IAS & IFS

(Objective & Conventional)
Previous Solved Questions

Strength of Materials

Previous 35 Years Solved Questions of
Civil & Mechanical Engineering

Useful for ESE, CSE, State Engg. Services, PSUs and Other Competitive Examinations

Dr. U.C. Jindal

M.Tech, Ph.D.
Former Professor & Head of the Department
Department of Mechanical Engineering
Delhi College of Engineering, Delhi

MADE EASY PUBLICATIONS

MADE EASY Publications

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016
E-mail: infomep@madeeasy.in
Contact: 011-45124660, 8860378007
Visit us at: www.madeeasypublications.org

IAS & IFS (Objective & Conventional) Previous Solved Questions : Strength of Materials

First Edition: 2015
Reprint : 2017
Second Edition (Revised) : 2018
Reprint : 2022
Reprint : 2023

Reprint : 2024

Preface

I am thankful to **Mr. B. Singh, CMD of MADE EASY Group**, who is ever ready to help the Student Community by providing them newest type of books, as in the present book with typical/thought provoking/mind racking questions asked in IFS and IAS. Prelims and Mains of UPSC, for the last 35 years for both Civil and Mechanical Engineering, in the subject of Strength of Materials. For the solution of each question a student must be equipped with strong concepts in the subject, and the students are the beneficiaries of the latest and comprehensive knowledge of the subject of the qualified and dedicated faculty of MADE EASY.

In the present form, the book has been thoroughly revised and enlarged including the question of IAS and IFS.

Further improvements in the text of the book will be made after getting the feedback from the students.

Any error in printing or calculations pointed out by the reader will be acknowledged with thanks by the author.

Dr. U.C. Jindal

Author

Contents

IAS & IFS (Objective & Conventional) Previous Solved Questions

Strength of Materials

01 CHAPTER

Simple Stresses in Uniform and Compound Bars

Q.1.1 A steel rod of length 300 mm and diameter 30 mm is subjected to a pull P, and the temperature rise is 100°C. If the total extension of the rod is 0.40 mm, calculate the magnitude of P. Take α for steel = 12×10^{-6}/°C and $E = 0.215 \times 10^6$ N/mm^2.

[CSE-Mains, 2011, CE : 12 Marks]

Solution:

$$P = \text{Pull in N}$$

$$A = \text{Area of cross-section} = \frac{\pi}{4} \times 30^2 = 706.86 \text{ mm}^2$$

Extension due to pull, (assuming pull axial)

$$\delta l_1 = \frac{P}{AE} \times L = \frac{P \times 300}{706.86 \times 0.215 \times 10^6} = 1.974 \times 10^{-6} P \text{ mm}$$

δl_2 extension due to temperature change

$$= \alpha L \Delta T$$

$$= 12 \times 10^{-6} \times 300 \times 100 = 0.36$$

$$0.36 + 1.974 \times 10^{-6} P = 0.4 \quad \text{total extension}$$

$$1.974 \times 10^{-6} P = 0.04$$

$$P = \frac{0.04 \times 10^6}{1.974} = 20263 \text{ N} = 20.263 \text{ kN}$$

Q.1.2 A metallic bar 250 mm × 100 mm × 50 mm is loaded as shown in the figure 1.1. Work out the change in volume. What should be the change that should be made in the 4 MN load in order that there should be no change in the volume of the bar.

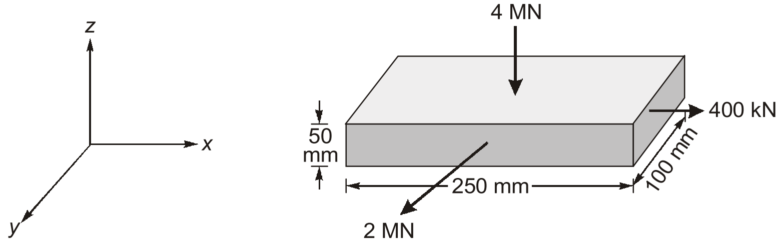


Fig. 1.1

Assume $E = 2 \times 10^5$ N/mm^2, Poisson's ratio = 0.25.

[IFS 2011, CE : 15 Marks]

$\sigma_{bb} = \sigma_{aa} \times (a)^2 = 100 \times (0.861)^2$
$= 75 \text{ N/mm}^2$

48. (a)
Maximum strain energy per unit volume without permanent distortion = Modulus of resilience.

49. (a)
P only, maximum slope of cable at *P*.

50. (b)

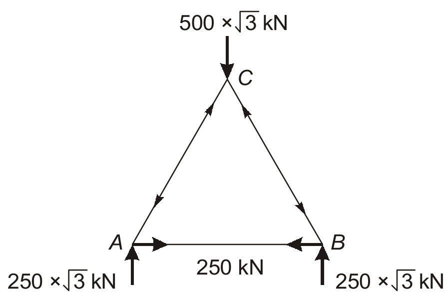


Fig. 1.27

Extension in AB – Components of contraction in CA and CB

$$\delta B = \frac{250\times 10^3}{500}\times\frac{1000}{2\times 10^5} - 2\times\frac{500\times 10^3\times 1000}{500\times 2\times 10^5}\times\cos 60°$$
$$= +2.5 - 5 = -2.5 \text{ mm or } 2.5 \text{ mm}$$

51. (b)

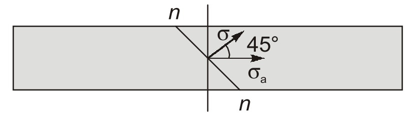


Fig. 1.30

$$\sigma_a = \frac{T}{a^2}$$
$$\sigma_{bb} = \frac{T}{a^2}\times(\cos 45)^2 = \frac{T}{2a^2}$$

