CHAPTER 9 : - MECHANICAL PROPERTIES OF SOLIDS

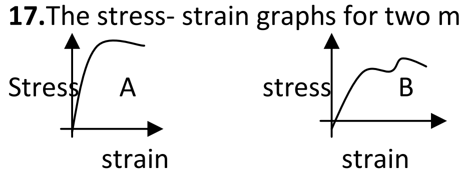
ONE MARK QUESTIONS:

1. What is elasticity of a body?
2. What is plasticity?
3. Which property of a body is responsible for regaining original shape and size of a body when deforming force acting on it is removed?
4. Elasticity is an internal property of a matter. Is it true or false?
5. What is the cause of the elasticity?
6. What is plastic substance?
7. Give one example for plastic substance.
8. Define stress.
9. Write the expression for magnitude of the stress.
10. Write the S.I unit of the stress.
11. Write the dimensional formula of the stress.
12. Dimensional formula of stress is same as that of the pressure. Is it true or false?
13. Stress is a vector quantity. Is it true or false?
14. Define strain.
15. Why strain is unit less and dimensionless physical quantity?
16. Define longitudinal strain.
17. Write the expression for longitudinal strain.
18. Define volume strain.
19. Write the expression for volume strain.
20. Define shearing strain.
21. Define elastic limit. (yield strength.)
22. Define ultimate tensile strength.
23. What are elastomers?
24. Elastomers does not obey Hooke`s law. Is it true or false?
25. Give one example for elastomers.
26. Define modulus of elasticity.
27. Modulus of elasticity of a body is dependent on the dimensions of a body. Is it true or false?
28. Dimensional formula of modulus of elasticity is same as that of the stress. Is it true or false?
29. Define Young`s modulus.
30. Write the expression for magnitude of the Young`s modulus.
31. What is the S.I unit of the Young`s modulus?
32. Write the dimensional formula of the Young`s modulus.
33. Why steel is preferred in heavy duty machines and in structural design?
34. Why springs are manufactured in steel instead of copper?
35. Define shear modulus **or** modulus of rigidity.
36. Define bulk modulus.
37. What is compressibility?
38. Solid are least are compressible since they have larger value of bulk modulus. Is it true or false?
39. Young`s modulus and shear modulus are relevant only for solid. Why?
40. Young`s modulus of rubber is greater than that of steel. Is it true or false?
41. Rubber is more elastic than that of steel. Is it true or false?
42. What is the buckling of the material of the road?
43. Stretching of coil is measured by its shearing modulus. Is it true or false?
44. Why load baring bar has cross sectional shape of the type **I**.
45. Why pillars or columns of the bridges and buildings have distributed shape at their ends?
46. What is the value of young`s modulus for a perfectly rigid body?
47. Why liquid and gas do not posses modulus of rigidity?
48. Write the S.I for the compressibility.
49. How does modulus of elasticity vary with increase of temperature of the body?
50. The material for given load stretches to a little extent is a more elastic body. Is it true or false

TWO MARK QUESTIONS:

1. State and explain Hooke's law.
2. Mention any two types of stress.
3. Mention any two types of strain.
4. Draw the typical stress-strain curve for a metal.
5. Which is more elastic-steel or rubber? Why?
6. Explain elastic behavior of the solid.
7. Write the expression for Young`s modulus of the material of the wire under stretching. Explain the terms.
8. Write the expression for rigidity modulus of the material. Explain the terms.
9. Write the expression for bulk modulus of the material. Explain the terms.
10. A square lead slab of side 50cm and thickness 10cm subjected to shearing force of $9X10^4$N.Calculate the shearing stress acting on the slab.
11. Write the expression for sag or depression of a bar when it is loaded at the middle. Explain the terms.
12. Write the expression for compressibility and explain the terms
13. Distinguish between ductile material and brittle material.
14. Write two application of elastic behavior of the material.
15. Mention two methods of decreasing the depression in the beam which loaded at the middle with weight.
16. A steel rod of area of cross section $3.14x10^{-4}m^2$ is stretched by a force of 100kN. Calculate the stress acting on the rod

17. The stress- strain graphs for two material A and B are shown in the figure



Which of the material has the greater Young's modulus? And which material is more elastic?

