times 2.4 \times 10^{-6}} \quad \textbf{(1)}$

$$= 1.3 \times 10^{-4} \text{ (m)} \quad \textbf{(1)} \quad (1.33 \times 10^{-4} \text{ (m)})$$

$$\Delta L_b = \frac{80 \times 1.4}{1.0 \times 10^{11} \times 2.4 \times 10^{-6}} = 4.7 \times 10^{-4} \text{ (m)} \quad \textbf{(1)} \quad (4.66 \times 10^{-4} \text{ (m)})$$

$$\text{total extension} = 6.0 \times 10^{-4} \text{ m} \quad \textbf{(1)}$$

- (ii) $m = \rho \times V$ **(1)**
 $m_s = 7.9 \times 10^3 \times 2.4 \times 10^{-6} \times 0.8 = 15.2 \times 10^{-3} \text{ (kg)} \quad \textbf{(1)}$
 $m_b = 8.5 \times 10^3 \times 2.4 \times 10^{-6} \times 1.4 = 28.6 \times 10^{-3} \text{ (kg)} \quad \textbf{(1)}$
(to give total mass of 44 or $43.8 \times 10^{-3} \text{ kg}$)

—

(c) (use of $m = \rho A l$ gives) $l = \frac{44 \times 10^{-3}}{8.5 \times 10^3 \times 2.4 \times 10^{-6}}$ **(1)**

$= 2.2 \text{ m}$ **(1)** (2.16 m)

(use of mass = $43.8 \times 10^{-3} \text{ kg}$ gives 2.14 m)

2

[11]

3

- (a) extension proportional to the applied force **(1)**
up to the limit of proportionality
[or provided the extension is small] **(1)**

2

(b) (i) $8 \times 9.81 = 78.5 \text{ N}$ **(1)**

(allow C.E. in (ii), (iii) and (iv) for incorrect value)

(ii) (use of $E = \frac{F l}{A \Delta L}$ gives) $2.0 \times 10^{11} = \frac{78.5}{2.8 \times 10^{-7}} \times \frac{2.5}{\Delta L}$ **(1)**

$\Delta L = 3.5 \times 10^{-3} \text{ m}$ **(1)**

- (iii) similar calculation **(1)**
to give $A_S = 5.6 \times 10^{-7} \text{ m}^2$ **(1)**
[or $A_B = 2A_S$ **(1)** and correct answer **(1)**]

(iv) (use of energy stored = $\frac{1}{2} Fe$ gives) energy stored
 $= \frac{1}{2} \times 78.5 \times 3.5 \times 10^{-3}$ **(1)**
 $= 0.14 \text{ J}$ **(1)**

7

- (c) (i) end A is lower **(1)**

(ii) $= \frac{1}{2} 3.5 \times 10^{-3} = 1.8 \times 10^{-3} \text{ m}$ **(1)** ($1.75 \times 10^{-3} \text{ m}$)

2

[11]

4

- (a) use of $mg = k\Delta l$ (or $0.90 \times 9.81 = 60\Delta l$) **(1)**
 $\Delta l = 0.15 \text{ m}$ **(1)**

(2)

- (b) no tipping if moment of weight of clamp about A > moment of 0.90 kg **(1)**
moment of 0.90 kg about A = $0.90 \text{ g} \times 0.18 = 0.16 \text{ g}$
moment of weight of clamp about A = $1.60 \text{ g} \times 0.12 = 0.19 \text{ g}$
 $\therefore$ no tipping **(1)**

(2)

- (c) as mass vibrates tension changes **(1)**
maximum tension increases as amplitude increases because maximum length increases **(1)**
tipping when moment of tension exceeds moment of weight of clamp **(1)**

(3)