52. (b)

$\delta L = 0.03$ mm
$L = 150$ mm
$E = 2 \times 10^5 \text{ N/mm}^2$
$$\sigma = \frac{\delta L}{L}\times E = \frac{0.03}{150}\times 2\times 10^5$$
$= 40 \text{ N/mm}^2$

53. (a)

$E = 2.1\times 10^5 \text{ N/mm}^2$, $\nu = 0.25$
$$G = \frac{E}{2(1+0.25)} = \frac{2.1\times 10^5}{2.5}$$
$= 0.84 \times 10^5 \text{ N/mm}^2$

■■■■

02
CHAPTER

Principal Stresses

Q.2.1 At a section in a beam the tensile stress due to bending is 50 N/mm^2 and there is shear stress of 20 N/mm^2. Determine from first principles, the magnitude and direction of principal stress and calculate the maximum shear stress

[IFS, 2012, ME : 10 Marks]

Solution:

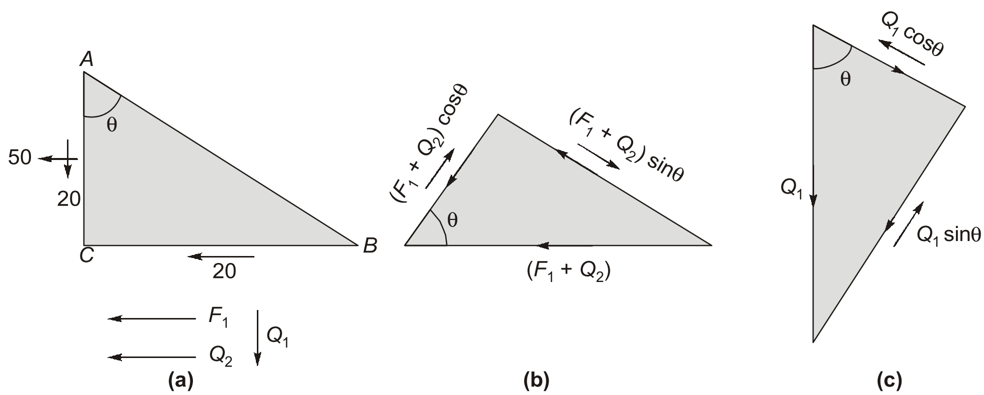


Fig. 2.1

Figure shows an element *ABC* unit of thickness subjected to normal and shear stresses as given. On plane *BC* there is complementary shear stress of 20 N/mm^2 as shown in figure 2.1(a).

Normal force, $F_1 = 50 \times AC$

Shear force, $Q_1 = 20 \times AC$

Shear force, $Q_2 = 20 \times BC$

Normal force on inclined plane *AB*

$$F_n = (F_1 + Q_2)\cos\theta + Q_1 \sin\theta$$

$$\sigma_n \times AB = (F_1 + Q_2)\cos\theta + Q_1 \sin\theta$$

or $$\sigma_n \times AB = 50\,AC\cos\theta + 20\,BC\cos\theta + 20\,AC\sin\theta$$

or $$\sigma_n = 50\cos^2\theta + 20\sin\theta\cos\theta + 20\cos\theta\sin\theta$$

$$= 50\cos^2\theta + 20\sin 2\theta$$

$$F_t = \text{tangential force on plane } AB$$

$$\tau_\theta \times AB = (F_1 + Q_2)\sin\theta - Q_1\cos\theta$$

or $$\tau_\theta = \frac{F_1\sin\theta}{AB} + \frac{Q_2\sin\theta}{AB} - \frac{Q_1\cos\theta}{AB}$$

Note *from figures, that internal resistance is equal and opposite to the applied forces on inclined plane.*

$$\frac{101}{3}E_A\left[1-\frac{G_B}{G_A}\right] = G_B$$

$$\frac{101E_A}{3} = G_B+\frac{101E_A}{3}\times\frac{G_B}{G_A}$$

$$G_B\left[1+\frac{101E_A}{3G_A}\right] = \frac{101E_A}{3}$$

$$G_B\left[\frac{3G_A+101E_A}{3G_A}\right] = \frac{101E_A}{3}$$

$$G_B = \frac{101E_A G_A}{3G_A+101E_A} = \frac{101E_A G_A}{101+3G_A/E_A}$$

$$= \frac{G_A}{1+\dfrac{3G_A}{101E_A}} = \frac{G_A}{1+0.03\dfrac{G_A}{E_A}}$$

Objective Questions

Q.1 The complementary shear stresses of intensity τ are induced at a point in the material, as shown in the figure 2.20. Which of the following is the correct set of orientation of principal planes with respect to AB.

