QB365

Important Questions - Mechanical Properties of Solids

11th Standard CBSE

Physics

Reg.No. :

Time : 01:00:00 Hrs

Total Marks : 50

Section-A

1) Stress and pressure are both forces per unit area. Then, in what respect does stress differ from pressure ? **1**

2) Which type of strain is there, when a spiral spring is stretched by a force ? **1**

3) Is it possible to double the length of a metallic wire by applying a force over it ? **1**

4) What is the Young's modulus for a perfect rigid body? **1**

5) Awire increase by $10^{-3}$of its lengyh when a stress of $10^8 Nm^{-2}$ is applied to it. What is the Young's modulus of the material of the wire? **1**

6) The star Sirius has a mass of $7x10^{30}$ kg, its distance from the earth is $8x10^{16m}$ and the mass of the earth is $6x10^{24}$kg. Calculate the cross-section of a steel cable that can withstand the gravitational pull between the Sirius and the earth. Given $G=6.67x10^{-11}Nm^2kg^{-2}$ and breaking stress=10^{10} Nm^{-2} **1**

7) A wire of length 2.5 m has a percentage strain of 0.012 % under a tensile force. Determine the extension in the wire. **1**

8) A wire elongates by 8 mm when a load of 9 kg is suspended from it. What is the elongation when its radius is doubled, if other quantities are the same as before? **1**

9) Find the change in volume which 1cc of water at the surface will undergo, when it is taken to the bottom of the lake 100m deep, given that volume elasticity is 22000 atmospheres. **1**

10) A square lead slab of side 50cm and thickness 10 cm is subjected to a shearing force (on its narrow edge) of $9.0x10^4$ N. The lower edge is reveted to the floor. How much will the upper edge be displaced? Modulus of rigidity of lead=$5.6x10^9$ N/m^2 **1**

Section-B

11) Two wires made of same material are subjected to forces in the ratio 1 : 4. Their lengths are in the ratio 2 : 1 and diameters in the ratio 1 : 3. What is the ratio of their extensions ? **2**

12) Two wires A and B are of the same material. Their lengths are in the ratio 1:2 and the diameters in the ratio 2:1 If they are pulled by the same force, then what will be the ratio of their increase in lengths? **2**

13) A solid sphere of radius R made of a material of bulk modulus B is surrounded by a liqiud in a cylindrical container. A massless piston of area A floats on the surface of the liqiud. When a mass M is placed on the piston on the piston to compress the liqiud, find fractiional change in the radius of the sphere? **2**

14) The Marina trench is located in the Pacific ocean and at one place, it is nearly 11 km beneath the surface of water. The water pressure at the bottom of the trench is about $1.1x10^8$ Pa. A steel ball of initial volume $0.32m^3$ is dropped into the ocean and falls to the bottom of trench. What is the change in the voulme of the ball when it reaches to the bottom if the Bulk modulus of steel is $1.6x10^{11}$ N/m^2? **2**

15) To what depth must a rubber ball be taken in deep sea so that its volume is decreased by 0.1%? **2**

16) Determine the fractional change in volume as the pressure of the atmosphere $1.0x10^5$ Pa around a metal block is reduced to zero by placing the block in vacuum. The Bulk modulus for the block is $1.25x10^{11}$ Nm^{-2} **2**

17) A steel wire of length 4.7 m and cross-sectional area $3.0x10^5$ m^2 stretches by the same amount as a copper wire of length 3.5m and cross-sectional area $4.0x10^{-5}m^2$ under a given load.
What is the ratio of the Young's modulus of stell to that of copper? **2**

18) 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 ands. The lengths of wires are in the ratio 4:5 and their radii are in the ratio 4:3. The increase in the length of the wire A is 1mm. Calculate the increase in the length of the wire B. **2**

19) Assume that if the shear stress in steel exceeds about $4x10^8 N/m^2$, the steel ruptures. Determine the shearing force necessary to (a) shear a steel bolt 1.00 cm in diameter and (b) punch a 1 cm diameter hole in a steel plate 0.5000 cm thick. **2**

