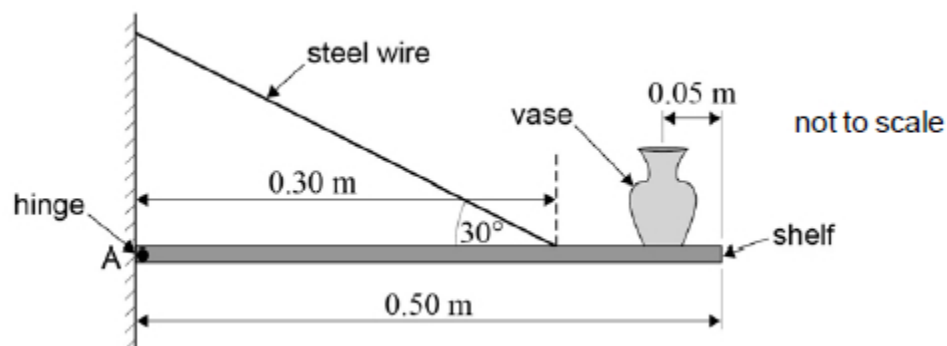


1

The diagram below shows a vase placed on a uniform shelf that is supported by a steel wire.



The mass of the vase is 0.65 kg and the mass of the shelf is 2.0 kg. The shelf is hinged at A. The steel wire is attached to the shelf 0.30 m from A and is at an angle of 30° to the shelf. The other end of the steel wire is attached to the wall.

(a) State the principle of moments.

(2)

(b) Show, by taking moments about A, that the tension in the steel wire is about 50 N.

(4)

- (c) The cross-sectional area of the steel wire is $7.8 \times 10^{-7} \text{ m}^2$. The steel has a Young modulus of 180 GPa.

Calculate the tensile strain of the steel wire when it is holding up the shelf and the vase.

tensile strain = _____

(2)

(Total 8 marks)

