Multiple-Choice Questions

Indian Engineering Services (IES) Examinations (2000–2009)

Year 2000

1. Match List I (end conditions of column) with List II (equivalent length in terms of length of hinged–hinged column) and select the correct answer:

List-I	List-II
(A) Both ends hinged	(1) L
(B) One end fixed and other end free	(2) $\sqrt{2}L$
(C) One end fixed and the other pin-jointed	(3) $2L$
(D) Both ends fixed	(4) $L/2$

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

Answer: (b)
Reference: Chapter 8

2. Match List-I with List-II and select the correct answer:

List-I	List-II
(A) Bending moment is constant	(1) Point of contraflexure
(B) Bending moment is maximum or minimum	(2) Shear force changes sign
(C) Bending moment is zero	(3) Slope of shear force diagram is zero over the portion of the beam
(D) Loading is constant	(4) Shear force is zero over the portion of the beam

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

Answer: (c)
Reference: Chapter 6

3.

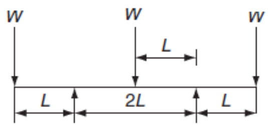
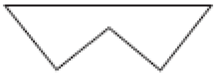
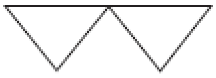
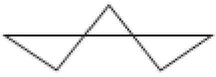


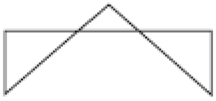
Figure 1

A loaded beam is shown in Figure 1 above. The bending moment diagram of the beam is best represented as:

(a) 

(b) 

(c) 

(d) 

Answer: (a)
Explanation: Let us draw the loading, shear force and bending moment diagrams sequentially as shown in Figure 2:

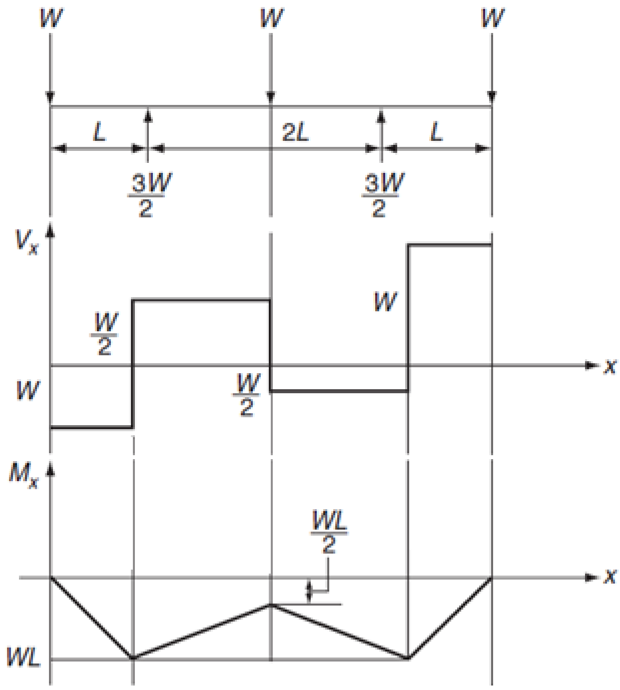


Figure 2

Reference: Chapter 5

4. Plane stress at a point in a body is defined by principal stresses 3σ and σ. The ratio of the normal stress to the maximum shear stress of the plane is:

(a) 1.0
(b) 2.0
(c) 3.0
(d) 4.0

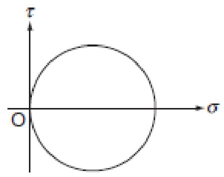
Answer: (b)
Explanation:

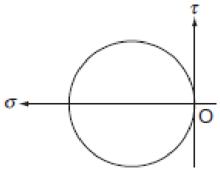
$$\tau_{\max} = M_{\max}\left(\frac{3\sigma}{2}, \frac{\sigma}{2}, \frac{3\sigma - \sigma}{2}\right) = \frac{3\sigma}{2}$$

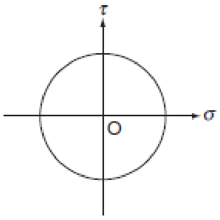
Therefore,

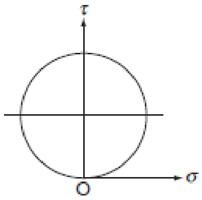
$$\frac{\sigma_{\max}}{\tau_{\max}} = \frac{3\sigma}{(3\sigma/2)} = 2$$

5. Which one of the following Mohr's circles represents the state of pure shear?

(a) 

(b) 

(c) 

(d) 

Answer: (c)
Reference: Chapter 4

6. The state of plane stress in a plate of 100 mm thickness is given as:

$$\sigma_{xx} = 100 \text{ N/mm}^2 \quad \text{and} \quad \sigma_{yy} = 200 \text{ N/mm}^2$$

Young's modulus = 300 N/mm^2;
Poisson's ratio = 0.3.
The stress developed in the direction of thickness is:
(a) 0
(b) 90 N/mm^2
(c) 100 N/mm^2
(d) 200 N/mm^2

Answer: (a)
Explanation: Since in the problem, it is known that *plane-stress situation*, so

$$\sigma_{zz} = 0$$

However, if it were a *plane-strain case*, then

$$\sigma_{zz} = \nu(\sigma_{xx} + \sigma_{yy}) = 0.3(100 + 200) = 90 \text{ N/mm}^2$$

Reference: Chapter 9

7. A circular solid shaft is subjected to a bending moment of 400 kN m and a twisting moment of 300 kN m. On the basis of the maximum principal stress theory, the direct stress is σ and according to the maximum shear stress theory, the shear stress is τ. The ratio $\sigma:\tau$ is
(a) 1:5
(b) 3:9
(c) 9:5
(d) 11:6

Answer: (c)
Explanation: For combined bending-twisting, we know that:

$$\sigma = \frac{32M_e}{\pi d^3}$$

$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

$$= \frac{1}{2}\left[400 + \sqrt{400^2 + 300^2}\right] \text{ kN m}$$

$$= 450 \text{ kN m}$$

Again,

$$\tau = \frac{16T_e}{\pi d^3}; \quad \text{where } T_e = \sqrt{M^2 + T^2} = \sqrt{400^2 + 300^2} = 500 \text{ kN m}$$

Thus,

$$\frac{\sigma}{\tau} = \frac{(32)(450)}{(16)(500)} = 9:5$$

Reference: Chapter 12

8.

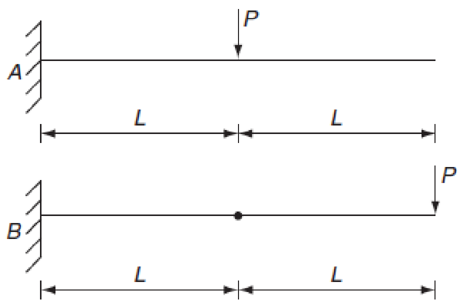


Figure 3

The two cantilevers A and B shown in Figure 3 have the same uniform cross-section and the same material. Free-end deflection of cantilever A is δ. The value of mid-span deflection of the cantilever B is:

(a) δ
(b) 2δ
(c) $\delta/2$
(d) $\delta/3$

Answer: (a)
Explanation: For cantilever A (Figure 4),

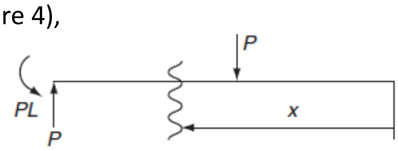


Figure 4

Here, $M_x = 0 - \langle x - L\rangle P(x - L)$. Thus,

$$(EI)y_2 = -M_x = \langle x - L\rangle P(x - L)$$

$$\Rightarrow (EI)y_1 = \langle x - L\rangle \frac{P(x - L)^3}{2} + C_1$$

$$\Rightarrow (EI)y = \langle x - L\rangle \frac{P(x - L)^3}{6} + C_1 x + C_2$$

at $x = 2L,\ y_1 = 0 \ \Rightarrow\ C_1 = -\frac{PL^2}{2}$

and at $x = 2L,\ y = 0 \ \Rightarrow\ C_2 - PL^3 + \frac{PL^3}{6} = 0 \ \Rightarrow\ C_2 = \frac{5PL^3}{6}$. Thus,

$$y = \left(\frac{1}{EI}\right)\left[\langle x-L\rangle \frac{P(x-L)^3}{6} - \frac{PL^2 x}{2} + \frac{5PL^3}{6}\right] \Rightarrow y\big|_{x=0} = \delta = \frac{5PL^3}{6EI}$$

Therefore,

$$\delta = \frac{5PL^3}{6EI}$$

For cantilever B (Figure 5),

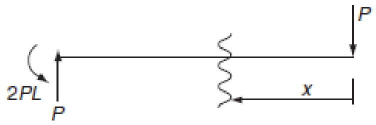


Figure 5

Here,

$$M_x = -P_x \quad \text{or} \quad (EI)y_2 = -M_x = P_x$$

$$(EI)y_1 = \frac{Px^2}{2} + C_1, \text{ at } x = 2L;\, y_1 = 0$$

$$\text{or} \quad C_1 = -2PL^2$$

Therefore,

$$(EI)y_1 = \frac{Px^2}{2} - 2PL^2$$

$$\Rightarrow (EI)y = \frac{Px^3}{6} - 2PL^2 x + C_2$$

at $x = 2L, y = 0 \Rightarrow C_2 = 4PL^3 - \frac{4PL^3}{3} = \frac{8PL^3}{3}$. Therefore,

$$(EI)y = \frac{Px^3}{6} - 2PL^2 x + \frac{8PL^3}{3}$$

or

$$y = \left(\frac{1}{EI}\right)\left[\frac{Px^3}{6} - 2PL^2 x + \frac{8PL^3}{3}\right]$$

and so

$$y\big|_{x=L} = \left(\frac{1}{EI}\right)\left[\frac{PL^3}{6} + \frac{8PL^3}{3} - 2PL^2\right]$$

$$= \frac{PL^3}{6EI}(1+16-12) = \frac{5PL^3}{6EI} = \delta$$

Reference: Chapter 7

Note: This can, however, be predicted quite easily from *Reciprocity Theorem*.

9.

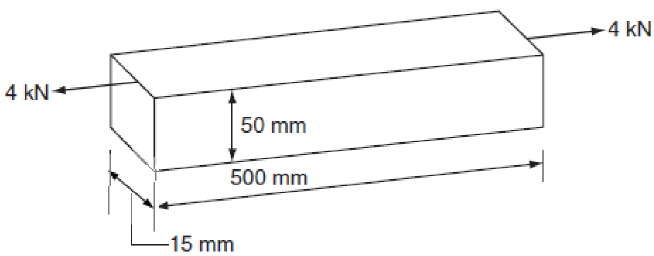


Figure 6

A link is under a pull which lies on one of the faces as shown in Figure 6. The magnitude of maximum compressive stress in the link would be

(a) 21.3 N/mm^2
(b) 16.0 N/mm^2
(c) 10.7 N/mm^2
(d) 0.0 N/mm^2

Answer: (c)
Explanation: The link is subjected to combined bending and stretching. Maximum compressive stress is

$$\left[\frac{(4)(10^3)(25)(6)}{(15)(50)^2} - \frac{(4)(10^3)}{(15)(50)^2}\right] \text{N/mm}^2$$

or stress = 10.67 N/mm^2.
Reference: Chapter 12

10. A long slender bar having uniform rectangular cross-section $B \times H$ is acted upon by an axial compressive force. The sides B and H are parallel to the x and y axes, respectively. The ends of the bar are fixed such that they behave as pin-jointed when the bar buckles in a plane normal to the x-axis, and as built-in when the bar buckles in a plane normal to the y-axis. If the load capacity in either mode of buckling is same, the value of $H : B$ is:
(a) 2.0
(b) 4.0
(c) 8.0
(d) 16.0

Answer: (a)
Explanation: Let us refer to the following Figure 7:

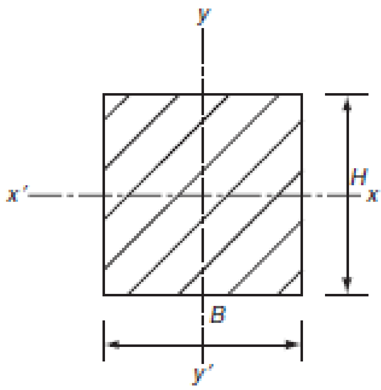


Figure 7

According to the given condition:

$$\frac{\pi^2 E\bar{I}_{xx}}{L^2} = \frac{4\pi^2 E\bar{I}_{yy}}{L^2}$$
$$\Rightarrow \bar{I}_{xx} = 4\bar{I}_{yy}$$
$$\Rightarrow \frac{1}{12}BH^3 = \frac{1}{12}(4HB^3)$$
$$\Rightarrow H^2 = 4B^2 \Rightarrow H : B = 2:1$$

Reference: Chapter 8

11. The property by which an amount of energy is absorbed by a material without plastic deformation is called:
(a) toughness
(b) impact strength
(c) ductility
(d) resilience

Answer: (d)
Reference: Chapter 10

12. A thick cylinder contains fluid at a pressure of 500 N/m^2, the internal diameter of the shell is 0.6 m and the tensile stress in the material is to be limited to 9000 N/m^2. The shell must have a minimum wall thickness of nearly

(a) 9.0 mm
(b) 11.0 mm
(c) 17.0 mm
(d) 21.0 mm

Answer: (c)
Explanation: We know that:

$$(\sigma_\theta)_{\max} = p_{\mathrm{i}}\frac{r_{\mathrm{i}}^2 + r_{\mathrm{o}}^2}{r_{\mathrm{o}}^2 - r_{\mathrm{i}}^2} = p_{\mathrm{i}}\frac{d_{\mathrm{i}}^2 + d_{\mathrm{o}}^2}{d_{\mathrm{o}}^2 - d_{\mathrm{i}}^2}$$

$$\Rightarrow 9000 = 500\left(\frac{d_{\mathrm{o}}^2 + 0.6^2}{d_{\mathrm{o}}^2 - 0.6^2}\right)$$

$$\Rightarrow \frac{d_{\mathrm{o}}^2 + 0.6^2}{d_{\mathrm{o}}^2 - 0.6^2} = 18$$

$$\Rightarrow d_{\mathrm{o}} = 0.6343\ \mathrm{m} = 634.3\ \mathrm{mm}$$

and $d_{\mathrm{i}} = 0.6\ \mathrm{m} = 600\ \mathrm{mm}$
Thus, the wall thickness is

$$t = \frac{1}{2}(d_{\mathrm{o}} - d_{\mathrm{i}}) = 17.2\ \mathrm{mm} \simeq 17\ \mathrm{mm}$$

Reference: Chapter 15

13. From a tension test, the yield strength of steel is found to be 200 N/mm^2. Using a factor of safety of 2.0 and applying maximum principal stress theory of failure, the permissible stress in the steel shaft subjected to torque will be:

(a) 50 N/mm^2
(b) 57.7 N/mm^2
(c) 86.6 N/mm^2
(d) 100 N/mm^2

Answer: (d)
Reference: Chapter 11

14. Which one of the following properties is more sensitive to increase in strain rate?

(a) Yield strength
(b) Proportional limit
(c) Elastic limit
(d) Tensile strength

Answer: (d)
Reference: Chapter 1

15. **Assertion (A):** Poisson's ratio of a material is a measure of change in dimension in one direction due to loading in the perpendicular direction.
Reason (R): The nature of lateral strain in a uniaxially loaded member is opposite to that of linear strain.

(a) Both (A) and (R) are true and (R) is the correct explanation of (A).
(b) Both (A) and (R) are true but (R) is NOT the correct explanation of (A).
(c) (A) is true but (R) is false.
(d) (A) is false but (R) is true.

