Date: 14/10/2021

Q1. What do you mean by the elastic limit?

Q2. What are the factors that may affect elasticity of a material?

Q3. Which type of substances are called elastomers? Give one example.

Q4. What are the factors on which modulus elasticity of a material depends?

Q5. Under what condition, the restoring forces are equal and opposite to the external deforming force?

Q6. What is a deforming force?

Q7. What is elastic energy?

Q8. What is plasticity?

Q9. What is elasticity?

Q10. Distinguish between elasticity and plasticity of materials.

Q11. Why does a cycle tube burst in summer?

Q12. Define Elasticity. Explain the cause of elasticity.

Q13. Determine the force required double the length of a steel wire of area of cross section 5×10^{-5} m^2. Given Y for steel = 2×10^{11} Nm^{-2}.

Q14. A rigid bar of mass 15 kg is supported symmetrically by three wires each 2.0 m long. Those at each end are of copper and the middle one is of iron. Determine the ratio of their diameters if each is to have the same tension.

Q15. The earth without its atmosphere would be inhospitably cold. Why?

Q16. Which is more elastic steel or rubber? Explain.

Q17. The breaking stress of steel is 8.0×10^9 Nm^{-2} and its density is 1.0×10^4 kg m^{-3}. Find the greatest length of the wire which can hang without breaking.

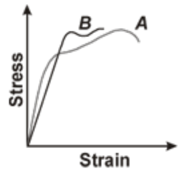
Q18. A wire 10 m long has a cross-sectional area 1.25×10^{-4} m^2. It is subjected to a load of 5 kgs. If Y for the material is 4×10^{10} Nm^{-2}, calculate the elongation produced in the wire. Take g = 10 ms^{-2}.

Q19. In a human pyramid in a circus, the entire weight of the balanced group is supported by the legs of a performer who is lying on his back (as shown in figure). The combined mass of all the persons performing the act, and the tables, plaques etc. involved is 280 kg. The mass of the performer lying on his back at the bottom of the pyramid is 60 kg. Each thighbone (femur) of this performer has a length of 50 cm and an effective radius of 2.0 cm. Determine the amount by which each thighbone gets compressed under the extra load.

Q20. (a) Is the Young's modulus of rubber is greater than that of steel? Explain.
(b) Is stretching of a coil is determined by its shear modulus? Explain.

Q21. Two wires, one of steel and the other of aluminum, each 2 m long and of diameter 2.0 mm, are joined end to end to form a composite wire of length 4.0 m. What tension in the wire will produce a total extension of 0.90 mm?
Y for steel = 2×10^{11} Nm^{-2}; Y for aluminum = 7×10^{11} Nm^{-2}.

Q22. The stress-strain graphs for materials *A* and *B* are shown. The graphs are drawn to the same scale.



(a) Which of the materials has the greater Young's modulus?
(b) Which of the two is the stronger material?

Q23. A cube of aluminum of each side 4 cm is subjected to a tangential (shearing) force. The top face of the cube is sheared through 0.012 cm with respect to the bottom face.

Find (a) shearing strain (b) shearing stress and (c) the shearing force.

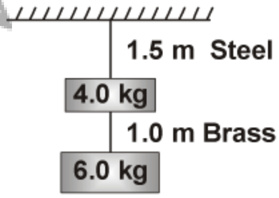
Given : $\eta = 2.08 \times 10^{11}$ dyne cm^{-2}.

Q24. A rubber cord 12 m long is suspended vertically. How much does it stretch under its own Weight / Density of rubber is 1.5 g cm^{-3} and Y = 5×10^{6} gf cm^{-2}

Q25. A 45 kg boy whose leg bones are 5 cm^2 in area and 50 cm long falls through a height of 2 m without breaking his leg bones. If the bones can withstand a stress of 0.9×10^{8} N/m^2, calculate the Young's modulus for the material of the bone. Use, g = 10 ms^{-2}.

Q26. (a) Prove that the work done in stretching a wire per unit volume is $\frac{1}{2} \times$ tension $\times$ extension.
(b) Prove that the work done per unit volume in stretching a wire for every type of strain $= \frac{1}{2} \times \text{stress} \times \text{strain}$.

Q27. Two wires of diameter 0.25 cm, one made of steel and the other made of brass are loaded as shown in Figure. The unloaded length of steel wire is 1.5 m and that of brass wire is 1.0 m. Compute the elongations of the steel and the brass wires.



Q28. What is elasticity and plasticity? A copper wire and a steel wire of the same diameter and lengths 100 cm and 200 cm respectively are connected end and a force is applied which stretches their combined length by 1 cm. Find by how much each wire is elongated.
Given : Y for copper = 12×10^{11} dyne cm^{-2}, and steel = 20×10^{11} dyne cm^{-2}.

Q29. What is elastic energy? Two parallel steel wires *A* and *B* are fixed to rigid support at the upper ends and subjected to the same load at the lower ends. The lengths of the wires are in the ratio 4 : 5 and their radii are in the ratio in the ratio 4 : 3 and their radii are in the wire *A* is 1 mm calculate the increase in the length of the wire. *B*.

Q30. What is elastic bodies and Plastic bodies? A rubber rope of length 8 m is hung from the ceiling of room. What is the increase in length of the rope due to its own weight? (Given : Young's modulus of elasticity of rubber = 5×10^{6} N m^{-2} and density of rubber = 1.5×10^{3} kg m^{-3}. Take g = 10 m s^{-2}).

Date: 14/10/2021

S1. When the deforming force is increased, a limit is reached beyond which the solid does not come back to its original shape or size but remains on removal of applied but remains deformed on removal of applied force. This limit is called the elastic limit.

S2. It is a material constant. So all the physical quantities that might alter nature like density can alter it.

S3. Those materials for which stress-strain variation is not straight line within elastic limit e.g. Rubber.

S4. Nature of the material and the manner in which it is deformed.

S5. When the body is deformed within its elastic limit.

S6. A force that produce a change in the shape or size of a body is called the deforming force.

S7. When a body regains its original state, the force of elasticity acts through a certain distance. So work is done by elastic force. This work is stored as potential energy in the system. This energy is called elastic energy.

S8. Plasticity is the property of remaining deformed even after the removal of deforming forces.

S9. The property of material of a body by virtue of which the body regains its original length, volume and shape after the deforming forces have been removed is called elasticity.

S10. ***Elasticity:*** The property of material of a body by virtue of which the body regains its original length, volume and shape after the deforming forces have been removed is called elasticity.

Those bodies which possess the property of elasticity are called elastic bodies.

Plasticity: Plasticity is the property of remaining deformed even after the removal of deforming forces.

Those bodies which do not show any tendency to recover their original form after the deforming forces are removed are called plastic bodies.

S11. Pressure in the tube increases with increasing temperature, but the volume expansion happens to a limited range. So the cycle tube bursts in summer.

S12. ***Elasticity:*** The property of matter by virtue of which it regains its original shape and size, when the deforming force have been removed is called elasticity.

Cause of Elasticity: When a body is compressed, the atoms constituting the body come close to each other. Due to this, the mean distance between the atoms decreases. A restoring force (repulsive in nature) comes into play, which tends to end the atoms back to their normal separation on removal deforming force.

On the other hand, when a body is elongated, the mean distance between the atoms increases. Now, the restoring force is attractive in nature and it tends to bring the atoms back their normal separation on removal of deforming force.

S13. Given, $Y = 2 \times 10^{11}\ Nm^{-2}$; $a = 5 \times 10^{-5}\ m^2$

If L is the length of the wire, then

Increase in length $l = L$

Now $Y = \dfrac{FL}{al}$

$$F = \frac{Yal}{L} = \frac{2 \times 10^{11} \times 5 \times 10^{-5} \times L}{L}$$

$$= \mathbf{1.0 \times 10^{7}\ N}.$$

S14. The tension force acting on each wire is the same. Thus, the extension in each case is the same. Since the wires are of the same length, the strain will also be the same.

The relation for Young's modulus is given as:

$$Y = \frac{\text{Stress}}{\text{Strain}} = \frac{\frac{F}{A}}{\text{Strain}} = \frac{\frac{4F}{\pi d^2}}{\text{Strain}} \quad \text{... (i)}$$

Where, F = Tension force

A = Area of cross-section

d = Diameter of the wire

It can be inferred from equation (i) that $Y \propto \dfrac{1}{d^2}$

Young's modulus for iron, $Y_1 = 190 \times 10^9$ Pa

Diameter of the iron wire $= d_1$

Young's modulus for copper, $Y_2 = 110 \times 10^9$ Pa

Diameter of the copper wire $= d_2$

Therefore, the ratio of their diameters is given as:

$$\frac{d_2}{d_1} = \sqrt{\frac{Y_1}{Y_2}} = \sqrt{\frac{190 \times 10^9}{110 \times 10^9}} = \sqrt{\frac{19}{11}} = 1.31 : 1$$

S15. Due to green house effect, the presence of atmosphere prevents heat radiations received by earth to go back. In the absence of atmosphere radiation will go back at night making the temperature very low and inhospitable.

