11, 15/mj/23-q4

Fig. 4.1 shows the values obtained in an experiment to determine the Young modulus E of a metal in the form of a wire.

quantity	value	instrument
diameter d	0.48 mm	
length l	1.768 m	
load F	5.0 N to 30.0 N in 5.0 N steps	
extension e	0.25 mm to 1.50 mm	

Fig. 4.1

(a) (i) Complete Fig. 4.1 with the name of an instrument that could be used to measure each of the quantities. [3]

(ii) Explain why a series of values of F, each with corresponding extension e, are measured.

....

....[1]

(b) Explain how a series of readings of the quantities given in Fig. 4.1 is used to determine the Young modulus of the metal. A numerical answer for E is not required.

....

....

....

....[2]

12, 16/mj/22-q3

(a) Define the *Young modulus*.

....

....[1]

(b) The Young modulus of steel is 1.9×10^{11} Pa. The Young modulus of copper is 1.2×10^{11} Pa.

A steel wire and a copper wire each have the same cross-sectional area and length. The two wires are each extended by equal forces.

(i) Use the definition of the Young modulus to determine the ratio
$$\frac{\text{extension of the copper wire}}{\text{extension of the steel wire}}.$$

ratio = ...[3]

(ii) The two wires are each extended by a force. Both wires obey Hooke's law.

On Fig. 3.1, sketch a graph for each wire to show the variation with extension of the force.

Label the line for steel with the letter **S** and the line for copper with the letter **C**.

Fig. 3.1

[1]

[Total: 5]

13, 16/on/22-q3

(a) State the two conditions for an object to be in equilibrium.

1. ....

....

2. ....

....
[2]

(b) A uniform beam AC is attached to a vertical wall at end A. The beam is held horizontal by a rigid bar BD, as shown in Fig. 3.1.

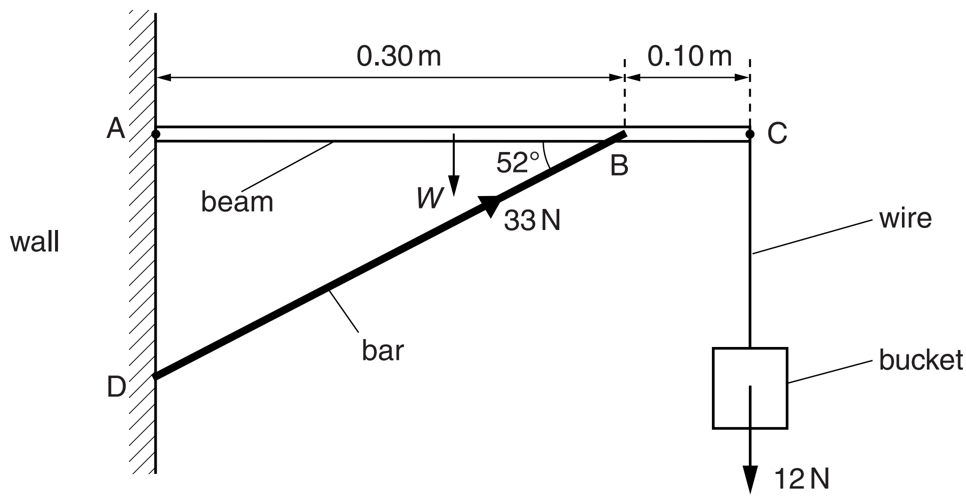

Fig. 3.1 (not to scale)

The beam is of length 0.40 m and weight W. An empty bucket of weight 12 N is suspended by a light metal wire from end C. The bar exerts a force on the beam of 33 N at 52° to the horizontal. The beam is in equilibrium.

(i) Calculate the vertical component of the force exerted by the bar on the beam.

component of the force = ... N [1]

(ii) By taking moments about A, calculate the weight W of the beam.

W = ... N [3]

(c) The metal of the wire in **(b)** has a Young modulus of 2.0×10^{11} Pa.
Initially the bucket is empty. When the bucket is filled with paint of weight 78 N, the strain of the wire increases by 7.5×10^{-4}. The wire obeys Hooke's law.

Calculate, for the wire,

(i) the increase in stress due to the addition of the paint,

increase in stress = ... Pa [2]

(ii) its diameter.

diameter = ... m [3]

[Total: 11]

14,17/mj/22-q3

The Young modulus of the material of a wire can be determined using the apparatus shown in Fig. 3.1.