20) A uniform heavy rod of weight W, cross-sectional area A and length I is hanging from a fixed , support. Young's modulus of the material of the rod is Y. Neglecting the lateral contraction, find the elongation produced in the rod. **2**

Section-C

21) Caluculate 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 $12.5x10^{11}$ dyne/sq cm. **5**

22) Ajay was a very naughty boy. One day , he bought a rubber cord catapult from market and started hitting passerby. When his father came to know about this, he immediately called Ajay and scolled him. He made him realise what damage his act could do. Ajay realised his mistake and apologised for his mistake. **5**

What values do you associate with Ajay?

23) The edge of an aluminium cube is 10 cm long.One face of the cube is firmly fixed to a vertical wall.Amass of 100 kg is then attached to the opposite face of the cube. **5**

The shear modulus of aluminium is 25 GPa.What is the vertical deflection of this face?

24) A14.5kg mass, fastened to one end of a steel wire of unstretched length 1m is whirled in a vertical circle with an angular frequency of 2 rev/s at the bottom ofthe circle. The **5**

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.

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Section-A

1) **1**

Pressure is an external force per unit area, while stress is the internal restoring force which comes into play in a deformed body acting transversely per unit area of body.

2) Longitudinal strain and shear strain. **1**

3) No, it is not possible because within elastic limit, strain is only order of 10^{-3} , wires actually break much before it is stretched to double the length. **1**

4) **1**

Young's modulus $Y=\frac{F}{A}\times\frac{l}{\Delta l}$ For a perfectly rigid body, change in length $\Delta l = 0$ $Y=\frac{F}{A}\times\frac{l}{0}=\infty$ Therefore, Young's modulus for a perfectly rigid bosy is ∞

5) **1**

Given, $\Delta L = 10^{-3}L$ with L as the original length Strain $Y=\frac{\Delta L}{L}=10^{-3}$ and Stress $=\frac{F}{A}=10^{8}N/m^{2}$

$Y=\frac{Stress}{Strain}=\frac{F/A}{\Delta L/L}$ $Y=\frac{1\times10^{8}}{10^{-3}}=10^{11}N/m^{2}$

6) 44m^2 **1**

7) Here, original length, L = 2.5 m **1**

Strain = $\frac{\Delta L}{L}$ = 0.012 % = $\frac{0.012}{100}$

ΔL = Strain x L

ΔL = extension = $\frac{0.012}{100}\times L$

= $\frac{0.012\times2.5}{100}$ = 3 x 10-4 m = 0.3 mm

8) 2 mm **1**

9) 0.00044 cc **1**

10) 0.16 mm **1**

Section-B

11) According to Hooke's law, **2**

Modulus of elasticity, E = $\frac{F}{\pi r^2}\times\frac{l}{\Delta l}$

or $\Delta l=\frac{Fl}{\pi r^2 E}$

or $\Delta l \propto \frac{Fl}{r^2}$ [$\because$ E is same for two wires]

$\therefore$ $\frac{\Delta l_1}{\Delta l_2}=\frac{F_1}{F_2}\times\frac{l_1}{l_2}\times\frac{r_2^2}{r_1^2}$

= $\frac{1}{4}\times\frac{2}{1}\times\left(\frac{3}{1}\right)^2=\frac{9}{2}$

So, $\Delta l_1 : \Delta l_2$ = 9 : 2

12) We know $\Delta L=\frac{FL}{AY},\frac{L_A}{L_B}=\frac{1}{2} and \quad \frac{r_A}{r_B}=\frac{2}{1}$ **2**

[the wires A and B are pulled by the same force and they are made up of same material,hence, $F_A=F_B=F, Y_A=Y_B=Y$]

$$\frac{\Delta L_A}{\Delta L_B}=\frac{L_A}{\pi r_B^2}\times\frac{\pi r_B^2}{L_B}\frac{\Delta L_A}{\Delta L_B}=\frac{L_A}{L_B}\times\left(\frac{r_B}{r_A}\right)^2\frac{\Delta L_A}{\Delta L_B}=\frac{1}{2}\times\left(\frac{1}{2}\right)^2=\frac{1}{8}\frac{\Delta L_A}{\Delta L_B}=\frac{1}{8}$$

