# Model Answer: Summer- 2019

**Subject: Strength of Materials** **Sub. Code: 22306**

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## Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more importance. (Not applicable for subject English and Communication Skills.)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by the candidate and those in the model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and the model answer.
6) In case of some questions credit may be given by judgment on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

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| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
|---|---|---|---|---|
| Q.1 | | **Attempt any Five of the following:** | | (10) |
| | a) | **Define:**<br>**(i) Moment of Inertia**<br>**(ii) Radius of Gyration** | | |
| | Ans. | **i) Moment of Inertia:** Moment of Inertia of a body about any axis is equal to the product of the area of the body and square of the distance of its centroid from that axis. | 1 | |
| | | **OR**<br>Moment of inertia of a body about any axis is defined as the sum of second moment of all elementary areas about that axis. | | 2 |
| | | **ii) Radius of Gyration:** Radius of Gyration of a given area about any axis is that distance from the given axis at which the entire area is assumed to be concentrated without changing the M. I. about the given axis. | 1 | |
| | b) | **State the relation between Young's modulus and bulk modulus.** | | |
| | Ans. | $E = 3K(1 - 2\mu)$<br>Where, E= Young's Modulus<br>K= Bulk Modulus<br>$\mu$= Poisson's Ratio | 2 | 2 |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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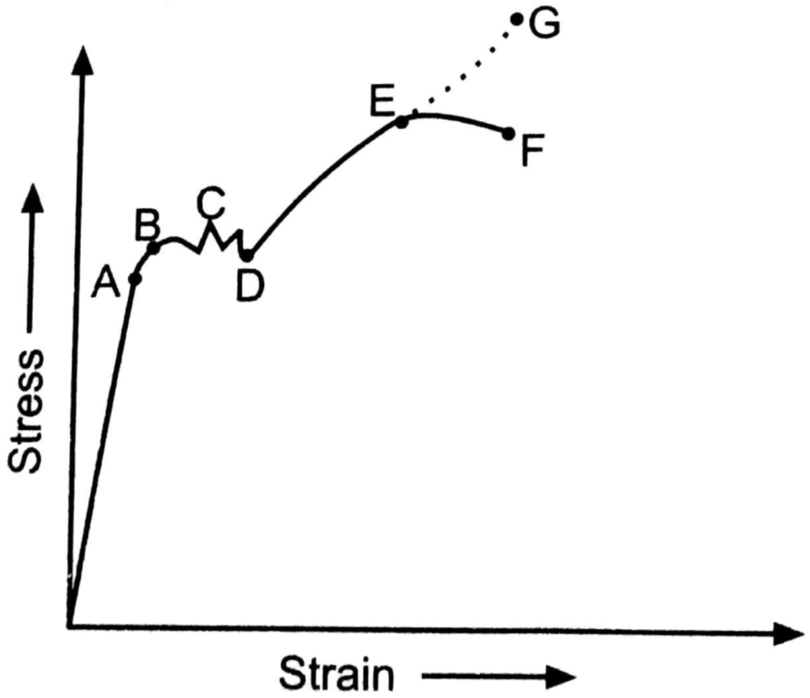
| Q.1 | c)<br>Ans. | **Draw stress-strain diagram for mild-steel rod and show different limits on it.**<br><br><br>Where,<br>A = Limit of proportionality<br>B = Elastic limit<br>C = Upper yield point<br>D = Lower yield point<br>E = Ultimate load point<br>F = Breaking point | 1<br><br>1 | 2 |
| | d)<br>Ans. | **Define point of contra-flexure of a loaded beam with sketch.**<br>**Point of Contra-flexure:** It is the point in bending moment diagram where bending moment changes its sign from positive to negative and vice versa. At that point bending moment is equal to zero. This point is called as point of contra-flexure. | 1 | |