Answer: (b)
Reference: Chapter 1

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16. For the same internal diameter, wall thickness, material and internal pressure, the ratio of maximum stress, induced in a thin cylindrical and in a thin spherical pressure vessel will be
(a) 2
(b) 1/2
(c) 4
(d) 1/4

Answer: (a)
Explanation: For cylindrical vessel,

$$\sigma_c = \frac{pd}{2t}$$

while for spherical vessel,

$$\sigma_s = \frac{pd}{4t} \Rightarrow \sigma_c : \sigma_s = 2:1$$

Reference: Chapter 3

17. Wire diameter, mean coil diameter and number of turns of a close-coiled steel spring are *d*, D and *N*, respectively, and stiffness of spring is *K*. A second spring is made of the same steel but with wire diameter, mean coil diameter and number of turns 2*d*, 2*D* and 2*N*, respectively. The stiffness of new spring is
(a) *K*
(b) 2*K*
(c) 4*K*
(d) 8K

Answer: (a)
Explanation: We know

$$K = \frac{Gd^4}{8nD^3}$$

and for the second spring,

$$K' = \frac{G(2)^4 d^4}{8(2)n(2)^3 D^3}$$

Thus,

$$K' = \frac{Gd^4}{8nD^3} = K$$

Reference: Chapter 2

18. Two identical springs labelled as (1) and (2) are arranged in series and subjected to force *F* as shown in Figure 8:

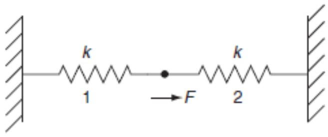


Figure 8

Assume that each spring constant is *K*. The strain-energy stored in spring (1) is:

(a) $\frac{F^2}{2K}$

(b) $\frac{F^2}{4K}$

(c) $\frac{F^2}{8K}$

(d) $\dfrac{F^2}{16K}$

Answer: (c)
Explanation: Each spring suffers same displacement is δ (let). Let us draw the free-body diagram (Figure 9) of the node where *F* is applied:

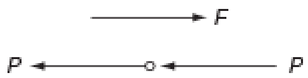


Figure 9

Therefore,

$$F = 2P = 2K\delta \Rightarrow \delta = \frac{F}{2K} \quad \text{and} \quad P = \frac{F}{2}$$

now, U_1 is strain-energy stored in (1) is

$$\frac{1}{2}P \cdot \delta = \frac{1}{2}\left(\frac{F}{2}\right)\left(\frac{F}{2K}\right) = \frac{F^2}{8K}$$

Reference: Chapter 10

19. A rod having cross-sectional area 100×10^{-6} m^2 is subjected to a tensile load. Based on the Tresca failure criterion, if the uniaxial yield stress of the material is 200 MPa, the failure load is:
(a) 10 kN
(b) 20 kN
(c) 100 kN
(d) 200 kN

Answer: (b)
Explanation: According to Tresca criterion,

$$\tau_{\max} = \tau_{yp} = \frac{\sigma_{yp}}{2}$$

to initiate failure. Therefore,

$$\frac{\sigma}{2} = \frac{\sigma_{\text{yp}}}{2} \Rightarrow \sigma = \sigma_{\text{yp}}$$

So the failure load is

$$\sigma \cdot A = \sigma_{\text{yp}} A = 200(10^6)(100)(10^{-6}) = 20 \times 10^3 \text{ N} = 20 \text{ kN}$$

Reference: Chapter 11

20. If diameter of a long column is reduced by 20%, the percentage reduction of Euler buckling load is
(a) 4
(b) 36
(c) 49
(d) 59

Answer: (d)
Explanation:

$$P_{cr} = \frac{\pi^2 EI}{12}$$

Therefore, $P_{\text{cr}} \propto I$ if other things are constants. Hence,

$$\frac{(P_{cr})_2}{(P_{cr})_1} = \frac{I_2}{I_1} = \frac{d_2^4}{d_1^4} = (0.8)^4 \frac{d_1^4}{d_1^4} = (0.8)^4$$

Thus, the % decrease in P_{cr} is

$$P_{\text{cr}} = \frac{(P_{\text{cr}})_1 - (P_{\text{cr}})_2}{(P_{\text{cr}})_1} \times 100 = \left[1 - \frac{(P_{cr})_2}{(P_{cr})_1}\right] \times 100 = [1 - (0.8)^4] \times 100 = 59.04\%$$

Reference: Chapter 8

21. With one end fixed and other free end, a column of length L buckles at load P_1. Another column of the same length and same cross-section fixed at both ends buckles at load P_2. The ratio of $P_2 : P_1$ is
(a) 1.0
(b) 2.0
(c) 4.0
(d) 16.0

Answer: (d)
Reference: Chapter 8

22. In a two-dimensional problem, the state of pure shear at a point is characterised by
(a) $\epsilon_{xx} = \epsilon_{yy}$ and $\gamma_{xy} = 0$
(b) $\epsilon_{xx} = -\epsilon_{yy}$ and $\gamma_{xy} \neq 0$
(c) $\epsilon_{xx} = 2\epsilon_{yy}$ and $\gamma_{xy} \neq 0$
(d) $\epsilon_{xx} = 0.5\epsilon_{yy}$ and $\gamma_{xy} = 0$

Answer: (b)
Reference: Chapter 9
Explanation: In two dimensions, pure shear is represented as

$$\sigma_{xx} = -\sigma_{yy} = \tau$$

Again from generalised Hooke's law,

$$\epsilon_{xx} = \frac{1}{E}(\sigma_{xx} - \nu\sigma_{yy}) = \frac{\tau}{E}(1+\nu)$$

and

$$\epsilon_{yy} = \frac{1}{E}(\sigma_{yy} - \nu\sigma_{xx}) = -\frac{\tau}{E}(1+\nu)$$

Thus,

$$\epsilon_{xx} = -\epsilon_{yy}$$

and

$$\gamma_{xy} = \frac{\tau_{xy}}{G} = \frac{\tau}{G} \neq 0$$

23. The principal stresses σ_1, σ_2 and σ_3 at a point, respectively, are 80 MPa, 30 MPa and –40 MPa. The maximum shear stress is
(a) 25 MPa
(b) 35 MPa
(c) 55 MPa
(d) 60 MPa

Answer: (d)
Explanation:

$$\tau_{\max} = \text{Max}\left[\left|\left(\frac{\sigma_1 - \sigma_2}{2}\right)\right|, \left|\left(\frac{\sigma_2 - \sigma_3}{2}\right)\right|, \left|\left(\frac{\sigma_3 - \sigma_1}{2}\right)\right|\right]$$
$$= \text{Max}[|25|, |35|, |-60|]\ \text{MPa} = 60\ \text{MPa}$$

Reference: Chapter 9

24. Bending moment distribution in a built-in beam is shown in the following Figure 10:

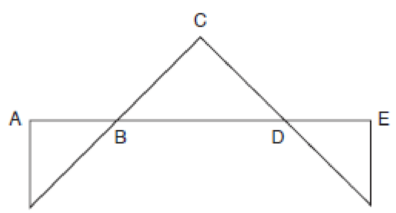
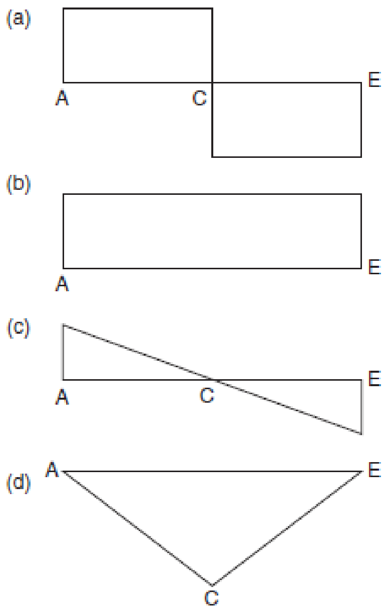


Figure 10

The shear force distribution in the beam is represented by:



Answer: (a)
Reference: Chapter 5

25. The outside diameter of a hollow shaft is twice that of its inside diameter. The torque-carrying capacity of this shaft is M_{t_1}. A solid shaft of the same material has the diameter equal to the outside diameter of the hollow shaft. The solid shaft can carry a torque of M_{t_2}. The ratio of $M_{t_1} : M_{t_2}$ is
(a) 15:16
(b) 3:4
(c) 1:2
(d) 1:16

Answer: (a)
Explanation: We know that

$$T = \frac{J}{r}\tau$$

so for solid shaft,

$$T_s = M_{t_2} = \frac{\pi}{16}d^3\tau$$

For the hollow shaft,

$$d_o = d \quad \text{and} \quad d_i = \frac{d}{2}$$

Thus,

$$T_h = M_{t_1} = \frac{\pi}{16}\frac{d_o^4 - d_i^4}{d}\tau = \frac{\pi}{16}\left[\frac{d^4 - (d^4/16)}{d}\right]\tau = \frac{15}{16}\left(\frac{\pi}{16}d^3\tau\right)$$

Therefore,

$$M_{t_1} = \frac{15}{16}M_{t_2}\,]$$

Reference: Chapter 2

26. The diameter of shaft A is twice the diameter of shaft B and both are made of the same material. Assuming both the shafts to rotate at same speed, the maximum power transmitted by B is
(a) the same as that of A
(b) half of A
(c) (1/8)th of A
(d) (1/4)th of A

Answer: (c)
Explanation: Power transmitted by the shaft, $P = kT$; where k is constant. Also,

$$T = \frac{J}{r}\tau = \frac{\pi}{16}d^3\tau$$

Therefore,

$$\frac{P_B}{P_A} = \left(\frac{d_B}{d_A}\right)^3 = \frac{1}{2^3} = \frac{1}{8}$$

Reference: Chapter 2

27. A body having weight of 1000 N is dropped from a height of 10 cm over a close-coiled helical spring of stiffness 200 N/cm. The resulting deflection of spring is nearly
(a) 5 cm
(b) 16 cm
(c) 35 cm
(d) 100 cm

Answer: (b)
Explanation: Applying conservation of energy,

$$\text{Initial potential energy of mass} = \text{Final potential energy of spring}$$

Thus,

$$W(h+\delta) = \frac{1}{2}K\delta^2 \Rightarrow K\delta^2 - 2W\delta - 2Wh = 0$$
$$\Rightarrow \delta^2 - 2\left(\frac{W}{K}\right)\delta - \left(\frac{2Wh}{K}\right) = 0$$

or

$$\delta = \left(\frac{W}{K}\right) + \sqrt{\left(\frac{W}{K}\right)^2 + \frac{2Wh}{K}}$$
$$= \left(\frac{W}{K}\right)\left[1 + \sqrt{1 + \frac{2Kh}{W}}\right] = \frac{1000}{(200)(100)}\left[1 + \sqrt{1 + \frac{(400)(100)(0.1)}{1000}}\right]$$
$$= 0.1618 \text{ m} = 16.18 \text{ cm} \simeq 16 \text{ cm}$$

Reference: Chapter 2

28. Figure 11 (all dimensions are in mm) shows an I-section of a beam:

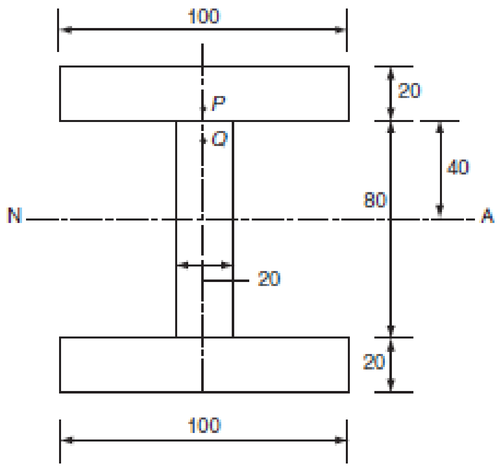


Figure 11
The shear stress at P (very close to the bottom of the flange) is 12 MPa.
The stress at Q in web (very close to the flange) is:
(a) indeterminable due to incomplete data

(b) 60 MPa
(c) 18 MPa
(d) 12 MPa

Answer: (b)
Explanation:

$$\tau_P = \frac{VQ}{bI} = \left(\frac{V}{I}\right)\left(\frac{Q}{b}\right) = \left(\frac{V}{I}\right)\frac{(100)(20)(40+10)}{100}$$

$$= \left(\frac{V}{I}\right)\frac{(100(20)(50)}{100} = \left(\frac{V}{I}\right)(50)(20) = 12$$

or

$$\frac{V}{I} = \frac{12}{(50)(20)} = \frac{12}{1000}\frac{\text{N}}{\text{mm}^4}$$

Again,

$$\tau_Q = \frac{VQ'}{b'I} = \left(\frac{V}{I}\right)\left(\frac{Q'}{b'}\right) = \left(\frac{12}{1000}\right)\frac{(100)(20)(50)}{(20)}\frac{\text{N}}{\text{mm}^2} = 60 \text{ MPa}$$

Reference: Chapter 6

29. A close-coiled helical spring is made of 5 mm diameter wire coiled to 50 mm mean diameter. Maximum shear stress in the spring under the action of an axial force is 20 N/mm^2. The maximum shear stress in a spring made of 3 mm diameter wire coiled to 30 mm mean diameter under the action of the same force will be nearly
(a) 20 N/mm^2
(b) 33.3 N/mm^2
(c) 55.6 N/mm^2
(d) 92.6 N/mm^2

Answer: (c)
Explanation: We know in a close-coiled spring that:

$$\tau_{\max} = \frac{16PR}{\pi d^3}\left(1+0.5\frac{d}{D}\right)$$

$$= \frac{8PD}{\pi d^3}\left(1+0.5\frac{d}{D}\right)$$

Now,

$$\frac{8P(0.05)}{\pi(0.005)^3}\left(1+0.5\frac{5}{50}\right) = (20)(10^6)$$

or

$$\Rightarrow \frac{8P}{\pi} = 47.619$$

For all latter cases

$$\tau'_{\max} = \frac{8P}{\pi}\frac{D'}{d'^3}\left(1+0.5\frac{d'}{D'}\right)$$

$$= (47.619)\frac{0.03}{(0.003)^3}\left(1+0.5\frac{3}{30}\right) \text{ N/m}^2$$

$$= 55.56(10^6) \text{ N/m}^2 \simeq 55.6 \text{ MPa}$$

Reference: Chapter 2

30. A horizontal beam carrying uniformly distributed load is supported with equal overhangs as shown in Figure 12.

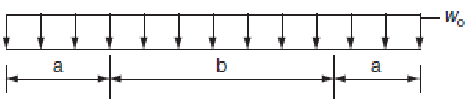


Figure 12

The bending moment at the midspan shall be zero if $a : b$ is
(a) 3 : 4

(b) 2 : 3
(c) 1 : 2
(d) 1 : 3

Answer: (c)
Explanation: Each reaction force from symmetry is

$$\frac{w_o(2a+b)}{2}$$

bending moment at midspan is:

$$M_x = \frac{w_o(2a+b)b}{4} - \frac{w_o\left(a+\frac{b}{2}\right)^2}{2}$$

If $M_x = 0$ then

$$4ab + 2b^2 = 4a^2 + b^2 + 4ab$$

or

$$b^2 = 4a^2 \Rightarrow \frac{a}{b} = \frac{1}{2}$$

Reference: Chapter 5

31.

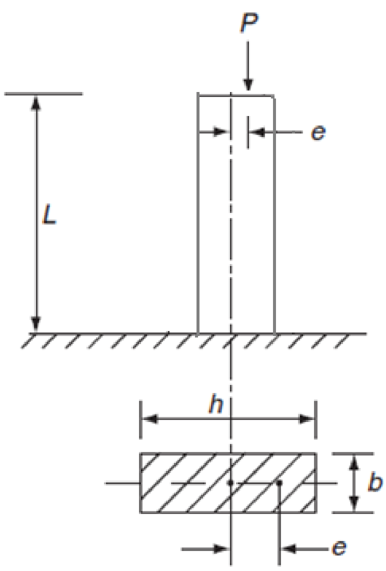


Figure 13

A short symmetric column made of a brittle material is subjected to an eccentric vertical load *P* at an eccentricity = *e* (Figure 13). To avoid tensile stress in the short column, *e* should be less than or equal to
(a) h/12
(b) *h*/6
(c) *h*/3
(d) *h*/2

Answer: (b)
Explanation: At any point on the cross-section, tensile stress is given by

$$\sigma = \frac{6M}{bh^2} - \frac{P}{A} = \frac{6Pe}{bh^2} - \frac{P}{bh}$$

for no tensile stress,

$$\sigma \le 0 \;\Rightarrow\; \frac{6Pe}{bh^2} \le \frac{P}{bh}$$

Therefore,

$$e \le \frac{h}{6}$$

Reference: Chapter 12

32. A thin cylindrical shell is subjected to internal pressure p. The Poisson's ratio of the material of the shell is 0.3. Due to internal pressure, the shell is subjected to circumferential strain and axial strain. The ratio of circumferential strain to axial strain is
(a) 0.425
(b) 2.25
(c) 0.225
(d) 4.25

Answer: (d)
Explanation: If σ_1 is circumferential stress and σ_2 is the meridional stress, then

$$\sigma_1 = \frac{pr}{t} \quad \text{and} \quad \sigma_2 = \frac{pr}{2t}$$

Also, from generalised Hooke's law in two dimensions,

$$\epsilon_1 = \frac{1}{E}(\sigma_1 - \nu\sigma_2) = \left(\frac{pr}{tE}\right)(1-0.5\nu)$$

and

$$\epsilon_2 = \frac{1}{E}(\sigma_2 - \nu\sigma_1) = \left(\frac{pr}{tE}\right)(0.5-\nu)$$

Thus,

$$\frac{\epsilon_1}{\epsilon_2} = \frac{1-0.5\nu}{0.5-\nu} = \frac{1-(0.5)(0.3)}{0.5-0.3} = 4.25\,]$$

Reference: Chapter 2

33. A cantilever of length L, moment of inertia I, Young's modulus E carries a concentrated load W at the middle of its length. The slope of the cantilever beam at free end is:

(a) $\dfrac{WL^2}{2EI}$

(b) $\dfrac{WL^2}{4EI}$

(c) $\dfrac{WL^2}{8EI}$

(d) $\dfrac{WL^2}{16EI}$

Answer: (c)
Explanation: Let us draw the bending moment diagram (Figure 14) and apply moment area theorem-I:

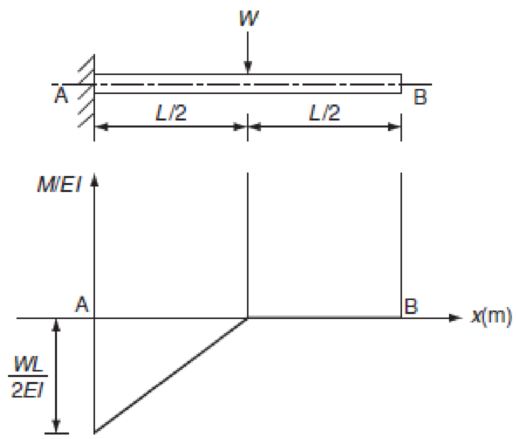


Figure 14

Required slope is equal to area under M/EI diagram, which is given by

$$\frac{1}{2}\left(\frac{WL}{2EI}\right)\left(\frac{L}{2}\right)=\frac{WL^2}{8EI}$$

Reference: Chapter 7

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34. A straight bar is fixed at edges A and B (Figure 15). Its elastic modulus is *E* and cross-section is *A*. There is load *P* = 120 N at C. Determine the support reactions at the two edges.

