Deformation of Solids

1-Nov 01-Q/5

(a) In the following list of solids, underline those materials which are crystalline.

rubber copper nylon glass aluminium [2]

(b) The three graphs A, B and C of Fig. 5.1 represent the variation with extension x of the tension F in specimens of three different materials. One of the materials is polymeric, one is brittle and the other is ductile. They are not shown in that order in Fig. 5.1.

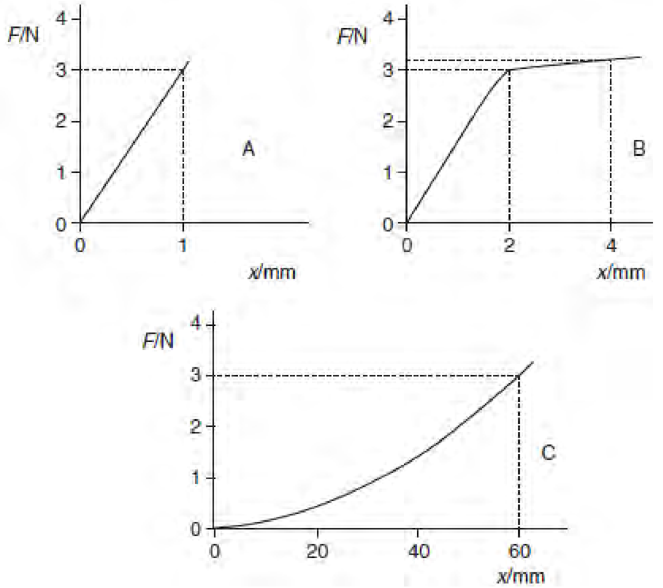


Fig. 5.1

(i) State the type of material which would produce the line shown in each graph.

Graph A is for a .... material.

Graph B is for a .... material.

Graph C is for a .... material. [2]

(ii) Use graph B to estimate the work done in stretching the specimen from 0 to 4 mm.

work done = ... J [3]

2-Nov 02-Q/9

An aluminium wire of length 1.8 m and area of cross-section $1.7\text{x}10^{-6}$ m^2 has one end fixed to a rigid support. A small weight hangs from the free end, as illustrated in Fig. 9.1.

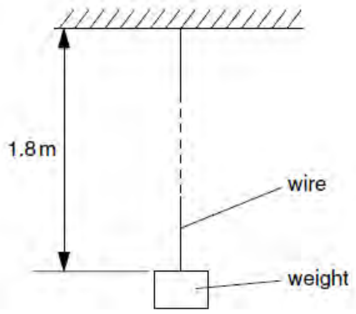


Fig. 9.1

The resistance of the wire is 0.030 Ω and the Young modulus of aluminium is $7.1\text{x}10^{10}$ Pa.

The load on the wire is increased by 25 N. (a) Calculate

(i) the increase in stress, increase = …………………… Pa

(ii) the change in length of the wire. change = ……… m [4]

(b) Assuming that the area of cross-section of the wire does not change when the load is increased, determine the change in resistance of the wire. change = ………………….. Ω [3]

3-May 03-Q/3

(a) Fig. 3.1 shows the variation with tensile force of the extension of a copper wire.

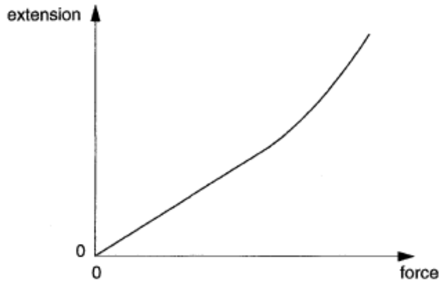


Fig. 3.1

(i) State whether copper is a ductile, brittle or polymeric material.

(ii) 1. On Fig. 3.1, mark with the letter L the point on the line beyond which Hooke's law does not apply.

2. State how the spring constant for the wire may be obtained from Fig. 3.1. [3]

(b) A copper wire is fixed at one end and passes over a pulley. A mass hangs from the free end of the wire, as shown in Fig. 3.2.

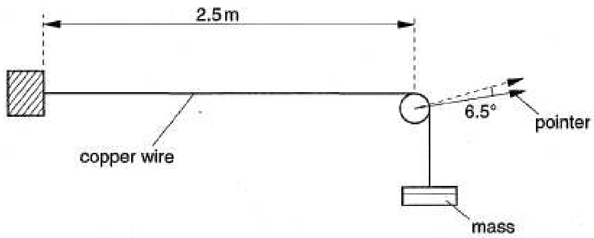


Fig. 3.2

The length of wire between the fixed end and the pulley is 2.5 m. When the mass on the wire is increased by 6.0 kg, a pointer attached to the pulley rotates through an angle of 6.5°. The pulley, of diameter 3.0 cm, is rough so that the wire does not slide over it.