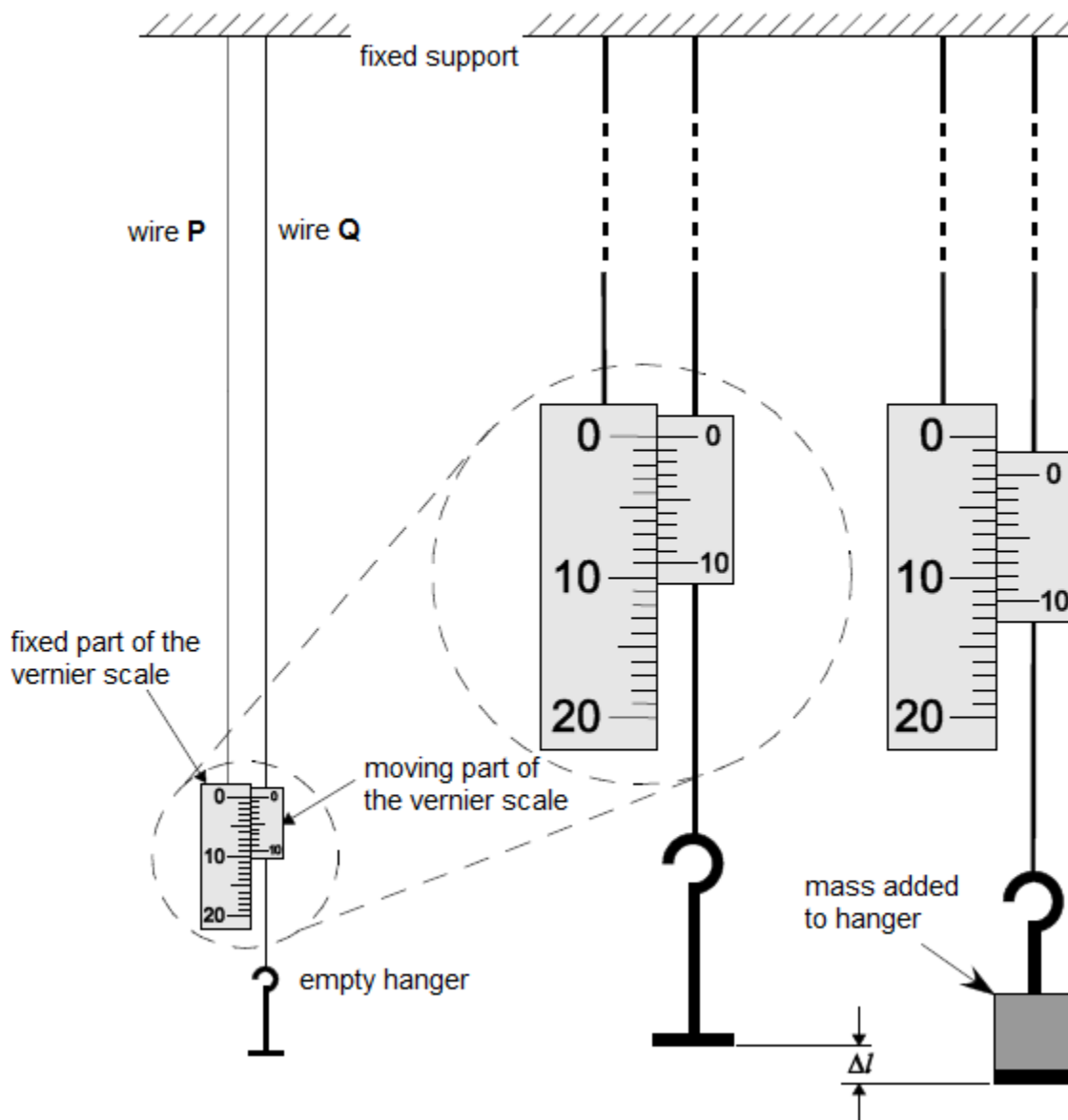
2

This question is about the determination of the Young modulus of the metal of a wire.

In an experiment, two vertical wires **P** and **Q** are suspended from a fixed support. The fixed part of a vernier scale is attached to **P** and the moving part of the scale is attached to **Q**. The divisions on the fixed part of the scale are in mm.

An empty mass hanger is attached to **Q** and the scale is set to zero. A load is added to the mass hanger so that the extension of **Q** can be measured as shown in **Figure 1**.

Figure 1



- (a) The reading on the vernier scale can be used to determine Δl , the extension of **Q**.

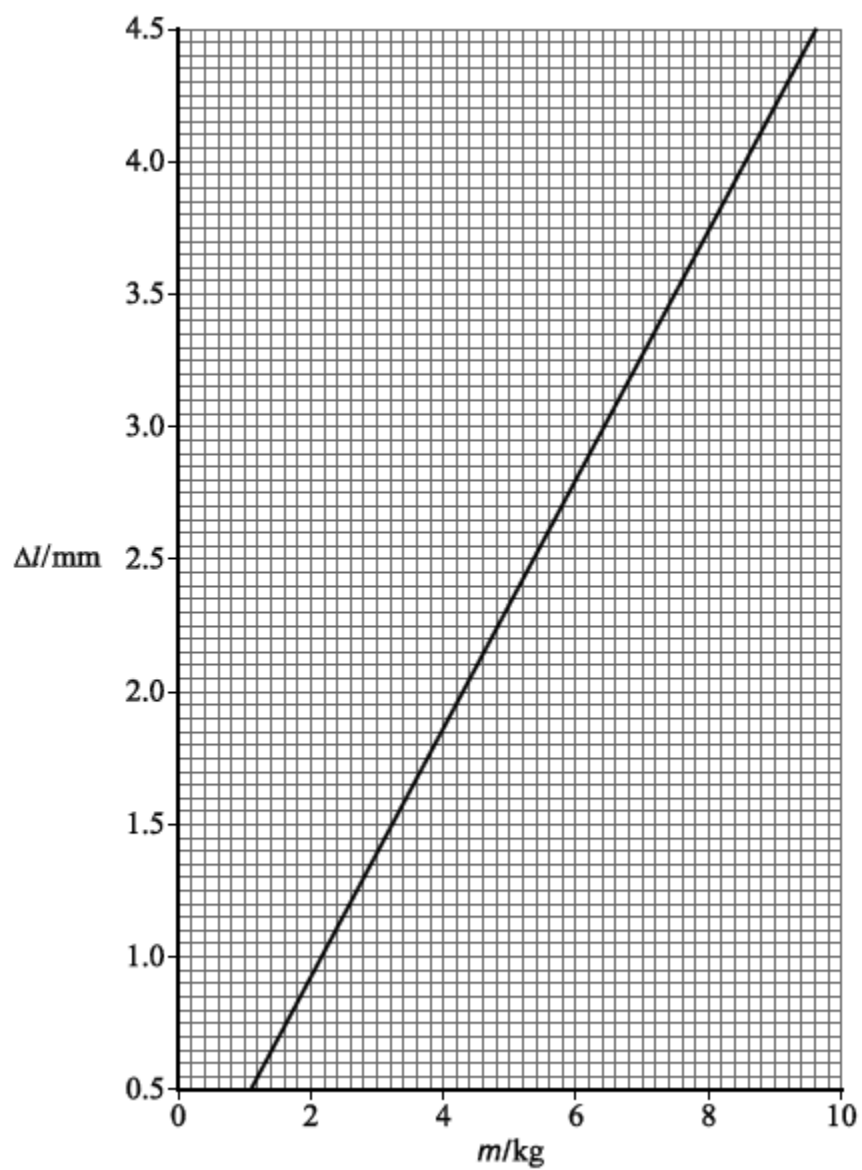
Determine Δl using **Figure 1**.

$$\Delta l = \underline{\hspace{2cm}} \text{ mm}$$

(1)

- (b) **Figure 2** shows how Δl varies with m , the mass added to the hanger. Determine the mass added to the hanger shown in **Figure 1**.