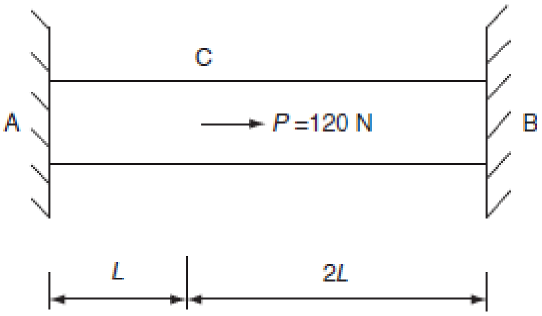


Figure 15

(a) 60 *N* at A, 60 *N* at B
(b) 30 *N* at A, 90 *N* at B
(c) 40 *N* at A, 80 *N* at B
(d) 80 *N* at A, 40 *N* at B

Answer: (d)
Explanation: Consider Figure 16:

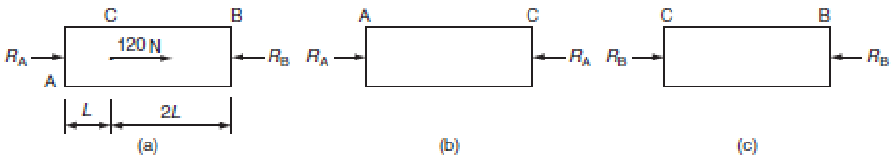


Figure 16

For equilibrium,

$$R_A+120=R_B \Rightarrow R_B-R_A=120 \tag{1}$$

Therefore,

$$\delta_{C/A}=-\frac{R_A L}{AE}=\delta_C-\delta_A=\delta_C \quad (\text{as } \delta_A=0)$$

Again,

$$\delta_{B/C}=\delta_B-\delta_C=-\delta_C=\frac{-R_B(2L)}{AE} \quad (\text{as } \delta_B=0)$$

Thus,

$$R_A+2R_B=0 \tag{2}$$

From Eqs. (1) and (2), δ_B = 40 N. Therefore,

$$R_A=-80 \text{ N} \Rightarrow R_A=80 \text{ N}(\leftarrow),\ R_B=40 \text{ N}(\leftarrow)$$

Reference: Chapter 1

35. For a given material, the modulus of rigidity is 100 GPa and Poisson's ratio 0.25. The value of modulus of elasticity in GPa is:
(a) 125
(b) 150
(c) 200
(d) 250

Answer: (d)
Reference: Chapter 1

36. A rigid beam of negligible weight is supported in a horizontal position by two rods of steel and aluminium, 2 m and 1 m long having values of cross-sectional areas 1.0 cm^2 and 2.0 cm^2 and *E* of 200 GPa and 100 GPa, respectively. A load *P* is applied as shown in Figure 17.

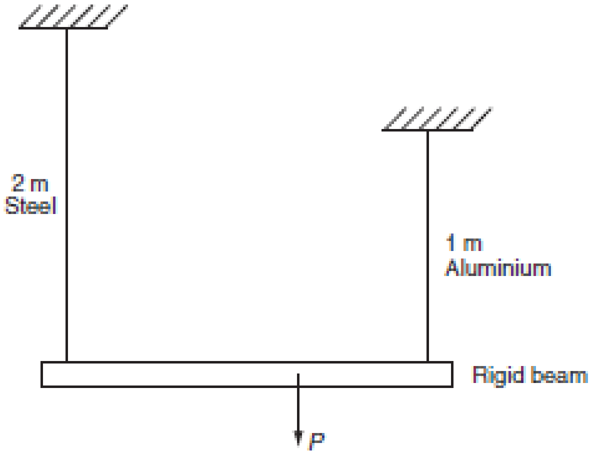


Figure 17

If the rigid beam is to remain horizontal then
(a) forces on both sides should be equal.
(b) force on aluminium rod should be twice the force on steel.
(c) force on steel rod should be twice the force on aluminium.
(d) force *P* must be applied at the centre of beam.

Answer: (b)
Explanation: For beam to be horizontal, $\delta_S = \delta_A$, therefore,

$$\frac{P_{St}L_{St}}{A_{St}E_{St}} = \frac{P_{Al}L_{Al}}{A_{Al}E_{Al}} \Rightarrow \frac{P_{St}}{P_{Al}} = \frac{A_{St}}{A_{Al}} \cdot \frac{L_{Al}}{L_{St}} \cdot \frac{E_{St}}{E_{Al}}$$

Thus,

$$\frac{P_{St}}{P_{Al}} = \left(\frac{1}{2}\right)\left(\frac{1}{2}\right)\left(\frac{200}{100}\right) = \frac{1}{2} \Rightarrow P_{Al} = 2P_{St}$$

Reference: Chapter 1

37. Shaft is subjected to torsion as shown in Figure 18.

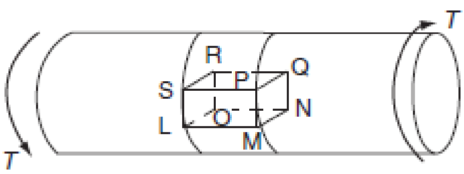
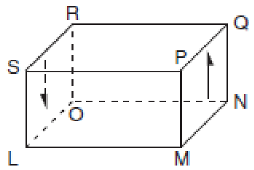
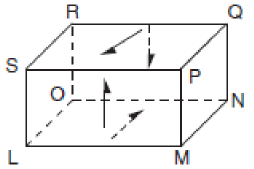
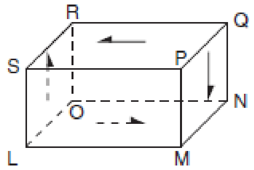


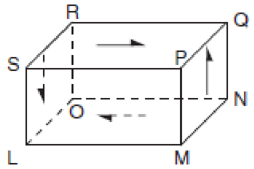
Figure 18

Which of following figures represents the shear stress on the element LMNOPQRS?

(a) 

(b) 

(c) 

(d) 

Answer: (d)
Reference: Chapter 2

38.

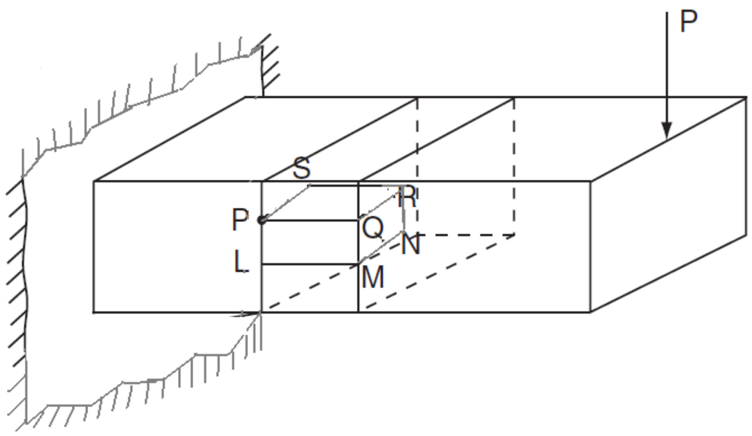
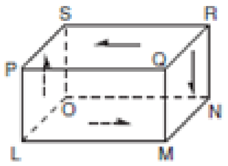
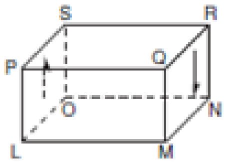
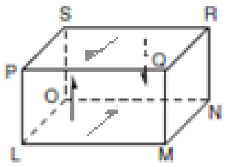


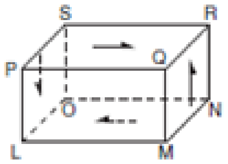
Figure 19

A cantilever is loaded by a concentrated load *P* at the free end (Figure 19). The shear stress in the element LMNOPQRS is under consideration. Which of the following figures represents the shear stress directions in the cantilever?

(a) 

(b) 

(c) 

(d) 

Answer: (a)
Reference: Chapter 6

39. A thin cylinder of radius *r* and thickness *t* when subjected to an internal hydrostatic pressure '*p*' causes radial displacement *u*, then the tangential strain caused is

(a) $\dfrac{\mathrm{d}u}{\mathrm{d}r}$

(b) $\dfrac{1}{r}\dfrac{\mathrm{d}u}{\mathrm{d}r}$

(c) $\dfrac{u}{r}$

(d) $\dfrac{2u}{r}$

Answer: (a)
Reference: Chapter 15

40. Determine the stiffness of the beam shown in Figure 20.

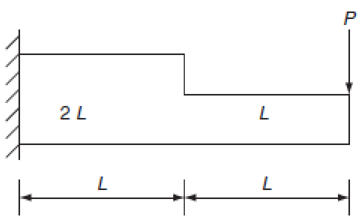


Figure 20

Given that: $I = 375 \times 10^{-6}\ \mathrm{m}^4;\ \ L = 0.5\ \mathrm{m};\ \ E = 200\ \mathrm{GPa}$

(a) 0.12×10^{10} N/mm
(b) 0.10×10^{10} N/mm
(c) 0.4×10^{10} N/mm
(d) 0.8×10^{10} N/mm

Answer: (a)

Explanation: Strain energy due to bending is

$$U = \int_0^{2L} \frac{M_x^2}{2EI}\,\mathrm{d}x$$

$$\Rightarrow\ U = \int_0^L \frac{P^2x^2dx}{2EI} + \int_0^L \frac{P^2x^2dx}{4EI}$$

$$= \left(\frac{P^2}{2EI}\right)\left[\frac{x^3}{3}\right]_0^L + \left(\frac{P^2}{4EI}\right)\left[\frac{x^3}{3}\right]_0^L$$

$$= \frac{P^2L^3}{6EI} + \frac{P^2L^3}{12EI} = \frac{P^2L^3}{4EI}$$

or

$$\delta = \frac{\partial U}{\partial P} = \frac{PL^3}{2EI}$$

Thus, bending stiffness is

$$K_\mathrm{b} = \frac{P}{\delta} = \frac{2EI}{L^3} = \frac{(2)(200)(10^9)(375)(10^{-6})}{(0.5)^3} = 1.2\times 10^9\ \mathrm{N/m}$$

Reference: Chapter 7

41. A thick open-ended cylinder (d_i = 10 cm, d_o = 20 cm) is made of a material with permissible normal and shear stresses 200 MPa and 100 MPa, respectively. The ratio of permissible pressure based on the normal and shear stress is

(a) 9:5
(b) 8:5
(c) 7:5
(d) 4:5

Answer: (b)

Explanation: Assuming the cylinder is subjected to internal pressure p_i only, we get:

$$\sigma_{\theta\theta}\big|_{r=r_\mathrm{i}} = \sigma_{\theta\theta}\big|_\mathrm{max} = p_\mathrm{i}\frac{r_\mathrm{o}^2 + r_\mathrm{i}^2}{r_\mathrm{o}^2 - r_\mathrm{i}^2} = p_\mathrm{i}\frac{20^2+10^2}{20^2-10^2} = 200$$

Thus,

$$p_\mathrm{i} = p_1(\mathrm{Let}) = 200\frac{300}{500} = 120\ \mathrm{MPa}$$

Again,

$$\sigma_{rr}\big|_{r=r_\mathrm{i}} = -p_\mathrm{i} \Rightarrow \tau_\mathrm{max} = 0.5(\sigma_{\theta\theta} - \sigma_{rr})\big|_\mathrm{max}$$

Therefore,

$$\tau_\mathrm{max} = 0.5p_\mathrm{i}\left(\frac{r_\mathrm{o}^2 + r_\mathrm{i}^2}{r_\mathrm{o}^2 - r_\mathrm{i}^2} + 1\right) = \frac{p_\mathrm{i}r_\mathrm{o}^2}{r_\mathrm{o}^2 - r_\mathrm{i}^2} = \frac{p_\mathrm{i}\,d_\mathrm{o}^2}{d_\mathrm{o}^2 - d_\mathrm{i}^2}$$

$$= p_\mathrm{i}\frac{20^2}{20^2-10^2} = 100\ \Rightarrow\ p_\mathrm{i} = p_2 = 100\frac{300}{400} = 75\ \mathrm{MPa}$$

Thus,

$$p_1 : p_2 = 120 : 75 = 8 : 5$$

Reference: Chapter 15

42. **Assertion (A):** Mohr’s circle of stress can be related to Mohr’s circle of strain by some constant of proportionality.

Reason (R): The relationship is a function of yield stress of the material.

(a) Both (A) and (R) are true and (R) is the correct explanation of (A)
(b) Both A and *R* are true but *R* is NOT the correct explanation of (A)
(c) (A) is true but (R) is false
(d) (A) is false but (R) is true

Answer: (c)

Explanation: Radius of Mohr's circle for stress is

$$R = \frac{1}{2}(\sigma_1 - \sigma_2) \text{ and centre is at } \left(\frac{\sigma_1 + \sigma_2}{2}, 0\right)$$

while radius of Mohr's circle for strain is

$$r = \frac{1}{2}(\in_1 - \in_2) \text{ and centre is at } \left(\frac{\in_1 + \in_2}{2}, 0\right)$$

where σ_1, σ_2, $\in_1$ and $\in_2$ are principal stresses and principal strains. But

$$\in_1 = \frac{1}{E}(\sigma_1 - \nu\sigma_2) \quad \text{and} \quad \in_2 = \frac{1}{E}(\sigma_2 - \nu\sigma_1)$$

Therefore,

$$\in_1 - \in_2 = \frac{1}{E}(1+\nu)(\sigma_1 - \sigma_2)$$

$$\Rightarrow r = \frac{1+\nu}{E}R \quad \text{and} \quad \in_1 + \in_2 = \frac{1-\nu}{E}(\sigma_1 + \sigma_2)$$

or

$$C_{\text{strain}} = \frac{1-\nu}{E}C_{\text{stress}}$$

Thus, scaling factors depend of E and *v*. Thus (A) is correct but (R) is not correct explanation.

Reference: Chapter 4

43. **Assertion (A):** If the bending moment diagram is a rectangle, it indicates that the beam is loaded by a uniformly distributed moment all along the length.
Reason (R): The bending moment *d* is a representation of internal forces in the beam and not the moment applied on the beam.
(a) Both (A) and (R) are true and (R) is the correct explanation of (A).
(b) Both (A) and (R) are true but (R) is **not** the correct explanation of (A).
(c) (A) is true but (R) is false.
(d) (A) is false but (R) is true.