S16.

$$Y_s = \frac{F}{A} = \frac{l}{\Delta l_s}$$

$$Y_r = \frac{F}{A} = \frac{l}{\Delta l_r}$$

For same force applied to wires made of steel & rubber of same length and same area of cross section

$$\Delta l_s < \Delta l_r$$

$$Y_r = \frac{\Delta l_r}{\Delta l_s} > 1$$

$\therefore$ $$Y_s > Y_r$$

S17. Let L be the maximum length of wire that can hang without breaking and a be its area of cross section, then

$$\text{Weight of wire } mg = L \times a \times \rho \times g$$

$$= La \times 10^4 \times g$$

Now $$\text{Breaking load} = \text{Breaking stress} \times a$$

$$L \times a \times 10^4 \times g = 8 \times 10^9 \times a$$

$$L = \frac{8 \times 10^9}{10^4 \times 9.8} = 81.63 \times 10^3 \text{ m}$$

$$= \mathbf{81.63\ km}.$$

S18. Here $L = 10$ m, $a = 1.25 \times 10^{-4}$ m^2

$Y = 4 \times 10^{10}$ Nm^{-2}, $F = 5$ kg $wt = 5 \times 10 = 50$ N

If l is the elongation produced, then

$$l = \frac{FL}{aY} = \frac{50 \times 10}{1.25 \times 10^{-4} \times 4 \times 10^{10}}$$

$$= \mathbf{1.0 \times 10^{-4}\ m}.$$

S19. Total mass of all the performers, tables, plaques etc.

= 280 kg

Mass of the performer = 60 kg

Mass supported by the legs of the performer at the bottom of the pyramid

= 280 – 60 = 220 kg

Weight of this supported mass = 220 kg wt. = 220 $\times$ 9.8 N = 2156 N.

Weight supported by each thighbone of the performer

$$= ½ (2156) \text{ N} = 1078 \text{ N}.$$

From Table 9.1, the Young's modulus for bone is given by

$$Y = 9.4 \times 10^9 \text{ N m}^{-2}.$$

Length of each thighbone, $L = 0.5$ m

The radius of thighbone = 2.0 cm

Thus the cross-sectional area of the thighbone

$$A = \pi \times (2 \times 10^{-2})^2 \text{ m}^2 = 1.26 \times 10^{-3} \text{ m}^2.$$

Using Eq. (9.8), the compression in each thighbone (ΔL) can be computed as

$$\Delta L = [(F \times L)/(Y \times A)]$$
$$= [(1078 \times 0.5)/(9.4 \times 10^9 \times 1.26 \times 10^{-3})]$$
$$= 4.55 \times 10^{-5} \text{ m} \quad \text{or} \quad 4.55 \times 10^{-3} \text{ cm}.$$

This is a very small change! The fractional decrease in the thighbone is $\Delta L/L$ = 0.000091 or 0.0091%.

S20. (a) No (b) Yes

Explanation:

(a) For a given stress, the strain in rubber is more than it is in steel.

Young's modulus, $Y = \dfrac{\text{Stress}}{\text{Strain}}$

For a constant stress: $Y \propto \dfrac{1}{\text{Strain}}$

Hence, Young's modulus for rubber is less than that of steel.

(b) Shear modulus is the ratio of the applied stress to the change in the shape of a body. The stretching of a coil changes its shape. Hence, shear modulus of elasticity is involved in this process.

S21. Y for steel, $Y_1 = 2 \times 10^{11}$ Nm^{-2}

Y for aluminum, $Y_2 = 7 \times 10^{11}$ Nm^{-2}

Length of each wire, $L = 2$ m ;

$d = 2.0$ mm

∴ Radius, $r = 1$ mm = 10^{-3} m

Area of cross-section, $A = \pi r^2 = \pi(10^{-3})^2$

$$= \pi \times 10^{-6} \text{ m}^2$$

Total extension $(\Delta l_1 + \Delta l_2) = 9 \times 10^{-4}$m

We know, $$Y = \frac{FL}{A\Delta l}$$

$$(\Delta l_1 + \Delta l_2) = \frac{FL}{A}\left(\frac{1}{Y_1} + \frac{1}{Y_2}\right)$$

or $$9 \times 10^{-4} = \frac{F \times 2}{\pi \times 10^{-6}}\left(\frac{1}{2 \times 10^{11}} + \frac{1}{7 \times 10^{11}}\right)$$

or $$F = \frac{9 \times 10^{-4} \times 3.14 \times 10^{-6} \times 14 \times 10^{11}}{2 \times 9}$$

$$= \mathbf{219.8\ N}.$$

S22. (a) *A* (b) *A*

Explanation:

(a) For a given strain, the stress for material *A* is more than it is for material *B*, as shown the two graphs.

$$\text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}}$$

For a given strain, if the stress for a material is more, then Young's modulus is also greater for that material. Therefore, Young's modulus for material *A* is greater than it is for material *B*.

(b) The amount of stress required for fracturing a material, corresponding to its fracture point, gives the strength of that material. Fracture point is the extreme point in a stress-strain curve. It can be observed that material *A* can withstand more strain than material *B*. Hence, material *A* is stronger than material.

S23. Given $l = 4$ cm, $\Delta l = 0.012$ cm,

$\eta = 2.08 \times 10^{11}$ dyne cm^{-2}

(a) Shearing strain $$\theta = \frac{\Delta l}{l} = \frac{0.012}{4\,\text{cm}} = \mathbf{0.003}$$

(b) Area of top face $= l^2 = 4$ cm $\times$ 4 cm

$= \mathbf{16\ cm^2}$.

Modulus of rigidity $$\eta = \frac{\text{Shearing stress}}{\text{Shearing strain}}$$

or Shearing stress $= \eta \times$ Shearing strain

$= 2.08 \times 10^{11} \times 0.003$ dyne cm^{-2}

$= \mathbf{6.24 \times 10^8\ dyne\ cm^{-2}}$

(c) Shearing force = Area × shearing stress

$$= 16 \times 6.24 \times 10^8 \text{ dyne}$$

$$= \mathbf{9.984 \times 10^9 \text{ dyne}}.$$

S24. Weight of rubber cord = $12 \times 1.5 \times 10^3 \times 9.8$N

Since the weight of cord acts at centre of gravity therefore the original length will be taken as 6 m.

Now, $Y = 5 \times 10^6 \text{ gf cm}^{-2}$

$$= 5 \times 10^6 \times 10^{-3} \times 9.8 \times 10^4 \text{ N m}^{-2}$$

$$= 5 \times 9.8 \times 10^7 \text{ N m}^{-2}$$

Again, $$5 \times 9.8 \times 10^7 = \frac{12 \times 1.5 \times 10^3 \times 9.8 \times 6}{\Delta l}$$

or $$\Delta l = \frac{12 \times 1.5 \times 10^3 \times 9.8 \times 6}{5 \times 9.8 \times 10^7}$$

$$= 2.16 \times 10^{-3} \text{ m} = \mathbf{0.216 \text{ cm}}.$$

S25. Here, $m = 45$ kg; $A = 5 \times 10^{-4}$ m^2

$h = 2$ m $L = 0.50$ m,

Volume = $AL = 5 \times 10^{-4} \times 0.50$

$$= 2.5 \times 10^{-4} \text{ m}^3$$

Stress = $0.9 \times 10^8 \text{ N m}^{-2}$

$g = 10 \text{ m s}^{-2}$.

Loss in gravitational energy = Gain in elastic energy in both leg bones

So, $$mgh = 2 \times \left[\frac{1}{2} \times \text{Stress} \times \text{Strain} \times \text{Volume}\right]$$

∴ $$45 \times 10 \times 2 = 2 \times \left[\frac{1}{2} \times 0.9 \times 10^8 \times \text{Strain} \times 2.5 \times 10^{-4}\right]$$

or $$\text{Strain} = \frac{45 \times 10 \times 2}{0.9 \times 2.5 \times 10^4} = 0.04$$

$$Y = \frac{\text{Stress}}{\text{Strain}} = \frac{0.9 \times 10^8}{0.04} = \mathbf{2.25 \times 10^9 \text{ Nm}^{-2}}.$$

S26. (a) $$\frac{\text{Work done}}{\text{Volume}} = \frac{1}{2}\frac{F}{L} \cdot \frac{\Delta l}{l}$$

$$\text{Work done} = \frac{1}{2} F \times A \frac{\Delta l}{l}$$

$$= \frac{1}{2} \text{ Tension} \times \text{extension}$$

(b) The wire has length l, area of cross-section A made of material constant Y. Let a force F be applied and at any instant, x be the extension associated ($x < L$), where L is the maximum extension. At this instant,

$$F = \frac{AY.x}{l}$$

Since force is a variable with x, Work done to stretch is,

$$W = \int_0^L F dx = \frac{AY}{l} \int_0^L x dx$$

$$= \frac{AY}{l} \frac{1}{2} [x^2]_0^L = \frac{AY}{l} \frac{1}{2} [L^2 - 0]$$

$$W = \frac{1}{2} \frac{AY}{l} . L^2$$

$$W = \frac{1}{2} (Al) \left(\frac{T.L}{l}\right) \left(\frac{L}{l}\right)$$

$$= \frac{1}{2} \text{ (Volume} \times \text{stress} \times \text{strain)}$$

∴ Work done per unit volume

$$= \frac{1}{2} \textbf{ stress} \times \textbf{strain}.$$

S27. Elongation of the steel wire = 1.49×10^{-4} m

Elongation of the brass wire = 1.3×10^{-4} m

Diameter of the wires, $d = 0.25$ cm

Hence, the radius of the wires, = $r = \frac{d}{2} = 0.125$ cm

Length of the steel wire, $L_1 = 1.5$ m

Length of the brass wire, $L_2 = 1.0$ m

Total force exerted on the steel wire: $F_1 = (4 + 6)\, g = 10 \times 9.8 = 98$ N