Figure 2



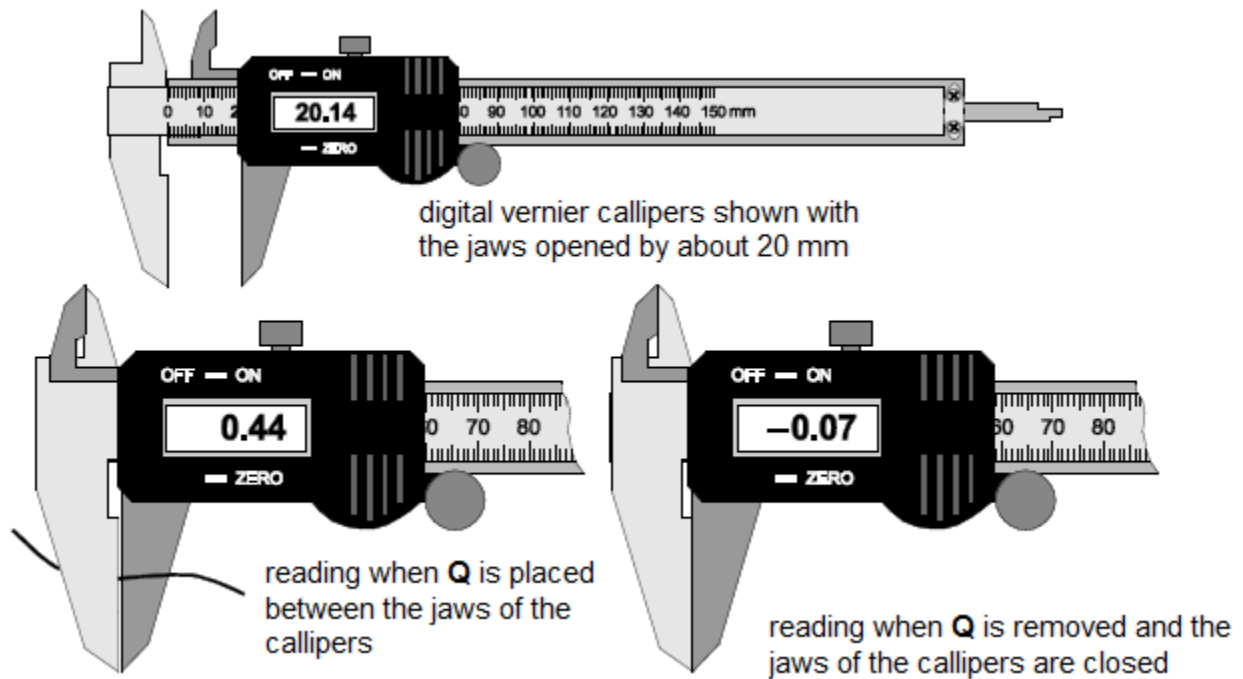
mass = _____ kg

(1)

- (c) A student uses digital vernier callipers to measure the diameter of **Q**. She places **Q** between the jaws of the callipers and records the reading indicated. Without pressing the zero button she removes **Q** and closes the jaws.

Views of the callipers before and after she closes the jaws are shown in **Figure 3**.

Figure 3



Calculate the true diameter of **Q**.

diameter = _____ mm

(1)

- (d) The original length of **Q** was 1.82 m.

Determine the Young modulus of the metal in **Q**.

Young modulus = _____ Pa

(4)

- (e) The student repeats her experiment using a wire of the same original length and metal but with a smaller diameter.

Discuss **two** ways this change might affect the percentage uncertainty in her result for the Young modulus.

1. _____

2. _____

(4)

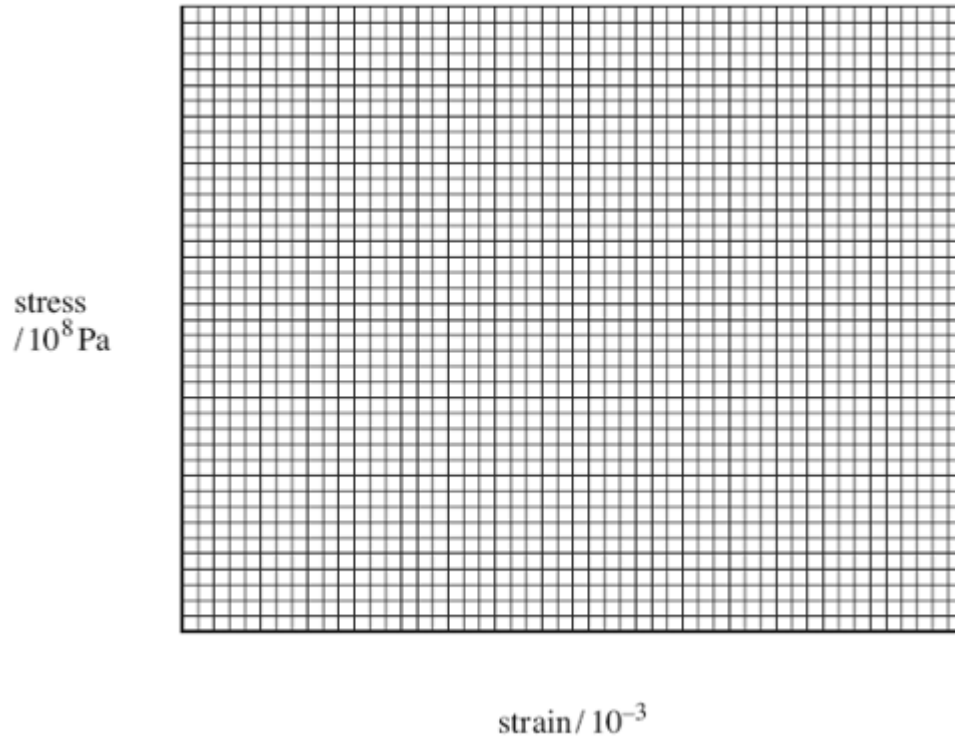
(Total 11 marks)