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| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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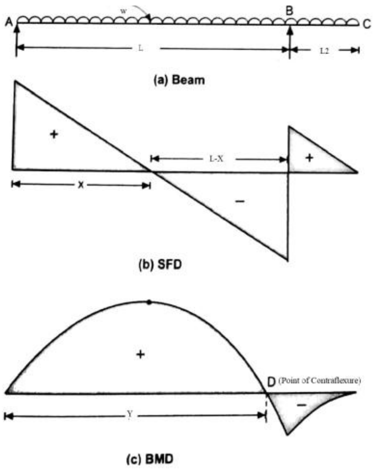
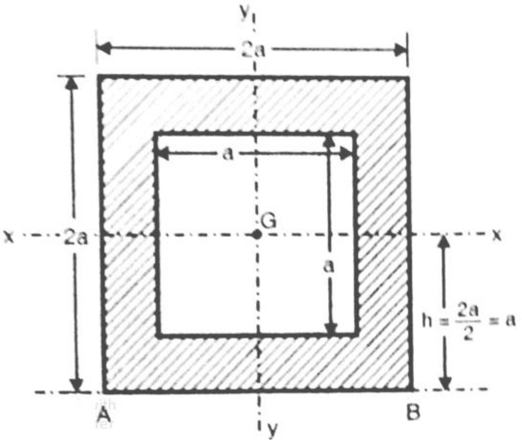
| Q.1 | |  | 1 | 2 |
| | e) Ans. | **Define section modulus and neutral axis.**<br>**Section Modulus:** It is the ratio of M. I. of the section about the neutral axis and the distance of the most extreme fiber from the neutral axis.<br>**Neutral Axis:** It is the axis shown in cross-section where bending stress is zero called as neutral axis.<br>**OR**<br>The intersection of the neutral layer with any normal cross section of a beam is called as neutral axis. | 1<br><br>1 | 2 |
| | f) Ans. | **State the condition for no tension at the base of a column.**<br>If the load acting in the middle third area or core of the section, then the material experiences only compressive stress without producing tensile stress. i.e. Direct stress is equal to bending stress. Minimum stress is zero, such condition is said to be no tension condition.<br>$\sigma_0 = \sigma_b$<br>i.e. $e \leq \frac{Z}{A}$ | 1<br><br>1 | 2 |
| | g) Ans. | **Define the core of a section.**<br>The centrally located portion of a within which the load must act so as to produce only compressive stress is called a core of the section. | 2 | 2 |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
|---|---|---|---|---|
| Q. 2 | | **Attempt any <u>THREE</u> of the following:** | | (12) |
| | a) | **A hollow square has inner dimensions a × a and outer dimensions 2a × 2a. Find moment of inertia about the outer side.** | | |
| | Ans. |  | 1 | |
| | | $I_{AB} = \left[I_G + Ah^2\right]_1 - \left[I_G + Ah^2\right]_2$ | 1 | |
| | | $I_{AB} = \left[\frac{b^4}{12} + Ah^2\right]_1 - \left[\frac{b^4}{12} + Ah^2\right]_2$ | | |
| | | $I_{AB} = \left[\frac{(2a)^4}{12} + (2a \times 2a) \times a^2\right]_1 - \left[\frac{(a)^4}{12} + (a \times a) \times a^2\right]_2$ | 1 | 4 |
| | | $I_{AB} = \left[\frac{16a^4}{12} + 4a^4\right]_1 - \left[\frac{a^4}{12} + a^4\right]_2$ | | |
| | | $I_{AB} = \left[\frac{64a^4}{12}\right]_1 - \left[\frac{13a^4}{12}\right]_2$ | | |
| | | $I_{AB} = a^4\left[\frac{64-13}{12}\right]$ | | |
| | | $I_{AB} = a^4\left[\frac{51}{12}\right]$ | | |
| | | $I_{AB} = 4.25a^4$ | 1 | |
| | b) | **In a bi-axial stress system the stresses along the two directions are $\sigma_x$ = 60 N/mm$^2$ (tensile) and $\sigma_y$ = 40 N/mm$^2$ (compressive). Find the maximum strain. Take E = 200 kN/mm$^2$ and m = 4.** | | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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| Q.2 | Ans. | $e_x=\left(\frac{\sigma_x}{E}\right)-\left(\mu\frac{\sigma_y}{E}\right)$ <br> $=\frac{1}{E}\left(\sigma_x-\mu\times\sigma_y\right)$ <br> $=\frac{1}{200\times10^3}\left(60\ +0.25\times40\right)$ <br> $\boxed{e_x=3.5\times10^{-4}}$ <br> $e_y=\left(\frac{\sigma_y}{E}\right)-\left(\mu\frac{\sigma_x}{E}\right)$ <br> $=\frac{1}{E}\left(\sigma_y-\mu\sigma_x\right)$ <br> $=\frac{1}{200\times10^3}\left(-40-0.25\times60\right)$ <br> $\boxed{e_y=-2.75\times10^{-4}}$ <br><br> **Maximum strain is $e_x$=3.5×10$^{-4}$** | 1 <br><br> 1 <br><br> 1 <br><br> 1 | 4 |
| | c) | **A simply supported beam of span 5 m carries two point loads of 5kN and 7 kN at 1.5 m and 3.5 m from the left hand support respectively. Draw S.F.D. and B.M.D. showing important values.** | | |
| | Ans. | I. Support Reactions: <br> $\sum M_A=0$ <br> $5\times1.5+7\times3.5-R_B\times5=0$ <br> $5\times R_B=32$ <br> $R_B=6.4$ kN <br> $\sum F_y=0$ <br> $R_A+R_B-5+7=0$ <br> $R_A+R_B=12$ <br> $R_A=5.6$ kN <br> II. SF calculations <br> SF at A = + 5.6 kN <br> $C_L=+5.6kN$ <br> $C_R=5.6-5=0.6kN$ <br> $D_L=+0.6kN$ <br> $D_R=+0.6-7=-6.4kN$ <br> $B_L=-6.4kN$ <br> $B=+6.4-6.4=0kN\ \ (\therefore ok)$ | 1 <br><br> 1 | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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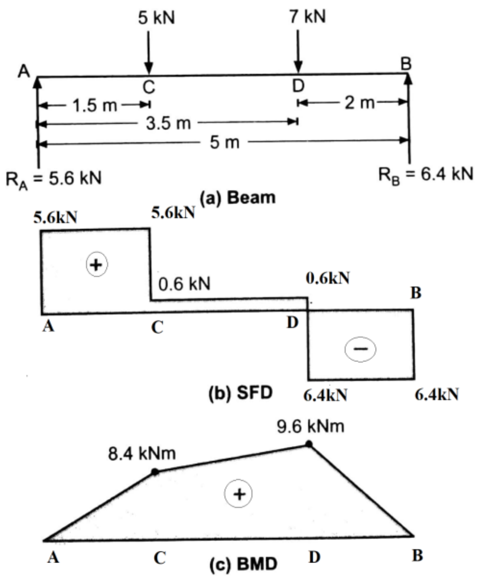
| **Q.2** | **c)** | B.M. calculation:-<br>B.M at A and B= 0 Since support A and B are simple.<br>B.M at C = 5.6 × 1.5=8.4 kN-m<br>B.M at D = 6.4× 1.5=9.6 kN-m | **1** | **4** |
| | |  | **1** | |
| | **d)** | **Explain the theory of pure torsion.** | | |
| | **Ans.** | A shaft is a rotating part of machine which transmits power from one point to other. When a force acts tangentially at a point on the surface of the shaft it rotates or twist. The twisting is due to the moment of a tangential force at the axis of rotation. The shaft is said to be in torsion.<br>The study of behavior of the shaft in torsion without taking into account bending moment due to self-weight or other longitudinal forces known as **pure torsion**.<br>Due to torsion shearing stress are induced in the material of the shaft. Every point in the material of the shaft is subjected to pure shear. | **3** | **4** |
| | | Torsional Equation is<br>$\frac{G\theta}{L}=\frac{T}{I_p}=\frac{\tau}{R}$ | **1** | |