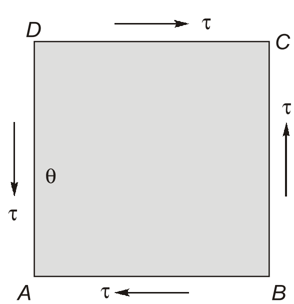


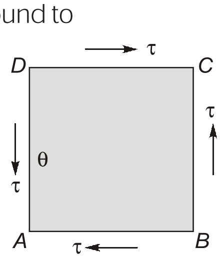
Fig. 2.20

(a) 30° and 120° (b) 45° and 135°
(c) 60° and 150° (d) 75° and 105°

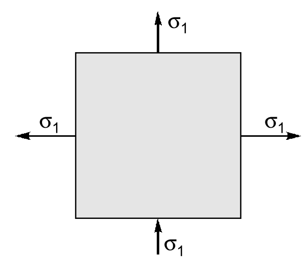
[CSE-Prelims, ME : 1998]

Q.2 A material element is subjected to a plane state of stress such that the maximum shear stress is equal to the maximum tensile stress would compound to

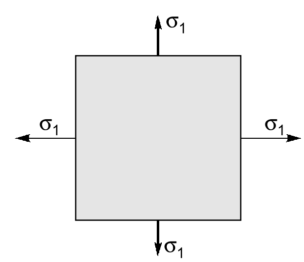
(a)



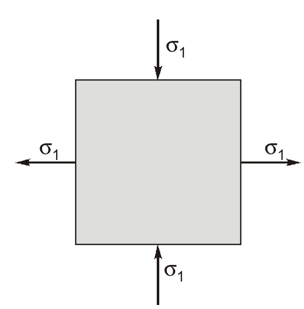
(b)



(c)



(d)



[CSE-Prelims, ME : 1998]

Q.3 For the given stress condition σ_x = 2 N/mm^2, σ_y = 0, τ_{xy} = 0, the correct Mohr's circle is

03 Thin and Thick Shells

CHAPTER

Q.3.1 Derive a formula for increase in volume of a thin metallic sphere when it is subjected to an internal pressure p. A thin spherical shell of copper has a diameter of 400 mm and a wall thickness of 2 mm and just full of water at atmospheric pressure. Calculate the volume of water pumped in to raise the inside pressure to 1.5 N/mm^2. The modulus of elasticity of copper is 1×10^5 N/mm^2. K (Bulk modulus) is 2.5×10^3 N/mm^2 and Poisson's ratio ν is 0.25)

[CSE-Mains, 2000, ME : 20 Marks]

Solution:

(a) When a thin spherical shell is subjected to internal pressure p, circumferential stress, σ_c is developed in wall of the shell as shown in figure 3.1.

$$\sigma_c = \frac{pD}{4t}$$

where p = pressure, D = diameter, t = wall thickness, ε_c = circumferential strain

$$\varepsilon_c = \frac{\sigma_c}{E} - \frac{\nu\sigma_c}{E} = \frac{pD}{4tE}(1-\nu)$$

Volumetric strain, $$\varepsilon_v = 3\varepsilon_c = \frac{3pD}{4tE}(1-\nu)$$

(Neglecting the effect of p)

$$V\text{, volume of shell} = \frac{\pi D^3}{6}$$

$$\delta V\text{, change in volume} = e_v V = \frac{3pD}{4tE}(1-\nu)\times\frac{\pi D^3}{6}$$

(b)

$$D = 400 \text{ mm}$$
$$t = 2 \text{ mm}$$
$$p = 1.5 \text{ N/mm}^2$$

$$\sigma_c = \frac{pD}{4t} = \frac{1.5\times 400}{4\times 2} = 75 \text{ N/mm}^2$$

$$\varepsilon_v = 3\frac{pD}{4tE}(1-\nu) = \frac{3\times 75}{E}(1-0.25)$$

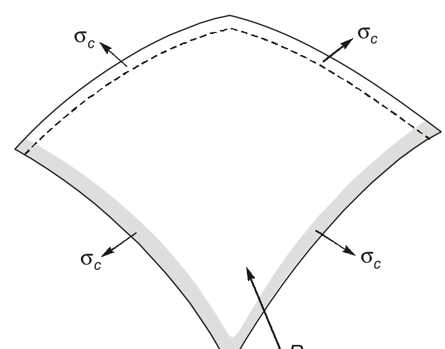


Fig. 3.1

$$50 = \frac{B}{900} - A \quad \text{...(ii)}$$

From these equation

Constant, $B = (150)(450)$

Constant, $A = \frac{B}{900} - 50 = \frac{150 \times 450}{900} - 50 = 25 \text{ MPa}$

Let as take, r = means radius

$$= \frac{30 + 51.96}{2} = 40.98 \text{ mm}$$

$$\sigma_{c\,mean} = \frac{150 \times 450}{40.98^2} + 25 = 40.2 + 25 = 65.2 \text{ MPa}$$

$$\sigma_{r\,mean} = \frac{150 \times 450}{40.98^2} - 25 = 40.2 - 25 = 15.2 \text{ MPa}$$

Variation of stresses

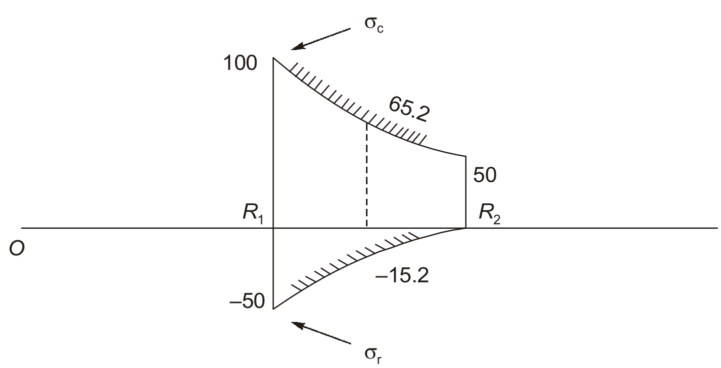


Fig. 3.11 *Variation of hoop and radial stresses along the thickness of the cylinder*

Objective Questions

Q.1 Match **List-I** (Terms used in thin cylinder stress analysis) with **List-II** (Mathematical expression) and select the correct answer.