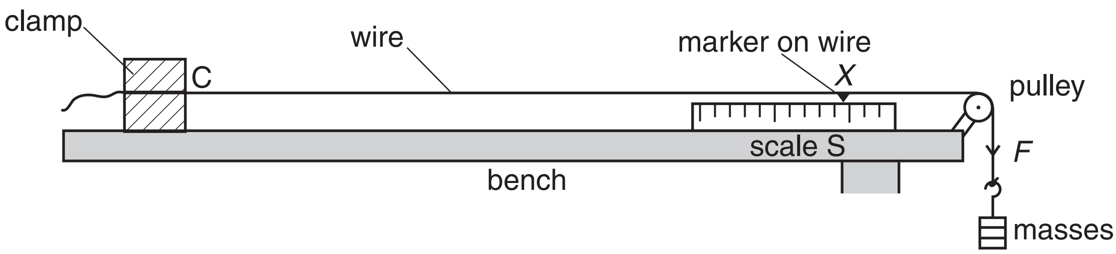

Fig. 3.1

One end of the wire is clamped at C and a marker is attached to the wire above a scale S. A force to extend the wire is applied by attaching masses to the other end of the wire.

The reading *X* of the marker on the scale S is determined for different forces *F* applied to the end of the wire. The variation with *X* of *F* is shown in Fig. 3.2.

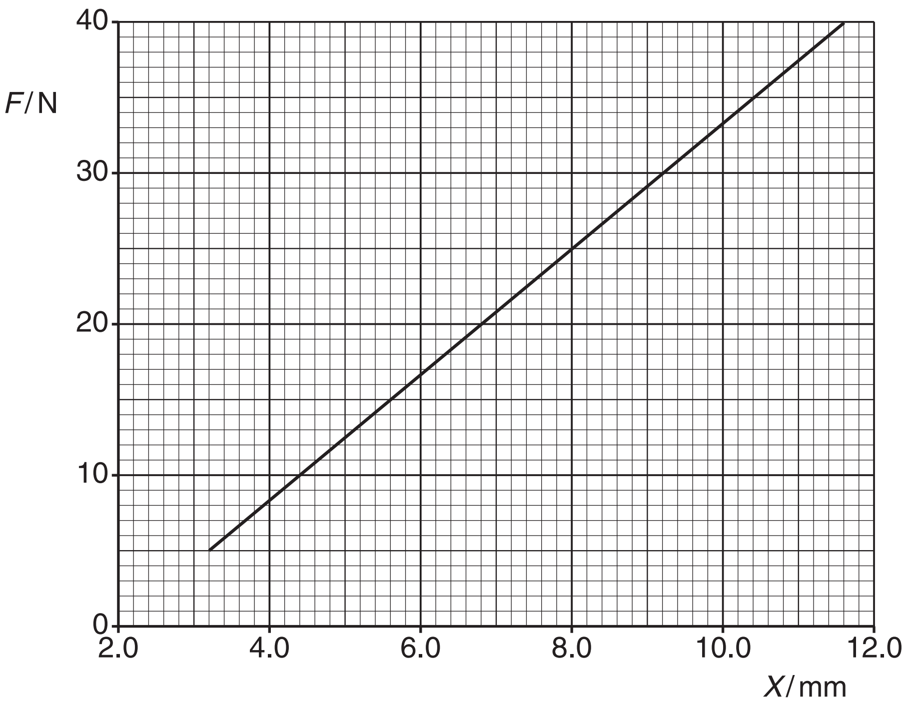

Fig. 3.2

(a) The length of the wire from C to the marker for $F = 0$ is 3.50 m. The diameter of the wire is 0.38 mm.

Use the gradient of the line in Fig. 3.2 to determine the Young modulus E of the material of the wire in TPa.

E = ... TPa [3]

(b) The experiment is repeated with a thicker wire of the same material and length.

State how the range of the force F must be changed to obtain the same range of scale readings as in Fig. 3.2.

....

....

....[1]

[Total: 4]

15,17/on/21-q4

(a) Define *strain*.

....