Answer: (b)
Reference: Chapter 5

44. While calculating stresses induced in a close-coiled helical spring, Wahl's factor must be considered to account for
(a) the curvature and stress concentration effect
(b) shock loading
(c) poor service conditions
(d) fatigue loading

Answer: (a)
Reference: Chapter 2

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45. Consider the following statements:
In a cantilever beam subjected to a concentrated load at the free end:
(i) Bending stress is maximum at the free end.
(ii) The maximum shear stress is constant along the length of the beam.
(iii) The slope of the elastic curve is zero at the fixed end.
Which of the above statements are correct?
(a) (i), (ii), (iii)
(b) (ii) and (iii)
(c) (i) and (iii)
(d) (i) and (ii)

Answer: (b)
Reference: Chapter 6

46. The shear stress distribution over a beam cross-section is shown in Figure 21.

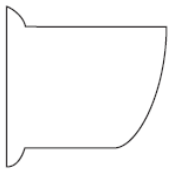

Figure 21

The beam is of

(a) equal flange I-section.
(b) unequal flange I-section.
(c) circular section.
(d) T-section.

Answer: (b)
Reference: Chapter 6

47. Slenderness ratio of a column is defined as the ratio of its length to its

(a) least radius of gyration.
(b) least lateral dimension.
(c) maximum lateral dimension.
(d) maximum radius of gyration.

Answer: (a)
Reference: Chapter 8

48. A circular shaft subjected to twisting moment results in maximum shear stress of 60 MPa. Then the maximum compressive stress in the material is

(a) 30 MPa
(b) 60 MPa
(c) 90 MPa
(d) 120 MPa

Answer: (b)
Reference: Chapter 4

49. One-half length of 50 mm diameter steel rod is solid, while the other half is hollow having a bore of 25 mm. The rod is subjected to equal and opposite torque at its ends. If the maximum shear stress in solid portion is τ, the maximum stress in the hollow portion is

(a) $\frac{15}{16}\tau$
(b) τ
(c) $\frac{4}{3}\tau$
(d) $\frac{16}{15}\tau$

Answer: (d)
Explanation:

$$\tau = \frac{Tr}{J}$$

Now, for solid shaft,

$$J_s = \frac{\pi}{32} d^4$$

while for hollow shaft,

$$J_h = \frac{\pi}{32}(d_0^4 - d_i^4)$$

Therefore,

$$\frac{\tau_{\text{hollow}}}{\tau_{\text{solid}}} = \frac{J_{\text{solid}}}{J_{\text{hollow}}}$$

as T and r are same. Hence,

$$\frac{\tau_{\text{hollow}}}{\tau} = \frac{50^4}{50^4 - 25^4} = \frac{16}{15} \Rightarrow \tau_{\text{hollow}} = \frac{16}{15}\tau \;]$$

Reference: Chapter 2

50. A thick cylinder with internal diameter '*d*' and outside diameter '2*d*' is subjected to internal pressure '*p*'. Then the maximum hoop stress developed in the cylinder is
(a) *p*
(b) 2*p*/3
(c) 5*p*/3
(d) 2*p*

Answer: (c)
Explanation: Hoop stress $\sigma_{\theta\theta}$ is maximum at internal radius of a thick cylinder. Thus,

$$(\sigma_{\theta\theta})_{\max} = p\frac{r_o^2 + r_i^2}{r_o^2 - r_i^2} = p\frac{d_o^2 + d_i^2}{d_o^2 - d_i^2} = \frac{5p}{3}$$

Reference: Chapter 15

51. The volumetric strain in case of a thin cylindrical shell of diameter '*d*' and thickness '*t*', subjected to internal pressure '*p*' is

(a) $\frac{pd}{2tE}(3-2\nu)$

(b) $\frac{pd}{3tE}(4-3\nu)$

(c) $\frac{pd}{4tE}(5-4\nu)$

(d) $\frac{pd}{4tE}(4-5\nu)$

where *E* is the modulus of elasticity and *v* is Poisson's ratio for the shell material.

Answer: (c)
Explanation: Assuming the cylinder to be closed, we note the stress-state is of biaxial nature where

$$\text{Axial stress, } \sigma_1 = \frac{pd}{4t}$$

$$\text{Circumferential stress, } \sigma_2 = \frac{pd}{2t}$$

Correspondingly, from Hooke's law:

$$\epsilon_1 = \frac{1}{E}(\sigma_1 - \nu\sigma_2) \quad \text{and} \quad \epsilon_2 = \frac{1}{E}(\sigma_2 - \nu\sigma_1)$$

Again, for the cylindrical shell,

$$V = \frac{\pi}{4}d^2 L \Rightarrow \ln V = (2\ln d + \ln L) + \ln\left(\frac{\pi}{4}\right)$$

Therefore,

$$\frac{\mathrm{d}V}{V} = \left(2\frac{\mathrm{d}d}{d} + \frac{\mathrm{d}L}{L}\right)$$

and volumetric strain, ϵ_V is given by

$$[2 \in_2 + \in_1] = \frac{1}{E}[2\sigma_2 - 2\nu\sigma_1 + \sigma_1 - \nu\sigma_2]$$

$$\text{or} \qquad \in_V = \frac{1}{E}[(\sigma_1 + 2\sigma_2) - \nu(2\sigma_1 + \sigma_2)]$$

$$= \frac{1}{E}\left[\left(\frac{pd}{4t} + \frac{pd}{t}\right) - \nu\left(\frac{pd}{2t} + \frac{pd}{2t}\right)\right] = \frac{pd}{4tE}(5 - 4\nu) = \in_V$$

Reference: Chapter 3

52. The commonly used technique of strengthening thin pressure vessel is:
(a) wire winding.
(b) shrink-fitting.
(c) autofrettage.
(d) multilayered construction.

Answer: (a)
Reference: Chapter 3

53. Under axial load each section of a close-coiled helical spring is subjected to
(a) tensile stress and shear stress due to load.
(b) compressive stress and shear stress due to torque.
(c) tensile stress and shear stress due to torque.
(d) torsional and direct shear stresses.

Answer: (d)
Reference: Chapter 2

54. A bar having length *L* and uniform cross-section with area *A* is subjected to both tensile force *P* and torque *T*. If *E* and *G* are moduli of elasticity and rigidity, respectively, the internal strain energy stored in the bar is:

(a) $\frac{T^2L}{2GJ} + \frac{P^2L}{AE}$

(b) $\frac{T^2L}{GJ} + \frac{P^2L}{2AE}$

(c) $\frac{T^2L}{2GJ} + \frac{P^2L}{2AE}$

(d) $\frac{T^2L}{GJ} + \frac{P^2L}{AE}$

Answer: (c)
Reference: Chapter 10

55. Toughness for mild steel under uniaxial loading is given by the shaded portion of the stress–strain diagram as shown in Figure 22:

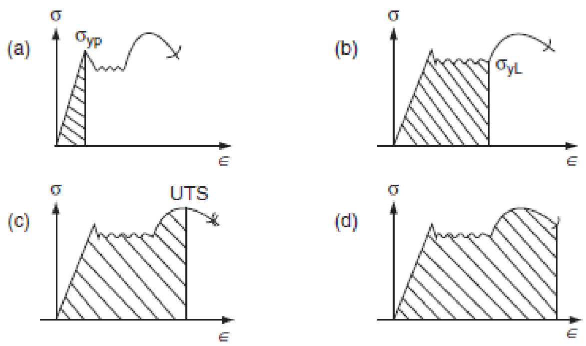

Figure 22

Answer: (d)

Reference: Chapter 10

56. A cube having each side of length '*a*' is constrained in all directions and is heated uniformly so that the temperature is raised to *T*°C. If α is the thermal coefficient of expansion of the cube material and *E* is the modulus of elasticity, the stress developed in the cube is:

(a) $\dfrac{\alpha TE}{\nu}$

(b) $\dfrac{\alpha TE}{(1-2\nu)}$

(c) $\dfrac{\alpha TE}{2\nu}$

(d) $\dfrac{\alpha TE}{1+2\nu}$

Answer: (b)

Explanation: Assuming ΔT = temperature rise = *T*. We note the cube is subjected to equal stresses in all directions. Therefore,

$$\in_1 = \in = \alpha\,\Delta T = \frac{1}{E}[\sigma_1 - \nu(\sigma_2 + \sigma_3)]$$

$$\Rightarrow E\alpha\,\Delta T = \sigma(1-2\nu) \quad (\text{as } \sigma_1 = \sigma_2 = \sigma_3 = \sigma)$$

Thus,

$$\sigma = \frac{E\alpha\,\Delta T}{(1-2\nu)}$$

Reference: Chapters 1 and 9

57. A simply supported beam has equal overhanging lengths and carries equal concentrated loads *P* at ends. Bending moment over the length between the supports

(a) is zero.
(b) is a non-zero constant.
(c) varies uniformly from one support to the other.
(d) is maximum at midspan.

Answer: (b)
Reference: Chapter 5

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58. Consider a two-dimensional state of stress given for an element as shown in Figure 23:

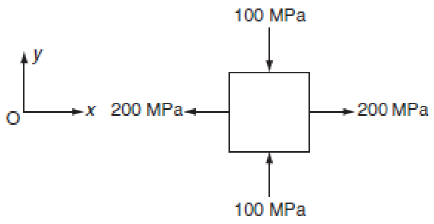


Figure 23

What are the coordinates of the centre of Mohr's circle?
(a) (0, 0)
(b) (100, 200)
(c) (200, 100)
(d) (50, 0)

Answer: (d)
Reference: Chapter 4

59. The modulus of elasticity for a material is 200 GN/m^2 and Poisson's ratio is 0.25. What is the modulus of rigidity?
(a) 80 GN/m^2
(b) 125 GN/m^2
(c) 250 GN/m^2
(d) 320 GN/m^2

Answer: (a)
Explanation:
Given that $E = 200\text{GN/m}^2$ and $\nu = 0.25$, thus,

$$G = \frac{E}{2(1+\nu)} = 80 \text{ GN/m}^2$$

Reference: Chapter 1

60. Which one of the following is correct in respect of Poisson's ratio (ν) for an isotropic elastic solid?
(a) $\infty \le \nu \le +\infty$
(b) $\frac{1}{4} \le \nu \le \frac{1}{3}$
(c) $-1 \le \nu \le \frac{1}{2}$
(d) $-\frac{1}{2} \le \nu \le \frac{1}{2}$

Answer: (c)
Reference: Chapter 1

61. A bar of length '*L*' tapers uniformly from diameter 1.1*D* at one end to 0.9*D* at the other end. The elongation due to axial pull is computed using mean diameter '*D*'. What is the approximate error in computed elongation?
(a) 10%
(b) 5%
(c) 1%
(d) 0.5%

Answer: (c)
Explanation: Consider Figure 24:

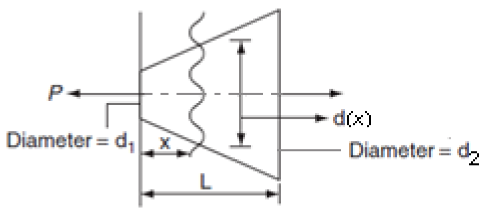


Figure 24

Diameter of rod at a distance *x* from end with diameter d_1 ($<d_2$) is:

$$d(x) = \left[d_1 + \left(\frac{d_2 - d_1}{L} \right) x \right]$$

So, stress on the section is

$$\sigma_{xx} = \frac{P}{A(x)} = \left(\frac{4P}{\pi} \right) \frac{1}{\left[d_1 + \left(\frac{d_2 - d_1}{L} \right) x \right]^2}$$

and strains

$$\in_{xx} = \frac{\sigma_{xx}}{E} = \frac{\mathrm{d}u}{\mathrm{d}x}$$

where u is the displacement along the x-direction. Therefore,

$$\mathrm{d}u = \left(\frac{4P}{\pi E}\right)\frac{\mathrm{d}x}{\left[d_1 + \left(\frac{d_2 - d_1}{L}\right)x\right]^2}$$

Hence,

$$u = \frac{4P}{\pi E}\int_0^L \frac{\mathrm{d}x}{\left[d_1 + \left(\frac{d_2 - d_1}{L}\right)x\right]^2} \quad \text{assuming } u(0) = 0$$

Therefore,

$$u = -\left(\frac{4P}{\pi E}\right)\left[\frac{1}{d_1 + \left(\frac{d_2 - d_1}{L}\right)x}\right]_0^L \frac{L}{(d_2 - d_1)}$$

$$= -\frac{4P}{\pi E}\left[\frac{1}{d_2} - \frac{1}{d_1}\right]\frac{L}{(d_2 - d_1)}$$

$$= \frac{4P(d_2 - d_1)}{\pi E d_1 d_2}\cdot\frac{L}{(d_2 - d_1)} = \frac{4PL}{\pi E\, d_1 d_2}$$

Thus, free elongation of the rod is

$$\delta_{\text{act}} = \frac{4PL}{\pi E d_1 d_2} = \left(\frac{4PL}{\pi D^2 E}\right)\frac{1}{(1.1)(0.9)} = 1.01\left(\frac{4PL}{\pi E D^2}\right)$$

Again, mean rod diameter is

$$\frac{1}{2}\left(1.1D + 0.9D\right) = D$$

Thus,

$$\delta = \frac{4PL}{\pi E D^2}$$

and

$$\%\ \text{error} = \frac{\delta_{\text{act}} - \delta}{\delta_{\text{act}}} \times 100\% \cong 1\%$$

Reference: Chapter 1

62. A bar of copper and steel form a composite system. They are heated to a temperature of 40°C. What type of stress is induced in the copper bar?
(a) Tensile
(b) Compressive
(c) Both tensile and compressive
(d) Shear

Answer: (b)
Explanation: As the coefficient of thermal expansion of copper rod is more than that of steel rod, copper elongates more than steel for given length and temperature rise of the assembly. To maintain compatibility, copper rod shortens and thus stress induced in copper rod must be compressive.
Reference: Chapter 1

63. A cube with a side of length of 1 cm is heated uniformly 1°C above the room temperature and all the sides are free to expand. What will be the increase in volume of the cube? (Given that the coefficient of thermal expansion is α/°C.)
(a) 3α cm^3
(b) 2α cm^3
(c) α cm^3
(d) 0

Answer: (a)

Explanation: From generalised Hooke's law,

$$\epsilon_1 = \frac{1}{E}\left[\sigma_1 - v(\sigma_2 + \sigma_3)\right] + \alpha\,\Delta T$$

$$\epsilon_2 = \frac{1}{E}\left[\sigma_2 - v(\sigma_1 + \sigma_3)\right] + \alpha\,\Delta T$$

$$\epsilon_3 = \frac{1}{E}\left[\sigma_3 - v(\sigma_2 + \sigma_1)\right] + \alpha\,\Delta T$$

So the volumetric strain is $\epsilon_V = \epsilon_1 + \epsilon_2 + \epsilon_3$

$$\epsilon_V = \frac{1}{E}(1-2v)\left(\sigma_1 + \sigma_2 + \sigma_3\right) + 3\alpha\,\Delta T$$

hence increase in volume = $\Delta V = V\epsilon_V$. For unconstrained thermal expansion,

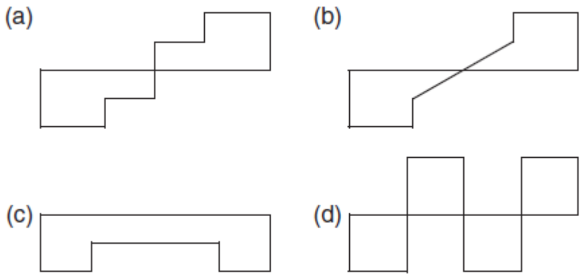
$$\sigma_1 = \sigma_2 = \sigma_3 = 0$$

Therefore,

$$\Delta V = 3V\alpha\,\Delta T = 3(1)^3\alpha(1)\text{cm}^3 = 3\alpha\ \text{cm}^3]$$

Reference: Chapter 1

64. A beam of length '4*L*' is simply supported on two supports with equal overhangs of '*L*' on either sides and carries three equal loads, one each at free ends and the third at the midspan. Which one of the following diagrams represents the correct distribution of shear force on the beam?



Answer: (d)
Explanation: Consider Figure 25:

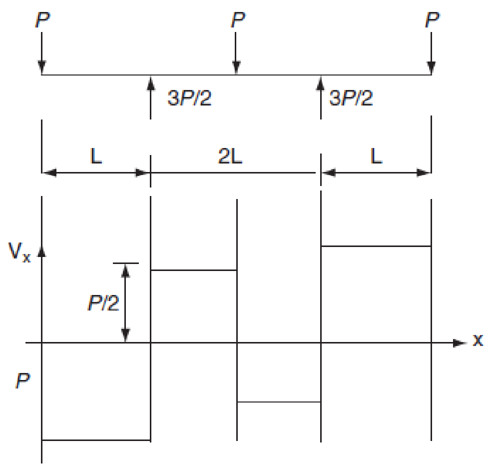


Figure 25

Reference: Chapter 5

65. A thin cylindrical shell of diameter '*d*', length '*L*' and thickness '*t*' is subjected to an internal pressure '*p*'. What is the ratio of longitudinal strain to hoop strain in terms of Poisson's ratio?