18. Compute the fractional change in the volume of glass sphere when subjected to a hydraulic pressure of $1.013x10^6Nm^{-2}$. Given bulk modulus of glass is $3.7x10^{10}$ Nm^{-2}

FOUR MARK QUESTIONS:

1.Define terms stress and strain. Draw the stress verses strain graph for a metallic wire stretched upto the fracture point

2. Define the following terms

a) Elastic limit b) permanent set c) plastic deformation d) fracture point

3. State and explain Hooke's law. Define modulus of elasticity and write its dimensional formula

FIVE MARK QUESTIONS:

1. Draw typical stress – strain graph for a metal and explain the important features in it.
2. Explain the experiment to determine Young's modulus of the material wire under stretching

FIVE MARK PROBLEMS:

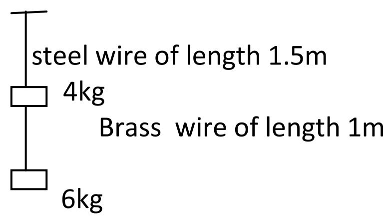
1. A steel rod of radius 10mm and length 2m is stretched by a force of 100kN along its length. The elongation in the wire is 3.2mm. Find the stress and Young's modulus of the material of the rod.

2. The upper face of a cube of edge 1m moves through a distance of 1mm relative to the lower fixed surface under action of a tangential force $1.5x10^8$N. Calculate tangential stress and rigidity modulus.

3. When a rubber ball is taken in deep of 100m in sea its volume is decrease by 0.1% due to hydraulic stress. If the density of sea water is $1000kgm^{-3}$, calculate the bulk modulus and compressibility of the rubber

4.A steel wire of length 5m and cross section $3x10^{-5}m^2$ stretched by the same amount as copper of length 3.7m and cross section $4x10^{-5}m^2$ under given load. Find the ratio of Young's modulus of steel to that of copper

5. Two wires of area of cross section $5x10^{-6}m^2$, one made of steel and the other made of brass are loaded as shown. The unloaded length of steel wire is 1.5m and that of brass wire is 1m. Find the elongations in each wires. Y for steel is$2x10^{11}$ Nm^{-2} and for brass is$0.91x10^{11}Nm^{-2}$



6.Find the force required to stretch a wire of area of cross section $2x10^{-4}$ m^2 so that its length becomes 1.5 times original length . Young's modulus=$3.6x10^{11}Nm^{-2}$.

ANSWERS

1) The property of a body due to which it tends to regain its original size and shape when the deforming force is removed is called elasticity

2) The property of a body due to which it does not regain its original size and shape when the deforming force is removed is called plasticity

3) Elasticity

4) True

5) It is due to intermolecular forces between the molecules of the material

6) Substance which does not regain its original size and shape when the deforming force is removed is called plastic substance

7) Putty (mud)

8) The restoring force per unit area of the body is called stress

9) Magnitude of stress =$\frac{F}{A}$

10) Nm^{-2} or Pa

11) [Stress] = $[L^{-1}MT^{-2}]$

12) True

13) False

14) Strain produced in a body is defined as ratio of change in dimension to the original dimension.

15) Because strain is ratio of same physical quantities

16) Longitudinal strain is defined as ratio of change in the length to the original length.

17) Longitudinal strain=$\frac{\Delta L}{L}$ where ΔL -change in the length, L-original length

18) Volume strain is defined as ratio of change in the volume to the original volume

19) Volume strain=$\frac{\Delta V}{V}$ where ΔV -change in the volume, V-original volume

20) It is the angle through which a vertical face of a body displaced when tangential deforming force applied on it.

21) The maximum stress below which Hooke's law is applicable is called elastic limit **OR** it is the maximum stress up to which body regain its original shape and size

22) The minimum stress needed to cause the fracture of the material is known as ultimate tensile strength

23) Material which can be stretched to a large value of strain without breaking is called elastomers

24) True

25) Rubber

26) Modulus of elasticity is defined as the ratio of stress acting on the body to the resulting strain in it.

27) False

28) True

29) Young's modulus is defined as ratio of longitudinal stress acting on the body to the longitudinal strain produced in it.