13) **2**

When mass M is placed on the piston, the excess pressure, p=Mg/A. As the pressure is equally applicable from all the direction on the sphere, hence there will be decrease in volume due to decrease in raius sphere. Volume of the sphere, $V = \frac{3}{4}\pi R^3$

Differentiating it , we get,

$$\Delta V = \frac{4}{3}\pi(3R^2)\Delta R = 4\pi R^2 \Delta R \frac{\Delta V}{V} = \frac{4\pi R^2 \Delta R}{\frac{4}{3}\pi R^3} = \frac{3\Delta R}{R}$$

We know that, $B = \frac{P}{dV/V} = \frac{Mg}{A} \Big/ \frac{3\Delta R}{R}$

$$or \quad \frac{\Delta R}{R} = \frac{Mg}{3BA}$$

14) Depth(h)=11km=11x10^3m **2**

Pressure at the bottom of the trench (p) =1.1x10^8 Pa

Initial voulme of the ball (V)=0.32 m^3

Bulk modulus of stell (B) =1.6x10^{11} N/m^2

Bulk modulus of steel $(B) = \frac{p}{(\Delta V/V)} = \frac{pV}{\Delta V}$

$$\Delta V = \frac{pV}{B} = \frac{1.1\times10^8\times0.32}{1.6\times10^{11}} \Delta V = 2.2\times10^{-4} m^3$$

15) Bulk modulus of rubber (b) = 9.8x10^8 N/m^2 **2**

Density of seawater (p)=10^3 kg/m^3

Percentage decrease in volume

$$\left(\frac{\Delta V}{V}\times 100\right) = 0.1 \quad or \quad \frac{\Delta V}{V} = \frac{0.1}{100} or \qquad \frac{\Delta V}{V} = \frac{1}{1000}$$

Let the rubber ball be taken up to depth h.

Change in pressure (p)=hpg

Bulk modulus $(B) = \frac{p}{(\Delta V/V)} = \frac{hpg}{(\Delta V/V)}$

$$or \quad h = \frac{B\times(\Delta V/V)}{pg} = \frac{9.8\times10^8\times\frac{1}{1000}}{10^3\times9.8} = 100m$$

16) 8x10^{-7} **2**

17) Given for steel wireLength (l_1)=4.7 m **2**

Area of cross-section (A_1)=3.0x$10^{-5}$$m^2$

For copper wire

Length (l_2) =3.5 m

Area of crosssection (A_2) = 4.0x$10^{-5}$$m^2$

Let F be the given load under which steel and copper wires be streched by the same amount Δl

Young's modulus $(Y) = \frac{F/A}{\Delta l/l} = \frac{F\times l}{A\times\Delta l}$

For steel $\quad Y_s = \frac{F\times l_1}{A_1\times\Delta l}$

For copper $\quad Y_c = \frac{F\times l_2}{A_2\times\Delta l}$

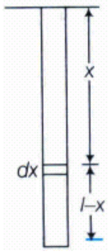
Dividing Eq (i)by Eq(ii) we get

$$\frac{Y_s}{Y_c} = \frac{F\times l_1}{A_1\times\Delta l}\times\frac{A_2\times\Delta l}{F\times l_2} \qquad = \frac{l_1}{l_2}\times\frac{A_2}{A_1} = \frac{4.7}{3.5}\times\frac{4.0\times10^{-5}}{3.0\times10^{-5}}\frac{Y_s}{Y_c} = \frac{18.8}{10.5} = 1.79 = 1.8$$

18) 2.22 mm **2**

19) 3.14x10^4N, 6.28x10^4N **2**

20) **2**



As shown in figure, consider a small element of thickness dx at distance x from the fixed support. Force acting on the element dx is

F = Weight of length (l- x) of the rod

$=\frac{W}{l}$(l-x)

