Access Tuition

A-Level Physics

The Young Modulus

Question Paper

Time available: 66 minutes
Marks available: 46 marks

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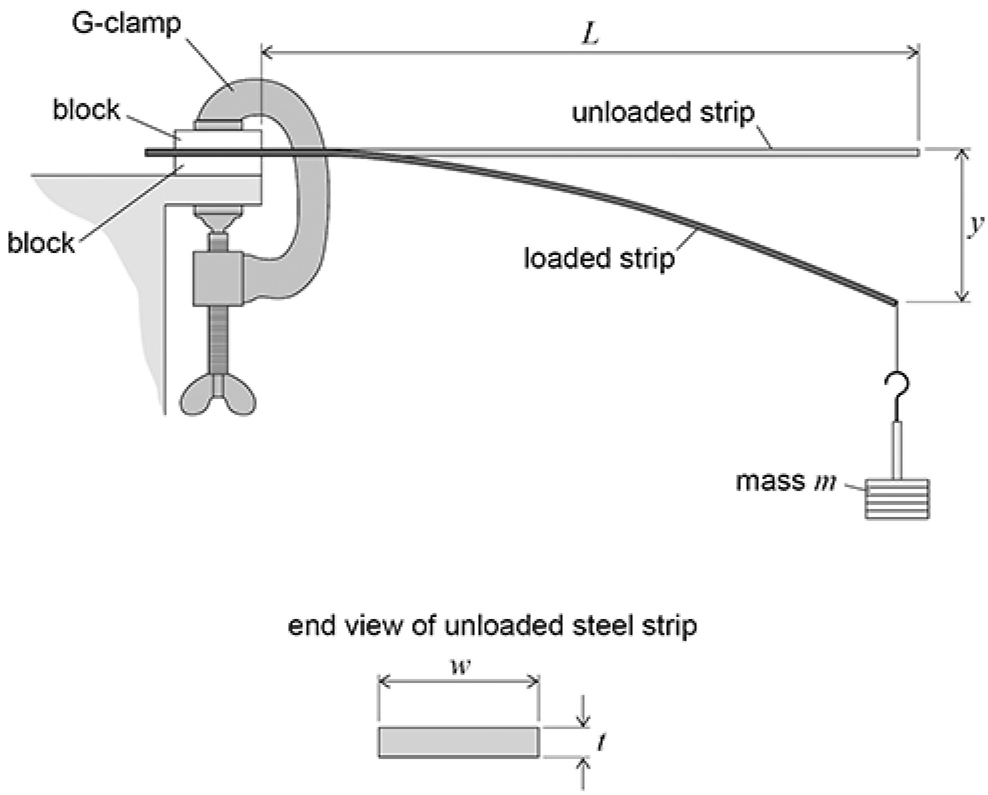
1. **Figure 1** shows a strip of steel of rectangular cross-section clamped at one end. The strip extends horizontally over the edge of a bench.