Young's modulus for steel: $Y_1 = \frac{\left(\frac{F_1}{A_1}\right)}{\left(\frac{\Delta L_1}{L_1}\right)}$

Where, ΔL_1 = Change in the length of the steel wire

A_1 = Area of cross-section of the steel wire πr_1^2

Young's modulus of steel, $Y_1 = 2.0 \times 10^{11}$ Pa

$$\therefore \quad \Delta L_1 = \frac{F_1 \times L_1}{A_1 \times Y_1} = \frac{F_1 \times L_1}{\pi r_1^2 \times Y_1}$$

$$= \frac{98 \times 1.5}{\pi\left(0.125 \times 10^{-2}\right)^2 \times 2 \times 10^{11}} = 1.49 \times 10^{-4} \text{ m}$$

Total force on the brass wire: $F_2 = 6 \times 9.8 = 58.8$ N

Young's modulus for brass: $$Y_2 = \frac{\left(\frac{F_2}{A_2}\right)}{\left(\frac{\Delta L_2}{L_2}\right)}$$

Where, ΔL_2 = Change in length

A_2 = Area of cross-section of the steel wire

$$\therefore \quad \Delta L_2 = \frac{F_2 \times L_2}{A_2 \times Y_2} = \frac{F_2 \times L_2}{\pi r_2^2 \times Y_2}$$

$$= \frac{58.8 \times 1.0}{\pi\left(0.125 \times 10^{-2}\right)^2 \times \left(0.91 \times 10^{11}\right)}$$

$$= 1.3 \times 10^{-4} \text{ m}$$

Elongation of the steel wire = 1.49×10^{-4} m

Elongation of the brass wire = 1.3×10^{-4}m

S28. ***Elasticity:*** The property of material of a body by virtue of which the body regains its original length, volume and shape after the deforming forces have been removed is called elasticity.

Plasticity: Plasticity is the property of remaining deformed even after the removal of deforming forces.

Given, Length of copper wire l_c = 100 cm, length of steel wire l_s = 200 cm

$$Y_c = \frac{F \times 1}{a \times \Delta l_c} \quad \text{... (i)}$$

$$Y_s = \frac{F \times 2}{a \times \Delta l_c} \quad \text{... (ii)}$$

Eq. (i) dividing by Eq. (ii), we get

or $$\frac{Y_c}{Y_s} = \frac{\Delta l_s}{2\Delta l_c}$$

or $$\frac{\Delta l_s}{\Delta l_c} = \frac{2Y_c}{Y_s} = \frac{2 \times 12 \times 10^{11}}{20 \times 10^{11}} = 1.2$$

or $$\Delta l_s = 1.2\ \Delta l_c$$

Again $$\Delta l = \Delta l_c + \Delta l_s = 1$$

or $$\Delta l_c + 1.2\ \Delta l_c = 1$$

or $$\Delta l_c = \frac{1}{2.2}\text{ cm} = 0.45\text{ cm}$$

$$\Delta l_s = 1 - 0.45 = 0.55\text{ cm}$$

S29. When a body regains its original state, the force of elasticity acts through a certain distance. So work is done by elastic force. This work is stored as potential energy in the system. This energy is called elastic energy.

Given, $l_A : l_B = 4 : 5$ and $r_A : r_B = 4 : 3$

$$Y = \frac{Fl}{a\Delta l} = \frac{Fl}{\pi r^2\ \Delta l}$$

In the given problem, Y and F are constants.

$\therefore$ $$\Delta l \propto \frac{l}{r^2},$$

$$\Delta l_A \propto \frac{l_A}{r_A^2}, \qquad \text{... (i)}$$

$$\Delta l_B \propto \frac{l_B}{r_B^2}, \qquad \text{... (ii)}$$

Eq. (i) divided by Eq. (ii), we get

Now, $$\frac{\Delta l_A}{\Delta l_B} = \frac{l_A}{r_A^2} \times \frac{r_B^2}{l_B}$$

$$= \frac{l_A}{r_B}\left(\frac{r_B}{r_A}\right)^2 = \frac{4}{5}\left(\frac{3}{4}\right)^2 = 0.45$$

Again, $$\frac{1\,mm}{\Delta l_B} = 0.45$$

or $$\Delta l_B = \frac{1}{0.45}\text{ mm} = 2.22\text{ mm}$$

S30. Those bodies which possess the property of elasticity are called elastic bodies.

Those bodies which do not show any tendency to recover their original form after the deforming forces are removed are called plastic bodies.

Given, $L = 8$ m, $\rho = 1.5 \times 10^3$ kg m^{-3}, $g = 10$ m s^{-2}

$$Y = \frac{Mg}{A} \times \frac{L/2}{\Delta L}$$

(Length is taken as $\frac{L}{2}$ because weight acts at C.G.)

Now, $$M = AL\rho$$

[For the purpose of calculation of mass, the whole of geometrical length L is to be considered].

$$Y = \frac{AL\rho gL}{2A\,\Delta L} \quad \text{or} \quad \Delta L = \frac{\rho g L^2}{2Y}$$

$$= \frac{1.5 \times 10^3 \times 10 \times 8 \times 8}{2 \times 5 \times 10^6}\, m$$

$$= 9.6 \times 10^{-2} \text{ m}$$

$$= 9.6 \times 10^{-2} \times 10^3 \text{ mm} = 96 \text{ mm}$$

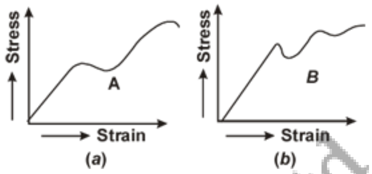
Date: 14/10/2021

Q1. The coolant used in chemical or in a nuclear plant should have high specific heat. Why?

Q2. If a drop of water falls on a very hot iron, it does not evaporate for a long time. Why?

Q3. Bridges are declared unsafe after long use. Why?

Q4. The stress versus strain graphs for two materials *A* and *B* are shown below:
The graphs are to the same scale.



(a) Which material has greater Young's modulus?
(b) Which material is more ductile?
(c) Which is more brittle?

Q5. The Young's modulus of a wire of length *L* and radius *r* is *Y*. If the length is reduced to L/2 and radius *r*/2. What will be its Young's modulus?

Q6. A metal bar of length *L*, area of cross-section *A*, Young's modulus *Y* and coefficient of linear expansion α is clamped between two stout pillars. What is the force exerted by the bar when it is heated through t °C?

Q7. What is the value of modulus of rigidity for a liquid?

Q8. Why are springs made of steel and not of copper?

Q9. A heavy wire is suspended from a roof but no weight is attached to its lower end. Is it under stress? Justify your answer.

Q10. A wire is stretched by a certain amount under a load. If the load and radius both are increased to four times, find the stretch caused in the wire.

Q11. Plot Load vs Extension curve for a metal on the graph and depict:
(a) Yield point, (b) Breaking point, (c) Elastic limit, (d) Crushing point.

Q12. Draw the graph showing the variation of potential energy and kinetic energy of a block attached to a spring, which obeys Hooke's law.

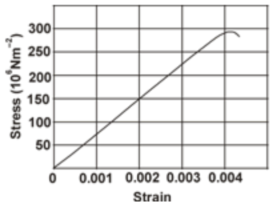
Q13. A wire suspended vertically from one of its end is stretched by attaching a weight of 200 N to the lower end. The weight stretches the wire by 1 mm. Find the elastic energy stored in the wire.

Q14. The stress versus strain graphs for wires of two materials *A* and *B* are as shown in figure (a) Which material is more ductile? (b) Which material is more brittle?

Q15. A cable is cut to half of its original length. Why this change has no effect on the maximum load, the cable can support?

Q16. How does the elasticity of material change on:
(a) increasing the temperature?
(b) on heating and cooling gradually?
(c) on hammering?

Q17. Figure shows the strain-stress curve for a given material. What are (a) Young's modulus and (b) approximate yield strength for this material?



Q18. How much will a 3.0 m long copper wire elongate if a weight of 10 kg is suspended from one end and the other end is fixed? The diameter of the wire is 0.4 mm. Given : Y for copper = 10^{11} N m^{-2} and g = 9.8 m s^{-2}.

Q19. A square lead slab of side 50 cm and thickness 10 cm is subject to a shearing force (on its narrow face) of 9.0×10^4 N. The lower edge is riveted to the floor. How much will the upper edge be displaced?

Q20. A 4 m long aluminum wire whose diameter is 3 mm is used to support a mass of 50 kgs. What will be the elongation of the wire? *Y* for aluminium is 7×10^{10} N m^{-2}. Given: $g = 9.8$ m s^{-2}.

Q21. A steel wire 2 mm in diameter is stretched between 2 clamps when its temperature is 40°C. Calculate the tension in the wire when its temperature falls to 30°*C*. Given coefficient of linear expansion of steel is 11×10^{-6}/°C and *Y* for steel is 21×10^{11} dyne/cm^2.

Q22. A 1000 kg lift is tied with metallic wires of maximum safe stress of 1.4×10^8 N m^{-2}. If the maximum acceleration of the lift is 1.2 m s^{-2}, then find the minimum diameter of the wire.

Q23. The length of a wire increases by 8 mm when a weight of 5 kgs is hung. If all conditions are the same but the radius of the wire is doubled, find the increases in length.