| Que No. | Sub. Que. | Model Answer | Marks | Total Marks |
|---|---|---|---|---|
| | | Where,<br>T = Torque or Turning moment (N-mm)<br>$I_p = I_{xx} + I_{yy}$ Polar momet of inertia of the shaft section ($mm^4$)<br>G = Modulus of rigidity of the shaft material ($N/mm^2$)<br>θ = Angle through which the shaft is twisted due to torque i.e. angle of twist (radians)<br>L= Lenght of the shaft (mm)<br>$\tau$ = Maximum shear stress induced at the outermost layer of the shaft ($N/mm^2$)<br>R= Radius of the shaft (mm) | | |
| **Q.3** | | **Attempt any THREE of the following:** | | **(12)** |
| | **a)** | **A cylindrical bar is 30mm in diameter and 2000mm long. The bar is subjected to uniform stress of 100 $N/mm^2$ in all directions. Calculate the modulus of rigidity and bulk modulus. If the modulus of elasticity is $1\times10^5$ $N/mm^2$ and Poisson's ratio is 0.2.** | | |
| | **Ans.** | Data: d=30mmØ, L=2000mm, σ =100 $N/mm^2$, E=$1\times10^5$ $N/mm^2$, μ =0.2<br>Find: K and G<br>$V = A\times L = \frac{\pi d^2}{4}\times L = \frac{\pi\times30^2}{4}\times2000 = 1413716.69\text{mm}^3$<br>$\delta V = \frac{3\sigma}{E}(1-2\mu)V$<br>$\delta V = \frac{3\times100}{1\times10^5}\times(1-2\times0.2)\times1413716.69 = 2544.69\text{mm}^3$<br>$K = \frac{\sigma}{\left(\frac{\delta V}{V}\right)} = \frac{100}{\left(\frac{2544.69}{1413716.69}\right)} = 5.55\times10^4\ \text{N/mm}^2$<br>**OR**<br>$E = 3K(1-2\mu)$<br>$1\times10^5 = 3K(1-2\times0.2)$<br>$K = 5.55\times10^4\ \text{N/mm}^2$<br>$E = 2G(1+\mu)$<br>$1\times10^5 = 2G(1+0.2)$<br>$G = 4.16\times10^4\ \text{N/mm}^2$ | **2**<br>**2** | **4** |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
|---|---|---|---|---|
| | b) | **Find the bending stress induced in the steel flat 40mm wide and 5mm thick if it is required to bend into an arc of a circle of radius 2.5m. Also calculate the moment required to bend the flat. Take E=2×10⁵ MPa.** | | |
| | Ans. | Data: b=40mm, t=5mm, R =2.5m, $E=2\times10^5$ MPa.<br>Find: $\sigma_b$ and BM<br>$I_{xx}=\frac{bd^3}{12}=\frac{40\times5^3}{12}=416.67mm^4$<br>$Y=\frac{t}{2}=\frac{5}{2}=2.5mm$ | 1 | |
| | | **Bending stress equation:**<br>$\frac{\sigma_b}{Y}=\frac{M}{I}=\frac{E}{R}$ | 1 | 4 |
| | | $\frac{\sigma_b}{Y}=\frac{E}{R}$<br>$\sigma_b=\frac{E}{R}\times Y=\frac{2\times10^5}{2500}\times2.5=200N/mm^2$ | 1 | |
| | | $\frac{M}{I}=\frac{E}{R}$<br>$M=\frac{E}{R}\times I=\frac{2\times10^5}{2500}\times416.67=3.33\times10^4$ N-mm | 1 | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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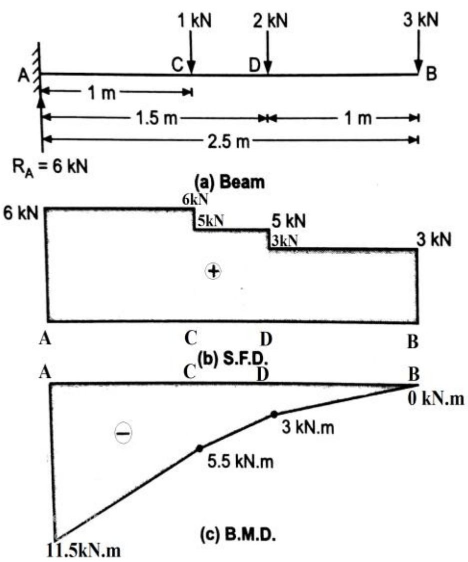
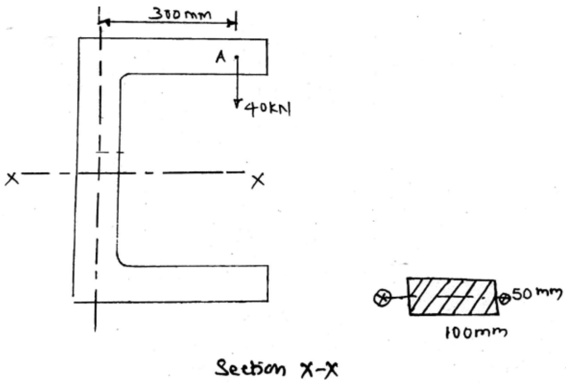
| Q.3 | c) | **A cantilever beam of span 2.5m carries three point loads of 1kN, 2kN, and 3kN at 1m, 1.5m, and 2.5m from the fixed end. Draw S.F.D. and B.M.D.** | | |
| | Ans. | I. To calculate reaction at support A<br>$\Sigma Fy = 0$<br>$R_A - 1 - 2 - 3 = 0$<br>$R_A = 6kN$ | | |
| | | II. SF calculation:<br>SF at A = +6kN<br>$C_L$ = +6kN<br>$C_R$ = +6-1= 5kN<br>$D_L$ = +5kN<br>$D_R$ = +5-2= 3kN<br>$B_L$ = +3kN<br>B= +3-3= 0 ( $\therefore$ ok) | 1 | |