....[1]

(b) A wire is designed to ensure that its strain does not exceed 4.0×10^{-4} when a force of 8.0 kN is applied. The Young modulus of the metal of the wire is 2.1×10^{11} Pa. It may be assumed that the wire obeys Hooke's law.

For a force of 8.0 kN, calculate, for the wire,

(i) the maximum stress,

maximum stress = ... Pa [2]

(ii) the minimum cross-sectional area.

minimum cross-sectional area = ... m^2 [2]

[Total: 5]

16, 17/on/22-q3

A spring is attached at one end to a fixed point and hangs vertically with a cube attached to the other end. The cube is initially held so that the spring has zero extension, as shown in Fig. 3.1.

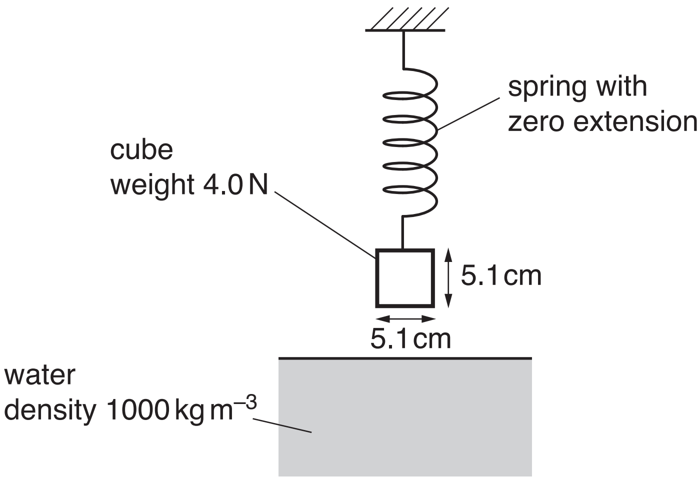

Fig. 3.1

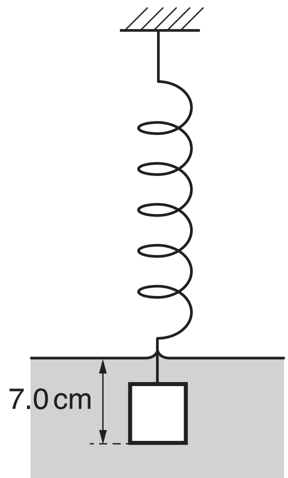

Fig. 3.2

The cube has weight 4.0 N and sides of length 5.1 cm. The cube is released and sinks into water as the spring extends. The cube reaches equilibrium with its base at a depth of 7.0 cm below the water surface, as shown in Fig. 3.2.
The density of the water is $1000\,kg\,m^{-3}$.

(a) Calculate the difference in the pressure exerted by the water on the bottom face and on the top face of the cube.

difference in pressure = ... Pa [2]

(b) Use your answer in **(a)** to show that the upthrust on the cube is 1.3 N.

[2]

(c) Calculate the force exerted on the spring by the cube when it is in equilibrium in the water.

force = ... N [1]

(d) The spring obeys Hooke's law and has a spring constant of 30 N m^{-1}.

Determine the initial height above the water surface of the base of the cube before it was released.

height above surface = ... cm [3]

(e) The cube in the water is released from the spring.

(i) Determine the initial acceleration of the cube.

acceleration = ...m s^{-2} [2]

(ii) Describe and explain the variation, if any, of the acceleration of the cube as it sinks in the water.

....

....

....[2]

[Total: 12]

17, 18/fm/22-q3

(a) For the deformation of a wire under tension, define

(i) *stress*,

....

....[1]

(ii) *strain*.

....

....[1]

(b) A wire is fixed at one end so that it hangs vertically. The wire is given an extension x by suspending a load F from its free end. The variation of F with x is shown in Fig. 3.1.