(i) For this increase in mass,

1. show that the wire extends by 0.17 cm,

2. calculate the increase in strain of the wire.

increase in strain =…………..[4]

(ii) The area of cross-section of the wire is $7.9\text{x}10^{-7}m^2$. Calculate the increase in stress produced by the increase in load. increase in stress = ... Pa [3]

(iii) Use your answers to (i) 2 and (ii) to determine the Young modulus of copper. Young modulus = ... Pa [2]

(iv) Suggest how you could check that the elastic limit of the wire is not exceeded when the extra load is added. [1]

4-Nov 04-Q/5

(a) A metal wire has an unstretched length L and area of cross-section A. When the wire supports a load F, the wire extends by an amount ΔL. The wire obeys Hooke's law.

Write down expressions, in terms of L, A, F and ΔL, for

(i) the applied stress,

(ii) the tensile strain in the wire,

(iii) the Young modulus of the material of the wire. [3]

(b) A steel wire of uniform cross-sectional area $7.9\text{x}10^{-7}$ m^2 is heated to a temperature of 650 K. It is then clamped between two rigid supports, as shown in Fig. 5.1.

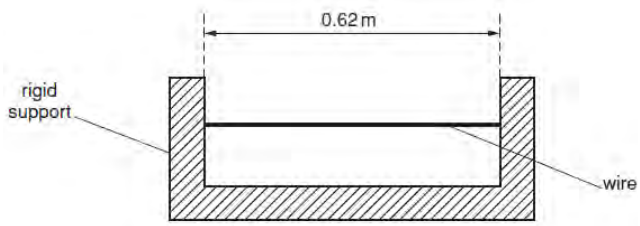


Fig. 5.1

The wire is straight but not under tension and the length between the supports is 0.62 m. The wire is then allowed to cool to 300 K.

When the wire is allowed to contract freely, a 1.00 m length of the wire decreases in length by 0.012 mm for every 1K decrease in temperature.
(i) Show that the change in length of the wire, if it were allowed to contract as it cools from 650K to 300 K, would be 2.6 mm. [2]
(ii) The Young modulus of steel is 2.0 x 10^{11} Pa. Calculate the tension in the wire at 300 K, assuming that the wire obeys Hooke's law. tension = …………………………… N [2]
(iii) The ultimate tensile stress of steel is 250 MPa. Use this information and your answer in (ii) to suggest whether the wire will, in practice, break as it cools. [3]

5-May 05-Q/4
A glass fibre of length 0.24m and area of cross-section $7.9\times10^{-7}\text{m}^2$ is tested until it breaks.
The variation with load F of the extension x of the fibre is shown in Fig. 4.1.

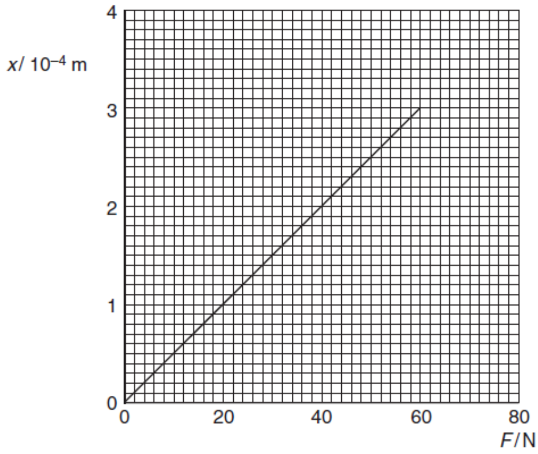


Fig. 4.1

(a) State whether glass is ductile, brittle or polymeric.[1]
(b) Use Fig. 4.1 to determine, for this sample of glass,
(i) the ultimate tensile stress,
ultimate tensile stress = ... Pa [2]
(ii) the Young modulus,
Young modulus = ... Pa [3]
(iii) the maximum strain energy stored in the fibre before it breaks.
maximum strain energy = ... J [2]
(c) A hard ball and a soft ball, with equal masses and volumes, are thrown at a glass window. The balls hit the window at the same speed. Suggest why the hard ball is more likely than the soft ball to break the glass window. [3]

6-May 06-Q/5
Fig. 5.1 shows the variation with force F of the extension x of a spring as the force is increased to F3 and then decreased to zero.

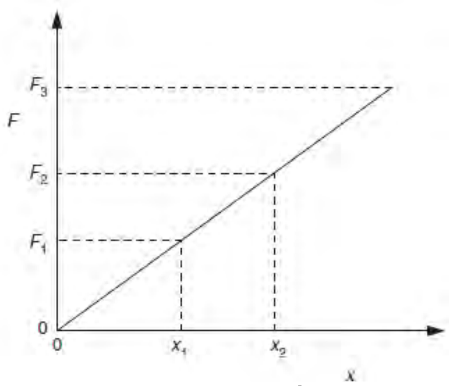


Fig. 5.1

(a) State, with a reason, whether the spring is undergoing an elastic change. [1]
(b) The extension of the spring is increased from x_1 to x_2. Show that the work W done in extending the spring is given by

$$W = \tfrac{1}{2}k(x_2^{\,2} - x_1^{\,2}),$$

(c) A trolley of mass 850 g is held between two fixed points by means of identical springs, as shown in Fig. 5.2.