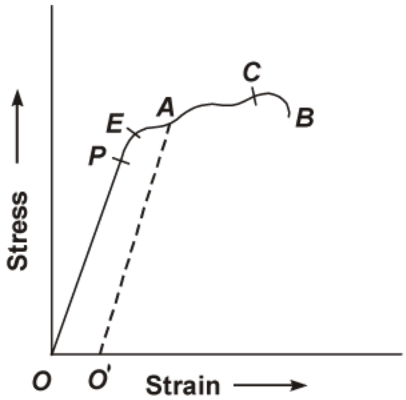
Q24. A steel wire of length 4.7 m and cross-sectional area 3.0×10^{-5} m^2 stretches by the same amount as a copper wire of length 3.5 m and cross-sectional area of 4.0×10^{-5} m^2 under a given load. What is the ratio of the Young's modulus of steel to that of copper?

Q25. Four identical hollow cylindrical columns of mild steel support a big structure of mass 50,000 kg. The inner and outer radii of each column are 30 cm and 60 cm respectively. Assuming the load distribution to be uniform, calculate the compressional strain of column.

Q26. A piece of copper having a rectangular cross-section of 15.2 mm $\times$ 19.1 mm is pulled in tension with 44,500 N force, producing only elastic deformation. Calculate the resulting strain?

Q27. The stress-strain graph for a metal wire shown in the figure.

Upto the point E, the wire returns to its original state O along the curve EPO, when it is gradually unloaded. The point B corresponds to the fracture of the wire.



(a) Upto what point on the curve is Hook's law obeyed? (This point is sometimes called' proportional limit').

(b) Which point on the curve corresponds to 'elastic' or 'yield point' of the wire?

(c) Indicate the plastic regions of the stress-strain graph.

(d) Describe what happens, when the wire is loaded up to a stress corresponding to the point A on the graph and then unloaded gradually. In particular, explain the dotted curve.

(e) What is peculiar about the portion of the stress-strain graph from C to B? Upto what stress can the wire be subjected without causing fracture?

Q28. (a) A steel wire has length 2 m, radius 1 mm and $Y = 2 \times 10^{11}$ N m^{-2}. A 1 kg sphere is attached to one end of the wire and whirled in a vertical circle with an angular velocity of 2 revolutions per second. What is the elongation of the wire when the sphere is at the lowest point of the vertical circle?

(b) A wire increases by 10^{-3} of its length when a stress of 1×10^8 N m^{-2} is applied to it. What is the Young's modulus of the material of the wire?

Q29. A uniform cylindrical wire is subjected to a longitudinal tensile stress of 5×10^7 N m^{-2}. The Young's modulus of the material of the wire is 2×10^{11} N m^{-2}. The volume change in the wire is 0.02 %. Calculate the fractional change in the radius.

Q30. The breaking stress of aluminum is 7.5×10^8 dyne cm^{-2}. Find the greatest length of aluminum wire that can hang vertically without breaking. Density of aluminum is 2.7 g cm^{-3}. Given g = 980 cm s^{-2}.

Q31. (a) What is Energy per unit Volume of wire? Explain.

(b) Two strips of metal are riveted together at their ends by four rivets, each of diameter 6.0 mm. What is the maximum tension that can be exerted by the riveted strip if the shearing stress on the rivet is not to exceed 6.9×10^7 Pa? Assume that each rivet is to carry one quarter of the load.

Q32. (a) Define the Energy stored in a wire.

(b) The edge of an aluminum cube is 10 cm long. One face of the cube is firmly fixed to a vertical wall. A mass of 100 kg is then attached to the opposite face of the cube. The shear modulus of aluminum is 25 GPa. What is the vertical deflection of this face?

Q33. Describe stress-strain relationship for a loaded steel wire and hence explain the terms: Elastic limit, yield point, tensile strength.

Q34. A copper wire of length 2.2 m and a steel wire of length 1.6 m, both of diameter 3.0 mm, are connected end to end. When stretched by a load, the net elongation is found to be 0.7 mm. Obtain the load applied. Give: Young's modulus of copper = 1.1×10^{11} Nm^{-2} and Young's modulus of steel = 2.0×10^{11} Nm^{-2}.

Date: 14/10/2021

S1. So, that it absorbs more heat with comparatively small change in temperature and extracts large amount of heat.

S2. A vapour film is formed between water drop and the hot iron. Vapour being a poor conductor of heat makes the water droplet to evaporate slowly.

S3. A bridge undergoes alternating stress and strain for a large number of times during its use. When bridge is used for long time, it loses its elastic strength. Therefore, the amount of strain in the bridge for a given stress will becomes large and ultimately, the bridge will collapse. So, they are declared unsafe after long use.

S4. (a) *A*, because for producing the same strain, more stress is required in case of the material *A*.

$$Y = \frac{\text{Stress}}{\text{Strain}}$$

(b) *A*, because it has a lesser plastic range.

(c) *B*, because it has a lesser plastic range.

S5. *Y*, since it is a material constant.

S6. Force exerted by bar (F) = $YA\,\alpha\,t$.

S7. Zero.

S8. Under a given deforming force, the steel spring is stretched lesser than copper spring.

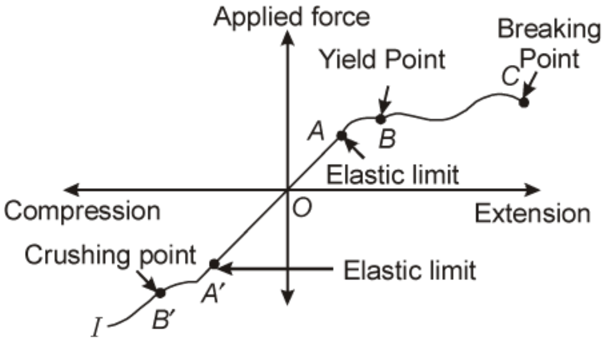
S9. A heavy wire (even when no weight is attached to it) is under stress, when it is suspended from a roof. It is because, the weight of the heavy wire acts deforming force.

S10. Given, $F = 4\,\text{F}$; $r = 4r$; $A = 16\,\text{A}$

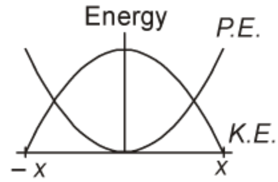
We have $$\Delta l \propto \frac{F}{A}$$

$$\frac{\Delta l'}{\Delta l} = \frac{4F}{F} \times \frac{A}{16\,A} = \frac{1}{4}.$$

S11. The plot Load vs Extension curve for a metal on the graph given below:



S12. The graph between potential energy and kinetic energy of a block attached to a spring as shown in figure, within elastic limit



$$\frac{\text{Stress}}{\text{strain}} = \text{Constant.}$$

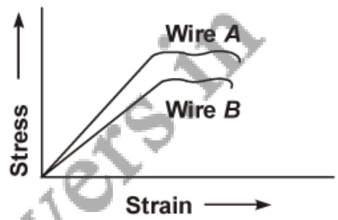
S13. Energy stored in the wire,

$$W = \frac{1}{2} \times F \times l$$

Here, $F = 200\text{ N}; \quad l = 1\text{ mm} = 10^{-3}\text{ m}$

$$W = \frac{1}{2} \times 200 \times 10^{-3} = \mathbf{0.1\ J}.$$

S14. (a) ***Material A*** is more ductile. It is because, the ***material A*** has greater plastic range (portion of graph between the elastic and breaking point).



(b) ***Material B*** is more brittle. It is because, the ***material A*** has lesser plastic range.

S15. The braking stress is a constant for the given material. We know that

breaking load = breaking stress $\times$ area of cross-section

When the cable is cut to half of its length, the area of cross-section does not change. Hence, there is no effect on the maximum load (breaking load), the cable can support.

S16. (a) Elasticity of material is *decreases* on increasing the temperature.

(b) Elasticity of material is *decreases* on heating and cooling gradually.

(c) Elasticity of material is *increases* on hammering.

S17. It is clear from the given graph that for stress $150 \times 10^6\text{ N/m}^2$, strain is 0.002.

$\therefore$ Young's modulus, $Y = \frac{\text{Stress}}{\text{Strain}}$

$$= \frac{150 \times 10^6}{0.002} = 7.5 \times 10^{10}\text{ N/m}^2.$$

Hence, Young's modulus for the given material is $7.5 \times 10^{10}\text{ N/m}^2$.

The yield strength of a material is the maximum stress that the material can sustain without crossing the elastic limit.

It is clear from the given graph that the approximate yield strength of this material is 300×10^6 N/m^2 or 3 / 10^8 N/m^2.

S18. Given, M = 10 kg, $F = Mg = 10 \times 9.8$, N = 98 N, l = 3 m, r = 0.2 mm = 0.2×10^{-3} m and $Y = 10^{11}$ N m^{-2},

Now, $$Y = \frac{F \times l}{A \times \Delta l}$$

$$\Delta l = \frac{F \times l}{A \times Y}$$

or $$\Delta l = \frac{98 \times 3 \times 7}{22 \times (0.2 \times 10^{-3})^2 \times 10^{11}} \text{ m}$$

$$= \frac{98 \times 21}{88 \times 10^3} \text{ m}$$

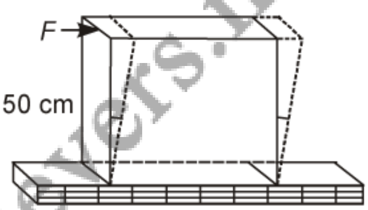
= 0.02339 m = **2.339 cm**.