Elongation of the element = Original length $\times \frac{Stress}{Y}$

$= dx \times \frac{F/A}{Y} = \frac{W}{l\ \ Ay}(l-x)dx$

Total elongation produced in the rod =

$$\frac{W}{l\ \ Ay}\int_0^l (l-x)dx = \frac{W}{l\ \ Ay}\left[lx - \frac{x^2}{2}\right]_0^l$$

$$= \frac{W}{l\ \ Ay}\left[l^2 - \frac{l^2}{2}\right] = \frac{W}{2Ay}$$

Section-C

21) **5**

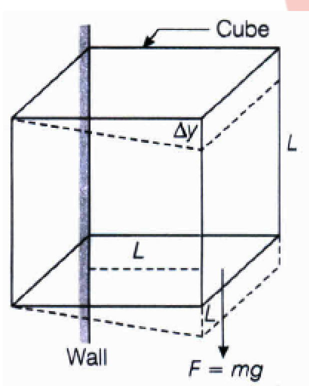
Here, 2r =2.5mm =0.25 cm

or r =0.125 cm

$a = \pi r^2 = \frac{22}{7} \times (0.125)^2 sq.\ cm$ $F = 100\ \ kg = 100x1000g$ $F = 10 \times 1000 \times 980\ \ dyne$ $Y = 12.5 \times 10^{11} dyne/sq.\ cmAs$ $Y = \frac{F \times l}{a \times \Delta l}$ $\frac{\Delta l}{l} = \frac{F}{aY}$

22) Ajay is naughty but when he is made to realise his mistake, he is ready to apologise **5**

23) **5**



Given, side of a cube (l) = 10 cm = 0.1 m

Area of its each face (A) = $l^2 = (0.1)^2 = 0.01\ m^2$

Load(m) = 100 kg

Tangential force acting on one face of the cube, F=mg=100 $\times$ 9.8 =980 N

Shear stress acting on this face = $\frac{F}{A} = \frac{980}{0.01}$ N/m2

$=9.8 \times 10^4\ N/m^2$

Shear modulus of aluminium (η) = 25 GPa

$=25 \times 10^9\ N/m^2$

Shear modulus (η)=$\frac{Shearing\ \ stress}{Shearing\ \ strain}$

or shearing strain $\left(\frac{\Delta L}{L}\right) = \frac{Shearing\ \ stress}{Shear\ \ modulus}$

or $\Delta L = \frac{Shearing\ \ stress}{Shear\ \ modulus} \times$ L = $\frac{9.8 \times 10^4}{25 \times 10^9} \times$ 0.1 = 0.0392 $\times$ 10_{-5}m = 3.92 $\times$ 10_{-7}m

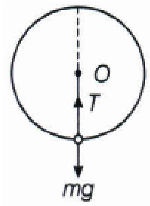
24) Given, mass(m)= 14 .5kg

Length of wire (l) = 1 m

Angular frequency (v) = 2 revls

Angular velocity (ω) = 2πv

$=2\pi \times 2$ rad/s = 4π rad/s



Area of cross-section of wire (A) = 0.065 cm^2

$=6.5 \times 10^{-6}$ m^2

Young's modulus for steel (Y) = 2×10^{11} N/m^2.

At lowest point of the vertical circle, T - mg = $ml\omega^2$

or T=mg+ $m\omega^2$

$= (14.5 \times 9.8)+14.5 \times 1 \times (4\pi)^2$

$=14.5(9.8+16\pi^2)$

$=14.5(9.8 \times 16 \times 9.87)$ $[\because \pi^2=9.87]$

$=14.5 \times 167.72$N=2431.94 N

Young's modulus (Y) $=\frac{Stress}{Strain} = \frac{(T/A)}{\Delta l/l} = \frac{Tl}{A.\Delta l}$

$\therefore \quad \Delta l = \frac{T.l}{A.Y} = \frac{2431.94 \times 1}{6.5 \times 10^{-6} \times 2 \times 10^{11}}$

$=1.87 \times 10^{-3}$ m =1.87 mm