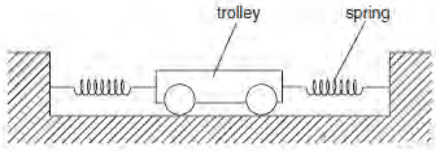


Fig. 5.2

When the trolley is in equilibrium, the springs are each extended by 4.5 cm. Each spring has a spring constant 16Ncm^{-1}.
The trolley is moved a distance of 1.5 cm along the direction of the springs. This causes the extension of one spring to be increased and the extension of the other spring to be decreased. The trolley is then released. The trolley accelerates and reaches its maximum speed at the equilibrium position.
Assuming that the springs obey Hooke's law, use the expression in **(b)** to determine the maximum speed of the trolley.
speed = ………………………… ms^{-1} [4]

7-Nov 06-Q/5
(a) Distinguish between the structure of a metal and of a polymer. [4]
(b) Latex is a natural form of rubber. It is a polymeric material.
(i) Describe the properties of a sample of latex. [2]
(ii) The process of heating latex with a small amount of sulphur creates cross-links between molecules. Natural latex has very few cross-links between its molecules.
Suggest how this process changes the properties of latex. [2]

8-Nov 06-Q/6
A straight wire of unstretched length L has an electrical resistance R. When it is stretched by a force F, the wire extends by an amount ΔL and the resistance increases by ΔR. The area of cross-section A of the wire may be assumed to remain constant.
(a) (i) State the relation between R, L, A and the resistivity ρ of the material of the wire. [1]
(ii) Show that the fractional change in resistance is equal to the strain in the wire.[2]
(b) A steel wire has area of cross-section $1.20\times10^{-7}\text{m}^2$ and a resistance of 4.17Ω.
The Young modulus of steel is 2.10×10^{11}Pa. The tension in the wire is increased from zero to 72.0 N. The wire obeys Hooke's law at these values of tension.
Determine the strain in the wire and hence its change in resistance. Express your answer to an appropriate number of significant figures.
change = ………………………… Ω [5]

9-Nov 07-Q/4
A sample of material in the form of a cylindrical rod has length L and uniform area of cross-section A. The rod undergoes an increasing tensile stress until it breaks.
Fig. 4.1 shows the variation with stress of the strain in the rod.

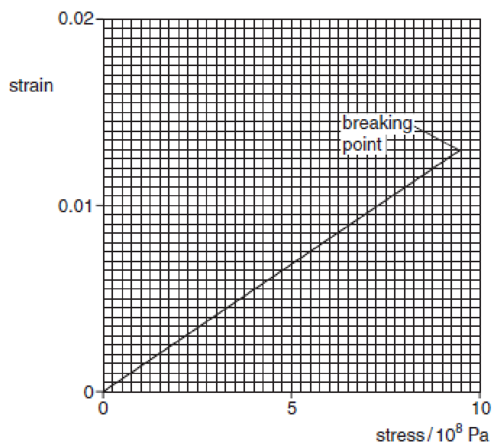


Fig. 4.1

(a) State whether the material of the rod is ductile, brittle or polymeric. [1]
(b) Determine the Young modulus of the material of the rod.
Young modulus = ... Pa [2]

(c) A second cylindrical rod of the same material has a spherical bubble in it, as illustrated in Fig. 4.2.

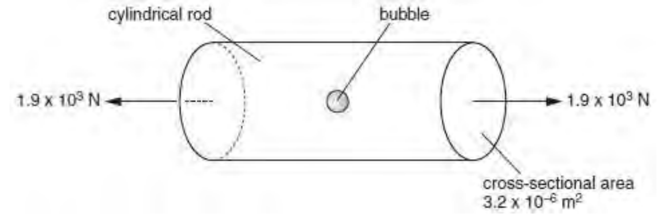


Fig. 4.2

The rod has an area of cross-section of 3.2×10^{-6} m^2 and is stretched by forces of magnitude 1.9×10^3 N.
By reference to Fig. 4.1, calculate the maximum area of cross-section of the bubble such that the rod does not break.

area = ... m^2 [3]

(d) A straight rod of the same material is bent as shown in Fig. 4.3.

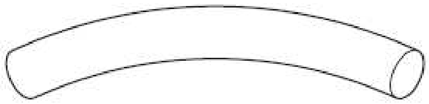


Fig. 4.3

Suggest why a thin rod can bend more than a thick rod without breaking. [2]

10-May 08-Q/2
A spring is placed on a flat surface and different weights are placed on it, as shown in Fig. 2.1.