| | | III. BM calculation:<br>BM at B = 0 $\because$ B is free end.<br>$D = -3\times1 = -3kN\text{-}m$<br>$C = -3\times1.5 - 2\times0.5 = -5.5kN\text{-}m$<br>$A = -3\times2.5 - 2\times1.5 - 1\times1 = -11.5kN\text{-}m$ | 1 | 4 |
| | |   | 1<br><br>1 | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
|---|---|---|---|---|
| | d) | **A rectangular rod of size 50mm×100mm is bent into 'C' shape as shown in Fig.no. 1 and applied load of 40kN at point A. Calculate the resultant stresses developed at section x-x.** | | |
| | |   Fig. No. 1 | | |
| | Ans. | Data: b=100mm, d=50mm, P=40kN | | |
| | | $A = b\times d = 50\times100 = 5000mm^2$ | | |
| | | $I = \frac{b\times d^3}{12} = \frac{50\times100^3}{12} = 4.17\times10^6 mm^4$ | 1 | |
| | | $Y = \frac{b}{2} = \frac{100}{2} = 50mm$ | | |
| | | $M = P\times e = 40\times10^3\times300 = 12\times10^6$ N-mm | | |
| | | $\sigma_o = \frac{P}{A} = \frac{40\times10^3}{5000} = 8N/mm^2$ | 1 | 4 |
| | | $\sigma_b = \frac{M}{I}\times Y = \frac{12\times10^6}{4.17\times10^6}\times50 = 143.88N/mm^2$ | 1 | |
| | | $\sigma_{max} = \sigma_o + \sigma_b$<br>$\sigma_{max} = 8 + 143.88 = 151.88N/mm^2$ | 1 | |
| | | $\sigma_{min} = \sigma_o - \sigma_b$<br>$\sigma_{min} = 8 - 143.88 = 135.88N/mm^2$ | | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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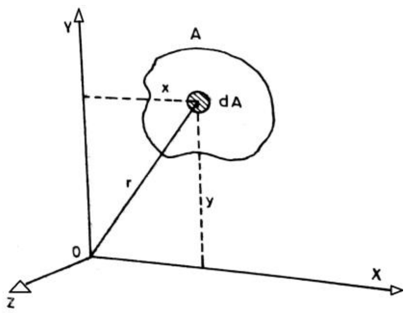
| Q.4 | | **Attempt any THREE of the following:** | | (12) |
| | a) | **State and explain perpendicular axis theorem of moment of Inertia.** | | |
| | Ans. | **Perpendicular axis theorem:** It states "MI of a plane lamina about an axis perpendicular to the plane of lamina and passing through the centroid of the lamina is equal to the addition of the moments of inertia of the lamina about its centroidal axes". | 1 | |
| | | Figure below shows the plane lamina laying in XY plane, OX and OY are mutually perpendicular and OZ is the axis perpendicular to plane XY of the lamina. | 1 | 4 |
| | |   | 1 | |
| | | **MI of lamina about OZ is** <br> $I_z = \Sigma dA(r^2)$ <br> $I_z = \Sigma dA(x^2 + y^2)$ <br> $I_z = \Sigma dA(x^2) + \Sigma dA(y^2)$ <br> $I_z = I_x + I_y$ | 1 | |
| | b) | **A steel bar 50 mm × 50 mm in section, 3m long is subjected to an axial pull of 20kN. Calculate the change in length and change in side of the bar. Take E = 200 GPa and Poission's ratio = 0.3.** | | |
| | Ans. | Data: b=50 mm, d =50 mm, L=3m, P = 20 kN, E = 200 GPa μ = 0.3 <br> Calculate: δL, δb, and δd <br> $\delta L = \frac{PL}{AE}$ | 1 | |
| | | $\delta L = \frac{20\times10^3\times3\times10^3}{50\times50\times200\times10^3}$ <br> $\delta L = 0.12 mm$ | 1 | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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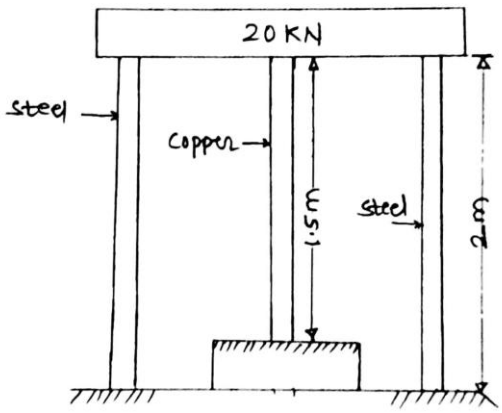
| Q.4 | b) | $\mu = \frac{Lateral\ Strain}{Linear\ Strain}$ <br> $\mu = \frac{\left(\frac{\delta b}{b}\right)}{\left(\frac{\delta L}{L}\right)}$ <br> $0.3 = \frac{\left(\frac{\delta b}{50}\right)}{\left(\frac{0.12}{3000}\right)}$ <br> $\delta b = 6\times10^{-4}mm$ | 1 | 4 |