30) Young's modulus= Y = $\frac{F\text{x}L}{A\text{x}\Delta L}$

31) Nm^{-2} or Pa

32) [Young's modulus] = $[L^{-1}MT^{-2}]$

33) Because Young's modulus of steel is highest and is more elastic

34) Because Young's modulus of steel is more than that of copper and hence steel is more elastic than copper

35) The ratio of shearing stress acting on the body to the corresponding shearing strain is called rigidity modulus

36) The ratio of hydraulic stress acting on the body to the corresponding volume strain is called bulk modulus

37) The reciprocal of the bulk modulus is called compressibility

38) True

39) Because only solid has length and definite shape

40) False

41) False

42) The bending of beam under a load is called buckling.

43) True

44) This shape reduces the weight and cost of the beam and is much stronger.

45) Pillars having distributed shape at the ends support more load than pillars with rounded ends.

46) Infinity.

47) Liquid and gas has no definite shape.

48) $N^{-1}m^{2}$ **OR** Pa^{-1}

49) Modulus of elasticity decrease with increases of temperature.

50)True

2Mark questions.

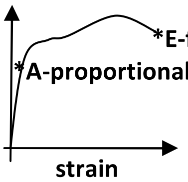
1) Within elastic limit stress and strain are proportional to each other. **(1 mark)**

Stress ∝ strain **OR** $\frac{\text{stress}}{\text{stain}}$ = constant (modulus of elasticity). **(1 mark)**

2) a) longitudinal stress b) shearing stress **1 mark each**

3) a) longitudinal strain b) shearing strain **[**c) bulk strain**]** **1 mark each**

4)



5) Steel. **(1 mark)**

Because Young`s modulus of steel is more than that of rubber.

Hence steel is more elastic than rubber. **(1 mark)**

6) When solid is deformed atoms or molecule are displaced from their equilibrium position resulting change in the interatomic distance. **(1 mark)**

Due to inter molecular attraction body regain its original shape and size when deforming force is removed. **(1 mark)**

7) $\mathbf{Y = \frac{MgL}{\pi r^2 \Delta L}}$. **(1 mark)**

Where M -- mass attached to the wire. L ,r—initial length and radius of the wire. ΔL- elongation in the wire. **(1 mark)**

8) $G=\frac{F}{A\,\theta}$. **(1 mark)**

Where F—tangential force. A—area of the face. θ- Shearing strain. **(1 mark)**

9) $\mathbf{B=-\frac{PV}{\Delta V}}$ **(1 mark)**

Where P-hydraulic stress, V-initial volume and ΔV-change in the volume **(1 mark)**

10) Area of the face on which force is acting =A=50cmx10cm=0.5mx0.1m=0.05m^2

Shearing stress=$\frac{\text{tangential force}}{\text{area of the face}}$ **(1 mark)**

Stress= $\frac{9.4\text{x}10^4}{0.05}$ = **$\underline{1.8\text{x}10^6\text{Nm}^{-2}}$** **(1 mark)**

11) $\mathbf{\delta = \frac{Wl^3}{4bd^3Y}}$ **(1 mark)**

Where W-load, *l*-length of the span, b-breadth of the beam,

d-depth (thickness) of the beam , Y-Young's modulus **(1 mark)**

12) $\mathbf{K = \frac{1}{B} = \frac{-\Delta V}{PV}}$ **(1mark)**

Where P-hydraulic stress, V-initial volume and ΔV-change in the volume **(1 mark)**

13)

Ductile material	**Brittle material**
1) The material showing large amount of plastic deformation b/n the elastic limit and the fracture point is called ductile material.	The material showing small amount of plastic deformation b/n the elastic limit and The fracture point is called brittle material. **1mark**
2)They have permanent stretch without breaking	They fractured soon after the elastic limit is crossed **1mark**

14) a)To estimate the maximum height of a mountain. b)In minimizing of the bending of loaded beam ((c)In selecting metallic rope for crane**) any two** **(1mark each)**

15)a)increasing the depth(thickness of the beam) b)increasing its breadth **(1mark each)**

16) longitudinal stress=$\frac{force}{area}$ =$\boldsymbol{\frac{F}{A}}$ **(1mark)**

=$\frac{100x10^3}{3.14x10^{-4}}$= **$\underline{3.18\text{x}10^8\text{Nm}^{-2}}$** **(1mark)**

17) Material A has larger Young's modulus, (since it has larger slope) **(1mark)**