List-I

A. Hoop stress, σ

B. Maximum in plane shear stress

C. Longitudinal stress

D. Cylinder thickness

List-II

1. $\frac{pd}{4t}$

2. $\frac{pd}{2t}$

3. $\frac{pd}{2\sigma}$

4. $\frac{pd}{8t}$

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	2	4	3	1
(c)	2	3	4	1
(d)	2	4	1	3

[CSE-Prelims, ME : 1998]

Q.2 A thin cylinder of diameter d, thickness t is subjected to an internal pressure 'p'. Change in diameter is (where E is the modulus of elasticity and μ is the Poisson's ratio.)

(a) $\frac{pd^2}{4tE}(2-\mu)$ (b) $\frac{pd^2}{2tE}(1+\mu)$

(c) $\frac{pd^2}{tE}(2+\mu)$ (d) $\frac{pd^2}{4tE}(2+\mu)$

[CSE-Prelims, ME :1998]

Q.12 **Note:** 'p' is the internal fluid pressure
A thin cylindrical shell is subjected to the loads as shown in figure. The element marked 'A' will be subjected to

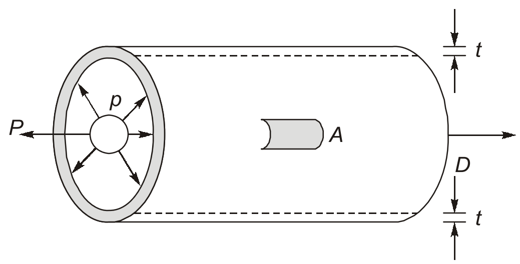


Fig. 3.12

(a) biaxial compressive stresses
(b) biaxial tensile stresses
(c) uniaxial compressive stresses
(d) tensile stress along the longitudinal direction only

[CSE-Prelims, ME : 2004]

Q.13 The maximum hoop stress in a thick cylinder under internal pressure would occur at which of the following locations?
(a) At the inner surface
(b) At the outer surface
(c) At mid thickness
(d) Between the inner surface and mid thickness

[CSE-Prelims, ME : 2008]

Q.14 A thin cylindrical pressure pipe with both ends closed has diameter 1000 mm. The pipe is subjected to an internal pressure of 4 N/mm^2. The permissible tensile stress in the material is 100 N/mm^2. What is the minimum required thickness of the pipe?

(a) 5 mm (b) 10 mm
(c) 40 mm (d) 20 mm

[CSE-Prelims, ME : 2008]

Q.15 What is the change in diameter D of a thin spherical shell of wall thickness t when subjected to an internal fluid pressure p? (E = Young's modulus of μ = Poisson's ratio)

(a) $\frac{pD^2}{3tE}(1-\mu)$ (b) $\frac{pD}{4tE}(1-\mu)$
(c) $\frac{pD^2}{4tE}(1-\mu)$ (d) $\frac{pD^2}{4tE}(1-2\mu)$

[CSE-Prelims, ME : 2010]

Q.16 A thin cylindrical shell is subjected to internal pressure, such that hoop strain is approximately five times the axial strain, what is the material of the shell (depending on Poisson's ratio)
(a) Steel (b) Cast iron
(c) Aluminium (d) Wrought iron

Q.17 A thin cylindrical shell made of steel is subjected to internal pressure such that hoop stress developed in shell is 120 MPa. This shell is subjected to axial compressive stress such that there is no change in the length of the shell. (There are end plates on the shell). If E = 200 GPa, Poisson's ratio is 0.3. What is axial compressive stress applied on cylinder
(a) 90 MPa (b) 60 MPa
(c) 36 MPa (d) 24 MPa

Answers

1. (d)	2. (a)	3. (d)	4. (c)	5. (c)
6. (a)	7. (c)	8. (b)	9. (c)	10. (d)
11. (c)	12. (b)	13. (a)	14. (d)	15. (c)
16. (c)	17. (d)			

Explanations

1. (d)

σ_1, Hoop stress $\frac{pD}{2t}$ — 2

Maximum shear stress, $\frac{pD}{8t}$ — 4

Longitudinal Stress, $\frac{pD}{4t}$ — 1

Cylinder thickness t , $\frac{pD}{2\sigma}$ —3

2. (a)

$$\varepsilon_c = \frac{pd}{2tE} - \frac{\nu pd}{4tE} = \frac{pd}{4tE}(2-\nu)$$

$$\delta d = \varepsilon_c \times d = \frac{pd^2}{4tE}(2-\nu)$$

04 CHAPTER Shear Force and Bending Moment Diagrams

Q.1 A beam *ABCD*, 10 m long is supported at *B*, 1 m from end *A* and at *C*, x is from end *D*. The beam carries a point load of 10 kN at end *A* and a UDL of 4 kN/m throughout its length fig. 4.1. Determine the value of x if centre of the beam is the point of contraflexure. Draw the BM diagram.