| | | $\mu = \frac{\left(\frac{\delta d}{d}\right)}{\left(\frac{\delta L}{L}\right)}$ <br> $0.3 = \frac{\left(\frac{\delta d}{50}\right)}{\left(\frac{0.12}{3000}\right)}$ <br> $\delta d = 6\times10^{-4}mm$ | 1 | |
| | c) <br> Ans. | **Two steel rods and one copper rod each of 20 mm in diameter together support a load of 20 kN as shown in Fig. No. 2. Find the stresses in the rod, Es = 210 GPa and Ec = 110 GPa.** <br>   <br> **Fig. No. 2** <br> Data: ds = 20mmΦ, dc = 20mmΦ, Ls = 2m, Lc = 1.5m, P = 20kN, Es = 210 GPa and Ec = 110 GPa. | | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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| Q.4 | c) | $As = 2\times\left(\frac{\pi d_s^{\ 2}}{4}\right) = 2\times\left(\frac{\pi\times 20^2}{4}\right) = 628.32\text{mm}^2$ <br> $Ac = \left(\frac{\pi d_c^{\ 2}}{4}\right) = \left(\frac{\pi\times 20^2}{4}\right) = 314.16\text{mm}^2$ | 1 | |
| | | $P = P_s + P_c$ <br> $p = \sigma_s A_s + \sigma_c A_c$ <br> $20\times10^3 = \sigma_s 628.32 + \sigma_c 314.16$ | 1 | |
| | | $\frac{\sigma_s L_s}{E_s} = \frac{\sigma_c L_c}{E_c}$ <br> $\frac{\sigma_s \times 2000}{210\times10^3} = \frac{\sigma_c \times 1500}{110\times10^3}$ <br> $\sigma_s = 1.43\sigma_c$ | 1 | 4 |
| | | $20\times10^3 = (1.43\sigma_c)628.32 + \sigma_c 314.16$ <br> $\sigma_c = 16.49\text{N/mm}^2$ <br> $\sigma_s = 1.43\sigma_c$ <br> $\sigma_s = 1.43\times16.49 = 23.58\text{N/mm}^2$ | 1 | |
| | d) Ans. | **Calculate safe axial load in tension for a steel bar of cross-section 75 mm × 12 mm, if allowable maximum stress is 155 MPa.** <br> Data: b = 75 mm, d = 12 mm, $\sigma_{allowable}$ = 155 MPa <br> Calculate: $P_{safe}$ | | |
| | | $A = b\times d = 75\times12 = 900\ \text{mm}^2$ | 1 | |
| | | $\sigma_{allowable} = \frac{P_{safe}}{A}$ | 1 | |
| | | $P_{safe} = \sigma_{allowable}\times A$ <br> $P_{safe} = 155\times 900 = 139500$ N | 1 | 4 |
| | | $\boxed{P_{safe} = 139.5\ \text{kN}}$ | 1 | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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| Q.4 | e) | **A bar of 30 mm diameter is subjected to a pull of 60 kN. The measured extension on gauge length of 200 mm is 0.09 mm and the change in diameter is 0.0039 mm. Calculate the Poission's ratio and modulus of elasticity.** | | |
| | Ans. | Data: d=30 mm, L=200 mm, P =60 kN, $\delta_L$=0.09 mm, $\delta_d$ = 0.0039 mm<br>Calculate: μ and E | | |
| | | $A = \frac{\pi d^2}{4} = \frac{\pi \times 30^2}{4} = 706.858 mm^2$ | | |
| | | $E = \frac{PL}{A\delta_L} = \frac{60\times10^3\times200}{706.858\times0.09} = 188628.08 N/mm^2$<br>$\boxed{E = 1.89 N/mm^2}$ | 2 | |
| | | $\mu = \frac{\text{Lateral Strain}}{\text{Linear Strain}}$<br>$\mu = \frac{\left(\frac{\delta_d}{d}\right)}{\left(\frac{\delta_L}{L}\right)} = \frac{\left(\frac{0.0039}{30}\right)}{\left(\frac{0.09}{200}\right)} = 0.29$<br>$\boxed{\mu = 0.29}$ | 2 | 4 |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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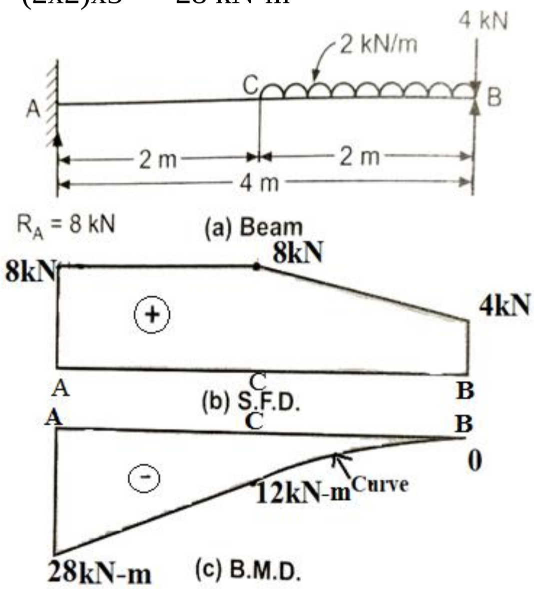