(a) $\dfrac{1-2\nu}{2+\nu}$

(b) $\dfrac{1-2\nu}{2-\nu}$

(c) $\dfrac{2-\nu}{1-2\nu}$

(d) $\dfrac{2+2\nu}{1-\nu}$

Answer: (b)
Explanation: We know that the longitudinal stress is

$$\sigma_1 = \frac{pd}{4t}$$

and hoop stress is

$$\sigma_2 = \frac{pd}{2t}$$

Now,

$$\epsilon_1 = \frac{1}{E}(\sigma_1 - \nu\sigma_2) \quad \text{and} \quad \epsilon_2 = \frac{1}{E}(\sigma_2 - \nu\sigma_1)$$

Hence,

$$\frac{\epsilon_1}{\epsilon_2} = \frac{\sigma_1 - \nu\sigma_2}{\sigma_2 - \nu\sigma_1} = \frac{\sigma_1 - \nu\sigma_2}{\sigma_2 - \nu\sigma_1} = \frac{\left(\dfrac{pd}{4t}\right) - \nu\left(\dfrac{pd}{2t}\right)}{\left(\dfrac{pd}{2t}\right) - \nu\left(\dfrac{pd}{4t}\right)} = \frac{1-2\nu}{2-\nu}$$

Reference: Chapter 3

66. A thick cylinder of internal radius '*a*' and external radius '*b*' is subjected to internal pressure '*p*' as well as external pressure '*p*'. Which one of the following statements is correct?
The magnitude of circumferential stress developed is
(a) maximum at radius *r* = *a*.
(b) maximum at radius *r* = *b*.
(c) maximum at radius $r = \sqrt{ab}$.
(d) constant.

Answer: (d)
Explanation: Circumferential stress at any radial location:

$$\sigma_\theta = \frac{1}{(b^2 - a^2)}\left[(p_i a^2 - p_o b^2) - \frac{a^2 b^2}{r^2}(p_o - p_i)\right]$$

with $p_o = p_i = p$, we get $\sigma_\theta = -p =$ constant.
Reference: Chapter 15

67. A simply supported beam is subjected to a distributed loading as shown in Figure 26.

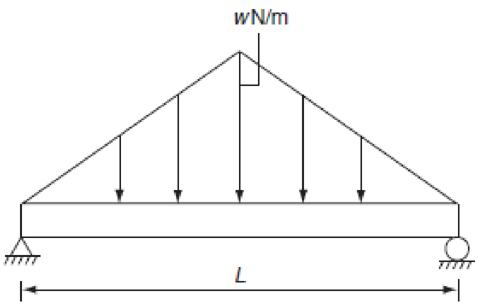


Figure 26

What is the maximum shear force in the beam?
(a) *wL*/4
(b) *wL*/2
(c) *wL*/3
(d) *wL*/6

Answer: (a)

Explanation: Refer to Figure 27:

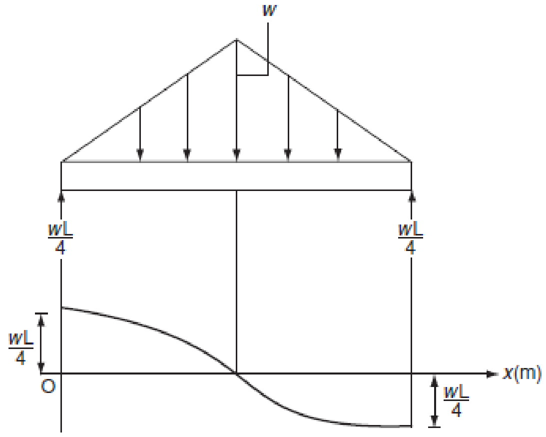


Figure 27

Reference: Chapter 5

68. A cantilever beam of length *L* is subjected to a concentrated force *P* at a distance of *L*/3 from its end. What is the deflection of the free-end of the beam? (*EI* is the flexural rigidity.)

(a) $\dfrac{2PL^3}{81EI}$

(b) $\dfrac{3PL^3}{81EI}$

(c) $\dfrac{14PL^3}{81EI}$

(d) $\dfrac{15PL^3}{81EI}$

Answer: (c)
Explanation: Refer to Figure 28

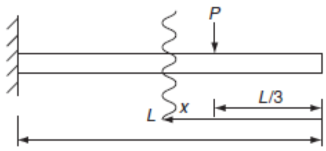


Figure 28

Here,

$$M_x = 0 \text{ for } 0 \le x \le \frac{L}{3}$$
$$= -P\left(x - \frac{L}{3}\right) \text{ for } \frac{L}{3} \le x \le L$$

Therefore,

$$EI\frac{d^2y}{dx^2} = -M_x = 0 + \left\langle x - \frac{L}{3}\right\rangle P\left(x - \frac{L}{3}\right)$$
$$\Rightarrow EIy_1 = H\left\langle x - \frac{L}{3}\right\rangle \frac{P}{2}\left(x - \frac{L}{3}\right)^2 + C_1$$
$$\Rightarrow (EI)y = \left\langle x - \frac{L}{3}\right\rangle \frac{P}{6}\left(x - \frac{L}{3}\right)^3 + C_1x + C_2$$

At $x = L$, $y = 0$ and $y_1 = 0$. Therefore,

$$C_1 + \frac{P}{2}\left(\frac{2L}{3}\right)^2 = 0 \Rightarrow C_1 = -\frac{2PL^2}{9}$$

and

$$C_1 L + C_2 + \frac{P}{6}\frac{8L^3}{27} = 0$$

$$\Rightarrow -\frac{2PL^3}{9} + C_2 + \frac{4PL^3}{81} = 0$$

$$\Rightarrow C_2 = \frac{2PL^3}{9} - \frac{4PL^3}{81} = \frac{14PL^3}{81}$$

So,

$$y|_{x=0} = \frac{C_2}{EI} = \frac{14PL^3}{81EI}$$

Reference: Chapter 7

69. What is the nature of distribution of shear stress in a rectangular beam?

(a) Linear
(b) Parabolic
(c) Hyperbolic
(d) Elliptic

Answer: (b)
Reference: Chapter 6

70. A solid circular rod AB of diameter '*D*' and length '*L*' is fixed at both ends. A torque is applied at a section *X* such that AX = *L*/4 and BX = 3*L*/4. What is the maximum shear stress developed in the rod?

(a) $\frac{16T}{\pi D^3}$

(b) $\frac{12T}{\pi D^3}$

(c) $\frac{8T}{\pi D^3}$

(d) $\frac{4T}{\pi D^3}$

Answer: (b)
Explanation: Consider Figure 29:

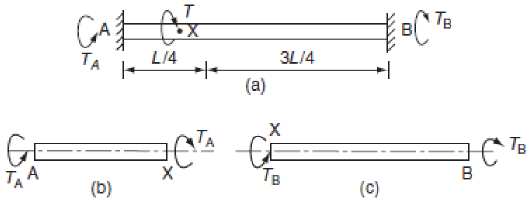


Figure 29

From Figure 29(a):

$$T_A - T - T_B = 0 \Rightarrow T_A - T_B = T \qquad (1)$$

From Figure 29(b): $\theta_{X/A} = \frac{T_A L}{4GJ} = \theta_X - \theta_A = \theta_X \quad (\text{as } \theta_A = 0)$

From Figure 29(c): $\theta_{B/X} = \theta_B - \theta_X = -\theta_X = \frac{3T_B L}{4GJ} \quad (\text{as } \theta_B = 0)$

$$T_A + 3T_B = 0 \qquad (2)$$

So from Eqs. (1) and (2):

$$-4T_B = T \Rightarrow T_B = -\frac{T}{4}$$

and
$$T_A = T + T_B = \frac{3T}{4}$$

Clearly AX carries larger torque,

$$\tau_{max} = \frac{16T_{max}}{\pi D^3} = \frac{12T}{\pi D^3}\ ]$$

Reference: Chapter 2

71. A spring with 25 active coils cannot be accommodated within a given space. Hence five coils of the spring are cut. What is the stiffness of the new spring?
(a) Same as the original spring
(b) 1.25 times the original spring
(c) 0.8 times the original spring
(d) 0.5 times the original spring

Answer: (b)
Explanation: We know that:

$$k = \frac{Gd^4}{64nR^3}$$

Thus,

$$k_{original} = \frac{\alpha}{25} \quad \left[\text{where } \alpha = \frac{Gd^4}{64R^3} = \text{constant}\right]$$

and
$$k_{new} = \frac{\alpha}{20}$$

Thus,

$$\frac{k_{new}}{k_{original}} = \frac{25}{20} = 1.25\ ]$$

Reference: Chapter 2

72. A closely coiled helical spring of 20 cm mean diameter is having 25 coils of 2 cm diameter rod. The modulus of rigidity of the material is 10^7 N/cm^2. What is the stiffness for the spring in N/cm?
(a) 50
(b) 100
(c) 250
(d) 500

Answer: (b)
Explanation:

$$k = \frac{Gd^4}{64nR^3} = \frac{10^7(2)^4}{(64)(25)(10)^3} = 100 \text{ N/cm}$$

Reference: Chapter 2

73. A shaft is subjected to simultaneous action of a torque *T*, bending moment *M* and an axial thrust *F*. Which one of the following statements is correct for this situation?
(a) One extreme end of the vertical diametric fibre is subjected to tensile/compressive stress only.
(b) The opposite extreme end of the vertical diametric fibre is subjected to tensile/compressive stress only.
(c) Every point on the surface of the shaft is subjected to maximum shear stress only.
(d) Axial longitudinal fibre of the shaft is subjected to compressive stress only.

Answer: (c)
Note: Depending on relative location of *T*, *M* and F, every extreme fibre located on vertical diameter is subjected to tension/compression and shear stress.
Reference: Chapter 12

74. A member is subjected to the combined action of bending moment 400 N m and torque 300 N m. What, respectively, are the equivalent bending moment and equivalent torque?
(a) 450 N m and 500 N m
(b) 900 N m and 350 N m
(c) 900 N m and 500 N m
(d) 400 N m and 500 N m

Answer: (a)
Explanation: Equivalent bending moment is

$$M_{\mathrm{e}} = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right] = 450 \text{ N m}$$

and equivalent torque $T_{\mathrm{e}} = \sqrt{M^2 + T^2} = 500$ N m.
Reference: Chapter 12

75. Match List I with List II and select the correct answer using the codes given below the lists:

List I	**List II**
(A) Wire Winding	(1) Hydrostatic stress
(B) Lame's theory	(2). Strengthening of thin cylindrical shell
(C) Solid sphere subjected to uniform pressure on the surface	(3) Strengthening of thick cylindrical shell
(D) Autofrettage	(4) Thick cylinders

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

Answer: (d)
Reference: Chapters 3and 15

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76. If σ_c and E denote the crushing stress and Young's modulus for the material of a column, then the Euler formula can be applied for determination of crippling load of a column made of this material only, if its slenderness ratio is:

(a) more than $\pi\sqrt{\frac{E}{\sigma_c}}$.

(b) less than $\pi\sqrt{\frac{E}{\sigma_c}}$.

(c) more than $\pi^2 \frac{E}{\sigma_c}$.

(d) less than $\pi^2\left(\frac{E}{\sigma_c}\right)$.

Answer: (c)
Explanation: Refer to the following graph in Figure 30:

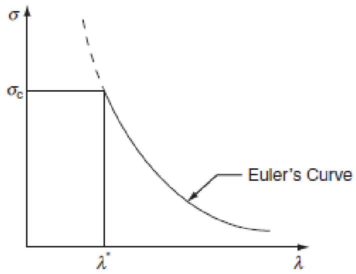

Figure 30

For Euler's theory to be applicable, $\lambda > \lambda^*$, that is, $\lambda^2 > (\lambda^*)^2$. But,

$$(\lambda^*)^2 = \frac{\pi^2 E}{\sigma_c}$$

or
$$\lambda^2 > \frac{\pi^2 E}{\sigma_c}$$

that is,
$$\lambda > \pi\sqrt{\frac{E}{\sigma_C}}$$

Reference: Chapter 8

77. Beam A is simply supported at its ends and carries uniformly distributed load of intensity *w* over its entire length. It is made of steel having Young's modulus *E*. Beam B is cantilever and carries a uniformly distributed load of intensity *w*/4 over its entire length. It is made of brass having Young's modulus *E*/2. The two beams are of same length and have same cross-sectional area. If σ_A and σ_B denote the maximum bending stresses developed in beams A and B, respectively, then which of the following is correct?

(a) $\frac{\sigma_A}{\sigma_B} = 1$

(b) $\frac{\sigma_A}{\sigma_B} < 1.0$

(c) $\frac{\sigma_A}{\sigma_B} > 1.0$

(d) $\frac{\sigma_A}{\sigma_B}$ depends on the shape of the cross-section

Answer: (a)
Explanation:
For beam A:

$$M_{\max} = \frac{wL^2}{8}$$

Therefore,

$$\sigma_A = \frac{M_{\max}}{Z} = \frac{wL^2}{8Z}$$

for beam B:

$$M_{\max} = \frac{wL^2}{8}$$

Therefore,

$$\sigma_B = \frac{M_{\max}}{Z} = \frac{wL^2}{8Z}$$

Reference: Chapter 6

78. A circular section rod ABC is fixed at ends A and C. It is subjected to torque T at B. AB = BC = L and the polar moment of inertia of portions AB and BC are $2J$ and J, respectively. If G is the modulus of rigidity, what is the angle of twist at B?

(a) $\dfrac{TL}{3GJ}$

(b) $\dfrac{TL}{2GJ}$

(c) $\dfrac{TL}{GJ}$

(d) $\dfrac{2TL}{GJ}$

Answer: (a)
Explanation: Refer to Figure 31:

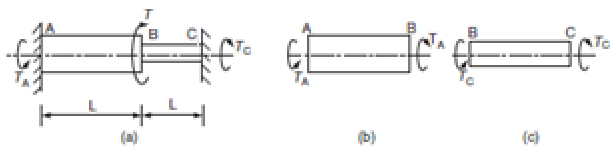

Figure 31

The equations are:

$$T_A - T_C = T \qquad (1)$$

$$\theta_{B/A} = \theta_B - \theta_A = \theta_B = \frac{T_A L}{2GJ}$$

and

$$\theta_{C/B} = \theta_C - \theta_B = -\theta_B = \frac{T_C L}{GJ}$$

so

$$\frac{T_A}{2} + T_C = 0 \qquad (2)$$

From Eqs. (1) and (2):

$$T_A = \frac{2}{3}T \quad \text{and} \quad T_C = -\frac{T}{3}$$

$$\theta_B = \frac{2TL}{(3)2GJ} = \frac{TL}{3GJ}$$

Reference: Chapter 2

79. At a section of a beam, shear force is F with bending moment zero. The cross-section is square with side 'a'. Point A lies on neutral axis and point B is midway between neutral axis and edge, that is, at distance $a/4$ above the neutral axis. If τ_A and τ_B denote shear stresses at points A and B, then what is the value of τ_A: τ_B?