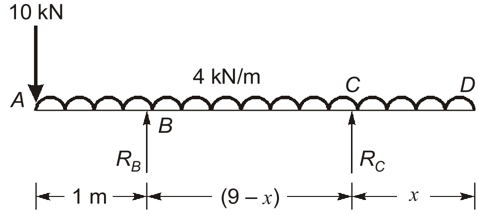


Fig. 4.1

[CSE-Mains, 2004, ME : 30 Marks]

Solution:

$$\text{Total load on beam} = 10 + 40 = 50 \text{ kN}$$

Reaction

Take moments about *B*

$$(9 - x)R_C + 10 \times 1 = 40 \times 4$$

$$R_C = \frac{150}{9 - x} \qquad \ldots(i)$$

$$R_B = 50 - \frac{150}{9-x} = \frac{450 - 50x - 150}{9-x} = \frac{300 - 50x}{9-x}$$

Moments about centre of the beam

$$-10 \times 5 + R_B \times 4 - 4 \times 5 \times 2.5 = 0$$

$$-50 + \frac{4(300 - 50x)}{9-x} - 50 = 0$$

$$\frac{4(300-50x)}{9-x} = 100$$

$$300 - 50x = 225 - 25x$$

$$75 = 25x$$

$$x = 3 \text{ m}$$

$$R_B = \frac{300 - 50x}{9-x} = \frac{150}{6} = 25 \text{ kN}$$

BMD

$$M_A = 0$$
$$M_B = -10 \times 1 - 4 \times 0.5 = -12 \text{ kNm}$$
$$M_3 = -10 \times 3 + 25 \times 2 - 4 \times 3 \times 1.5$$
$$= -30 + 50 - 18 = +2 \text{ kNm}$$
$$M_5 = -10 \times 5 + 25 \times 4 - 5 \times 4 \times 2.5$$
$$= -50 + 100 - 50 = 0$$
$$M_C = M_7 = -3 \times 4 \times 1.5 = -18 \text{ kNm}$$
$$M_D = 0$$

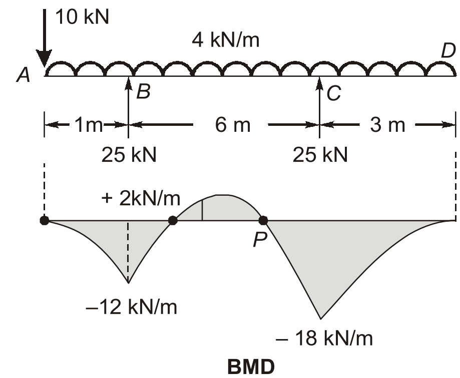


Fig. 4.2

Q.4.2 On a simply supported beam (10 m span), a concentrated load (10 kN) and a moment of 40 kNm act a section 7 m from one of the ends. Draw the shear force and bending moment diagrams. Indicate the points of contraflexure, if any

[ICSE-Mains, 2012, ME : 10 Marks]

Solution:

Fig. shows a beam *AB*, 10 m long, simply supported at ends carrying a load of 10 kN at *C* and moment 40 kNm at *C*, 7 m from *A*

Reaction

Taking moment about *A*

$$70 + 40 = 10\,R_B$$

Reactions, $R_B = 11$ kN

Reaction, $R_C = 10 - 11 = -1$ kN

SF diagrams

$$F_{AC} = -1 \text{ kN}$$
$$F_{CB} = -1 - 10 = -11 \text{ kN}$$

Fig. (b) shows SFD

BM diagram

$$M_A = 0$$
$$M_C = -1 \times 7 = -7 \text{ kNm}$$
$$M_C' = -7 + 40 = +33 \text{ kNm}$$
$M_B = 0$, Fig. (C) shows BMD

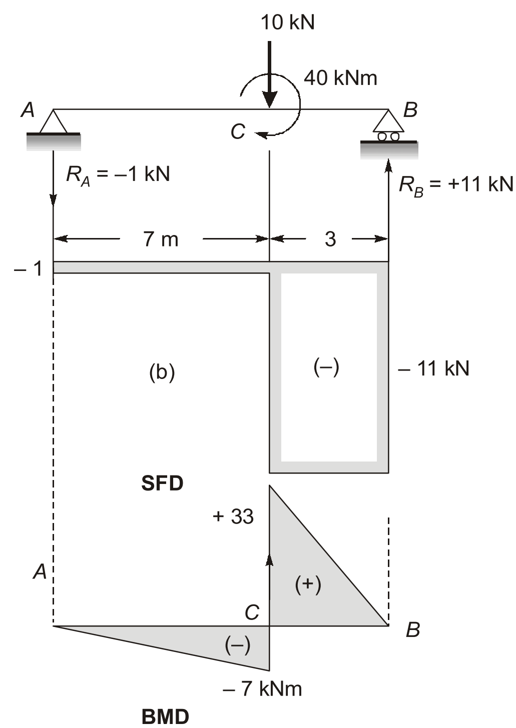


Fig. 4.3

Q.4.3 A beam *ABCD* is loaded as shown in figure 4.4. The beam is of rectangular section 50 mm × 100 mm.

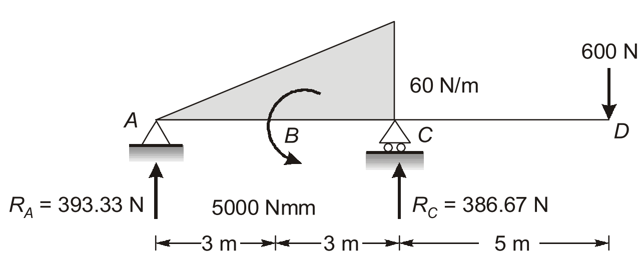


Fig. 4.4

(i) Sketch the SF and BM diagrams of the beam

(ii) Determine the maximum bending stress at section B of the beam

[CSE-Mains, 2011, ME : 25 Marks]

07 Chapter

Torsion

Q.7.1 Design two solid circular shafts to transmit 200 HP each without exceeding a shear stress of 70 MPa at 20 rpm and other at 20,000 rpm. Give your inference about the final results from the view point of economy. Do you have any other suggestion to improve the economy further?