3

The table below shows the results of an experiment where a force was applied to a sample of metal.

(a) On the axes below, plot a graph of stress against strain using the data in the table.

Strain / 10^{-3}	0	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Stress / 10^8 Pa	0	0.90	2.15	3.15	3.35	3.20	3.30	3.50	3.60	3.60	3.50



(3)

(b) Use your graph to find the Young modulus of the metal.

answer = _____ Pa

(2)

- (c) A 3.0 m length of steel rod is going to be used in the construction of a bridge. The tension in the rod will be 10 kN and the rod must extend by no more than 1.0mm. Calculate the minimum cross-sectional area required for the rod.

Young modulus of steel = 1.90×10^{11} Pa

answer = _____ m²

(3)

(Total 8 marks)

4

- (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)

5

A uniform wooden beam of mass 35.0 kg and length 5.52 m is supported by two identical vertical steel cables **A** and **B** attached at either end, as shown in **Figure 1**.

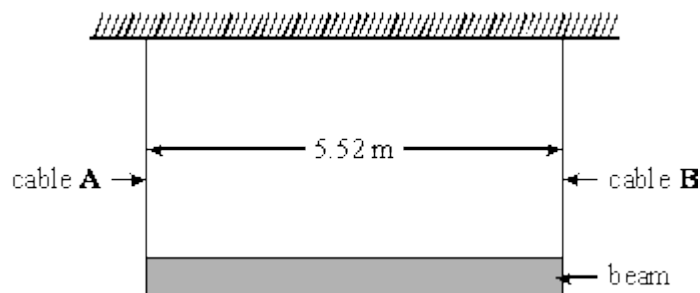


Figure 1

- (a) Calculate

- (i) the weight of the beam,

- (ii) the tension in each cable.

(2)

- (b) Each unstretched cable has a diameter of 8.26 mm and a length 2.50 m. Calculate the extension of each cable when supporting the beam.

The Young modulus for steel = 2.10×10^{11} Pa

(4)

- (c) An object of mass 20.0 kg is hung from the beam 1.00 m from cable **A**, as shown in **Figure 2**.

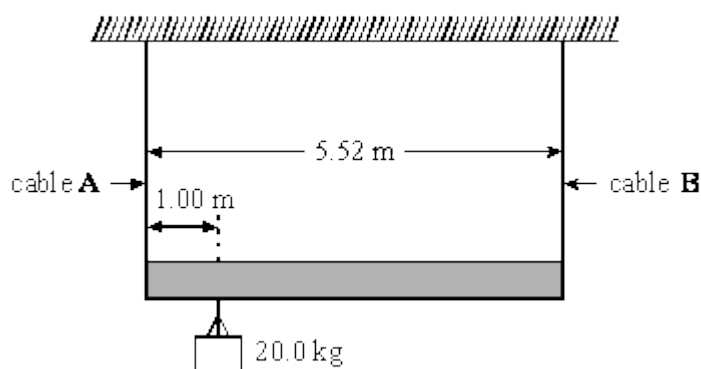


Figure 2

- (i) Show that the new tension in cable **A** is 332 N.

- (ii) Calculate the new tension in cable **B**.

(6)

(Total 12 marks)

6

- (a) (i) Define the Young modulus for a material.

- (ii) Explain what is meant by the *elastic limit* for a wire.

(2)

- (b) A wire supported at its upper end, hangs vertically. The table shows readings obtained when stretching the wire by suspending masses from its lower end.

load / N	0	2.0	4.0	6.0	7.0	8.0	9.0	10.0	10.5
extension / mm	0	1.2	2.4	3.6	4.2	4.9	5.7	7.0	8.0

- (i) Plot a graph of load against extension.

(One sheet of graph paper should be provided)

- (ii) Indicate on your graph the region where Hooke's law is obeyed.