Figure 1



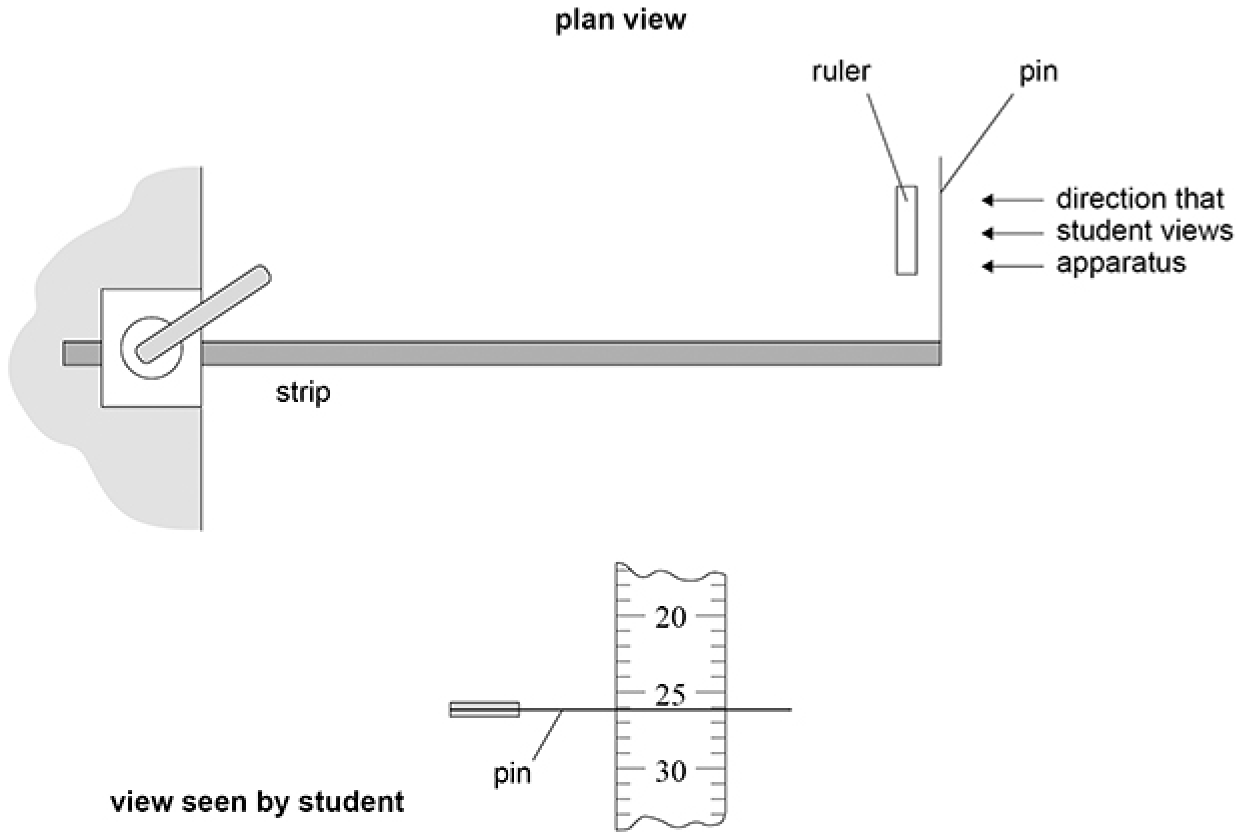
(a) A mass m is suspended from the free end of the strip.

This produces a vertical displacement y.

A student intends to measure y with the aid of a horizontal pin fixed to the free end of the steel strip.

She positions a clamped vertical ruler behind the pin, as shown in **Figure 2**.

Figure 2



Explain a procedure to avoid parallax error when judging the reading indicated by the position of the pin on the ruler.

You may add detail to **Figure 2** to illustrate your answer.

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(2)

(b) It can be shown that

$$y = \frac{4mgL^3}{Ewt^3}$$

where:

L is the distance between the free end of the **unloaded** strip and the blocks
w is the width of the strip and is approximately 1 cm
t is the thickness of the strip and is approximately 1 mm
E is the Young modulus of the steel.

A student is asked to determine E using the arrangement shown in **Figure 1** with the following restrictions:

- only one steel strip of approximate length 30 cm is available
- m must be made using a 50 g mass hanger and up to four additional 50 g slotted masses
- the experimental procedure must involve only **one** independent variable
- a graphical method must be used to get the result for E.

Explain what the student must do to determine E.