| Q.5 | | **Attempt any TWO of the following:** | | **(12)** |
| | a) | **A cantilever beam 4 m long carries a u.d.l. of 2 kN/m over 2 m from free end and point load of 4 kN at free end. Draw SF and BM diagrams.** | | |
| | Ans. | i) Support Reaction Calculation:<br>$\Sigma Fy = 0$<br>$R_A - 4 - (2x2) = 0$<br>$R_A = 8$ kN | | |
| | | ii) Shear Force Calculations:<br>$(F)_A = +8$ kN<br>$(F_R)_A = +8$ kN<br>$(F)_C = +8$ kN<br>$(F)_B = +4 = 4$ kN<br>$(F_R)_B = 4 - 4 = 0$ kN | 2 | |
| | | iii) Bending Moment Calculations:<br>$M_B = 0$ kN-m B is free end.<br>$M_C = -(4x2) - (2x2)x1 = -12$ kN-m<br>$M_A = -(4x4) - (2x2)x3 = -28$ kN-m | 2 | 6 |
| | |  | 1<br>1 | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
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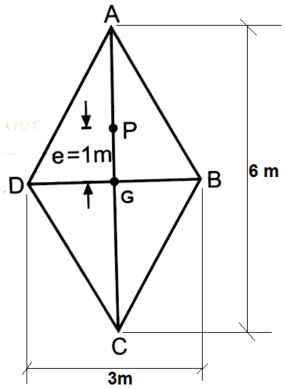
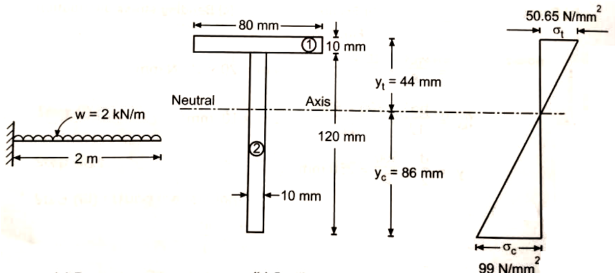
| Q.5 | b) | **Select a suitable diameter for a solid circular shaft to transmit 200HP at 180 rpm. The allowable shear stress is 80 N/mm$^2$ and the allowable angle of twist is 1° in a length of 3m. Take C = 0.82 x 10$^5$ N/mm$^2$.** | | |
| | Ans. | Data: P = 200 HP, N = 180 rpm, $\tau$ = 80 N/mm$^2$ $\theta$=1°, L = 3 m<br>C = 0.82 x 10$^5$ N/mm$^2$<br><br>Find d<br><br>**Case – I**<br>Diameter of shaft based on Shear Strength Criteria:<br>$P = \left(\frac{2\pi NT}{4500}\right) HP$<br>$200 = \left(\frac{2\pi \times 180 \times T}{4500}\right)$<br>T = 795.775 kg-m<br>T = 795.775 x 9.81 N-m<br>T = 7806.5499 x 10$^3$ N-mm | 1<br><br>1 | |
| | | By using the relation<br>$T = \frac{\pi}{16} \times \tau \times d^3$<br>$7806.5499 \times 10^3 = \frac{\pi}{16} \times 80 \times d^3$<br>**d = 79.21 mm** | 1 | 6 |
| | | **Case – II**<br>Diameter of shaft based on Rigidity Criteria:<br>By using the relation:<br>$\frac{T}{J} = \frac{C\theta}{L}$<br>$\frac{7806.5499 \times 10^3}{\frac{\pi}{32} d^4} = \frac{0.82 \times 10^5 \times \left(1^0 \times \frac{\pi}{180}\right)}{3 \times 10^3}$<br><br>d = 113.63 mm | 1<br><br>1 | |
| | | Choose the diameter of solid circular shaft equal to 114mm to satisfy the given conditions. | 1 | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
|---|---|---|---|---|
| Q.5 | c) | **A diamond shaped pier with diagonals 3 m and 6 m is subjected to an eccentric load of 1500 kN at a distance of 1 m from centroid and on the longer diagonal. Calculate the maximum stress induced in the section.** | | |
| | Ans. | **Data:** P = 1500 kN e = 1 m<br>To find $\sigma_{max}$ = ?<br><br> | | |
| | | Direct stress, $\sigma_0 = \frac{P}{A} = \frac{1500\times10^3}{2\left(\frac{1}{2}\times3000\times3000\right)} = 0.1667\,\text{N/mm}^2$ | 1 | |
| | | Bending Moment, M = Pxe =(1500 x $10^3$)x(1 x $10^3$) = 1.5 x $10^9$ N-mm | 1 | |
| | | As the eccentricity is about Centroidal X-X axis, therefore<br>$I_{xx} = I_{DB} = I_{base} = 2 \text{ x } \left(\frac{bh^3}{12}\right) = 2\times\left(\frac{3000\times3000^3}{12}\right)$ = 13.5 x $10^{12}$ $mm^4$ | 1 | |
| | | Distance of extreme layer (i.e. point A or C) from X-X axis –<br>Y = 6000/2 = 3000 mm | | |