(a) 0
(b) 3/4
(c) 4/3
(d) None of the above

Answer: (c)
Explanation: Refer to Figure 32:

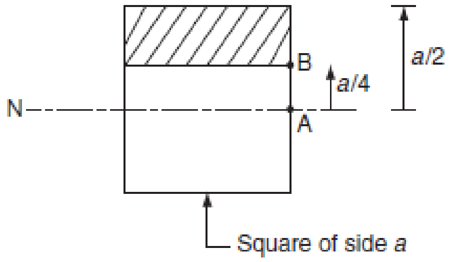

Figure 32

Clearly,

$$\tau_A = \frac{VQ}{bI} = \left(\frac{F}{aI}\right)\left(a \times \frac{a}{2} \times \frac{a}{4}\right) = \left(\frac{F}{I}\right)\left(\frac{a^2}{8}\right)$$

and

$$\tau_B = \left(\frac{F}{aI}\right)\left(a \times \frac{a}{4} \times \frac{3a}{8}\right) = \left(\frac{F}{I}\right)\left(\frac{3a^2}{32}\right)$$

so

$$\tau_A : \tau_B = \frac{a^2}{8} \times \frac{32}{3a^2} = \frac{4}{3}$$

Reference: Chapter 6

80. If the area of cross-section of a circular section beam is made four times, keeping the loads, length, support conditions and material of the beam unchanged, then the qualities (List I) will change through different factors (List II). Match List I with List II and select the correct answer using the code given below the lists:

List I	**List II**
(A) Maximum bending moment	(1) 8
(B) Deflection	(2) 1
(C) Bending stress	(3) 1/8
(D) Section modulus	(4) 1/16

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

Answer: (b)
Explanation: Let previous diameter = *d*
Therefore,

previous area moment of inertia is $I = \dfrac{\pi d^4}{64}$

previous section modulus is $Z = \dfrac{\pi d^3}{32}$

previous area is $\dfrac{\pi d^2}{4}$

new area is $(4)\left(\dfrac{\pi d^2}{4}\right) = \dfrac{\pi}{4}(2d)^2$

new diameter is 2*d*

new moment of inertia is $I = (16)\dfrac{\pi d^4}{64}$

new section modulus is $Z = (8)\dfrac{\pi d^3}{32}$

Deflection $\propto \dfrac{1}{I}$ and bending stress $\propto \dfrac{1}{Z}$

So bending moment is unchanged.
Reference: Chapters 6 and 7

81. Normal stresses of equal magnitude *p* but of opposite signs act at a point of a strained material in perpendicular direction. What is the magnitude of the resultant normal stress on a plane inclined at 45° to the applied stresses?
(a) 2*p*
(b) *p*/2
(c) *p*/4
(d) 0

Answer: (d)
Explanation: Draw the Mohr's circle as shown in Figure 33:

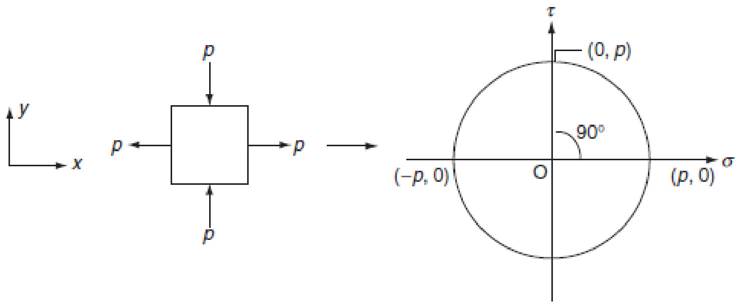

Figure 33

Clearly, on 45° plane, $\sigma_n = 0$.

Reference: Chapter 4

82. A solid metal bar of diameter '*D*' and length '*L*' is hanging vertically from its upper end. The elongation of the bar due to its self-weight is:
(a) proportional to *L* and inversely proportional to D^2
(b) proportional to L^2 and inversely proportional to D^2
(c) proportional to *L* but independent of *D*
(d) proportional of L^2 but independent of *D*

Answer: (d)
Explanation: Refer to Figure 34:

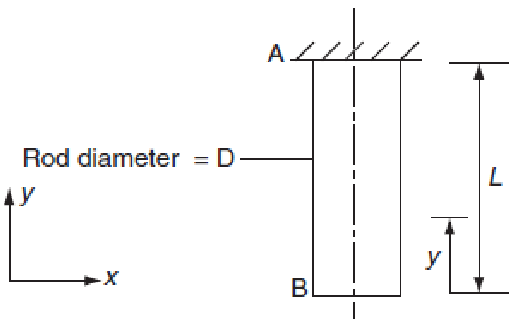

Figure 34

Let γ be the specific weight of rod material. Clearly,

$$\sigma_{yy} = \frac{\gamma y A}{A} = \gamma y = E \in_{yy} = E\frac{\mathrm{d}v}{\mathrm{d}y}$$

where v is the displacement of the bar in *y*-direction. So,

$$\frac{\mathrm{d}v}{\mathrm{d}y} = \left(\frac{\gamma}{E}\right)y \Rightarrow v = \frac{\gamma y^2}{2E} + C$$

at $y = L$, $v = 0 \Rightarrow C = -\frac{\gamma L^2}{2E}$. Therefore,

$$v\big|_{y=0} = C = -\frac{\gamma L^2}{2E}$$

and $$\delta_B = \frac{\gamma L^2}{2E}\ (\downarrow)\ ]$$

Reference: Chapter 1

83. What is the total angle of twist of the stepped-shaft subjected to torque T shown in Figure 35?

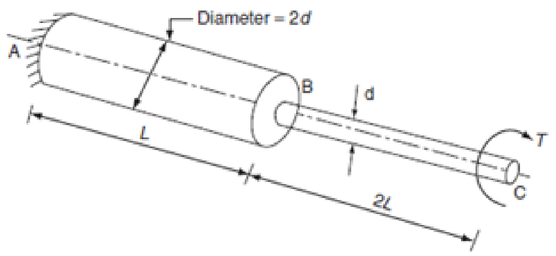

Figure 35

(a) $\frac{16TL}{\pi G d^4}$

(b) $\frac{38TL}{\pi G d^4}$

(c) $\frac{64TL}{\pi G d^4}$

(d) $\frac{66TL}{\pi G d^4}$

Answer: (d)
Explanation:

$$J_{AB} = \frac{\pi(2d)^4}{32} = 16\left(\frac{\pi d^4}{32}\right) \quad \text{and} \quad J_{BC} = \left(\frac{\pi d^4}{32}\right)$$

Thus,

$$\theta_C = \theta_{B/A} + \theta_{C/B} = \frac{TL}{GJ_{AB}} + \frac{T(2L)}{GJ_{BC}}$$
$$= \left(\frac{TL}{G}\right)\left[\frac{32}{16\pi d^4} + \frac{64}{\pi d^4}\right] = \left(\frac{TL}{G}\right)\left[\frac{2}{\pi d^4} + \frac{64}{\pi d^4}\right] = \frac{66TL}{\pi G d^4}$$

Reference: Chapter 2

84. For a power-transmission shaft, transmitting power P at N rpm, its diameter is proportional to:

(a) $\left(\frac{P}{N}\right)^{1/3}$

(b) $\left(\frac{P}{N}\right)^{1/2}$

(c) $\left(\frac{P}{N}\right)^{2/3}$

(d) $\left(\frac{P}{N}\right)$

Answer: (a)
Explanation: Torque is given by

$$T = \frac{60P}{2\pi N} = \left(\frac{30}{\pi}\right)\left(\frac{P}{N}\right)$$

Again,

$$\tau = \frac{16T}{\pi d^3} \Rightarrow d = \sqrt[3]{\frac{16T}{\pi\tau}} = \sqrt[3]{\frac{16}{\pi}\cdot\frac{30}{\pi}\frac{1}{\tau}\left(\frac{P}{N}\right)}$$

Therefore,

$$d \propto \sqrt[3]{\frac{P}{N}}\ ]$$

Reference: Chapter 2

85. A hollow shaft of the same cross-sectional area and material as that of a solid shaft transmits:
(a) same torque.
(b) lesser torque.
(c) more torque.
(d) cannot be predicted without more data.

Answer: (c)
Explanation: If d_o and d_i be the outer and inner diameters of the hollow shaft, while d be diameter of the solid shaft, then by the problem:

$$(d_0^2 - d_i^2) = d^2$$

Again,

$$T_h = \left(\frac{\pi}{16}\tau\right)\left(\frac{d_o^4 - d_i^4}{d_o}\right) \quad \text{and} \quad T_s = \left(\frac{\pi}{16}\tau\right)d^3$$

Therefore,

$$\frac{T_h}{T_s} = \frac{d_o^4 - d_i^4}{d_o d^3} = \frac{(d_o^2 + d_i^2)(d_o^2 - d_i^2)}{d_o d^3} = \frac{(d_o^2 + d_i^2)d^2}{d_o d^3} = \frac{d_o^2 + d_i^2}{d_o d}$$

and

$$\left(\frac{T_h}{T_s}\right)^2 = \frac{(d_o^2 + d_i^2)^2}{d_o^2 d^2} = \frac{(d_o^2 + d_i^2)}{d_o^2}\frac{d_o^2 + d_i^2}{d_o^2 - d_i^2}$$

Clearly both factors are greater than 1, so

$$T_h > T_s$$

Reference: Chapter 2

86. If E, G and K denote Young's modulus, modulus of rigidity and bulk modulus, respectively, for an elastic material, then which one of the following can be possibly true?
(a) $G = 2K$
(b) $G = E$
(c) $K = E$
(d) $G = K = E$

Answer: (c)
Explanation: We know that:

$$G = \frac{E}{2(1+\nu)}$$

and

$$K = \frac{E}{3(1-2\nu)}$$

Therefore,

$$\frac{G}{K} = \frac{3}{2}\left(\frac{1-2\nu}{1+\nu}\right)$$

if

$$\frac{G}{K} = 2 \Rightarrow 3 - 6\nu = 4 + 4\nu \Rightarrow 10\nu = -1 \Rightarrow \nu = -\frac{1}{10} \quad \text{(not possible)}$$

as G can never be equal to E. If K/E = 1 then

$$1-2\nu=\frac{1}{3} \Rightarrow \nu=\frac{1}{3} \quad \text{(possible)}$$

Reference: Chapters 1 and 9

87. At a point in a two-dimensional stress system, σ_{xx} = 100 N/mm^2 and σ_{yy} = τ_{xy} = 40 N/mm^2. What is the radius of the Mohr's circle for stress drawn with a scale of 1 cm = 10 N/mm^2?
(a) 3 cm
(b) 4 cm
(c) 5 cm
(d) 6 cm

Answer: (c)
Reference: Chapter 4

88. The point of contra flexure is a point where
(a) shear force changes sign.
(b) bending moment changes sign.
(c) shear force is maximum.
(d) bending moment is maximum.

Answer: (b)
Reference: Chapter 7

89. Consider the following statements:
(i) Strength of steel increases with carbon content.
(ii) Young's modulus of steel increases with carbon content.
(iii) Young's modulus of steel remains unchanged with variation of carbon content.
Which of the statements given above is/are correct?
(a) (i) only
(b) (ii) only
(c) (i) and (ii)
(d) (i) and (iii)

Answer: (d)
Reference: Chapter 1

90. A hollow pressure vessel is subjected to internal pressure. Consider the following statements:
(i) Radial stress at inner radius is always zero.
(ii) Radial stress at outer radius is always zero.
(iii) Tangential stress is always higher than other stresses.
(iv) Tangential stress is always lower than other stresses.
Which of the statements given above are correct?
(a) (i) and (iii)
(b) (i) and (iv)
(c) (ii) and (iii)
(d) (ii) and (iv)

Answer: (c)
Reference: Chapter 15

91. Autofrettage is a method of
(a) joining thick cylinders.
(b) relieving stresses from thick cylinders.
(c) prestressing thick cylinders.
(d) increasing the life of thick cylinders.

Answer: (c)
Reference: Chapter 15

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92. A 30 CS steel has its yield strength of 400 N/mm^2 and modulus of elasticity of 2×10^5 MPa. Assuming the material to obey Hooke's law up to yielding, what is the proof resilience?
(a) 0.8 N/mm^2
(b) 0.4 N/mm^2
(c) 0.6 N/mm^2
(d) 0.7 N/mm^2

Answer: (b)
Explanation:

$$\text{Proof resilience } = \frac{1}{2}\frac{\sigma^2}{E} = \frac{(400)^2}{2(2)(10^5)} = 0.4 \text{ N/mm}^2$$

Reference: Chapter 10

93. In power-transmission shafts, if the polar moment of inertia of a shaft is doubled, then what is the torque required to produce the same angle of twist?
(a) (1/4) of the original value
(b) (1/2) of the original value
(c) Same as the original value
(d) Double the original value

Answer: (d)
Reference: Chapter 2

94. What is the expression for the crippling load for a column of length L with one end fixed and other end free?

(a) $P = \dfrac{2\pi^2 EI}{L^2}$

(b) $P = \dfrac{\pi^2 EI}{4L^2}$

(c) $P = \dfrac{4\pi^2 EI}{L^2}$

(d) $P = \dfrac{\pi^2 EI}{L^2}$

Answer: (b)
Reference: Chapter 8

95. Match List-I (theory of failure) with List-II (predicted ratio of shear stress to direct stress at yield condition for steel specimen) and select the correct answer using the code given below the lists:

List-I	**List-II**
(A) Maximum shear stress theory	(1). 1.0
(B) Maximum energy distortion theory	(2) 0.77
(C) Maximum principal stress theory	(3). 0.62
(D) Maximum principal strain theory	(4) 0.50

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

Answer: (b)
Explanation:
According to (A):

$$\tau = \frac{\sigma_{yp}}{2} \Rightarrow \frac{\tau}{\sigma_{yp}} = 0.5$$

According to (B):

$$(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 = 2\sigma_{yp}^2$$

for $\sigma_3 = 0$,

$$\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 = \sigma_{yp}^2$$

Assuming von Mises' ellipse, $\tau = 0.577\ \sigma_{yp}$ (given 0.62 value is wrong).
According to (C):

$$\sigma_1 = \sigma_{yp} \quad \text{and} \quad \sigma_2 = -\sigma_{yp}$$

Therefore,

$$\tau = \sigma_{yp}$$

According to (D):

$$\sigma_1 - \nu\sigma_2 = \sigma_{yp} \quad \text{and} \quad \sigma_1 + \sigma_2 = 0$$

Therefore,

$$\sigma_1 = -\sigma_2 = \frac{\sigma_{yp}}{1+\nu}$$

Assuming $\nu = 0.30$, $\tau = 0.77\ \sigma_{yp}$. Therefore, option (b) is correct.
Reference: Chapter 11

96. What is the strain energy stored in a body of volume V with stress σ due to gradually applied load?

(a) $\frac{\sigma E}{V}$

(b) $\frac{\sigma E^2}{V}$

(c) $\frac{\sigma V^2}{E}$

(d) $\frac{\sigma^2 V}{2E}$

Answer: (d)
Reference: Chapter 10

97. In a Mohr's circle, the radius of circle is taken as:

(a) $\sqrt{\left(\frac{\sigma_{xx} - \sigma_{yy}}{2}\right)^2 + \tau_{xy}^2}$

(b) $\sqrt{\left(\frac{\sigma_{xx} - \sigma_{yy}}{2}\right)^2 + \tau_{xy}^2}$

(c) $\sqrt{\left(\frac{\sigma_{xx} - \sigma_{yy}}{2}\right)^2 - \tau_{xy}^2}$

(d) $\sqrt{(\sigma_{xx} - \sigma_{yy})^2 + \tau_{xy}^2}$

where σ_{xx} and σ_{yy} are the normal stresses along x and y directions, respectively, and τ_{xy} is the shear stress.

Answer: (a)
Reference: Chapter 4

98. Disruptive strength is the maximum strength of a metal, when
(a) subjected to three principal tensile stresses at right angles to one another and of equal magnitude.
(b) loaded in tension
(c) loaded in compression
(d) loaded in shear

Answer: (a)
Reference: Chapter 9

99. E, G, K and ν represent the elastic modulus, shear modulus, bulk modulus and Poisson's ratio, respectively, of a linearly elastic, isotropic and homogenous material. To express the stress–strain relations completely for this material, at least
(a) E, G and ν must be known.
(b) E, K and ν must be known.
(c) any two of the four must be known.
(d) all the four must be known.

Answer: (c)
Reference: Chapter 9

100. Principal strains at a point are 100×10^{-6} and 200×10^{-6}. What is the shear strain at the point?
(a) 300×10^{-6}
(b) 200×10^{-6}
(c) 150×10^{-6}
(d) 100×10^{-6}

Answer: (a)
Explanation: From the Mohr's circle of strain, we get:

$$\frac{\gamma}{2} = \frac{1}{2}(100 + 200) \times 10^{-6}$$

or
$$\gamma = 300 \times 10^{-6}$$

Reference: Chapter 9

101. A metal rod is rigidly fixed at its both ends. The temperature of the rod is increased by 100°C. If the coefficient of linear expansion and elastic modulus of the metal rod are 10×10^{-6}/°C and 200 GPa, respectively, then what is the stress produced in the rod?
(a) 100 MPa (tensile)
(b) 200 MPa (tensile)
(c) 200 MPa (compressive)
(d) 100 MPa (compressive)

Answer: (c)
Reference: Chapter 1

102. Figure 36 represents the bending moment diagram for a simply supported beam. The beam is subjected to which one of the following?
(a) A concentrated load at its midlength.
(b) A uniformly distributed load over its length.
(c) A couple at its midlength
(d) Couple at (1/4)th of the span from each end.