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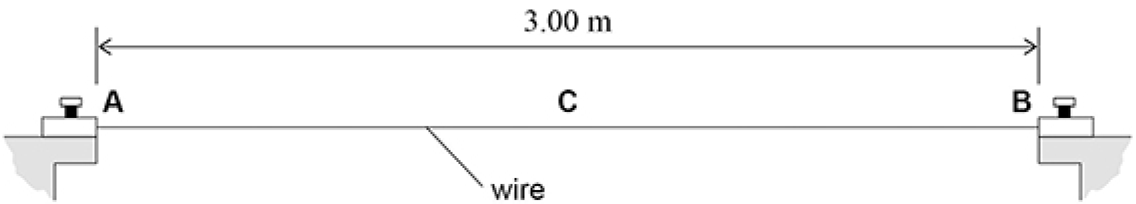
(5)

(Total 7 marks)

2. A student does an experiment to determine the Young modulus of a metal.
Figure 1 shows a wire made from the metal clamped at points **A** and **B** so that the wire is horizontal. The horizontal distance between **A** and **B** = 3.00 m.
C is the mid-point on the wire between **A** and **B**.

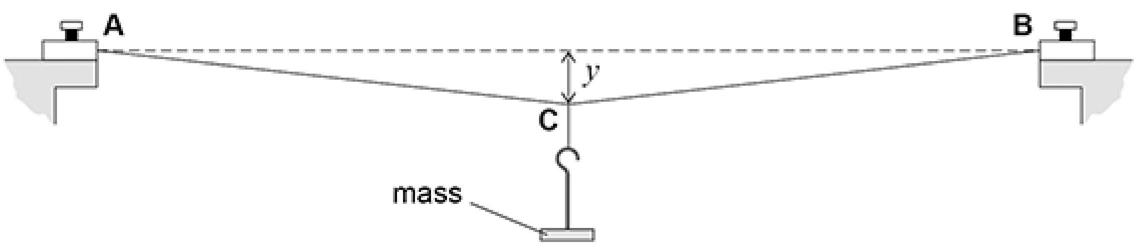
Figure 1



A mass of weight W is suspended at **C** to extend the wire. **Figure 2** shows that **C** moves vertically downwards by a distance y.

Figure 2

not to scale



(a) When W is 1.0 N, y is 6.34 cm.

Show that the wire extends by approximately 3 mm.

(1)

(b) Calculate the tension in the wire when W is 1.0 N.

tension = ________________ N

(2)