[CSE-Mains, 2013, CE: 10 Marks]

Solution:

$$HP = 200$$

Shaft-1

$$RPM = 20$$

$$\omega_1 = \frac{2\pi \times 20}{60} = 2.0944 \text{ rad/sec}$$

Torque,
$$T_1 = \frac{200 \times 746}{2.094} = 71251.194 \text{ Nm} = 71251.194 \times 10^3 \text{ Nmm}$$

$$71251194 = \frac{\pi}{16} \times d_1^3 \times \tau = \frac{\pi}{16} \times d_1^3 \times 70$$

$$d_1^{\,3} = 5183990.724 \text{ mm}^3$$

$$d_1 = 172.98 \text{ mm, shaft diameter}$$

Shaft-2

$$\text{RPM} = 20{,}000$$

$$\omega_2 = \frac{2\pi \times 20000}{60} = 2094.4 \text{ rad/sec}$$

Torque,
$$T_2 = \frac{200 \times 746}{2094.4} = 71.251 \text{ Nm} = 71.25 \times 10^3 \text{ Nmm}$$

$$71251 = \frac{\pi}{16} d_2^3 \times \tau = \frac{\pi}{16} d_2^3 \times 70,\ d_2^3 = 5183.0$$

$$d_2 = 17.3 \text{ mm, shaft diameter}$$

Shaft 1 at 20 rpm

Shaft diameter is too large. There is hardly any machine which runs at 20 rpm for power transmission.

Shaft 2 at 20,000 rpm

Shaft diameter is reduced to one tenth from 173 mm to 17.3 mm. There is saving in material by 99%. But at high speed of rotation, large centrifugal forces are developed if there is any eccentric mass on shaft, which will produce large deflection and slope in the shaft, rigidity is drastically reduced. Even to instal any gear, pulley for power transmission, keyways cannot be made on a shaft of 17.3 mm.

(a) 900 Nm (b) 700 Nm
(c) 500 Nm (d) 450 Nm

[CSE-Prelims, ME : 2002]

Q.6 A hollow shaft of length L is fixed at its both ends. It is subjected to torque T at a distance of $L/3$ from one end. What is the reaction torque at the other end of the shaft?

(a) $\frac{2T}{3}$ (b) $\frac{T}{2}$
(c) $\frac{T}{3}$ (d) $\frac{T}{4}$

[CSE-Prelims, ME : 2007]

Q.7 Consider the following statements, in connection with a metallic rod of a circular section being subjected to equal and opposite torque T within elastic limit:

1. The transverse section of the rod does not experience warping.
2. The diameter of rod does not alter.
3. Angle of relative twist between two sections is proportional to the lengths between these sections.
4. A surface element of the rod is under pure shear state of stress.

Which of these statements are correct?

(a) 1, 2, 3 and 4 (b) 1, 2 and 3 only
(c) 2 and 3 only (d) 2, 3 and 4 only

[CSE-Prelims, ME : 2009]

Q.8 Which one of the following is true for torsional shear stress at the axis of a circular shaft?

(a) Minimum (b) Maximum
(c) Negative (d) Zero

Q.9 A circular shaft of length 'L' is held at two ends without rotation. A twisting moment 'T' is applied at a distance 'L'/3 from left support as shown in the given figure 7.17. The twisting moment in the portion AB will be

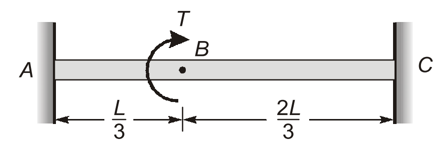


Fig. 7.17

(a) T (b) $T/3$
(c) $T/2$ (d) $2T/3$

Q.10 A circular shaft of length 'L' a uniform cross-sectional area 'A' and modulus of rigidity 'G' is subjected to a twisting moment that produces maximum shear stress 'τ' in the shaft. Strain energy in the shaft is given by the expression $\tau^2 AL/kG$, where k is equal to

(a) 2 (b) 4
(c) 8 (d) 16

[CSE-Prelims, CE : 2001]

Q.11 When subjected to a torque, a circular shaft undergoes a twist of 1° in a length of 1200 mm, and the maximum shear stress induced is 80 N/mm^2. The modulus of rigidity of the material of the shaft is 0.8×10^5 N/mm^2. What is the radius of the shaft?

(a) $90/\pi$ mm (b) $108/\pi$ mm
(c) $180/\pi$ mm (d) $216/\pi$ mm

[CSE-Prelims, CE : 2008]

Q.12 Power is transmitted through a shaft, rotating at 2.5 Hz (150 rpm). The mean torque on the shaft is 20×10^3 Nm. What magnitude of power in kW is transmitted by the shaft?

(a) 50π (b) 120π
(c) 100π (d) 150π

[CSE-Prelims, CE : 2009]

Answers

1. (d)	2. (d)	3. (c)	4. (a)	5. (d)
6. (c)	7. (a)	8. (d)	9. (d)	10. (b)
11. (d)	12. (c)			

Explanations

1. (d)

$$\frac{G\theta}{L} = \frac{\tau}{0.5D} = \frac{\tau'}{0.5D}$$

Same θ, same outer diameter

$$\tau = \tau'$$

2. (d)

$$SF = 400 \text{ N}$$
$$BM = 100 \text{ Nm}$$

11 CHAPTER

Strain Energy Methods

Q.11.1 The L-shaped bar shown in figure 11.1 is of uniform cross-section 60 mm × 120 mm. Calculate the total strain energy. Take $E = 2 \times 10^5$ MPa, $G = 0.8 \times 10^5$ MPa.