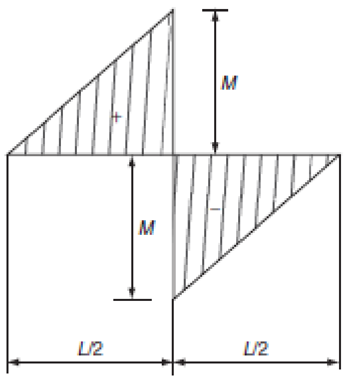


Figure 36

Answer: (c)
Explanation: The beam loading, shear force and bending moment diagrams are shown in Figure 37:

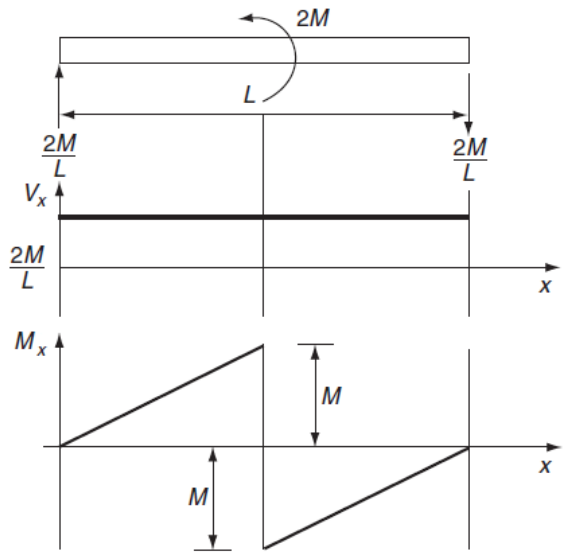


Figure 37

Reference: Chapter 5

103. Which one of the following statements is correct?
Beams of uniform strength vary in section such that
(a) bending-moment remains constant.
(b) deflection remains constant.
(c) maximum bending stress remains constant.
(d) shear force remains constant.

Answer: (c)
Reference: Chapters 6 and 17

104. In the case of beams with circular cross-section, what is the ratio of the maximum shear stress to average shear stress?
(a) 3:1
(b) 2:1
(c) 3:2
(d) 4:3

Answer: (d)
Reference: Chapter 6

105. What is the maximum torque transmitted by a hollow shaft of external radius *R* and internal radius *r*?

(a) $\frac{\pi}{16}(R^3 - r^3) f_s$

(b) $\frac{\pi}{2R}(R^4 - r^4) f_s$

(c) $\frac{\pi}{8R}(R^4 - r^4) f_s$

(d) $\frac{\pi}{32}\left(\frac{R^4 - r^4}{R}\right) f_s$

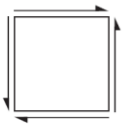
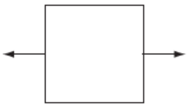
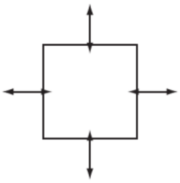
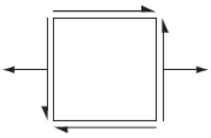
where f_s is the maximum shear stress in the shaft material.

Answer: (b)
Reference: Chapter 2

106. Consider the following statements at given point in the case of thick cylinder subjected to fluid pressure:
(i) Radial stress is compressive.
(ii) Hoop stress is tensile.
(iii) Hoop stress is compressive.
(iv) Longitudinal stress is tensile and it varies along the length.
(v) Longitudinal stress is tensile and remains constant along the length of the cylinder.
Which of the statements given above are correct?
(a) only (i), (ii) and (iv)
(b) only (iii) and (iv)
(c) only (i), (ii) and (v)
(d) only (i), (iii) and (v)

Answer: (c)
Reference: Chapter 15

107. Match List-I (state of stress) with List-II (kind of loading) and select the correct answer using the code given below the lists:

List-I		List-II
(A)		(1) Combined bending and torsion of circular shaft
(B)		(2) Torsion of circular shaft
(C)		(3) Thin cylinder subjected to internal pressure
(D)		(4) Tie bar subjected to tensile force

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

Answer: (c)
Reference: Chapters 2, 3 and 12

108. A body is subjected to a pure tensile stress of 100 units. What is the maximum shear produced is the body at some oblique plane due to the above?
(a) 100 units
(b) 75 units
(c) 50 units
(d) 0 unit

Answer: (c)

Explanation: Shear stress at any plane whose normal makes an angle θ with the applied stress direction is given by

$$\tau = \frac{\sigma_o}{2}\sin 2\theta = 50\sin 2\theta \text{ units}$$

Clearly,

$$(\tau)_{\max} = 50 \text{ units}$$

Reference: Chapter 1

109. While transmitting the same power by a shaft, if its speed is doubles, what should be its new diameter if the maximum shear stress induced in the shaft remains same?

(a) (1/2) of the original diameter

(b) (b) $(1/\sqrt{2})$ of the original diameter

(c) (c) $\sqrt{2}$ times the original diameter

(d) (d) $1/\sqrt[3]{2}$ of the original diameter

Answer: (d)

Explanation: Power transmitted by the shaft of diameter *d* is

$$P = TW = \tau\frac{J}{r}W = \tau\frac{\pi d^3}{16}W$$

According to the condition given: Wd^3 is constant. Thus, $\frac{d_2^3}{d_1^3} = \frac{W_1}{W_2} = \frac{1}{2}$

Hence,

$$d_2 = \frac{1}{\sqrt[3]{2}}d_1$$

Reference: Chapter 2

110. In a tensile test, near the elastic limit zone

(a) tensile stress increases at a faster rate.

(b) tensile stress decreases at a faster rate.

(c) tensile stress increases in linear proportion to the strain.

(d) tensile stress decreases in linear proportion to the strain.

Answer: (c)

Reference: Chapter 1

111. Two tapering bars of the same material are subjected to a tensile load *P*. The lengths of both the bars are the same. The larger diameter of each bar is *D*. The diameter of the bar A at its smaller end is *D*/2 and that of the bar B is *D*/3. What is the ratio of elongation of the bar A to that of the bar B?

(a) 3:2

(b) 2:3

(c) 4:9

(d) 1:3

Answer: (b)

Explanation: Refer to the explanation of Question 61 above, we had shown that for a tapered rod of diameter d_1 and d_2 ($d_1 < d_2$) and length *L*, we know that elongation due to a centric axial load *P* is given by:

$$\delta = \frac{4PL}{\pi E d_1 d_2}$$

Therefore,

$$\frac{\delta_A}{\delta_B} = \frac{(d_1)_B}{(d_1)_A}\cdot\frac{(d_2)_B}{(d_2)_A} = \frac{(D/3)}{(D/2)}\frac{D}{D} = \frac{2}{3}$$

Reference: Chapter 1

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112. A solid circular shaft is subjected to a bending moment *M* and twisting moment *T*. What is the equivalent twisting moment T_e which will produce the same maximum shear stress as the above combination?

(a) $M^2 + T^2$
(b) $M + T$
(c) $\sqrt{M^2 + T^2}$
(d) $M - T$

Answer: (c)
Reference: Chapter 12

113. Which one of the following statements is correct?
If a helical spring is halved in length, its spring stiffness,
(a) remains same.
(b) halves.
(c) doubles.
(d) triples.

Answer: (c)
Reference: Chapter 2

114. The diameter of a solid shaft is *D*. The inside and outside diameters of a hollow shaft of same material and length are $D/\sqrt{3}$ and $2D/\sqrt{3}$, respectively. What is the ratio of the weight of the hollow shaft to that of the solid shaft?
(a) 1:1
(b) $1:\sqrt{3}$
(c) 1:2
(d) 1:3

Answer: (a)
Reference: Chapter 2

115. Which one of the following statements is correct?
When a rectangular section beam is loaded transversely along the length, shear stress develops on
(a) top fibre of rectangular beam.
(b) middle fibre of rectangular beam.
(c) bottom fibre of rectangular beam.
(d) every horizontal plane.

Answer: (b)
Reference: Chapter 6

116. A cantilever beam of 2 m length supports a triangularly distributed load over its entire length, the maximum of which is at the free end. The total load is 37.5 kN. What is the bending moment at the fixed end?
(a) 50×10^6 N m
(b) 12.5×10^6 N mm
(c) 100×10^6 N mm
(d) 25×10^6 N mm

Answer: (a)
Explanation: Refer to Figure 38:

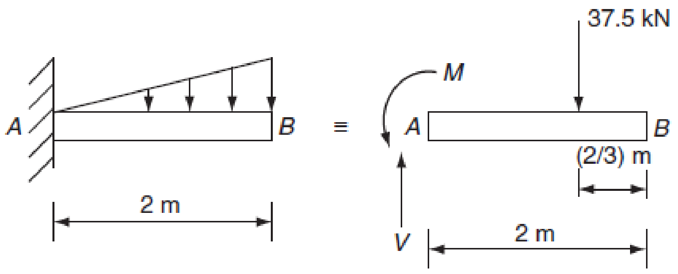

Figure 38

From the figure,

$$\overset{+}{\uparrow}\sum M_A = 0 \Rightarrow M - \left(2 - \frac{2}{3}\right)(37.5)(10^6) = 0 \Rightarrow M = 50 \times 10^6 \text{ N mm}$$

Reference: Chapter 5

117. Which of the following statements is correct?
If a material expands freely due to heating, it will develop
(a) thermal stress.
(b) tensile stress.
(c) compressive stress.
(d) no stress.

Answer: (d)
Reference: Chapter 1

118. What is the phenomenon of progressive extension of the material, that is, strain increasing with time at a constant load, called?
(a) Plasticity
(b) Yielding
(c) Creeping
(d) Breaking

Answer: (b)
Reference: Chapter 11

119. What are the materials which show direction dependent properties, called?
(a) Homogenous materials
(b) Viscoelastic materials
(c) Isotropic materials
(d) Anisotropic materials

Answer: (d)
Reference: Chapter 1 and 9

120. If the ratio *G* : *E* (*G* = modulus of rigidity, *E* = Young's modulus of elasticity) is 0.4, then what is the value of Poisson's ratio?
(a) 0.20
(b) 0.25
(c) 0.30
(d) 0.33

Answer: (b)
Explanation:

$$G = \frac{E}{2(1+\nu)} \Rightarrow \frac{G}{E} = \frac{1}{2(1+\nu)} = 0.4 \Rightarrow \nu = 0.25$$

Reference: Chapter 1

121. For a general two-dimensional stress system, what are the coordinates of the centre of Mohr's circle?

(a) $\left(\frac{\sigma_{xx}-\sigma_{yy}}{2}, 0\right)$

(b) $\left(0, \frac{\sigma_{xx}+\sigma_{yy}}{2}\right)$

(c) $\left(\frac{\sigma_{xx}+\sigma_{yy}}{2}, 0\right)$

(d) $\left(0, \frac{\sigma_{xx}-\sigma_{yy}}{2}\right)$

Answer: (c)
Reference: Chapter 4

122. In a strained material one of the principal stresses is twice the other. The maximum shear stress in the same case is τ_{max}. Then, what is the value of the maximum principal stress?

(a) τ_{max}
(b) $2\tau_{max}$
(c) $4\tau_{max}$
(d) $8\tau_{max}$

Answer: (c)
Explanation: Given $\sigma_1 = 2\sigma_2$. Also,

$$\tau_{max} = \frac{1}{2}(\sigma_1 - \sigma_2) = \frac{1}{2}\left(\sigma_1 - \frac{\sigma_1}{2}\right) = \frac{\sigma_1}{4}$$

or,

$$\sigma_1 = 4\tau_{max}$$

Reference: Chapter 4

123. Which one of the following expresses the total elongation of a bar of length '*L*' with a constant cross-section of *A* and modulus of elasticity *E* hanging vertically and subject to its own weight *W*?

(a) $\frac{WL}{AE}$

(b) $\frac{WL}{2AE}$

(c) $\frac{2WL}{AE}$

(d) $\frac{WL}{4AE}$

Answer: (b)
Explanation: Refer to the explanation of Question 82 above. We know that free-end deflection is

$$\delta = \frac{\gamma L^2}{2E} = \frac{(\gamma LA)L}{2AE} = \frac{WL}{2AE}$$

Reference: Chapter 1

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124. A structural member subjected to an axial compressive force is called

(a) beam.
(b) column.
(c) frame.
(d) strut.

Answer: (b)
Remarks: It can also be called strut, if the length of the member is small.
Reference: Chapter 8

125. In I-section of a beam subjected to transverse shear force, the maximum shear stress is developed

(a) at the centre of the web.
(b) at the bottom edge of top flange.
(c) at the top edge of top flange.
(d) none of the above.

Answer: (a)
Reference: Chapter 6

126. Maximum deflection of a cantilever beam of length *L* carrying uniform distributed load '*w*' per unit length will be:

(a) $\dfrac{wL^4}{EI}$

(b) $\dfrac{wL^4}{4EI}$

(c) $\dfrac{wL^4}{8EI}$

(d) $\dfrac{wL^4}{384EI}$

where *E* is modulus of elasticity of beam material and *I* is moment of inertia of beam cross-section.

Answer: (c)
Explanation: Consider Figure 39:

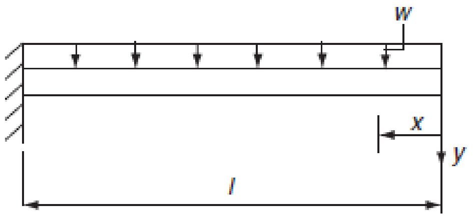


Figure 39

We know that:

$$EI\frac{d^4y}{dx^4} = w(x) = +w$$

$$(EI)y_3 = wx + C_1, \text{ at } x = 0, \; EIy_3 = 0 \Rightarrow C_1 = 0$$

$$(EI)y_2 = \frac{wx^2}{2} + C_2, \text{ at } x = 0, \; EIy_2 = 0 \Rightarrow C_2 = 0$$

$$(EI)y_1 = \frac{wx^3}{6} + C_3 \text{ at } x = L, \; y_1 = 0 \Rightarrow C_3 = -\frac{wL^3}{6}$$

$$(EI)y = +\frac{wx^4}{24} - \frac{wL^3x}{6} + C_4 \text{ at } x = L, \; y = 0 \Rightarrow C_4 = \frac{wL^4}{6} - \frac{wL^4}{24} = \frac{wL^4}{8}$$

Therefore,

$$y = \left(\frac{w}{EI}\right)\left[\frac{x^4}{24} - \frac{xL^3}{6} + \frac{L^4}{8}\right] \Rightarrow y\big|_{x=0} = \frac{wL^4}{8EI}$$

Reference: Chapter 7

127. Maximum shear stress in a Mohr's circle

(a) is equal to radius of Mohr's circle.
(b) is greater than radius of Mohr's circle.
(c) is less than radius of Mohr's circle.
(d) could be any of the above.

Answer: (a)

Reference: Chapter 4

128. Consider the following statements:

Maximum shear stress induced in a power transmitting shaft is

(i) directly proportional to torque being transmitted

(ii) inversely proportional to the cube of its diameter

(iii) directly proportional to its polar moment of inertia

Which of the statements given above are correct?

(a) (i), (ii) and (iii)

(b) (i) and (iii) only

(c) (ii) and (iii) only

(d) (i) and (ii) only

Answer: (d)

Reference: Chapter 2

129. A closed-coil helical spring of mean coil diameter *D* and made from a wire of diameter *d* is subjected to a torque *T* about the axis of spring. What is the maximum stress developed in the spring wire?

(a) $\frac{8T}{\pi d^3}$

(b) $\frac{16T}{\pi d^3}$

(c) $\frac{32T}{\pi d^3}$

(d) $\frac{64T}{\pi d^3}$

Answer: (c)

Reference: Chapter 2

130. A helical coil spring with wire diameter *d* and coil diameter *D* is subjected to external load. A constant ratio of *d* and *D* has to be maintained, such that the extension of spring is dependent of *d* and *D*. What is this ratio?

(a) $\frac{D^3}{d^4}$

(b) $\frac{d^3}{D^4}$

(c) $\frac{D^{4/3}}{d^3}$

(d) $\frac{d^{4/3}}{D^3}$

Answer: (a)

Explanation: We know that

$$\delta = \frac{64nPR^3}{Gd^4} = \frac{8nPD^3}{Gd^4}$$

now let $d = \lambda D$. Therefore,

$$\delta = \frac{8nPD^3}{G\lambda^4 D^4} = \frac{8Pn}{G}\frac{1}{\lambda^4 D}$$

Let $\lambda^4 D$ be constant, sod^4/D^3 is constant.

Reference: Chapter 2

131. Which one of the following expresses the stress factor used for design of close-coiled helical spring?

(a) $\frac{4C-4}{4C-1}$

(b) $\dfrac{4C-1}{4C-4}+\dfrac{0.615}{C}$

(c) $\dfrac{4C-4}{4C-1}+\dfrac{0.615}{C}$

(d) $\dfrac{4C-1}{4C-4}$

where C is spring index.