- (iii) The unstretched length of the wire is 1.6 m and the area of cross-section $8.0 \times 10^{-8} \text{ m}^2$. Calculate the value of the Young modulus of the material.

(8)

- (c) (i) By considering the work done in stretching a wire, show that the energy stored is given by $\frac{1}{2}Fe$, where F is the force producing an extension e .

- (ii) Calculate the energy stored in the wire in part (b) when the extension is 4.0 mm.

(4)

(Total 14 marks)

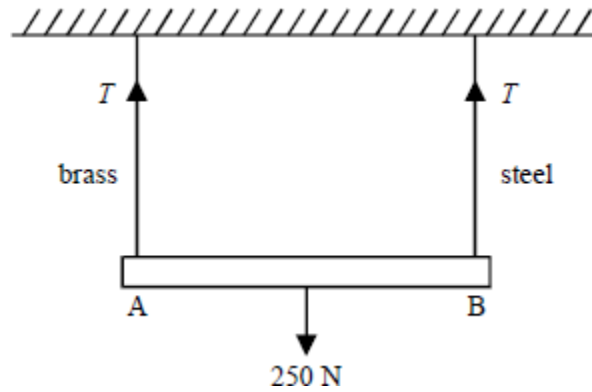
7

- (a) (i) Draw and label suitable apparatus required for measuring the Young modulus of a material in the form of a long wire.
- (ii) List the measurements you would make when using the apparatus described in part (i).

(iii) Describe briefly how the measurements listed in part (ii) would be carried out.

(iv) Explain how you would calculate the Young modulus from your measurements.

- (b) A uniform heavy metal bar of weight 250 N is suspended by two vertical wires, supported at their upper ends from a horizontal surface, as shown.



One wire is made of brass and the other of steel. The cross-sectional area of each wire is $2.5 \times 10^{-7} \text{ m}^2$ and the unstretched length of each wire is 2.0 m.

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

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

- (i) If the tension, T , in each wire is 125 N, calculate the extension of the steel wire.

- (ii) Estimate how much lower the end A will be than the end B.

(3)

(Total 16 marks)

8

As part of a quality check, a manufacturer of fishing line subjects a sample to a tensile test. The sample of line is 2.0 m long and is of constant circular cross-section of diameter 0.50 mm. Hooke's law is obeyed up to the point when the line has been extended by 52 mm at a tensile stress of $1.8 \times 10^8 \text{ Pa}$. The maximum load the line can support before breaking is 45 N at an extension of 88 mm.

- (a) Calculate

- (i) the value of the Young modulus,

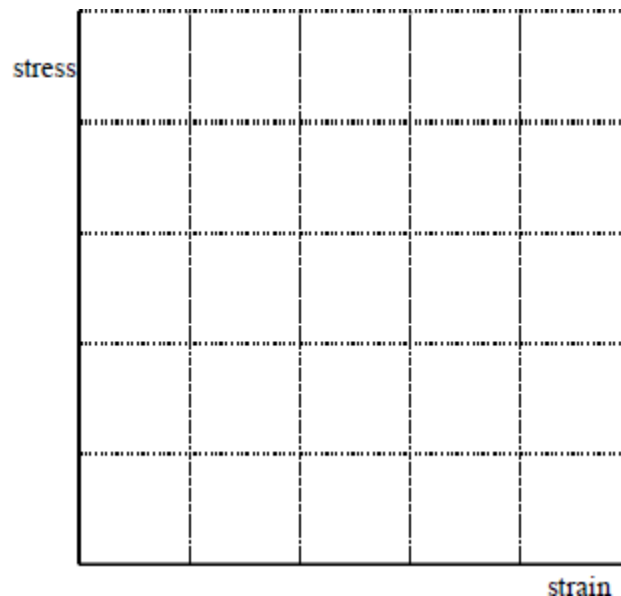
- (ii) the breaking stress (assuming the cross-sectional area remains constant),

- (iii) the breaking strain.

(5)

- (b) Sketch a graph on the axes below to show how you expect the tensile stress to vary with strain. Mark the value of stress and corresponding strain at

- (i) the limit of Hooke's law,
(ii) the breaking point.



(4)

(Total 9 marks)

9

- (a) The Young modulus is defined as the ratio of *tensile stress* to *tensile strain*. Explain what is meant by each of the terms in italics.

tensile stress _____

tensile strain _____

(3)

- (b) A long wire is suspended vertically and a load of 10 N is attached to its lower end. The extension of the wire is measured accurately. In order to obtain a value for the Young modulus of the material of the wire, two more quantities must be measured. State what these are and in each case indicate how an accurate measurement might be made.

quantity 1 _____

method of measurement _____

quantity 2 _____

method of measurement _____

(4)

- (c) Sketch below a graph showing how stress and strain are related for a ductile substance and label important features.