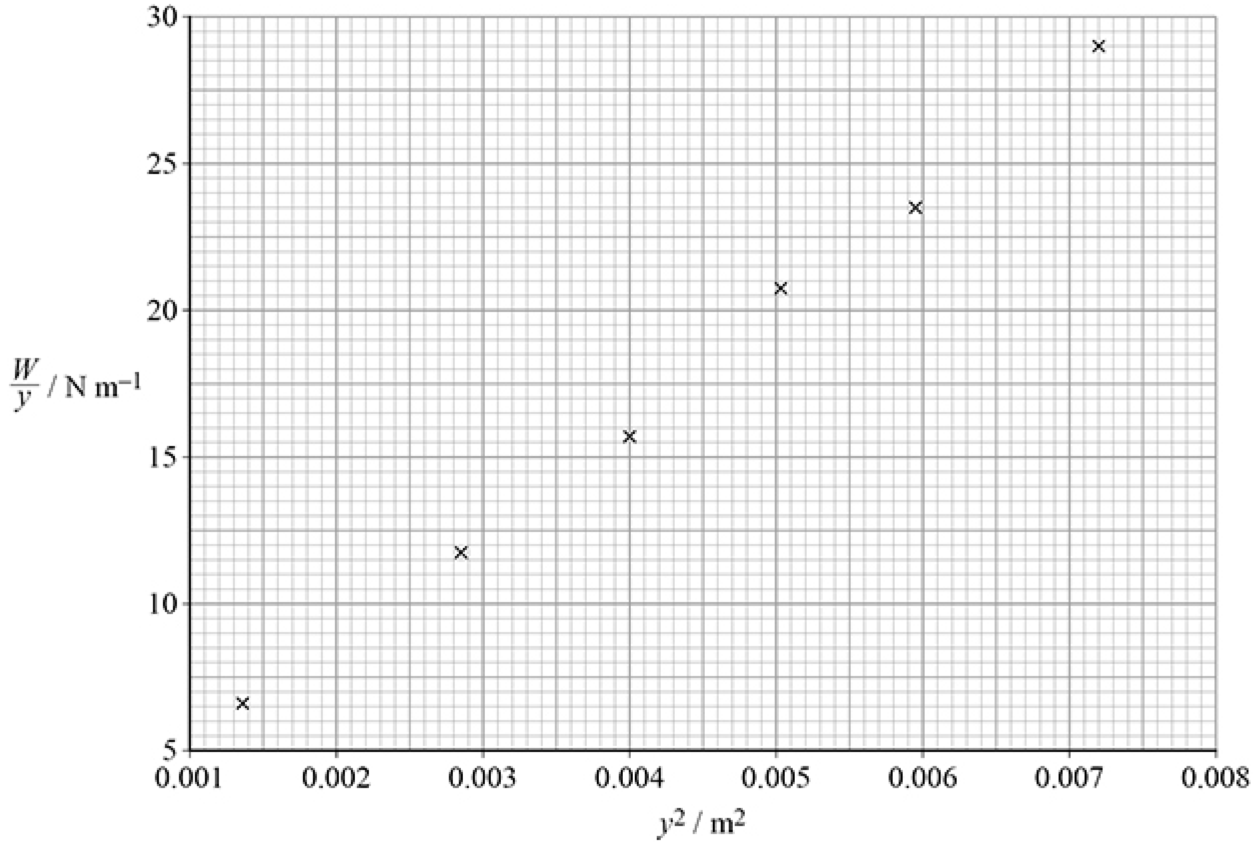
It can be shown that

$$\frac{W}{y} = \frac{EAy^2}{x^3} + k$$

where E = Young modulus of the metal
$A = 1.11 \times 10^{-7}$ m^2
x = 1.50 m
k = a constant.

A student measures y for different values of W and plots the graph shown in **Figure 3**.

Figure 3



(c) Determine E using **Figure 3**.

E = ________________ Pa

(4)

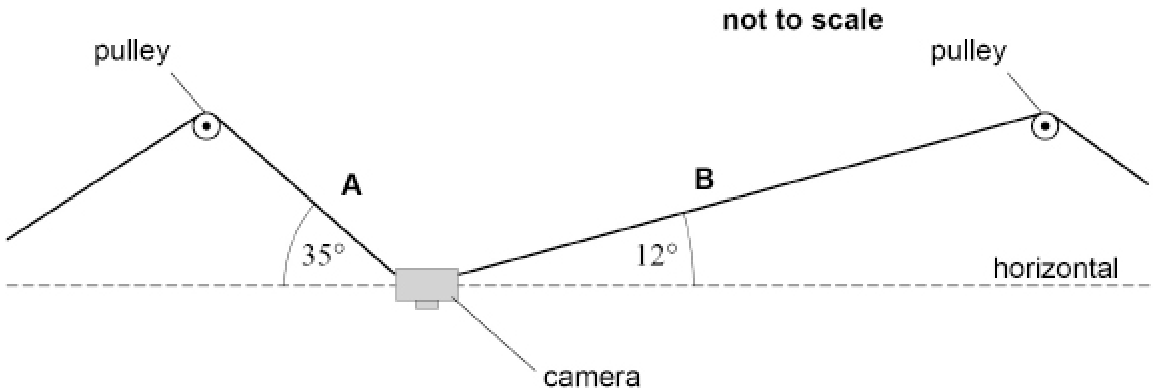
(d) Deduce the fundamental base units for k.

fundamental base units for k = _______________

(1)

(Total 8 marks)

3. The diagram shows a camera filming a sports event from above. The position of the camera is controlled by two steel cables, **A** and **B**, that pass over fixed, smooth pulleys.