S19. The lead slab is fixed and the force is applied parallel to the narrow face as shown in figure. The area of the face parallel to which this force is applied is

A = 50 cm × 10 cm

= 0.5 m × 0.1 m

= 0.05 m^2



Therefore, The stress applied is = (9.4×10^4 N/0.05 m^2)

= 1.80×10^6 N.m^{-2} [∵ Stress = F/A]

We know that shearing strain = $(\Delta x/L)$ = Stress $/G$. Therefore,

The displacement Δx = (Stress × L)/G

= (1.8×10^6 N m^{-2} × 0.5 m)/(5.6×10^9 N m^{-2})

= 1.6×10^{-4} m = 0.16 mm

S20. Given, l = 4 m, r = 1.5 mm = 1.5×10^{-3} m, M = 50 kg, $Y = 7 \times 10^{10}$ N m^{-2}, $F = 50 \times 9.8$ N = 490 N, and Δl = ?

∴ $$Y = \frac{F \times l}{A \times \Delta l}$$

or $$\Delta l = \frac{F \times l}{\pi r^2 \times Y} = \frac{490 \times 4 \times 7}{22 \times (1.5 \times 10^{-3})^2 \times 7 \times 10^{10}} \text{ m}$$

= 3.96×10^{-3} m = **3.96 mm**.

S21. Given, $Y = 21 \times 10^{11}$ dyne/cm^2 = 21×10^{10} Nm^{-2}; $\alpha = 11 \times 10^{-6}$/°C

Diameter = 2 mm $\times 10^{-3}$m

$\therefore$ Radius $r = 10^{-3}$ m and area $a = \pi \times 10^{-6}$ m^2

Increase in length $l = L\,\alpha\,t$

or $$\text{Strain} = \frac{l}{L} = \alpha\,t = 11 \times 10^{-6}\,(40 - 30) = 11 \times 10^{-5}$$

If F is the tension in the wire due to decrease of temperature, then

$$\text{Stress} = \frac{F}{a} = \frac{F}{\pi \times 10^{-6}}\ \text{Nm}^{-2} \quad \text{... (i)}$$

$$\text{Stress} = Y \times \text{strain} \quad \text{... (ii)}$$

From Eq. (i) and (ii), we get

or $$\frac{F}{\pi \times 10^{-6}} = 21 \times 10^{10} \times 11 \times 10^{-5}$$

$$= 231 \times 10^5$$

or $$F = \pi \times 10^{-6} \times 231 \times 10^5$$

= **72.57 N**.

S22. Given, $T = 1000\,[9.8 + 1.2]$, $N = 11000$ N

$$\text{Maximum stress} = \frac{11000 \times 7}{22 \times r_{\min}^2}$$

or $$r_{\min.}^2 = \frac{11000 \times 7}{22 \times 1.4 \times 10^8}$$

$$= \frac{50^2}{(10^4)^2} \quad \text{or} \quad r_{\min} = 50 \times 10^{-4}\text{m}$$

$D_{\min.} = 100 \times 10^{-4}$ = **0.01 m**.

S23. Given, $l = 8$ mm $= 8 \times 10^{-3}$ m, $F = 5 \times 9.8 = 49\,N$

Now, $$Y = \frac{FL}{al}$$

or $$l = \frac{FL}{Y\pi r^2} \quad \text{... (i)}$$

If l' is the increase in length when radius is doubled, then

$$l' = \frac{FL}{Y\pi(2r)^2} \quad \text{.. (ii)}$$

Dividing (ii) by (i), we get

$$\frac{l'}{l} = \frac{1}{4}$$

or $$l' = \frac{1}{4} l = \frac{1}{4} \times 8 \times 10^{-3}$$

$$= \mathbf{2 \times 10^{-3}\ m}.$$

S24. Length of the steel wire, $L_1 = 4.7$ m

Area of cross-section of the steel wire,

$$A_1 = 3.0 \times 10^{-5}\ \text{m}^2$$

Length of the copper wire, $L_2 = 3.5$ m

Area of cross-section of the copper wire,

$$A_2 = 4.0 \times 10^{-5}\ \text{m}^2$$

Change in length = $\Delta L_1 = \Delta L_2 = \Delta L$

Force applied in both the cases = F

Young's modulus of the steel wire:

$$Y_1 = \frac{F_1}{A_1} \times \frac{L_1}{\Delta L}$$

$$= \frac{F \times 4.7}{3.0 \times 10^{-5} \times \Delta L} \quad \text{… (i)}$$

Young's modulus of the copper wire:

$$Y_2 = \frac{F_2}{A_2} \times \frac{L_2}{\Delta L_2}$$

$$= \frac{F \times 3.5}{4.0 \times 10^{-5} \times \Delta L} \quad \text{… (ii)}$$

Dividing (i) by (ii), we get:

$$\frac{Y_1}{Y_2} = \frac{4.7 \times 4.0 \times 10^{-5}}{3.0 \times 10^{-5} \times 3.5} = 1.79:1$$

The ratio of Young's modulus of steel to that of copper is 1.79 : 1.

S25. Given, Mass of the big structure, $M = 50{,}000$ kg

Inner radius of the column, $r = 30$ cm $= 0.3$ m

Outer radius of the column, $R = 60$ cm $= 0.6$ m

Young's modulus of steel, $Y = 2 \times 10^{11}$ Pa

Total force exerted, $F = Mg = 50000 \times 9.8$ N

Stress = Force exerted on a single column

$$= \frac{50000 \times 9.8}{4} = 122500 \text{ N}$$

Young's modulus, $Y = \dfrac{\text{Stress}}{\text{strain}}$

$$\text{Strain} = \frac{F}{AY}$$

Where,

Area, $A = \pi (R^2 - r^2) = \pi ((0.6)^2 - (0.3)^2)$

$$\text{Strain} = \frac{122500}{\pi\left[(0.6)^2 - (0.3)^2\right] \times 2 \times 10^{11}} = 7.37 \times 10^8$$

Hence, the compressional strain of each column is 7.37×10^8.

S26. Given, Length of the piece of copper, $l = 19.1$ mm $= 19.1 \times 10^{-3}$ m

Breadth of the piece of copper, $b = 15.2$ mm $= 15.2 \times 10^{-3}$ m

Area of the copper piece: $A = l \times b$

$= 19.1 \times 10^{-3} \times 15.2 \times 10^{-3}$

$= 2.9 \times 10^{-4}$ m^2

Tension force applied on the piece of copper, $F = 44500$ N

Modulus of elasticity of copper, $\eta = 42 \times 10^9$ N/m^2

Modulus of elasticity, $\eta = \dfrac{\text{Stress}}{\text{Strain}} = \dfrac{\frac{F}{A}}{\text{Strain}}$

$\therefore$ $$\text{Strain} = \frac{F}{A\eta}$$

$$= \frac{44500}{2.9 \times 10^{-4} \times 42 \times 10^9}$$

$$= 3.65 \times 10^{-3}$$

S27. (a) Hooke's law is obeyed up to the ***point P***. It is because, Hook's law is obeyed, till the graph between stress and strain is a straight line.

(b) The ***point E*** on the graph corresponds to the elastic limit. It is because, the wire return to its original state *O* after being unloaded upto the point *E* only.

(c) The portion of the graph ***from the point O to E*** represents the elastic region, while ***from the point E to B*** represents the plastic region.

(d) Strain is proportional to stress only upto the ***point P***. After that, strain increase much more rapidly than warranted by Hook's law. When the wire is unloaded corresponding to the point *A*, wire does not retrace the curve *AEPO*, but follows the dotted line *AO*'. Thus, when the loads become zero, a permanent increase in strain equal to *OO*' is left in the wire.

(e) The portion of graph between *C* to *B* indicates that the length of the wire increases, even when the load is being decreased and corresponding to the point *B*, it breaks. So that the wire does not break, stress can be applied only upto the value corresponding to the ***point C***.

S28. (a) Given, $Y = 2 \times 10^{11}\ \text{N m}^{-2}$, $\omega = 2$ rev/sec, $l = 2\text{m}$, $r = 1\ \text{mm} = 1 \times 10^{-3}\ \text{m}$

$$Y = \frac{[mg + ml\omega^2]\, l}{\pi r^2 \Delta l} \quad \text{or} \quad \Delta l = \frac{m[g + l\omega^2]\, l}{\pi r^2 Y}$$

or $$\Delta l = \frac{1[10 + 2 \times 4\pi^2 \times 4] \times 2}{\pi (1 \times 10^{-3})^2 \times 2 \times 10^{11}}\ \text{m}$$

or $$\Delta l = \frac{[20 + 64 \times 9.88] \times 7}{2 \times 22 \times 10^5}\ \text{m}$$

$$= \mathbf{\frac{4566.24}{44 \times 10^5} \times 10^3\ mm \approx 1\, mm}.$$

(b) $$\text{Stress} = 1.0 \times 10^8\ \text{N m}^{-2}, \quad Y = ?$$

$$\text{Strain}, \frac{\Delta l}{l} = 10^{-3}$$

$$Y = \frac{\text{Sress}}{\text{Strain}} = \frac{10^8\ \text{N m}^{-2}}{10^{-3}}$$
$$= \mathbf{10^{11}\ N\, m^{-2}}.$$

S29. Given, Stress $= 5 \times 10^7$ N/m, $Y = 2 \times 10^{11}\ \text{Nm}^2$

$$Y = \frac{\text{Stress}}{\Delta L / L}$$

or $$\frac{\Delta L}{L} = \frac{\text{Stress}}{Y} = \frac{5 \times 10^7}{2 \times 10^{11}} = 2.5 \times 10^{-4}$$

Now, $$V = \pi r^2 L$$

$$\frac{dV}{V} = \frac{2Lrdr + r^2dL}{r^2L}$$

or $$\frac{dV}{V} = \frac{2dr}{r} + \frac{dL}{L}$$

or $$2\frac{dr}{r} = \frac{0.02}{100} - 2.5 \times 10^{-4}$$

or $$\frac{dr}{r} = 1 \times 10^{-4} - \frac{2.5}{2} \times 10^{-4} = -0.25 \times 10^{-4}$$

S30. Let l be the greatest length of the wire that can hang vertically without breaking.