Material A is more elastic (since it has large Young's modulus) **(1mark)**

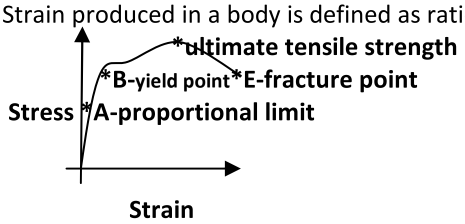
18)$B=\frac{p}{\frac{\Delta V}{V}}$ therefore $\frac{\Delta V}{V}=\frac{P}{B}$ **1mark**

$\frac{\Delta V}{V}=\frac{1.013\text{x}10^6}{3.7\text{x}10^{10}}$ =**$\underline{2.74\text{x}10^{-5}}$** **1mark**

Four mark questions answer;-

1) The restoring force per unit area of the body is called stress **1mark**

Strain produced in a body is defined as ratio of change in dimension to the original dimension **1mark**



2mark

2) a) The maximum stress below which Hooke's law is applicable is called elastic limit **1mark**

b)When a wire is stretched more ,then it has permanent strain even when the stress is zero. Then wire is said to have permanent set . **1mark**

c) When a wire is stretched too much ,then it has permanent strain even when the stress is zero. This behavior of the material is called plastic deformation **1mark**

d)The stretched wire breaks for certain applied stress is fracture point **1mark**

3) Within elastic limit stress and strain are proportional to each other. **(1 mark)**

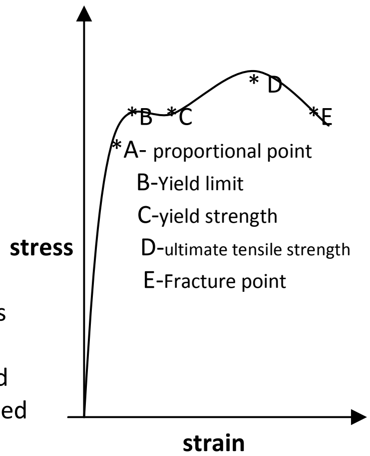
Stress ∝ strain **OR** $\frac{\text{stress}}{\text{stain}}$ = constant (modulus of elasticity). **(1 mark)**

Modulus of elasticity is defined as ratio of stress acting on the body to the resulting strain in it.1mark

[Modulus of elasticity]= $[L^{-1}MT^{-2}]$ **1mark**

FIVE MARK QUESTION ANSWER;-

1) Stress and strain curve for metal is as shown in fig. When a metal Wire is stretched, for small value of load the elongation produced Is proportional to the load. Hence stress is directly proportional to the strain upto point A , obeying Hooke's law. Stress corresponding to the point A is called proportional limit.

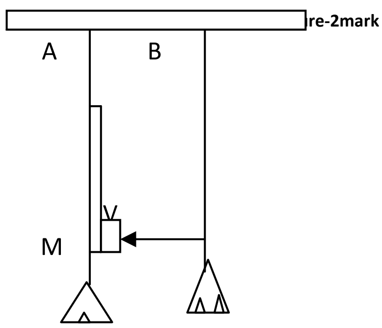


When stress increased beyond A, for a small stress change, there is a large strain up to point B so that stress is directly proportional to strain. But on removal of load the body is still regain its original shape and size , when applied load is less than certain limit. This limit is called elasticity limit.(point B). Metals shows elasticity behavior .

If stress is increased beyond B strain further increase rapidly and if load is removed wire does not regain its original length i.e. the stain produced in the wire is permanent and it is said to have permanent set. Such a deformation is called is plastic deformation.

As stress increased further (beyond C) large strain is produced and wire breaks at E which is known as fracture point

2) Experimental arrangement to determine Young`s modulus of a material wire under tension as shown in the figure. Two identical wires of same length and radius suspended side by side from a fixed rigid support. Reference wire A carries millimetre main scale M and a pan to place the weight. Experimental wire B also carries a pan in which known weights can be placed. Vernier scale V is attached to a pointer at the bottom of the experimental wire helps to find elongation of wire.