(2)

(Total 9 marks)

Mark schemes

1

- (a) Sum of / total clockwise moments = sum of / total anticlockwise moments✓

For a body in equilibrium✓

2

- (b) Clockwise moments = $2.0 \times 9.81 \times 0.25 + 0.65 \times 9.81 \times 0.45$

$$= 7.77 \text{ (N m)}✓$$

$$\text{Anticlockwise moments} = T \sin 30 \times 0.3✓$$

$$T \sin 30 \times 0.3 = 7.77 \text{ or } T = 7.77 / (\sin 30 \times 0.3) ✓$$

$$T = 52.0 \text{ (N)} ✓$$

First mark for clockwise moments, workings or correct answer.

Second mark for anticlockwise moments.

Third mark for equating clockwise and anticlockwise moments.

Fourth mark for correct answer.

4

- (c) tensile stress = $52.0 / (7.8 \times 10^{-7}) = 6.6 \times 10^7 ✓$

$$\text{tensile strain} = 6.6 \times 10^7 / (180 \times 10^9) = 3.7 \times 10^{-4} ✓$$

2

[8]

2

- (a) extension of wire Q = 2.7 (mm) ✓

ignore any precision given eg $\pm 0.1 \text{ mm}$

if > 2 sf condone if this rounds to 2.7

1

- (b) mass = 5.8 (kg) ✓

allow ce for incorrect 0.1.1 (only look at 01.1 if answer here is incorrect)

allow $\pm 0.1 \text{ kg}$

1

- (c) 0.51 (mm) ✓

ignore any precision given eg $\pm 0.005 \text{ mm}$

1

(d) method 1:

$$\text{use of } E = \frac{(\text{tensile}) \text{ stress}}{(\text{tensile}) \text{ strain}} \quad 1\checkmark$$

for $1\checkmark$ expect to see some substitution of numerical data

$$\text{cross-section area from } \frac{\pi \times d^2}{4} \quad 2\checkmark$$

correct use of diameter for $2\checkmark$; ignore power of ten error; expect

$CSA = 2.0(4) \times 10^{-7}$; allow ce from 01.3 (eg for $d = 0.37 \text{ mm}$)

$CSA = 1.0(8) \times 10^{-7} \text{ m}^2$

$$(\text{tensile}) \text{ stress} = \frac{mg}{CSA} \quad 3\checkmark$$

penalise use of $g = 10 \text{ N kg}^{-1}$

$$(\text{tensile}) \text{ strain} = \frac{\Delta l}{l} \quad 4\checkmark$$

value of Δl must correspond to Figure 2 value of m ; answers to 01.1 and 01.2 are acceptable

expect $l = 1.82 \text{ m}$ but condone 182 etc; accept mixed units for l and Δl

MAX 3

method 2:

$$\text{evidence of } \frac{\Delta l}{\Delta m} \text{ from Figure 2 to calculate gradient} \quad 1\checkmark$$

expect gradient between 0.45 to 0.48 mm kg^{-1}

$$E = \frac{g \times \text{original length}}{CSA \times \text{gradient}} \quad 2\checkmark \quad 3\checkmark$$

missing g loses $3\checkmark$

substitution of $l = 1.82 \text{ m}$ $4\checkmark$

condone 182 etc $4\checkmark$

$$\text{cross-sectional area from } \frac{\pi \times d^2}{4} \quad 5\checkmark$$

correct use of diameter for $2\checkmark$; ignore power of ten error; expect

$CSA = 2.0(4) \times 10^{-7}$; allow ce from 01.3 (eg for $d = 0.37 \text{ mm}$)

$CSA = 1.0(8) \times 10^{-7} \text{ m}^2$

MAX 3

result in range 1.84×10^{11} to 1.91×10^{11} $5\checkmark$

condone 1.9×10^{11}

$5\checkmark$ mark requires correct working and no power of ten errors: allow ce for error(s) in 01.1, 01.2 and for false/incorrect CSA

(eg for $d = 0.37 \text{ mm}$ allow result in range 3.49×10^{11} to 3.63×10^{11} , 3.5×10^{11} or 3.6×10^{11})

- (e) (smaller diameter) produces larger extensions $_1\checkmark$
 reduces (percentage) uncertainty (in extension and in result for Young Modulus) $_2\checkmark$

(smaller diameter) increases (percentage) uncertainty in diameter
or cross sectional area is smaller **or** increases (percentage)
 uncertainty in cross sectional area $_3\checkmark$
 increases (percentage) uncertainty (in result for Young Modulus) $_4\checkmark$

(smaller diameter) increases likelihood of wire reaching limit of
 proportionality or of wire snapping or reduces range of readings $_5\checkmark$
 increases (percentage) uncertainty (in result for Young Modulus) $_6\checkmark$

outcome and correct consequence for 2 marks, ie $_1\checkmark$ followed by

$_2\checkmark$, $_3\checkmark$ followed by $_4\checkmark$ etc

dna 'error' for 'uncertainty'