Mass of wire, m = Cross-sectional area (a) $\times$ length (l) $\times$ density (ρ)

Weight of wire, $mg = a\,l\,\rho\,g$

This is equal to the maximum force that the wire can withstand.

$\therefore$ Breaking stress = $\frac{la\rho g}{a} = l\rho g$

or $7.5 \times 10^8 = l \times 2.7 \times 980$

or $$l = \frac{7.5 \times 10^8}{2.7 \times 980} \text{ cm} = 2.834 \times 10^5 \text{ cm} = 2.834 \text{ km}.$$

S31. (a)

Energy stored = $\frac{1}{2}F\Delta l$; Volume of wire = al

Energy per unit volume = $\frac{\frac{1}{2}F\Delta l}{al} = \frac{1}{2}\left(\frac{F}{a}\right)\left(\frac{\Delta l}{l}\right)$

$= \mathbf{\frac{1}{2}}$ **stress × strain**

The SI unit of energy per unit volume *i.e.*, energy density is J m^{-3}.

(b) Diameter of the metal strip, $d = 6.0 \text{ mm} = 6.0 \times 10^{-3}$ m

Radius, $r = \frac{d}{2} = 3.0 \times 10^{-3}$ m

Maximum shearing stress = 6.9×10^7 Pa

Maximum force = Maximum stress × Area

$= 6.9 \times 10^7 \times \pi \times (r)^2$

$= 6.9 \times 10^7 \times \pi \times (3 \times 10^{-3})^2$

= **1949.94 N**

Each rivet carries one quarter of the load.

$\therefore$ Maximum tension on each rivet = 4 × 1949.94 = 7799.76 N.

S32. (a) Consider an elastic wire of length l. Suppose it is stretched by a length Δl when a force F is applied at one end. If the elastic limit is not exceeded, then the extension is directly proportional to the applied load. Consequently, the force in the wire has increased in magnitude from zero to F. So, the average force in the wire while stretching was $\frac{F}{2}$.

Now, work done = average force × extension

$$= \frac{F}{2} \times \Delta l$$

This is the amount of energy stored in the wire. It is the gain in molecular potential energy of the molecules due to their displacement form their mean positions.

Again, $$Y = \frac{Fl}{a\Delta l} \quad \text{or} \quad F = \frac{Ya\Delta l}{l}$$

$\therefore$ $$\text{Work done} = \frac{1}{2} Ya \frac{\Delta l^2}{l}.$$

(b) Edge of the aluminum cube, L = 10 cm = 0.1 m

The mass attached to the cube, m = 100 kg

Shear modulus (η) of aluminum = 25 GPa = 25×10^9 Pa

$$= \frac{\text{Shear stress}}{\text{Shear strain}} = \frac{\frac{F}{A}}{\frac{\Delta L}{L}}$$

Where, F = Applied force = mg = 100 × 9.8 = 980 N

A = Area of one of the faces of the cube

= 0.1 × 0.1 = 0.01 m

ΔL = Vertical deflection of the cube

$\therefore$ $$\Delta L = \frac{FL}{A\eta}$$

$$= \frac{980 \times 0.1}{10^{-2} \times (25 \times 10^9)}$$

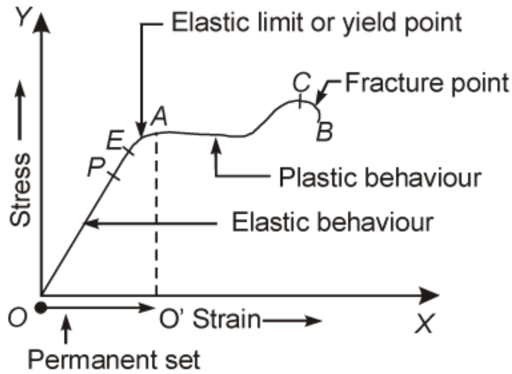
$$= \mathbf{3.92 \times 10^{-7}\ m}$$

The vertical deflection of this face of the cube is 3.92×10^{-7} m.

S33. In figure

Elastic region: *O* to *E*.

Plastic region: *E* to *B*.



Upto the point *E*, the steel wire will regain its status immediately on the removal of stress and the ratio of $\frac{\text{Stress}}{\text{Strain}}$ will be a constant.

(a) Strain increases in proportion to the load upto *P*.

But beyond *P*, it increases by an increasingly greater amount for a given increase in the load. Beyond the elastic limit *E*, it does not retrace the curve backward. The wire is unloaded but return to '*O*' along the dotted line *AO*'. Point *O*' corresponding to zero load which implies a permanent strain in wire.

(b) From *C* to *B*, strain increases even if the wire is being unloaded and at *B* it fractures. Stress upto that corresponding to *C* can be applied without causing fracture.

S34. Given, $Y_s = 2 \times 10^{11}\,\text{N m}^{-2}$, $Y_c = 1.1 \times 10^{11}\,\text{N m}^{-2}$, $L_c = 2.2\,\text{m}$,

$L_s = 1.6\,\text{m}$, $d = 3.0\,\text{mm} = 1.5 \times 10^{-3}\,\text{m}$.

The copper and steel wires are under a tensile stress because they have the same tension (equal to the load *W*) and the same area of cross-sectional *A*.

$$\text{Young's modulus} = \frac{\text{stress}}{\text{strain}}$$

or

$$\text{stress} = \text{Young's modulus} \times \text{strain}$$

$$\frac{W}{A} = Y_c\left(\frac{\Delta L_c}{L_c}\right) \quad \text{... (i)}$$

$$\frac{W}{A} = Y_s\left(\frac{\Delta L_s}{L_s}\right) \quad \text{... (ii)}$$

Eq. (i) divided by Eq. (ii), we get.

The subjects *c* and s refer to copper and stainless steel respectively.

Now,
$$\frac{\Delta L_c}{\Delta L_s} = \left(\frac{Y_s}{Y_c}\right)\left(\frac{L_c}{L_s}\right)$$

$$= \left(\frac{2.0 \times 10^{11}}{1.1 \times 10^{11}}\right)\left(\frac{2.2}{1.6}\right) = 2.5$$

$$\Delta L_c = 2.5\,\Delta L_s.$$

Net elongation = $\Delta L_c + \Delta L_s = 0.7$ mm $= 7 \times 10^{-4}$ m

Now, $2.5\ \Delta L_s + \Delta L_s = 7 \times 10^{-4}$ m

or $$\Delta L_s = \frac{7 \times 10^{-4}}{3.5} \text{ m} = 2 \times 10^{-4} \text{m}$$

Again, $$\Delta L_c = 2.5\ \Delta L_s = 2.5 \times 2 \times 10^{-4} \text{ m} = 5 \times 10^{-4} \text{ m}$$

Now, $$W = \frac{AY_c \Delta L_c}{L_c}$$

$$= \frac{\frac{22}{7}(1.5 \times 10^{-3})^2(1.1 \times 10^{11})(5 \times 10^{-4})}{2.2} \text{N}$$

$$= \mathbf{1.8 \times 10^2\ N}.$$

Date: 14/10/2021

Q1. What is compressibility?

Q2. A wire fixed at the upper end stretches by length by applying a force F. What is the work done in stretching the wire?

Q3. Why are electric poles given hollow structure?

Q4. Does the nature of forces differ solids and liquids? If yes, what is the difference there?

Q5. Why a solid is ductile or brittle?

Q6. Two metal plates are held together by two rivets width radii of 0.2 cm. If the maximum shear stress a single rivet can withstand is $5 \times 10^8\ \text{N m}^{-2}$, how much force must be applied parallel to the plates to shear off both the rivets?

Q7. Give the similarities and differences between intermolecular and interatomic forces.

Q8. A cable is replaced by another cable of the same length and material but twice the diameter. How will this affect the elongation under a given load?

Q9. Calculate the percentage increase in length of a wire of diameter 2.5 mm stretched by a force of 100 kg weight. Young's modulus of elasticity of wire is 12.5×10^{11} dyne/sq. cm.

Q10. A 5 cm cube has its upper face displaced by 0.2 cm by a tangential force of 8 N. Calculate the shearing strain, shearing stress and modulus of rigidity of the material of cube.

Q11. What is the density of water at a depth where pressure is 80.0 atm? Given that density at the surface is $1.03 \times 10^{-3}\text{kg } m^{-3}$, compressibility of water = $45.8 \times 10^{-11}\ \text{Pa}^{-1}$.