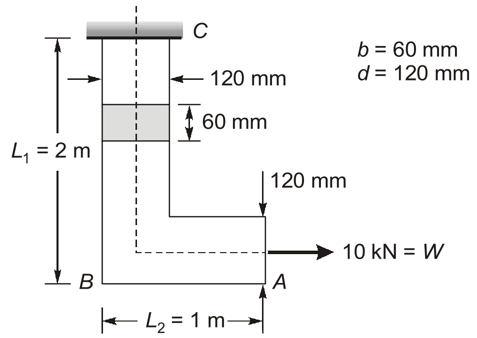


Fig. 11.1

[IFS 2011, CE : 10 Marks]

Solution:

Total strain energy

$$U = U_B + U_S + U_A$$

= Strain energy due to bending of BC + Strain energy due to shear of BC + Strain energy due to axial load W

$$= \frac{W^2 L_1^3}{6EI} + \frac{3W^2 L_1}{5Gbd} + \frac{W^2 L_2}{2AE}$$

Where, W = 10,000 N, L_1 = 2000 mm, L_2 = 1000 mm, $E = 2 \times 10^5$ MPa, $G = 0.8 \times 10^5$ MPa

$$I = \frac{bd^3}{12} = \frac{60 \times 120^3}{12} = 8.64 \times 10^6 \text{ mm}^4$$

b = 60 mm, d = 120 mm

$A = b \times d = 60 \times 120 = 7200 \text{ mm}^2$

Putting the values

Strain energy,
$$U = \frac{(10000)^2 \times (2000)^3}{6 \times 2 \times 10^5 \times 8.64 \times 10^6} + \frac{(10000)^2 \times 0.6 \times 2000}{0.8 \times 10^5 \times 60 \times 120} + \frac{(10000)^2 \times 1000}{2 \times 7200 \times 2 \times 10^5}$$

= 77160.5 + 208.33 + 357.143 Nmm

= 77725.967 Nmm = 77.725 Nm

Solution:

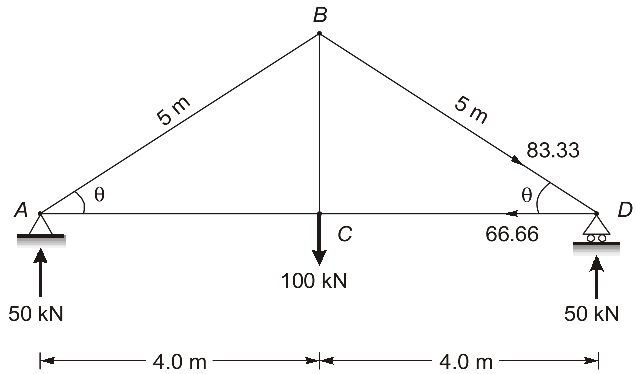


Fig. 11.15

$$\tan\theta = \frac{3}{4}$$

$$\theta = 36.87°$$

$$\sin\theta = 0.6$$

$$\cos\theta = 0.8$$

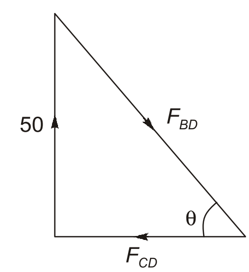
Forces in members

$$F_{BC} = +100 \text{ kN (T)}$$

$$F_{AC} = F_{CD} = +66.66 \text{ kN (T)}$$

$$F_{AB} = F_{BD} = -83.33 \text{ kN (C)}$$

at D



Unit load at B

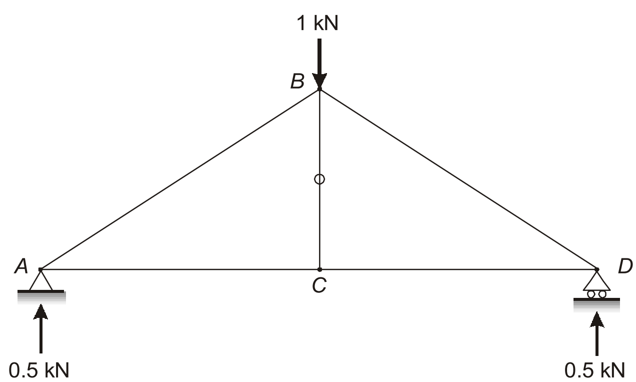


Fig. 11.16

Force in members

$$F'_{BC} = 0$$

$$F_{AB}' = F' = -0.833 \text{ (C)}$$

$$F_{AC}' = F_{CD}' = +0.666 \text{ (T)}$$

$$\delta, \text{ deflection at } B = \frac{\Sigma nNL}{AE} = \frac{1046}{AE} \text{ m}$$

A, area of cross-section in m^2

E, Young's modulus is kN/m^2.