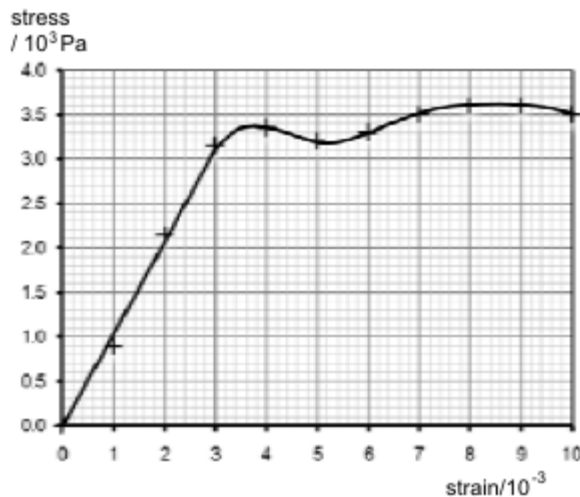
*no mark for consequence if outcome not sensible, eg 'it gets longer
 and reduces uncertainty' earns no mark for 'diameter smaller so
 uncertainty greater' award $_1\checkmark$ (need to see further mention of
 uncertainty to earn $_2\checkmark$)*

MAX 4

[11]

3

(a)



Suitable scale on both axes (eg not going up in 3s) **and** $> \frac{1}{2}$ space used $\checkmark$

$\geq$ points correct (within half a small square) $\checkmark$

line is straight up to at least stress = 2.5×10^8 **and** curve
 is smooth beyond straight section $\checkmark$

- (b) understanding that $E = \text{gradient} (= \Delta y / \Delta x)$ ✓✓

allow y/x if line passes through origin

$= 1.05 \times 10^{11}$ (Pa) (allow 0.90 to 1.1) **ecf** from their line in (a)
if answer outside this range **and** uses a y value ≥ 2 ✓✓

when values used from table;

- two marks can be scored only if candidates line passes through them
- one mark only can be scored if these points are not on their line

2

- (c) correct rearrangement of symbols or numbers ignoring incorrect

powers of ten, eg $A = \frac{FL}{E\Delta L}$ ✓✓

correct substitution in any correct form of the equation,

$$\text{eg } = \frac{10(000) \times 3.0}{1.90(\times 10^{11}) \times 1.0(\times 10^{-3})} \quad \checkmark \checkmark$$

allow incorrect powers of ten for this mark

$$= 1.6 \times 10^{-4} \quad \checkmark \checkmark \quad (1.5789) \text{ (m}^2\text{)}$$

3

[8]

4

- (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)**

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

[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]

5

- (a) (i) $(35 \times 9.81) = 343 \text{ N}$

- (ii) tension in each cable $\left(= \frac{mg}{2} \right) = 172 \text{ N} \quad \mathbf{(1)}$

2

- (b) area of cross-section $\left(= \frac{\pi d^2}{4} \right) = \frac{\pi (8.26 \times 10^{-3})^2}{4} = 5.36 \times 10^{-5} \text{ (m}^2\text{)}$

$$e = \frac{Fl}{EA} \quad \mathbf{(1)}$$

$$= \frac{172 \times 2.5}{5.36 \times 10^{-5} \times 2.1 \times 10^{11}}$$

$$= 3.8 \times 10^{-5} \text{ m} \quad \mathbf{(1)}$$

4

- (c) (i) moments about T_2 , (cable B) gives

$$5.52 T_1 \quad \mathbf{(1)} = 343 \times 2.76 \quad \mathbf{(1)} + 196 \times 4.52 \quad \mathbf{(1)}$$

$$T_1 = \left(\frac{1833}{5.52} \right) \quad \mathbf{(1)} (= 332 \text{ N})$$

- (ii) $T_1 + T_2 = 343 + 196 = 539 \text{ (N)} \quad \mathbf{(1)}$
 $T_2 = 539 - 332 = 207 \text{ N} \quad \mathbf{(1)}$

(allow C.E. for. value of T_1 , from (i))

[or moments about T_1 gives $5.52 T_2 = (343 \times 2.76) + (196 \times 1.) \quad \mathbf{(1)}$

$$T_2 = 1143/5.52 = 207 \text{ N} \quad \mathbf{(1)}$$

6

6

- (a) (i) the Young modulus: tensile stress / tensile strain **(1)**
 (ii) maximum force or load which can be applied without wire being permanently deformed
 [or point beyond which (when stress removed,) material does not regain original length] **(1)**

2

- (b) (i) graph: suitable scale **(1)**
 correct points **(1) (1)**
 best straight line followed by curve **(1)**
 (ii) indication of region or range of Hooke's law **(1)**
 (iii) (use of $E = \frac{Fl}{Ae}$)
 values of F and e within range or correct gradient **(1)**

$$\begin{aligned} \text{to give } E &= \frac{67}{4 \times 10^{-3}} \times \frac{1.6}{8.0 \times 10^{-8}} \text{ (1)} \\ &= 3.3(5) \times 10^{10} \text{ Pa (1)} \end{aligned}$$