(a) In the diagram above the camera is stationary. The tension in **A** is 430 N and **A** makes an angle of 35° to the horizontal. **B** makes an angle of 12° to the horizontal.

Calculate the tension in **B**.

tension in **B** = _______________ N

(2)

(b) The cross-sectional area of **A** is 7.0×10^{-6} m^2. The unstretched length of **A** is 150 m.

Calculate the extension of **A** when the tension in it is 430 N.

Young modulus of steel = 210 GPa

extension = _______________ m

(2)

(c) The camera is moved horizontally to the right to a new stationary position. The tension in **A** is now different from that in the diagram above.

Deduce whether the tension in **A** has increased or decreased.

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(3)

(d) The camera's signal is transmitted as a series of pulses through an optical fibre. The table shows data for two optical fibres **X** and **Y**. Both optical fibres are identical except for their core diameter.

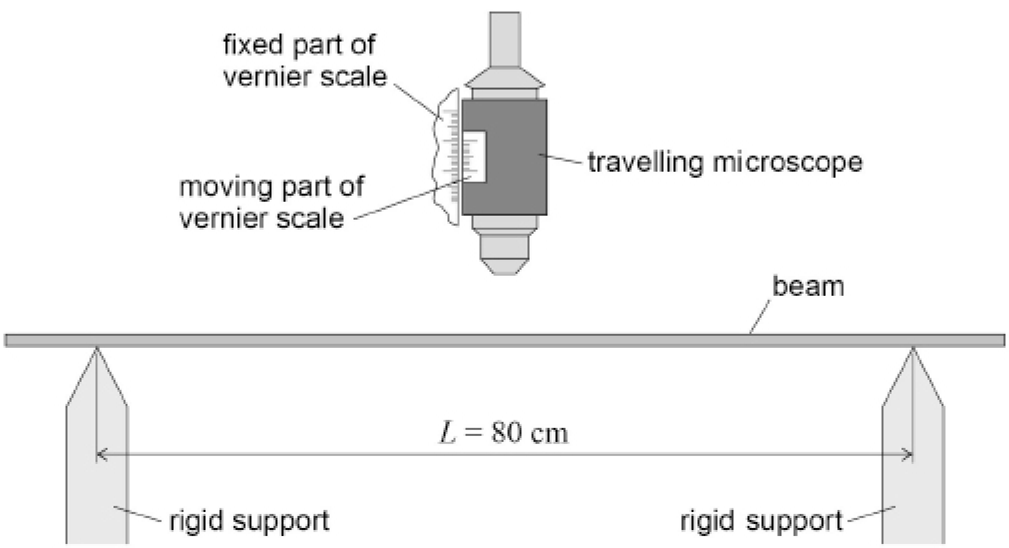
Optical fibre	**Core diameter / μm**
X	8
Y	50

Deduce which fibre allows a greater pulse transmission rate.

(3)
(Total 10 marks)

4. **Figure 1** shows apparatus used to investigate the bending of a beam.

Figure 1

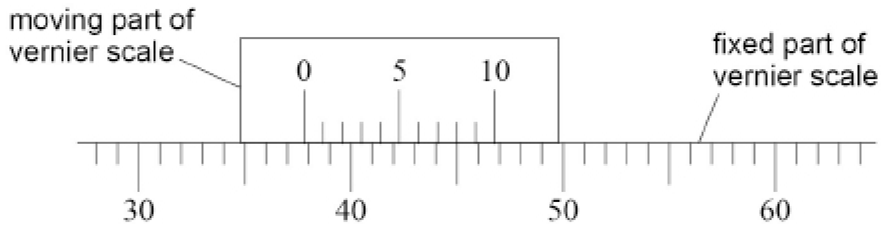


The beam is placed horizontally on rigid supports.
The distance L between the supports is 80 cm.

A travelling microscope is positioned above the midpoint of the beam and focused on the upper surface.