Members	n	N	L	nNL
AB	–0.833	–83.33	5 m	+347
BD	–0.833	–83.33	5 m	+347
AC	+0.666	+66.66	4 m	+176
CD	+0.666	+66.66	4 m	+176
BC	0	100	3 m	0

■■■■

Chapter 13

Rotational Stresses

Q.13.1 A circular disc 50 cm outside diameter has a central hole and rotates at a uniform speed about an axis through its center. The diameter of the hole is such that the maximum stress due to rotation is 85% of that in the thin ring whose mean diameter is also 50 cm. If both are of the same material and rotate at the same speed, determine the diameter of the central hole and speed of the disc for the datas given

Allowable stress = 900 kg/cm^2

Specific weight = 7.8 gm/cm^3

Poisson's ratio = 0.3

[CSE-Mains, 2006, ME : 30 Marks]

Solution:

In a thin disc, $\sigma_{C\,max}$ occurs at inner radius, R_1

If R_2 is outer radius = 250 mm

$$\sigma_{C\,max} = \frac{\rho w^2}{g}\left[k_1\left(2R_2^2 + R_1^2\right) - k_2 R_1^2\right]$$

$$k_1 = \frac{3+\nu}{8} = \frac{3.3}{8} = 0.4125$$

$$k_2 = \frac{1+3\nu}{8} = \frac{1.9}{8} = 0.2375$$

$$= \frac{\rho\omega^2}{g}\left[0.4125\left(2\times 250^2 + R_1^2\right) - 0.2375 R_1^2\right]$$

$$= 0.85\frac{\omega^2 \times 250^2}{g}\times\rho \qquad \left[\text{stress in ring} = \frac{\omega^2 r^2 \rho}{g}\right]$$

$$0.85 \times 250^2 = 0.825 \times 250^2 + 0.175\, R_1^{\,2}$$

$$0.025 \times 250^2 = 0.175\, R_1^{\,2}$$

$$R_1 = 94.5 \text{ mm}$$

$$\text{Allowable stress} = 900 \text{ kg/cm}^2 = 900 \times 9.81/\text{cm}^2 = 88.29 \text{ N/mm}^2$$

$$7.8\times 10^{-6}\times\frac{0.85\times\omega^2\times 250^2}{9810} = 88.29 \text{ N/mm}^2$$

$$\omega^2 = 2090195.84$$

$$\omega = 1445.175 \text{ rad/sec}$$

$$N = 13806 \text{ rpm}$$

Answers

1. (a)	2. (c)	3. (b)	4. (b)	5. (a)
6. (d)	7. (b)	8. (d)	9. (c)	10. (c)
11. (c)	12. (c)	13. (c)	14. (b)	15. (b)
16. (d)	17. (c)	18. (b)	19. (a)	20. (d)
21. (b)	22. (b)	23. (a)		

Explanations

1. (a)
Both A and R are true, R is the correct explanation of A.

2. (c)
A is true but R is false,
Line of action of the load must pass through the shear centre.

3. (b)
Both, A and R are true but R is not the correct explanation of A.

4. (b)
Both A and R are true but R is not the correct explanation of A.

5. (a)

A. Proof stress	2. Tensile test
B. Endurance limit	3. Fatigue test
C. Leaf spring	4. Beam of uniform strength
D. Modulus of rigidity	1. Torsion test

6. (d)
A is false, R is true.

7. (b)
Both A and R are true but R is not the correct explanation of A.

8. (d)
A is false but R is true.

9. (c)
A is true but R is false.

10. (c)

A. Membrane stress	3. Cylindrical shell subjected to fluid pressure
B. Torsional shear stress	2. Close coiled helical spring under axial load
C. Double shear stress	4. Rivets of double strap butt joint
D. Maximum shear stress	1. Neutral axis of beam

11. (c)

A. Square thread	3. Used is screw jack
B. Acme thread	2. Used is lead screw
C. Buttress thread	1. Used in vice
D. Trapezoidal thread	4. Used in power transmission devices in machine tool

12. (c)
A. Structural member falls in axial compression
B. A member falls along a 45° helical plane subjected to torsion
C. A structural member bends and collapse under axial compression load
D. A member falls in double shear for a joint
3. Strut
4. Cast iron round bar subjected to torsion
2. Long column
1. Knuckle joint

13. (c)
Granular helicoid — Type of fracture in brittle material under torsion.

14. (b)
Modulus of rigidity ≠ strain energy per unit volume.

15. (b)
Both A and R are individually correct but R is not the correct explanation of A.

16. (d)
Fatigue life of a ball bearing is inversely proportional to cube of load.

17. (c)

A. $\frac{dU}{dW}$	4. Deflection
B. $\frac{dy}{dx}$	2. Slope

C. $\frac{d^2y}{dx^2}$ 3. Equation of BM

D. $\frac{dM}{dx}$ 1. Shear force

18. (b)
Both A and R are individually true but R is not the correct explanation of A.

19. (a)

A. Beam	4. Bending
B. Column	3. Buckling
C. Shaft	1. Twisting
D. Spring	2. Strain energy storage

20. (d)
F = MLT^{-2}, β = MLT^{-4}

21. (b)

$$F_1 + F_2 = 6\hat{i} + 6\hat{j} + 6\hat{k}$$

$$\text{Unit vector} = \frac{6\hat{i} + 6\hat{j} + 6\hat{k}}{\sqrt{108}}$$

$$= \frac{6\hat{i} + 6\hat{j} + 6\hat{k}}{6\sqrt{3}}$$

$$= \frac{\hat{i}}{\sqrt{3}} + \frac{\hat{j}}{\sqrt{3}} + \frac{\hat{k}}{\sqrt{3}}$$

22. (b)

A. Modulus of elasticity	4. ML^{-1}T^{-2}
B. Work	3. ML^{2}T^{-2}
C. Force	2. MLT^{-2}
D. Frequency	1. T^{-1}

23. (a)

A. *MI* about diametral axis	4. $\frac{\pi D^4}{64}$
B. *MI* about an axis tangent to perimeter	3. $\frac{5\pi D^4}{64}$
C. *MI* centroidal axis	2. $\frac{17\pi D^4}{64}$
D. Polar moment of inertia	1. $\frac{\pi D^4}{32}$

■■■■