Q12. A platform is suspended by wires at its corners. The wires are 3 m long and have a diameter of 2.0 mm. Young's modulus for the material of the wires is $1.8 \times 10^{11}\ \text{N m}^{-2}$. How far will the platform drop due to elongation of the wires if a 50 kg load is placed at the centre of the platform?

Q13. A steel cable with a radius of 1.5 cm supports a chairlift at a ski area. If the maximum stress is not to exceed $10^8\ \text{N m}^{-2}$, what is the maximum load the cable can support?

Q14. The Marina trench is located in the Pacific Ocean, and at one place it is nearly eleven km beneath the surface of water. The water pressure at the bottom of the trench is about 1.1×10^8 Pa. A steel ball of initial volume $0.32\ \text{m}^3$ is dropped into the ocean and falls to the bottom of the trench. What is the change in the volume of the ball when it reaches to the bottom?

Q15. An Indian rubber cube of side 7 cm has one side fixed while a tangential force equal to the weight of 200 kg is applied to the opposite face. Find the shearing strain produced and the distance through which the strained side moves. Given: modulus of rigidity for rubber is 2×10^{-7} dyne cm^{-2}.

Q16. A 1 m long wire of cross-sectional area 10^{-6} m^2 is used to suspend a load of 840 N. (a) Calculate (i) the stress developed in the wire (ii) the strain (iii) the energy stored. (b) What would be the rise in temperature if the wire snaps? Given: $Y = 12 \times 10^{10}$ Pa, $\rho = 7000$ kg m^{-3}, $S = 420$ J kg^{-1} K^{-1}.

Q17. A cube of aluminum of side 10 cm is subjected to a shearing force of 100 N. The top surface of the cube is displaced by 0.01 cm with respect to the bottom. Calculate the shearing stress. Shearing strain and co-efficient of rigidity.

Q18. (a) A composite wire of uniform diameter 3.0 mm consisting of a copper wire of length 2.2 m and a steel wire of length 1.6 m stretches under a load by 0.7 mm. Calculate the load, given that the Young's modulus for copper is 1.1×10^{11} Pa and for steel is 2.0×10^{11} Pa.

(b) An Indian rubber cord 10 m long is suspended vertically. How much does it it stretch under. its own weight. Density of rubber = 1.5×10^3 kg m^{-3} and Young's modulus of rubber = 6×10^6 gf cm^{-2}.

Q19. (a) A 14.5 kg mass, fastened to the end of a steel wire of unscratched length 1.0 m, is whirled in a vertical circle with an angular velocity of 2 rev/s at the bottom of the circle. The cross-sectional area of the wire is 0.065 cm^2. Calculate the elongation of the wire when the mass is at the lowest point of its path.

(b) A mass of 100 g is attached to the end of a rubber string 49 cm long and of cross-sectional area 20 mm^2. When the mass is whirled round at a constant angular speed of 40 r.p.s., it moves along a circular path of radius 51 cm.

Q20. (a) A 60 kg motor sits on four cylindrical rubber blocks Each cylinder has a height of 3 cm and a cross-sectional area of 15 cm^2. The shear modulus for this rubber is 2×10^6 N m^{-2}. If a sideways force of 300 N is applied to the motor, how far will it move sideways?

(b) A copper wire 2 m long is stretched by 1mm. If the energy stored in stretched by 1 mm. If the energy stored in stretched wire is converted into heat, calculate the rise in temperature of the wire. Given $Y = 12 \times 10^{10}$ Nm^{-2}, density of copper = 9000 kg m^{-3} and specific heat = 0.1 kcal/kg.

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S1. The reciprocal of K, the bulk modulus, is called the compressibility of the substance.

$\therefore$ compressibility = $\dfrac{\Delta V}{V\,\Delta P}$. $K = \dfrac{\Delta P}{\dfrac{\Delta V}{V}}$

S2. Work done in stretching the wire,

$$W = \frac{1}{2} \text{ stretching force} \times \text{increase in length}$$

$$W = \frac{1}{2} F l. \qquad [\, l = \text{ increase in lenght}]$$

S3. A hollow shaft is stronger than a solid shaft made from the same and equal amonuts of material.

S4. Yes, in case of liquids, there is a force of attraction between the atoms and molecules whereas in case of solids, there is a strong force of repulsion between them.

S5. In the stress versus strain graph for a wire, the portion of graph between elastic limit and breaking point is called plastic region.

A solid is said to be more ductile, if the plastic region of the graph is longer; and brittle, if the plastic region is shorter.

S6. Given Maximum shear stress = 5×10^8 N m^{-2}

Radius of the rivet, $r = 0.2$ cm $= 0.002$ m^2

Therefore, area of cross-section of a rivet,

$$a = \pi r^2 = \pi \times 0.002^2 \text{ m}^2$$

The required force,

$$F = \text{shear stress} \times \text{area of cross-section of the two rivets}$$
$$= 5 \times 10^8 \times 2 \times \pi \times 0.002^2$$
$$= \mathbf{1.26 \times 10^4\ N}.$$

S7. ***Similarities:***

(a) Electrical by nature.

(b) Active over short distances.

Differences:

(a) Force between molecules or atoms.

(b) Molecular forces are weaker than inter atomic forces.

S8. Let Y be the Young's modulus of the material of the wire, L the length and D the diameter. Let the wire be loaded with a mass M kg. If Δl is the elongation, we can write,

$$\Delta l = \frac{MgL}{\pi\left(\frac{D}{2}\right)^2 Y} = \frac{4MgL}{\pi D^2 Y}$$

When the diameter is doubled for the same length (l) and mass (m), the elongation is given by.

$$\Delta l_1 = \frac{MgL}{\pi\left(\frac{2D}{2}\right)^2 Y} = \frac{MgL}{\pi D^2 Y}$$

$$\therefore \quad \frac{\Delta l_1}{\Delta l} = \frac{MgL}{\pi D^2 Y} \times \frac{\pi D^2 Y}{4MgL} = \frac{1}{4}$$

or $$\Delta l_1 = \frac{1}{4}\Delta l$$

Therefore, the elongation is one fourth the elongation with the diameter D of the wire.

S9. Here, $2r = 2.5\text{ mm} = 0.25\text{ cm}$

or $r = 0.125\text{ cm}$

$$\therefore \quad a = \frac{22}{7} \times (0.125)^2 \text{ sq. cm}$$

$$m = 100\text{ kg} = 100 \times 1000\text{ g}$$

$$Y = 12.5 \times 10^{11}\text{ dyne/sq. cm}$$

As $$Y = \frac{F \times l}{a \times \Delta l} \quad \therefore \quad \frac{\Delta l}{l} = \frac{F}{aY}$$

Hence, % increase in length

$$= \frac{\Delta l}{l} \times 100 = \frac{F}{aY} \times 100$$

$$= \frac{(100 \times 1000 \times 980) \times 7 \times 100}{22 \times (0.125)^2 \times 12.5 \times 10^{11}}$$

$$= \mathbf{0.159\ \%}.$$

S10. $$L = 5 \times 10^{-2}\text{ m}$$

$$\Delta L = 0.2\text{ cm} = 0.2 \times 10^{-2}\text{ m} ; F = 8\text{ N}$$

$$\text{Searing strain} = \frac{\Delta L}{L} = \frac{0.2}{5} = 0.04$$

$$\text{Shearing stress} = \frac{F}{L \times L} = \frac{8}{(5 \times 10^{-2})^2} = 3200 \text{ N m}^{-2}$$

$$\text{Modulus of rigidity, } \eta = \frac{\text{Shearing stress}}{\text{Shearing strain}}$$

$$= \frac{3200}{0.04} = 80000 \text{ N/m}^2$$

$$= \mathbf{8 \times 10^4 \text{ N/m}^2}.$$

S11. ρ' = density of water at given depth.

V = Volume of certain mass M of ocean water at surface.

then $V = \frac{M}{\rho}$ and $V' = \frac{M}{\rho'}$

Change in volume $\Delta V = V - V' = M\left(\frac{1}{\rho} - \frac{1}{\rho'}\right)$

Volumetric strain. $\frac{\Delta V}{V} = M\left(\frac{1}{\rho} - \frac{1}{\rho'}\right) \times \frac{\rho}{M}$

$$\frac{\Delta V}{V} = 1 - \frac{\rho}{\rho'} = 1 - \left(\frac{1.03 \times 10^3}{\rho'}\right) \quad \text{... (i)}$$

Bulk modulus $B = \frac{PV}{\Delta V}$ or $\frac{\Delta V}{V} = \frac{P}{B}$

$$\frac{\Delta V}{V} = (80.0 \times 1.013 \times 10^5) \times 45.8 \times 10^{-11}$$

$$= 3712 \times 10^{-3}$$

Putting this value in Eq. (i)

$$1 - \left(\frac{1.03 \times 10^3}{\rho'}\right) = 3.712 \times 10^{-3}$$

$$\rho' = 1.034 \times 10^3 \text{ kg/m}^3.$$

S12. $F = \frac{50}{4} \times 9.8 \text{N}, \quad l = 3 \text{m},$

$r = 1 \times 10^{-3}$ m and $Y = 1.8 \times 10^{11}$ Nm^{-2}

$$\Delta l = \frac{Fl}{aY}$$

$$= \frac{50}{4} \times 9.8 \times 3 \times \frac{7}{22(10^{-3})^2} \times \frac{1}{1.8 \times 10^{11}} \text{ m}$$

$$= 64.96 \times 10^{-5} \text{ m} = 0.65 \text{ mm.}$$

S13. Radius of the steel cable, r = 1.5 cm = 0.015 m

Maximum allowable stress = 10^8 N m^{-2}

$$\text{Maximum stress} = \frac{\text{Maximum force}}{\text{Area of cross-section}}$$

$\therefore$ Maximum force = Maximum stress × Area of cross-section

$$= 10^8 \times \pi (0.015)^2$$

$$= 7.068 \times 10^4 \text{ N}$$

Hence, the cable can support the maximum load of 7.068×10^4 N.

