4 An L-shaped steel rod was held horizontally in a stand clamped by its shorter end as shown.

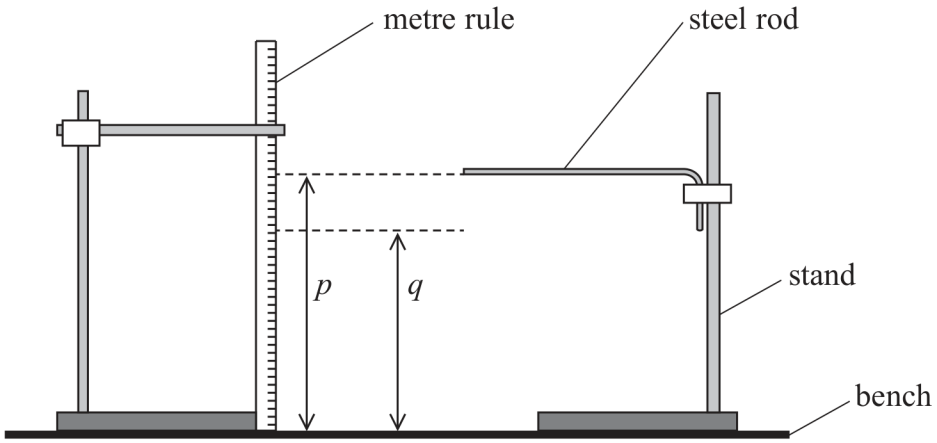

Diagram not to scale

The end of the steel rod was at a height p above the bench.

A student attached a mass m to the end of the steel rod causing it to bend towards the bench. The end of the steel rod was then at a height q above the bench.

(a) (i) Describe two techniques she should use when measuring p and q.

(2)

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(ii) The difference between p and q was recorded as 26 mm ± 1 mm.

Explain why the uncertainty in this value is given as 1 mm.

(2)

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(b) The steel rod had a circular cross-section with a diameter d of approximately 2 mm.

(i) Explain the most appropriate instrument the student should use to measure d.

(2)

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(ii) Explain one technique that she should use to measure d.

(2)

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(iii) She recorded the following measurements.

d / mm				
2.35	2.37	2.34	2.35	2.33

Calculate the mean value of d in mm and its uncertainty.

(2)

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Mean value of d = ... mm ± ..... mm

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(c) The shear modulus G is a measure of a material's resistance to bending, and is given by

$$G = \frac{32mglx^2}{\pi yd^4}$$

where m is the mass attached to the end of the rod and y is the vertical deflection.

l and x are the lengths as shown below.

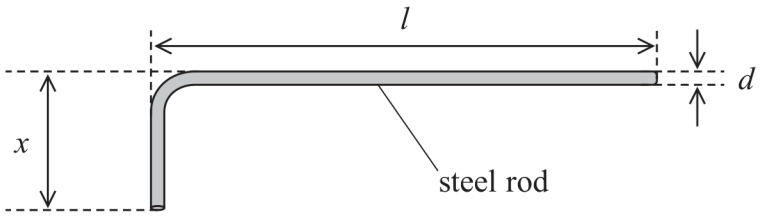

Diagram not to scale

Determine a value of G for steel in $\mathrm{N\,m^{-2}}$.

m = 100 g with negligible uncertainty
l = 58.9 cm ± 0.1 cm
x = 10.3 cm ± 0.1 cm
y = 26 mm ± 1 mm

(2)

$G =$ ..... $\mathrm{N\,m^{-2}}$

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(d) The table shows values of G for different types of steel.

Type of steel	Structural steel	Carbon steel
$G / 10^9\ \mathrm{N\ m^{-2}}$	79.3	77.0

Deduce whether the data provided in part (c) would allow the student to determine the type of steel the rod was made from.

(4)

(Total for Question 4 = 16 marks)