| | | Section modulus:<br>$Z_{xx} = \frac{I_{xx}}{Y} = \frac{13.5\times10^{12}}{3000} = 4.5\times10^9\,\text{mm}^3$ | 1 | 6 |
| | | Bending Stress:<br>$\sigma_b = \frac{M}{Z_{xx}} = \frac{1.5\times10^9}{4.5\times10^9} = 0.333\,\text{N/mm}^2$ | 1 | |
| | | Maximum Bending Stress:<br>$\sigma_{max} = \sigma_0 + \sigma_b$ = 0.1667 + 0.333 = 0.5 $N/mm^2$ (Compressive) | 1 | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
|---|---|---|---|---|
| **Q.6** | | **Attempt any <u>TWO</u> of the following:** | | **(12)** |
| | **a)** | **A cantilever is 2 m long and is subjected to udl of 2 kN/m. The cross section of cantilever is tee section with flange 80 mm x 10 mm and web of 10 mm x 120 mm such that its total depth is 130 mm. The flange is at the top and web is vertical. Determine maximum tensile stress and compressive stress developed and their positions.** | | |
| | **Ans.** | Data: L = 2 m, $w$ = 2 kN/m<br>To find: $\sigma_{c(max)}$ and $\sigma_{t(max)}$ | | |
| | |   (a) Beam (b) Section (c) Bending stress distribution | 1 | |
| | | $M_{max} = \frac{wL^2}{2} = \frac{(2\times10^3)\times2^2}{2} = 4\times10^3\,N-m = 4\times10^6\,N-mm$ | 1 | |
| | | $\overline{Y}_{base} = \frac{a_1y_1 + a_2y_2}{a_1+a_2} = \frac{(80\times10)\times125+(10\times120)\times60}{(80\times10)+(10\times120)} = 86mm$ | | |
| | | $I_{NA} = I_{XX} = \left[\left(\frac{bd^3}{12}\right)+Ah^2\right]_1 + \left[\left(\frac{bd^3}{12}\right)+Ah^2\right]_2$ | | |
| | | $I_{XX} = \left[\left(\frac{80\times10^3}{12}\right)+(80\times10)\times(44-5)^2\right]_1 + \left[\left(\frac{10\times120^3}{12}\right)+(10\times120)\times(86-60)^2\right]_2$ | | |
| | | $I_{NA} = I_{XX} = 347.466\text{x}10^4\ mm^4$ | 1 | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
|---|---|---|---|---|
| Q.6 | a) | $\bar{Y}_{base} = Y_C = 86$ mm<br>$Y_t = 130 - 86 = 44$ mm | 1 | 6 |
| | | Maximum Compressive and Tensile Stress developed:<br>$\frac{M_{max}}{I} = \frac{\sigma_C}{Y_C} = \frac{\sigma_t}{Y_t}$ | 1 | |
| | | $\frac{4\times10^6}{347.466\times10^4} = \frac{\sigma_C}{86} = \frac{\sigma_t}{44}$<br>$\sigma_C = \frac{4\times10^6\times86}{347.466\times10^4} = 99.002 N/mm^2$ (At Bottom fiber)<br>$\sigma_t = \frac{4\times10^6\times44}{347.466\times10^4} = 50.652 N/mm^2$ (At Top fiber) | 1 | |
| | b) (i) | **A steel rod 800 mm long and 60 mm x 20 mm in cross section is subjected to an axial push of 89 kN. If the modulus of elasticity is 2.1 x $10^5$ N/mm$^2$. Calculate the stress, strain and reduction in the length of rod.** | | |
| | Ans. | Data: L=800mm, b=60mm, d=20mm, P=89kN, E=2.1x$10^5$N/mm$^2$<br>Find $\sigma$, e , $\delta_L$ | | |
| | | Stress induced in the steel rod:<br>**$\sigma = \frac{P}{A} = \frac{89\times10^3}{60\times20}$ = 74.17 N/mm$^2$** | 1 | |
| | | Strain induced in the steel rod:<br>$E = \frac{\sigma}{e}$<br>$2.1 \times 10^5 = \frac{74.17}{e}$<br>**e = 3.53 x $10^{-4}$** | 1 | |
| | | Reduction in the length:<br>$\delta_L = \frac{PL}{AE} = \frac{89\times10^3\times800}{(60\times20)\times2.1\times10^5}$ | 1 | |
| | | **$\delta_L$ = 0.2835 mm** | 1 | |