(a) **Figure 2** shows an enlarged view of both parts of the vernier scale.

Figure 2



The smallest division on the fixed part of the scale is 1 mm.

What is the value of the vernier reading R_0 in mm?
Tick (✓) **one** box.

34.8 ☐

37.8 ☐

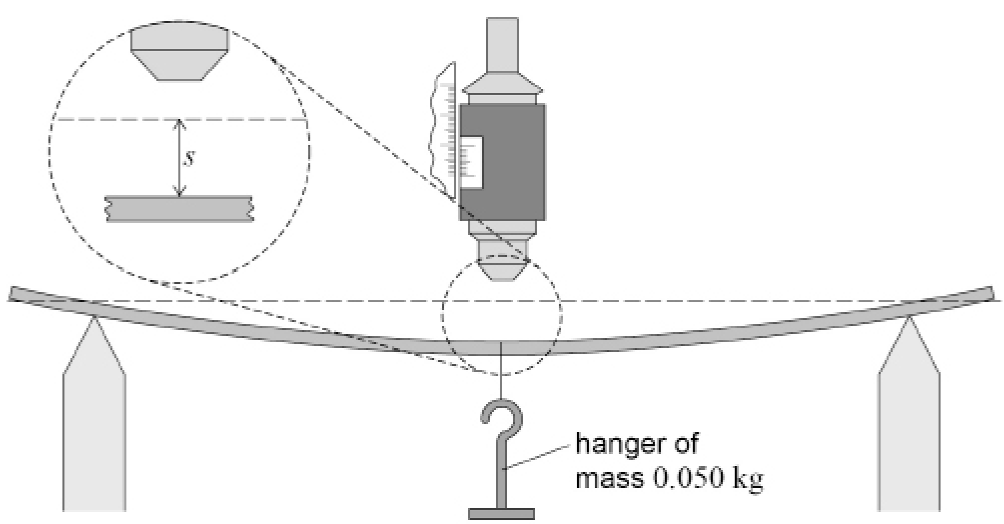
45.8 ☐

49.8 ☐

(1)

(b) **Figure 3** shows the beam bending when a hanger of mass 0.050 kg is suspended from the midpoint.

Figure 3



The microscope is refocused on the upper surface and the new vernier reading R is recorded.
The vertical deflection s of the beam is equal to $(R - R_0)$.

The total mass m suspended from the beam is increased in steps of 0.050 kg.
A value of s is recorded for each m up to a value of m = 0.450 kg.
Further values of s are then recorded as m is decreased in 0.050 kg steps until m is zero.

Student **A** performs the experiment and observes that values of s during unloading are **sometimes** different from the corresponding values for loading.

State the type of error that causes the differences student **A** observes.

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(1)

(c) Student **B** performs the experiment using a thinner beam but with the same width and made from the same material as before.

Discuss **one** possible advantage and **one** possible disadvantage of using the thinner beam.