Both wire are given an initial small load to keep straight and initial reading is noted. Now experimental wire is gradually loaded with more weights and reading is noted. The difference between two reading gives elongation ΔL of the wire of initial length L and radius r for a load mass M. **2mark**

The Young`s modulus of the material of the experimental wire is given by **Y =** $\frac{\mathbf{MgL}}{\pi r^2 \Delta L}$. **1mark**

Answers to the 5mark problems

1) Stress = $\frac{\text{force}}{\text{area}} = \frac{F}{A} = \frac{\mathbf{F}}{\pi r^2}$ **1mark**

$= \frac{100x10^3}{3.14X(10^{-2})^2}$

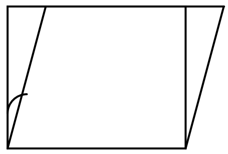
= 3.18x108Nm^{-2} **1mark**

Y=$\frac{\text{stress}}{\frac{\Delta L}{L}}$ **1mark**

$= \frac{3.14x10^8}{\frac{3.2\ x10^{-3}}{2}}$ 1mark

=**$1.96\ x10^{11}Nm^{-2}$** 1mark

2) from figure $\tan\theta = \frac{BC}{AB}$ = 1mm/1m = 0.001 **or** **1mark**



Shearing strain = θ = 0.001(θ small)

Shearing stress = $\frac{\text{tangential force}}{\text{area of the face}}$ = $\frac{F}{A}$ 1mark

$= \frac{1.5\ X\ 10^8}{1}$ = **$1.5x10^8Nm^{-2}$** **1mark**

Modulus of rigidity, G =$\frac{\text{stress}}{\text{strain}}$ 1mark

$= \frac{1.5\ X\ 10^8}{0.001}$ = **$1.5\ x\ 10^{11}Nm^{-2}$** **1mark**

3)ΔV=0.1%of original volume V

=$\frac{0.1}{100}$ =10^{-3}V 1mark

P=ρgh=1000x9.8x100=$9.8x10^5Nm^{-2}$ 1mark

B=$\frac{p}{\frac{\Delta V}{V}}$ 1mark

=$\frac{9.8x10^5}{\frac{10^{-3}V}{V}}$=**$9.8x10^8Nm^{-2}$** 1mark

Compressibility=K=1/B= **$0.1x10^{-8}\ N^{-1}m^2$** 1mark

4)length of steel wire =Ls=5m , area of cross section As=$3x10^{-5}m^2$
length of copper wire =Lc=3.7m , area of cross section Ac=$4x10^{-5}m^2$
extension of steel wire= extension of copper wire=*l*

Young's modulus=**Y=$\frac{FL}{Al}$** 1mark

For steel Ys=$\frac{FLs}{Asl}$

For copper Yc=$\frac{FLc}{Acl}$ 1mark

$\frac{Y_S}{Y_C} = \frac{\frac{FLs}{Asl}}{\frac{FLc}{Acl}} = \frac{L_S A_C}{L_C A_S}$ 1mark

=$\frac{5x4x10^{-5}}{3.7x3x10^{-5}}$ 1mark

=**1.8** 1mark

5)total load on steel wire =Fs=4+6=10Kgwt=10x9.8=98N
Ls=1.5m ΔLs=? Ys=$2x10^{11}Nm^{-2}$ A=$5x10^{-6}$ m^2
Load on brass wire=Fb=6kgwt=6x9.8=58.8N 1mark
Lb=1m ΔLb=? Yb=$0.91x10^{11}Nm^{-2}$ A=$5x10^{-6}$ m^2

Young's modulus=**Y=$\frac{FL}{A\Delta L}$** 1mark

For steel Ys=$\frac{FsLs}{A\Delta Ls}$ hence elongation for steel= ΔLs=$\frac{FsLs}{AYs}$=$\frac{98x1.5}{5x10^{-6}x2x10^{11}}$ 1mark

=**$1.47X10^{-4}m$** 1mark

For brass Yb=$\frac{FbLb}{A\Delta Lb}$ hence elongation for brass= ΔLb=$\frac{FbLb}{AYb}$=$\frac{58.8x1}{5x10^{-6}x0.91x10^{11}}$ 1mark

=**$1.29X10^{-4}m$**

6)A=$2x10^{-4}m^2$, Y=$3.6x10^{11}Nm^{-2}$

Let L original length then ΔL=1.5L- L=0.5L 1mark

Young's modulus=**Y=$\frac{FL}{A\Delta L}$** **1mark**

F=$\frac{YA\Delta L}{L}$ =$\frac{3.6x10^{11}x2x10^{-4}x0.5L}{L}$ 2mark

=**$3.6x10^7N$** **1mark**