S14. Given, Water pressure at the bottom, $P = 1.1 \times 10^8$ Pa

Initial volume of the steel ball, $V = 0.32$ m^3

Bulk modulus of steel, $B = 1.6 \times 10^{11}$

The ball falls at the bottom of the Pacific Ocean, which is 11 km beneath the surface.

Let the change in the volume of the ball on reaching the bottom of the trench be ΔV.

$$\text{Bulk modulus, } B = \frac{P}{\frac{\Delta V}{V}}$$

$$\Delta V = \frac{PV}{B} = \frac{1.1 \times 10^8 \times 0.32}{1.6 \times 10^{11}}$$

$$= 2.2 \times 10^{-4} \text{ m}^3$$

Therefore, the change in volume of the ball on reaching the bottom of the trench is $2.2 \times 10^{-4} m^3$.

S15.

$$l = 7 \text{ cm, F} = 200 \text{ kgf}$$

$$= 200 \times 1000 \times 981 \text{ dyne,}$$

$$\eta = 2 \times 10^7 \text{ dyne cm}^{-2}$$

Area of the face of the cube, $A = l^2 = 7 \text{ cm} \times 7 \text{ cm} = 49 \text{ cm}^2$

$$\eta = \frac{F}{A\theta}$$

or

$$\theta = \frac{F}{A\eta} = \frac{200 \times 1000 \times 981}{49 \times 2 \times 10^7} \text{ rad} = 0.2 \text{ rad}$$

shearing strain, $\theta = \frac{\Delta l}{l}$

or $\Delta l = l\theta = 7 \times 0.2$ cm = 1.4 cm.

S16. (a) (i) Stress = $\frac{840}{10^{-6} m^2} = 84 \times 10^7$ N m^{-2}

(ii) Strain = $\frac{\text{Stress}}{Y} = \frac{84 \times 10^7 \text{Nm}^{-2}}{12 \times 10^{10} \text{Nm}^{-2}} = 7 \times 10^{-3}$

(iii) Volume = 1×10^{-6} m^3 = 10^{-6} m^3

Energy = $\frac{1}{2} \times 84 \times 10^7 \times 7 \times 10^{-3} \times 1 \times 10^{-6}$ J = 2.94 J

(b) $\theta = \frac{2.94 \text{ J}}{10^{-6} \times 7000 \times 420} = 1^\circ$ C

S17. Given, L = 10 cm = 0.1 m

Area of the face a = 0.1×0.1 = 0.01 m^2

Tangential force F = 100 N

Shearing stress $T = \frac{F}{a} = \frac{100}{0.01} = 10^4$ Nm^{-2}

Displacement l = 0.01 cm = 0.0001 m

Shearing strain $\theta = \frac{l}{L} = \frac{0.0001}{0.1} = 10^{-3}$

Modulus of rigidity $\eta = \frac{T}{\theta} = \frac{10^4}{10^{-3}} = \mathbf{10^7}$ **Nm^{-2}**.

S18. (a) Given, l_c = 2.2 m, l_s = 1.6 m, $Y_c = 1.1 \times 10^{11}$ Pa, $Y_s = 2.0 \times 10^{11}$ Pa

$\Delta l_c + \Delta l_s = 0.7 \times 10^{-3}$ m

Also, $\frac{\Delta l_c}{\Delta l_s} = \frac{Y_s \times l_c}{Y_c \times l_s}$

$= \frac{2 \times 10^{11} \times 2.2}{1.1 \times 10^{11} \times 1.6} = 2.5$

or $\Delta l_c = 2.5\ \Delta l_c$; $3.5\ \Delta l_s = 0.7 \times 10^{-3}$

or $\Delta l_s = \frac{0.7 \times 10^{-3}}{3.5}$ m $= 2 \times 10^{-4}$ m

Now, $$Y_s = \frac{F l_s}{\pi r_s^2 \Delta l_s}$$

or $$F = \frac{Y_s \times \pi r_s^2 \times \Delta l_s}{l_s}$$

$$= \frac{2\times10^{11}\times3.14\times1.5\times10^{-3}\times1.5\times10^{-3}\times2\times10^{-4}}{1.6}\text{ N}$$

$$= \mathbf{1.77\times10^2\ N}.$$

(b) Here, $L = 10$ m ; $\rho = 1.5\times10^3$ kg m^{-3};

$Y = 6\times10^6\ g\,f\,\text{cm}^{-2}$

$= \mathbf{6\times10^6\times980\ dyne\ cm^{-2}}$.

Let a be the area of cross-sectional of the rubber cord. Then,

F = weight of the rubber cord

$= 5.88\times10^8$ N m^{-2}

Let a be the area of cross sectional of the rubber cord. Then,

$= L\times a\times\rho\times g$

The weight of the rubber cord acts at its centre of gravity and hence the weight of the rubber cord will produce extension in the length $L/2$ of the cord.

Now, $$Y = \frac{F(L/2)}{al}$$

or $$l = \frac{F\times L}{2a\times Y} = \frac{La\rho g\times L}{2a\times L} = \frac{L^2\rho g}{2Y}$$

$$= \frac{10^2\times1.5\times10^3\times9.8}{2\times5.88\times10^8} = 1.25\times10^{-3}\text{ m}$$

$= \mathbf{1.25\ mm}$.

S19. (a) Given, Mass, $m = 14.5$ kg

Length of the steel wire, $l = 1.0$ m

Angular velocity, $\omega = 2$ rev/s

Cross-sectional area of the wire, $a = 0.065$

Let δl be the elongation of the wire when the mass is at the lowest point of its path.

When the mass is placed at the position of the vertical circle, the total force on the mass is:

$$F = mg + ml\omega^2$$

$$= 14.5\times9.8 + 14.5\times1\times(2)^2$$

$$= 200.1\text{ N}$$

$$\text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}}$$

$$Y = \frac{\frac{F}{A}}{\frac{\Delta l}{l}} = \frac{F}{A}\frac{l}{\Delta l}$$

$\therefore$ $$\Delta l = \frac{Fl}{AY}$$

Young's modulus for steel = 2×10^{11} Pa

$\therefore$ $$\Delta l = \frac{200.1 \times 1}{0.065 \times 10^{-4} \times 2 \times 10^{11}} = 1539.23 \times 10^{-7}$$

$$= \mathbf{1.539 \times 10^{-4}}$$

Hence, the elongation of the wire is 1.539×10^{-4} m.

(b) When the mass attached to the string is whirled, the length of the string increases under the effect of centrifugal force.

Here, $L = 49$ cm; $l = 51 - 49 = 2$ cm;

$a = 20 \text{ mm}^2 = 0.2 \text{ cm}^2$

m = 100 g; $R = 51$ cm; $\omega = 40$ r.p.s. $= 80\,\pi$ rad s^{-1}

The centrifugal force, $F = m\,R\omega^2 = 100 \times 51 \times (80\,\pi)^2$

Now, $$Y = \frac{FL}{al} = \frac{100 \times 51 \times (80\,\pi)^2 \times 49}{0.2 \times 2}$$

$$= \mathbf{3.95 \times 10^{10} \text{ dyne cm}^{-2}}.$$

S20. (a)

$$F = \frac{300\,\text{N}}{4} = 75\,\text{N},$$

$l = 0.03$ m, $a = 15 \times 10^{-4}$ m^2

$\Delta l = ?$, $\eta = 2 \times 10^6$ N m^{-2},

$$\eta = \frac{F/a}{\Delta l / l} = \frac{Fl}{a\Delta l}$$

or $$\Delta l = \frac{Fl}{a\eta} = \frac{75 \times 0.03}{15 \times 10^{-4} \times 2 \times 10^6}\,\text{m}$$

$$= \mathbf{0.075 \text{ cm}}.$$

(b) Here $L = 2m$, $l = 1$ mm $= 10^{-3}$ m; $Y = 12 \times 10^{10}$ Nm^{-2}

$$\text{Strain} = \frac{l}{L} = \frac{10^{-3}}{2} = 5 \times 10^{-4}$$

$$\text{Stress} = Y \times \text{strain} = 12 \times 10^{10} \times 5 \times 10^{-4} = 6 \times 10^{7}\ \text{Nm}^{-2}$$

$$\text{Energy per unit volume} = \frac{1}{2} \times \text{stress} \times \text{strain}$$

$$= \frac{1}{2} \times 6 \times 10^{7} \times 5 \times 10^{-4} = 15 \times 10^{3}\ \text{Jm}^{-3}$$

$$\text{Heat produced } H = \frac{W}{J} = \frac{15 \times 10^{+3}}{4.2 \times 10^{3}}$$

$$= \mathbf{3.57\ K\text{-}cal/kg}.$$

If θ is the in temperature, then

$$\text{Heat produced} = \rho s\theta = 9000 \times 0.1 \times \theta$$

$\therefore$ $$900\theta = 3.57$$

or $$\theta = \frac{3.57}{900} = \mathbf{3.967 \times 10^{-3}\ °C}.$$