Advantage ____

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Disadvantage ____

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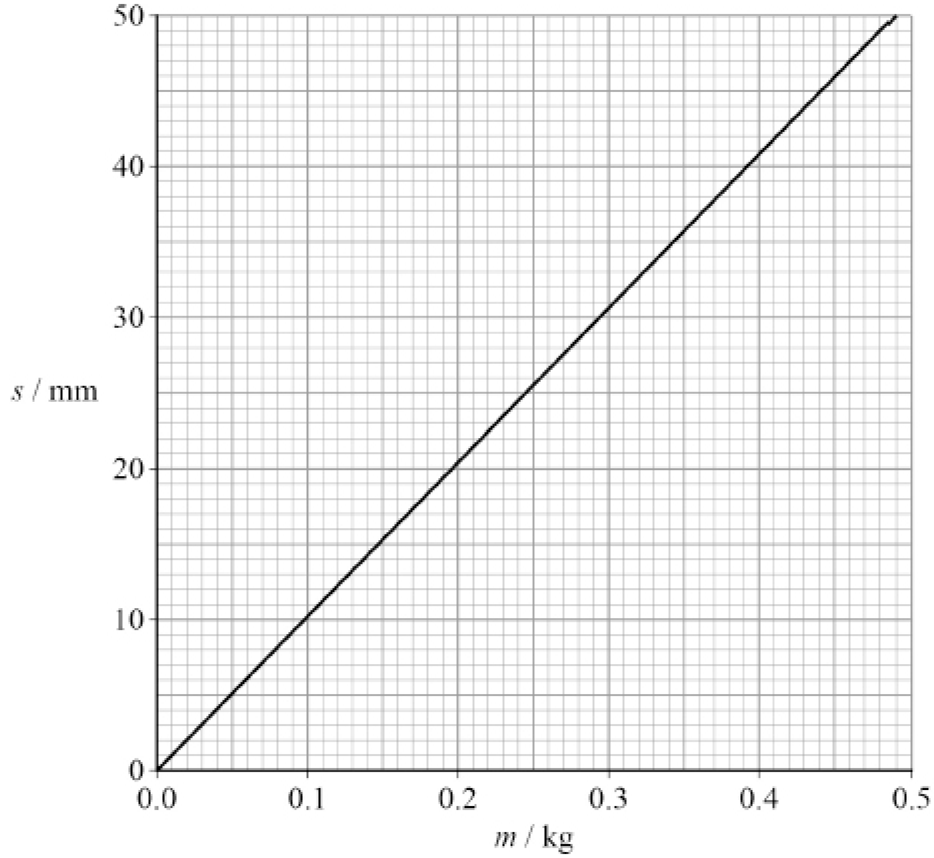
(3)

(d) **Figure 4** shows the best-fit line produced using the data collected by student **A**.

Figure 4



It can be shown that $s = \frac{\eta m}{E}$

where E is the Young modulus of the material of the beam and η is a constant.

Deduce in s^{-2} the order of magnitude of η.

E = 1.14 GPa

order of magnitude of η = _______________ s^{-2}

(4)

(e) Student **C** performs a different experiment using the same apparatus shown in **Figure 1**.
A mass M is suspended from the midpoint of the beam.
The vertical deflection s of the beam is measured for different values of L.

Figure 5 shows a graph of the results for this experiment.