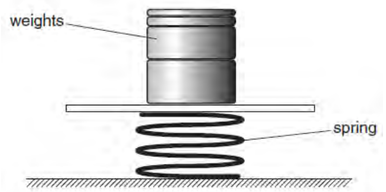


Fig. 2.1

The variation with weight of the compression of the spring is shown in Fig. 2.2.

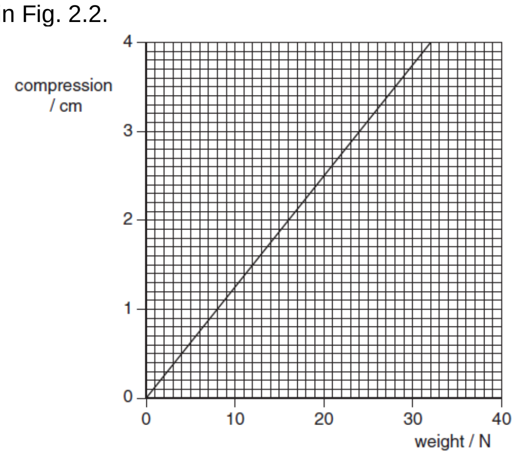


Fig. 2.2

The elastic limit of the spring has not been exceeded.
(a) (i) Determine the spring constant *k* of the spring.

k = ... N m^{-1} [2]

(ii) Deduce that the strain energy stored in the spring is 0.49 J for a compression of 3.5 cm. [2]
(b) Two trolleys, of masses 800 g and 2400 g, are free to move on a horizontal table. The spring in **(a)** is placed between the trolleys and the trolleys are tied together using thread so that the compression of the spring is 3.5 cm, as shown in Fig. 2.3.

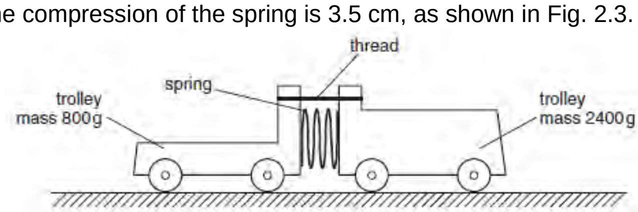


Fig. 2.3

Initially, the trolleys are not moving.
The thread is then cut and the trolleys move apart.

(i) Deduce that the ratio

$$\frac{\text{speed of trolley of mass 800 g}}{\text{speed of trolley of mass 2400 g}}$$

is equal to 3.0. [2]

(ii) Use the answers in **(a)(ii)** and **(b)(i)** to calculate the speed of the trolley of mass 800 g.

speed = ... m s^{-1} [3]

11-May 08-Q/4
(a) (i) Define the terms **1.** tensile stress, [1]
2. tensile strain, [1] **3.** the Young modulus. [1]

(ii) Suggest why the Young modulus is not used to describe the deformation of a liquid or a gas. [1]
(b) The change ΔV in the volume V of some water when the pressure on the water increases by Δp is given by the expression

$$\Delta p = 2.2 \times 10^9 \, \frac{\Delta V}{V},$$

where Δp is measured in pascal.
In many applications, water is assumed to be incompressible.
By reference to the expression, justify this assumption. [2]

(c) Normal atmospheric pressure is 1.01×10^5 Pa.
Divers in water of density 1.08×10^3 kg m^{-3} frequently use an approximation that every 10 m increase in depth of water is equivalent to one atmosphere increase in pressure.
Determine the percentage error in this approximation.

error = ... % [3]

12-May 09-Q/4
A spring having spring constant *k* hangs vertically from a fixed point. A load of weight *L*, when hung from the spring, causes an extension *e*. The elastic limit of the spring is not exceeded.
(a) State **(i)** what is meant by an *elastic deformation*, [2]
(ii) the relation between *k*, *L* and *e*. [1]
(b) Some identical springs, each with spring constant *k*, are arranged as shown in Fig. 4.1.

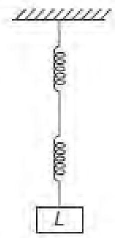
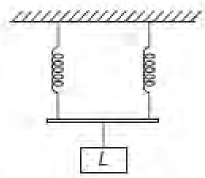
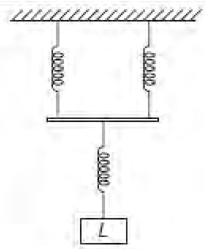
arrangement	total extension	spring constant of arrangement
	....	....
	....	....
	....	....

Fig. 4.1

The load on each of the arrangements is *L*.
For each arrangement in Fig. 4.1, complete the table by determining
(i) the total extension in terms of *e*,
(ii) the spring constant in terms of *k*. [5]