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
|---|---|---|---|---|

**Q.6 b) (ii)** **Differentiate between linear and lateral strain.**

**Ans.**

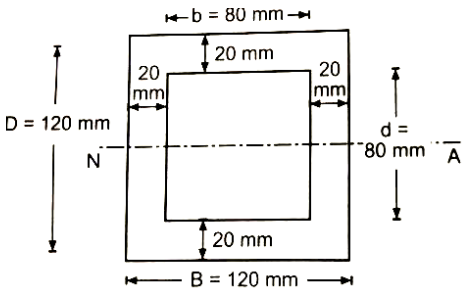
| Linear Strain | Lateral Strain |
|---|---|
| The change in dimensions occurs in the direction of applied load is called as Linear Strain. $e = \frac{\delta_L}{L}$ | The change in dimensions occurs in the direction perpendicular to the line of action of applied load is called as Lateral Strain. $e = \frac{\delta_b}{b}$, $e = \frac{\delta_t}{t}$, $e = \frac{\delta_d}{d}$ |

Marks: 2 — Total Marks: 6

**c)** **A hollow rectangular beam section square in size having outer dimensions 120 mm x 120 mm with uniform thickness of material 20 mm is carrying a shear force of 125 kN. Calculate the maximum shear stress induced in the section.**

**Ans.** Data: B = D = 120 mm, t = 20mm, F = 125 kN

Find $\tau_{max}$




**Beam Section**

b = d = 120 – 2t = 120 – 2 x 20 = 80 mm

Consider the area above the N.A.

Shear stress ($\tau_1$) at the bottom of flange by taking width (b=120mm)

$$\tau_1 = \frac{FA\overline{Y}}{I\,b}$$ (1)

$$\overline{Y} = 60 - \frac{20}{2} = 50mm$$

# Model Answer: Summer- 2019

**Subject: Strength of Materials** **Sub. Code: 22306**

| Que. No. | Sub. Que. | Model Answer | Marks | Total Marks |
|---|---|---|---|---|
| Q.6 | c) | I = $\frac{1}{12}\left(BD^3 - bd^3\right) = \frac{1}{12}\left(120\times120^3 - 80\times80^3\right) = 13.866\times10^6\, mm^4$ | 1 | |
| | | $\therefore \tau_1 = \frac{(125\times10^3)\times(120\times20)\times50}{13.866\times10^6\times120}$ **= 9.015 N/mm²** | 1 | |
| | | Shear stress ($\tau_2$) at the bottom of flange by taking width (b=20+20=40mm) | | |
| | | $\therefore \tau_2 = \tau_1 \times \frac{120}{40} = 9.015 \times \frac{120}{40}$ **27.045 N/mm²** | 1 | |
| | | Width at N.A. = 20 + 20 = 40 mm | | 6 |
| | | Web area above the N.A. | | |
| | | A = 2 x (40x20) = 1600 mm² | | |
| | | C.G. of this area from N.A. | | |
| | | $\overline{Y} = \frac{40}{2} = 20mm$ | | |
| | | $\therefore$ Additional Shear Stress due to web area above the N.A. is given by | | |
| | | $\tau_{additional} = \frac{FA\overline{Y}}{I\,b} = \frac{(125\times10^3)(1600)(20)}{13.866\times10^6\times40} = 7.212 N/mm^2$ | 1 | |
| | | $\tau_{max} = \tau_{NA} = \tau_2 + \tau_{additional}$ | | |
| | | = 27.045 + 7.212 | | |
| | | **= 34.256 N/mm²** | 1 | |