Figure 5

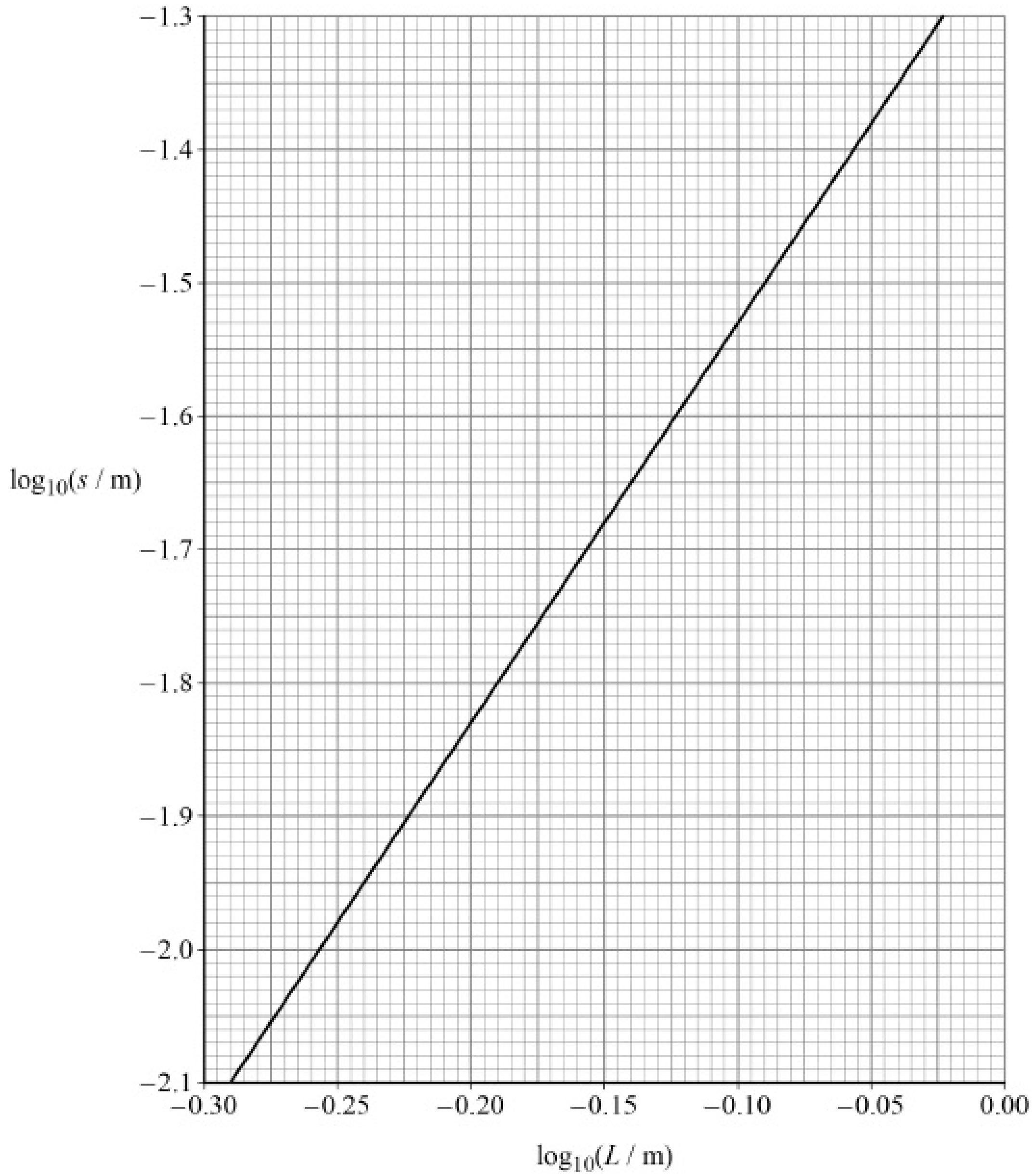


Figure 5 shows that log10(s / m) varies linearly with log10(L / m).

State what this shows about the mathematical relationship between s and L. You do **not** need to do a calculation.

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(1)

(f) Deduce, using **Figure 5**, the value of s when L = 80 cm.

s = __________________ m

(2)

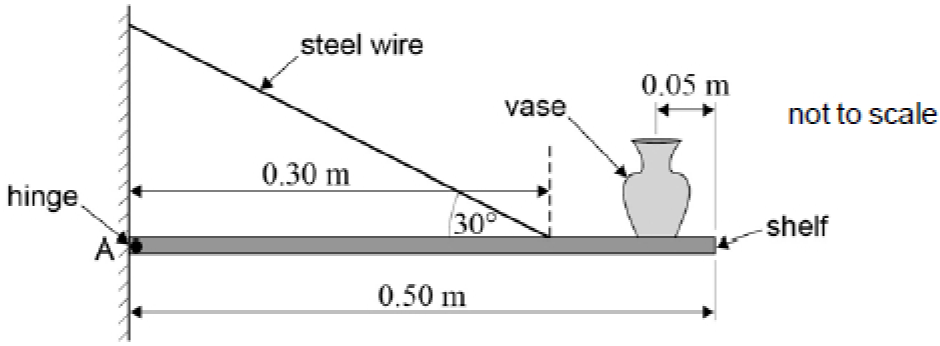
(g) Determine M using **Figure 4**.

M = __________________ kg

(1)

(Total 13 marks)

5. 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.

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(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 7.8×10^{-7} 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)