8

- (c) (i) work done = force $\times$ distance **(1)**
 = average force $\times$ extension (= $\frac{1}{2}Fe$) **(1)**
 [or use work done = area under graph
 area = $\frac{1}{2}$ base $\times$ height]

$$\begin{aligned} \text{(ii) energy stored} &= \frac{67 \times 4 \times 10^{-3}}{2} \text{ (1)} \\ &= 13.(4) \times 10^{-3} \text{ J (1)} \end{aligned}$$

4

[14]**7**

- (a) (i) diagram to show:
 (long) wire fixed at one end **(1)**
 mass / weight at other end **(1)**
 measuring scale **(1)**
 mark on wire, or means to measure extension **(1)**

max 3

[alternative for two vertical wires:
 two wires fixed to rigid support **(1)**
 mass / weight at end of one wire **(1)**
 other wire kept taut **(1)**
 spirit level and micrometer or sliding vernier scale **(1)**]

- (ii) measurements:
 length of the wire between clamp and mark **(1)**
 diameter of the wire **(1)**
 extension of the wire **(1)**
 for a known mass **(1)**

max 3

- (iii) length measured by metre rule **(1)**
 diameter measured by micrometer **(1)**
 at several positions and mean taken **(1)**
 (known) mass added and extension measured
 by noting movement of fixed mark against vernier scale
 (or any suitable alternative) **(1)**
 repeat readings for increasing (or decreasing) load **(1)**

max 5

- (iv) graph of mass added / force against extension **(1)**

gradient gives $\frac{F}{e}$ or $\frac{m}{e}$ **(1)**

correct use of data in $E = \frac{Fl}{eA}$ where A is cross-sectional area **(1)**

[if no graph drawn, then mean of readings
 and correct use of data to give $2_{\max}$ **(1)**

max 2
 (13)

The Quality of Written Communication marks are awarded for the quality of answers to this question.

- (b) (i) for steel (use of $E = \frac{Fl}{eA}$ gives) $e = \frac{FL}{EA}$ **(1)**

$$e = \frac{125 \times 2}{2.0 \times 10^{11} \times 2.5 \times 10^{-7}} \text{ (1)}$$

$$= 5.0 \times 10^{-3} \text{ m (1)}$$

- (ii) extension for brass would be $10 \times 10^{-3} \text{ (m)}$ (or twice that of steel) **(1)**
 end A is lower by 5 mm $\checkmark$ (allow C.E. from (i))

max 3

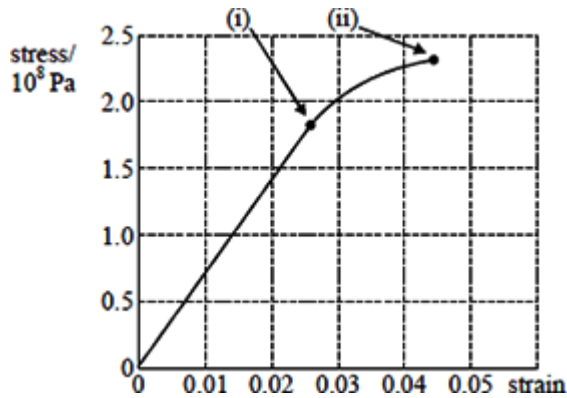
[16]

- (a) (i) strain = 0.026 **(1)**
 $E = 6.92 \times 10^9 \text{ Pa (1)}$

- (ii) $A = 1.96 \times 10^{-7} \text{ (m}^2\text{)}$ **(1)**
 stress = $230 \times 10^8 \text{ Pa}$ **(1)**
- (iii) breaking strain = 0.044 **(1)**

5

(b)



shape overall **(1)**

- (i) straight line **(1)**
 0 to (0.026, 1.8) **(1)**
- (ii) curve **(1)**
 to (0.044, 2.3) **(1)**

max 4

[9]

9

- (a) tensile stress = $\frac{\text{(tensile) force}}{\text{cross - sectional area}}$ **(1)**

$$\text{tensile strain} = \frac{\text{extension}}{\text{original length}} \quad \mathbf{(1)}$$

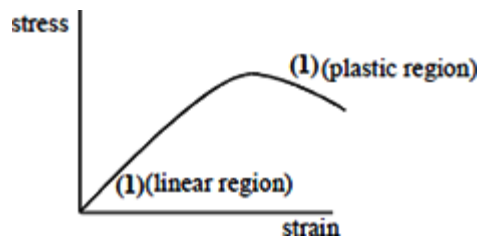
mention of tensile **and** original **(1)**

(3)

- (b) diameter of wire **(1)**
 in several *places* [or repeated] **(1)**
 using a micrometer **(1)**
 (original) length of wire **(1)**
 using a metre rule (or tape measure) **(1)**

(max 4)

(c)



(2)

[9]