Answer: (b)
Reference: Chapter 2

132. A solid shaft transmits a torque T. The allowable shear stress is τ. What is the diameter of the shaft?

(a) $\sqrt[3]{\dfrac{16T}{\pi\tau}}$

(b) $\sqrt[3]{\dfrac{32T}{\pi\tau}}$

(c) $\sqrt[3]{\dfrac{16T}{\tau}}$

(d) $\sqrt[3]{\dfrac{T}{\tau}}$

Answer: (a)
Reference: Chapter 2

133. What is the shape of the shear stress distribution across a rectangular cross-section beam?

(a) Triangular
(b) Parabolic only
(c) Rectangular only
(d) A combination of rectangular and parabolic shapes.

Answer: (b)
Reference: Chapter 6

134. Match List-I (formula/theorem/method) with List-II (deals with topic) and select the correct answer using the code given below the lists:

List-I	**List-II**
(A) Clapeyron's theorem	(1) Deflection of beam
(B) Macaulay's method	(2) Eccentrically loaded column
(C) Perry's formula	(3) Rivetted joints
	(4) Continuous Beam

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

Answer: (b)
Reference: Chapters 7 and 8

135. The shear force diagram for a beam is shown in Figure 40. The bending moment diagram is represented by which one of the figures?

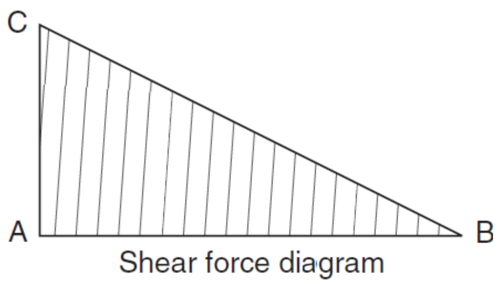
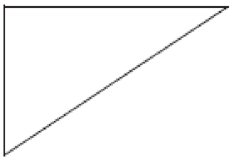
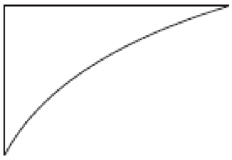
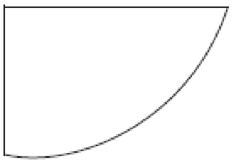
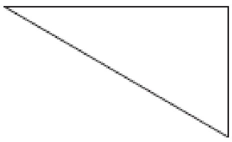


Figure 40

(a) 

(b) 

(c) 

(d) 

Answer: (b)
Reference: Chapter 5

136. What is the relationship between the linear elastic properties: Young's modulus (*E*), modulus of rigidity (*G*) and bulk modulus (*K*)?

(a) $\frac{1}{E}=\frac{9}{K}+\frac{3}{G}$

(b) $\frac{3}{E}=\frac{9}{K}+\frac{1}{G}$

(c) $\frac{9}{E}=\frac{3}{K}+\frac{1}{G}$

(d) $\frac{9}{E}=\frac{1}{K}+\frac{3}{G}$

Answer: (d)
Explanation: From explanation of Question 86 above, we know that:

$$G=\frac{E}{2(1+\nu)} \Rightarrow 2+2\nu=\frac{E}{G}$$

and $$K=\frac{E}{3(1-2\nu)} \Rightarrow 1-2\nu=\frac{E}{3K}$$

so, $$\frac{E}{G}+\frac{E}{3K}=3 \Rightarrow \frac{3}{G}+\frac{1}{K}=\frac{9}{E}]$$

Reference: Chapter 1

137.

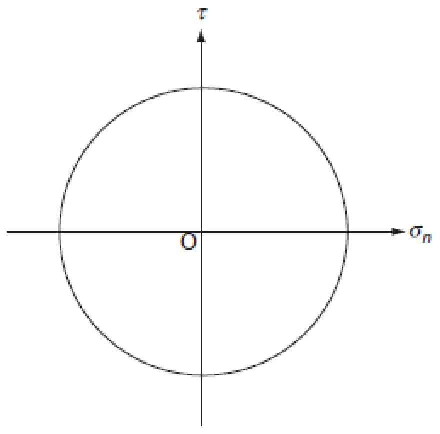


Figure 41

Consider the Mohr's circle shown in Figure 41. What is the state of stress represented by the circle?

(a) $\sigma_{xx} = \sigma_{yy} \neq 0,\ \tau_{xy} = 0$

(b) $\sigma_{xx} = \sigma_{yy} = 0,\ \tau_{xy} \neq 0$

(c) $\sigma_{xx} = 0,\ \sigma_{yy} = \tau_{xy} \neq 0$

(d) $\sigma_{xx} \neq 0,\ \sigma_{yy} = \tau_{xy} = 0$

Answer: (b)
Explanation: Since the centre coordinates are (0,0).
Reference: Chapter 4

138. A point in a two-dimensional state of strain is subjected to pure shear strain of magnitude γ_{xy} radians. Which one of the following is the maximum principal strain?

(a) γ_{xy}

(b) $\dfrac{\gamma_{xy}}{2}$

(c) $\dfrac{\gamma_{xy}}{\sqrt{2}}$

(d) $2\,\gamma_{xy}$

Answer: (b)
Explanation:

$$\in_{max} = \frac{1}{2}(\in_{xx} + \in_{yy}) + \frac{1}{2}\sqrt{(\in_{xx} - \in_{yy})^2 + \gamma_{xy}^2} = \frac{\gamma_{xy}}{2} \quad (\text{as } \in_{xx} = \in_{yy} = 0)$$

Reference: Chapter 9

139. The principal stresses at a point in two-dimensional stress system are σ_1 and σ_2. Corresponding principal strains are $\in_1$ and $\in_2$. If E and ν denote Young's modulus and Poisson's ratio, respectively, then which one of the following is correct?

(a) $\sigma_1 = E \in_1$

(b) $\sigma_1 = \dfrac{E}{1-\nu^2}(\in_1 + \nu \in_2)$

(c) $\sigma_1 = \dfrac{E}{1-\nu^2}(\in_1 - \nu \in_2)$

(d) $\sigma_1 = E(\in_1 - \nu \in_2)$

Answer: (b)
Explanation: From generalised Hooke's law in two dimensions,

$$\in_1 = \frac{1}{E}(\sigma_1 - \nu\sigma_2) \quad \text{and} \quad \in_2 = \frac{1}{E}(\sigma_2 - \nu\sigma_1)$$

Therefore,

$$\sigma_1 - \nu\sigma_2 = E \in_1$$

$$\sigma_2 - \nu\sigma_1 = E \in_2 \quad \Rightarrow \quad \nu\sigma_2 - \nu^2\sigma_1 = E\nu \in_2$$

Hence,

$$\sigma_1 = \frac{E}{1-\nu^2}(\in_1 + \nu \in_2) \,]$$

140. The ratio of torque carrying capacity of a solid shaft to that of a hollow shaft is given by:

(a) $1-K^4$

(b) $(1-K^4)^{-1}$

(c) K^4

(d) $1/K^4$

where $K = D_i/D_o$ and where D_i is the inside diameter of a hollow shaft and D_o is the outside diameter of the hollow shaft material are same.

Answer: (b)

Explanation:

$$T_s = \frac{\pi}{16} D^3 \tau$$

Assuming outer diameter of shafts being same,

$$T_h = \frac{\pi}{16} \frac{D_o^4 - D_i^4}{D_o} \quad \Rightarrow \quad \frac{T_s}{T_h} = \frac{D_o D^3}{D_o^4 - D_i^4} = \frac{D_o^4}{D_0^4 - D_i^4}$$

Therefore,

$$\frac{T_s}{T_h} = \frac{1}{1-K^4} = (1-K^4)^{-1}$$

Reference: Chapter 2

141. A shaft is subjected to combined twisting moment *T* and bending moment *M*. What is the equivalent bending moment?

(a) $\frac{1}{2}\sqrt{M^2 + T^2}$

(b) $\sqrt{M^2 + T^2}$

(c) $\frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$

(d) $M + \sqrt{M^2 + T^2}$

Answer: (c)

Reference: Chapter 12

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142. Assertion (A): Mohr's construction is possible for stresses, strains and are moment of inertia.

Reason (R): Mohr's circle represents the transformation of second-order tensor.

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

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

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

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

Answer: (a)

Reference: Chapter 2

143. An overhanging beam ABC is supported at points A and B as shown in Figure 42. Find the maximum bending-moment and the point where it occurs.

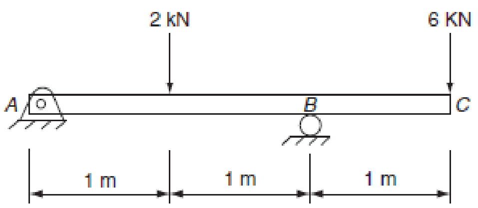


Figure 42

(a) 6 kN m at the right support
(b) 6 kN m at the left support
(c) 4.5 kN m at the right support
(d) 4.5 kN m at the midpoint between the support.

Answer: (a)
Explanation: Let us draw Figure 43:

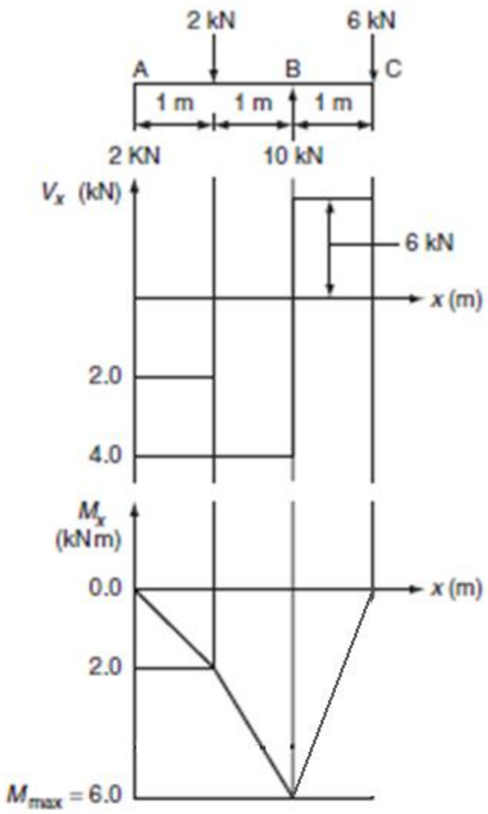


Figure 43

Therefore,

$$|M_{\text{max}}| = 6.0 \text{ kN m at B}$$

Reference: Chapter 5

144. A freely supported beam at its ends carries a central concentrated load, and maximum bending-moment is *M*. If the same load is uniformly distributed over the beam length, then what is the maximum bending moment?
(a) *M*
(b) *M*/2
(c) *M*/3
(d) 2*M*

Answer: (b)

Explanation: For a simply-supported beam of length L with central concentrated load P, the maximum bending, M is given by $M = PL/4$.

For the second case, if w_o is the uniformly distributed loading intensity, then

$$M'_{\max} = \frac{w_o L^2}{8} = \frac{(w_o L)L}{8} = \frac{PL}{8} \quad (\text{as } w_o L = P)$$

Hence,

$$M'_{\max} = \frac{M}{2}$$

Reference: Chapter 5

145. A uniformly distributed load w (in kN/m) is acting over the entire length of 3 m long cantilever beam. If the shear force at the midpoint of cantilever is 6 kN, what is the value of w?

(a) 2
(b) 3
(c) 4
(d) 5

Answer: (c)

Explanation:

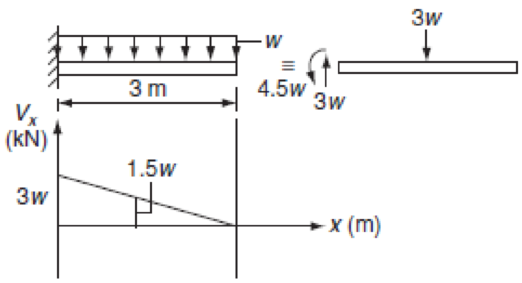


Figure 44

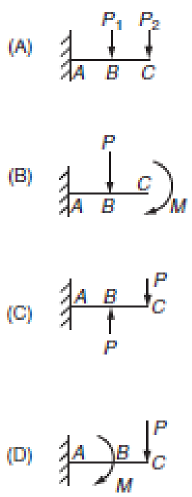
From the above figure,

$$1.5w = 6 \text{ kN} \Rightarrow w = 4 \text{ kN/m}$$

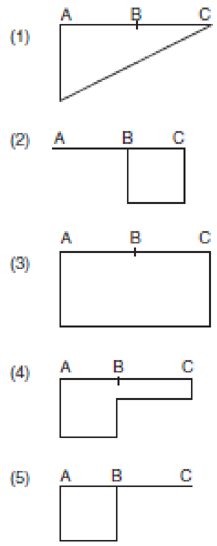
Reference: Chapter 5

146. Match List-I (cantilever loading) with List-II (shear force) and select the correct answer using the code given below the lists:

List-I



List-II



Code	A	B	C	D
(a)	1	5	2	4
(b)	4	5	4	3
(c)	1	3	4	5
(d)	4	2	5	3

Answer: (b)
Reference: Chapter 5

147. Consider the following statements:
When two springs of equal lengths are arranged to form a cluster spring
(i) angle of twist in both the springs will be equal.
(ii) deflection of both the springs will be equal.
(iii) load taken by each spring will half the total load.
(iv) shear stress in each spring will be equal.
Which of the above statements is/are correct?
(a) (i) and (ii)
(b) (iii) and (iv)
(c) (ii) only
(d) (iv) only

Answer: (a)
Reference: Chapter 2

148. What is the expression for the strain energy due to bending of a cantilever beam (length *L*, modulus of elasticity *E* and moment of inertia *I*)?
(a) $\frac{P^2L^3}{3EI}$
(b) $\frac{P^2L^3}{6EI}$
(c) $\frac{P^2L^3}{4EI}$
(d) $\frac{P^2L^3}{48EI}$

Answer: (b)
Explanation: Assume *p* is the concentrated load at free-end of the beam. Therefore, bending moment at a distance *x* from the free-end is:

$$M_x = -P_x$$

The strain energy due to bending U_b is:

$$U_b = \int_0^L \frac{M_x^2 dx}{2EI} = \left(\frac{P^2}{2EI}\right)\int_0^L x^2 dx = \frac{P^2L^3}{6EI}$$

Reference: Chapter 10

149. A steel specimen 150 mm^2 in cross-section stretches by 0.05 mm over a 50 mm gauge length under an axial load of 30 kN. What is the strain-energy stored in the specimen? (Take *E* = 200 GPa.)
(a) 0.75 N m
(b) 1.0 N m
(c) 1.5 N m
(d) 3.0 N m

Answer: (d)
Explanation: Strain-energy stored within the specimen is

$$\frac{1}{2}P\cdot\delta = \frac{1}{2}(30)(10^3)(0.05)(10^{-3})\ \text{N m} = 0.75\ \text{N m}$$

Reference: Chapter 10

150. Four vertical columns of same material, height and weight have the same end condition. Which cross-section will carry the maximum load?

(a) Solid circular cross-section
(b) Thin hollow circular section
(c) Solid square section
(d) I-section

Answer: (d)
Explanation: Area-moment of inertia of I-beam is more than other cross-section mentioned above.
Reference: Chapter 8

151. Consider the following statements:

(i) Two-dimensional stresses applied to a thin plate in its own plane represent the plane-stress condition.
(ii) Under plane-stress condition, the strain in the direction perpendicular to the plane is zero.
(iii) Normal and shear stresses may occur simultaneously on a plane.
Which of the above statements is/are correct?

(a) (i) only
(b) (i) and (ii)
(c) (ii) and (iii)
(d) (i) and (iii)

Answer: (d)
Explanation: Please refer to Section 9.4 of Chapter 9 of Part B of the book.
Reference: Chapter 9

152. A water main of 1 m diameter contains water at a pressure head of 100 m. The permissible tensile stress in the material of the water main is 25 MPa. What is the minimum thickness of the water main? (Assume g = 10 m/s^2.)

(a) 10 mm
(b) 20 mm
(c) 50 mm
(d) 60 mm

Answer: (b)
Explanation: Assume the water main to be a thin-cylinder pressure vessel with maximum stress (in circumferential direction) given by the equation:

$$\sigma_1 = \frac{pr}{t} = \frac{pd}{2t}$$

Thus,

$$t = \frac{pd}{2\sigma_1} = \frac{(Pgh)d}{2\sigma_1} \quad (\text{as } p = Pgh;\ h = \text{ pressure head of water})$$

Therefore,

$$t = \frac{(10^3)(10)(10^2)(1.0)}{(2)(25)(10^6)}\,\text{m} = 0.02\text{ m} = 20\text{ mm}$$

Reference: Chapter 3