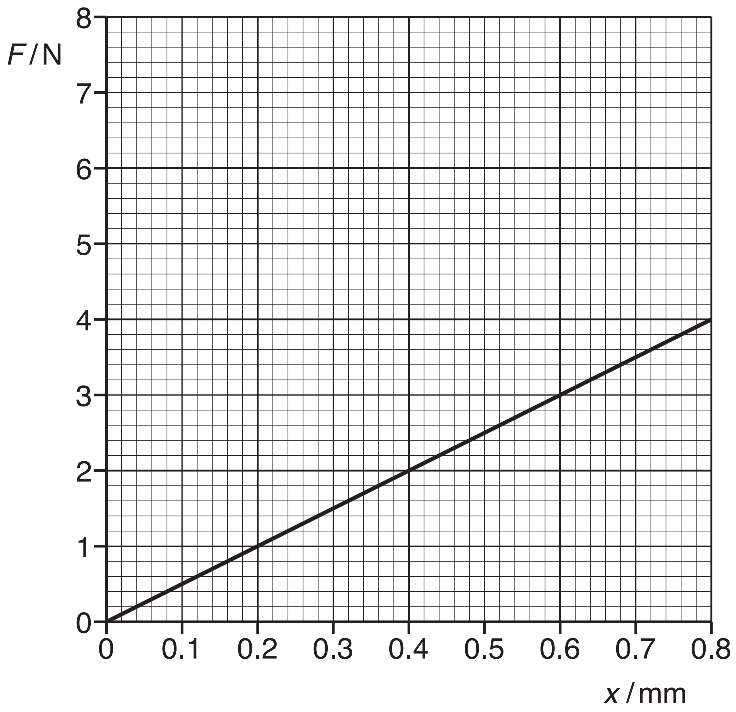

Fig. 3.1

The wire has cross-sectional area $9.4 \times 10^{-8}\,\text{m}^2$ and original length 2.5 m.

(i) Describe how measurements can be taken to determine accurately the cross-sectional area of the wire.

....

....

....

....

....[3]

(ii) Determine the Young modulus E of the material of the wire.

E = ... Pa [2]

(iii) **Use Fig. 3.1** to calculate the increase in the energy stored in the wire when the load is increased from 2.0 N to 4.0 N.

increase in energy = ... J [2]

(c) The wire in **(b)** is replaced by a new wire of the same material. The new wire has twice the length and twice the diameter of the old wire. The new wire also obeys Hooke's law.

On Fig. 3.1, sketch the variation with extension x of the load F for the new wire from $x = 0$ to $x = 0.80$ mm. [2]

[Total: 11]

18, 18/on/23-q1

(a) Mass, length and time are all SI base quantities.

State two other SI base quantities.

1. ....

2. .... [2]

(b) A wire hangs between two fixed points, as shown in Fig. 1.1.

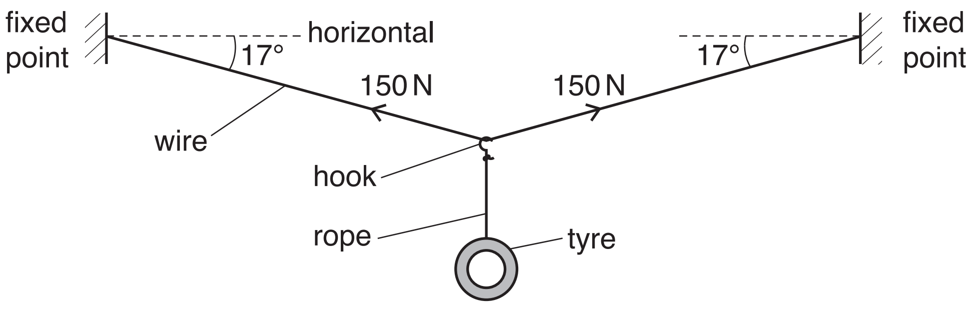

Fig. 1.1 (not to scale)

A child's swing is made by connecting a car tyre to the wire using a rope and a hook. The system is in equilibrium with the wire hanging at an angle of 17° to the horizontal. The tension in the wire is 150 N. Assume that the rope and hook have negligible weight.

(i) Determine the weight of the tyre.

weight = ... N [2]

(ii) The wire has a cross-sectional area of $7.5\,\text{mm}^2$ and is made of metal of Young modulus 2.1×10^{11} Pa. The wire obeys Hooke's law.

Calculate, for the wire,

1. the stress,

stress = ... Pa [2]

2. the strain.

strain = ... [2]

[Total: 8]

19, 19/mj/22-q2

(a) State Newton's second law of motion.

....

....[1]

(b) A car of mass 850 kg tows a trailer in a straight line along a horizontal road, as shown in Fig. 2.1.

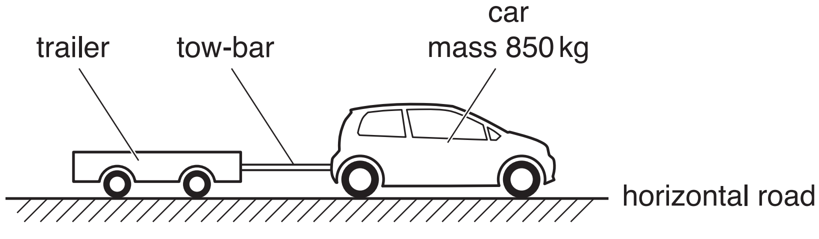

Fig. 2.1

The car and the trailer are connected by a horizontal tow-bar.

The variation with time t of the velocity v of the car for a part of its journey is shown in Fig. 2.2.

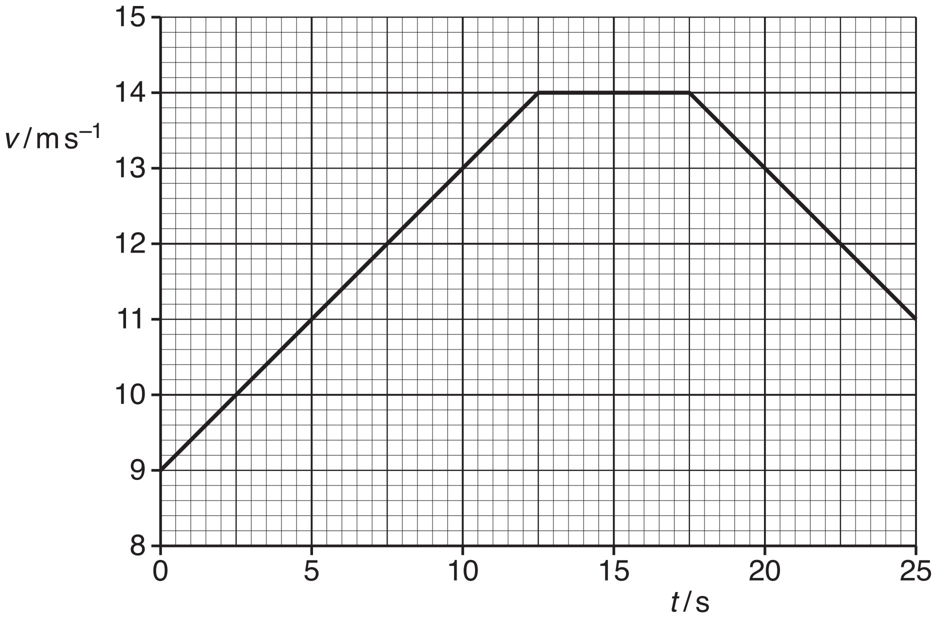

Fig. 2.2

(i) Calculate the distance travelled by the car from time $t = 0$ to $t = 10$ s.

distance = ... m [2]

(ii) At time $t = 10$ s, the resistive force acting on the car due to air resistance and friction is 510 N. The tension in the tow-bar is 440 N.

For the car at time $t = 10$ s:

1. use Fig. 2.2 to calculate the acceleration

acceleration = ... m s^{-2} [2]

2. use your answer to calculate the resultant force acting on the car

resultant force = ... N [1]

3. show that a horizontal force of 1300 N is exerted on the car by its engine

[1]

4. determine the useful output power of the engine.

output power = ... W [2]

(c) A short time later, the car in **(b)** is travelling at a constant speed and the tension in the tow-bar is 480 N.

The tow-bar is a solid metal rod that obeys Hooke's law. Some data for the tow-bar are listed below.

Young modulus of metal = 2.2×10^{11} Pa

original length of tow-bar = 0.48 m

cross-sectional area of tow-bar = $3.0 \times 10^{-4}\ m^2$

Determine the extension of the tow-bar.

extension = ... m [3]

(d) The driver of the car in **(b)** sees a pedestrian standing directly ahead in the distance. The driver operates the horn of the car from time t = 15 s to t 17 s. The frequency of the sound heard by the pedestrian is 480 Hz. The speed of the sound in the air is 340 m s^{-1}.

Use Fig. 2.2 to calculate the frequency of the sound emitted by the horn.

frequency = ... Hz [2]

[Total: 14]