

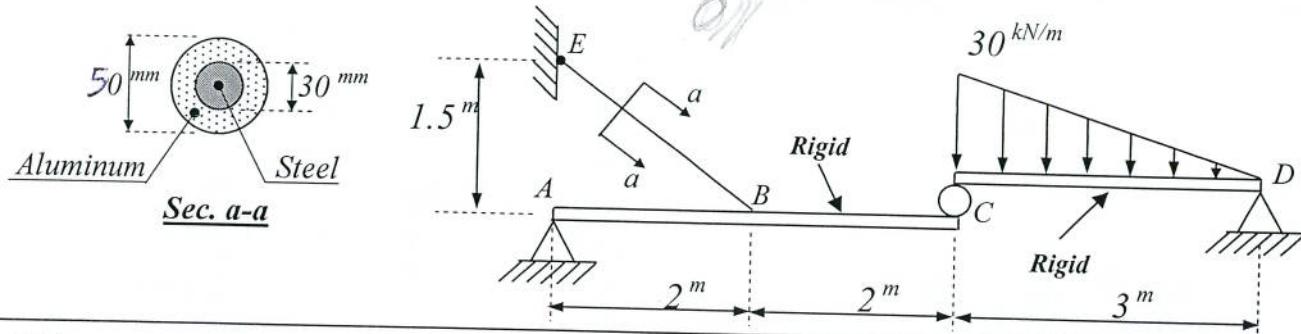


Note: Answer FIVE questions only

Q.1 (20 Marks)

Two rigid beams ABC & CD are connected together by an internal roller at (C) and supported by a composite flexible cable (steel & aluminum) at (B) as shown in the figure below. If $E_s = 200 \text{ GPa}$ and $E_{al} = 70 \text{ GPa}$, determine:

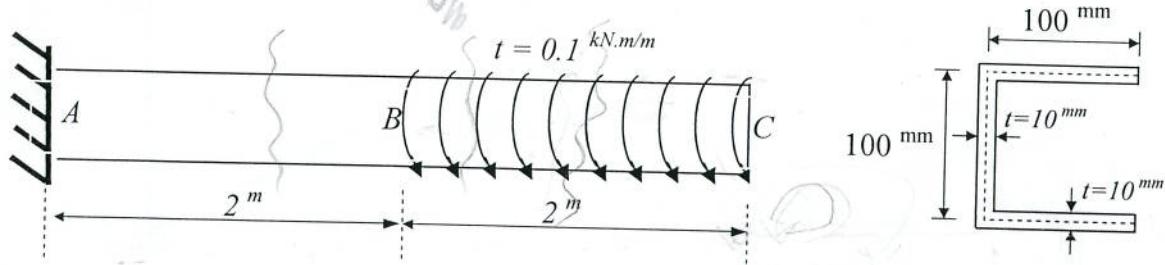
1. The stresses developed in steel & aluminum.
2. The vertical deflection at C.



Q.2 (20 Marks)

(13 Marks) A. For the figure shown. If $E = 200000 \text{ MPa}$ & $\nu = 0.25$, determine:

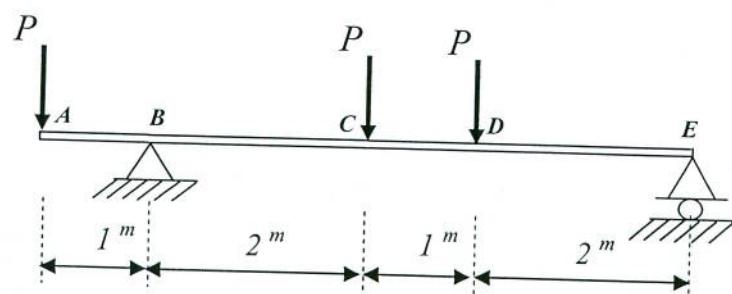
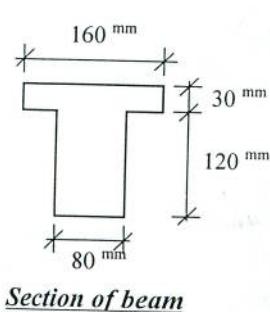
1. The angle of twist at the free end.
2. The maximum shearing stress.



(7 Marks) B. Derive the torsion formula for a solid circular shaft.

Q.3 (20 Marks)

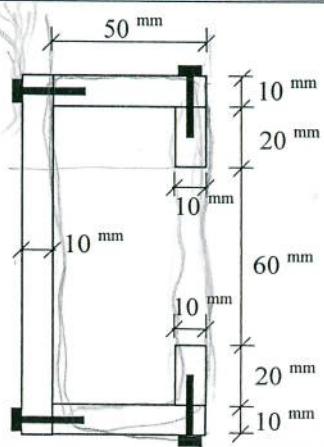
The beam shown in the figure below is supporting three concentrated forces each of (P) at A, C & D. If the allowable stresses in beam material are 80 MPa and 6 MPa for bending and shear respectively, calculate the safe force (P) that can be applied.



Q.4 (20 Marks)

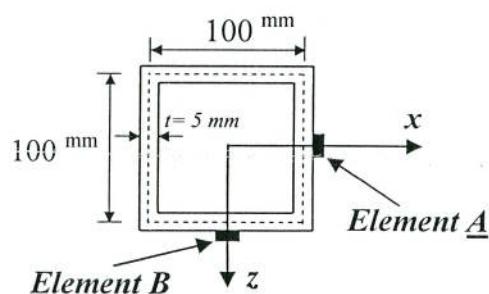
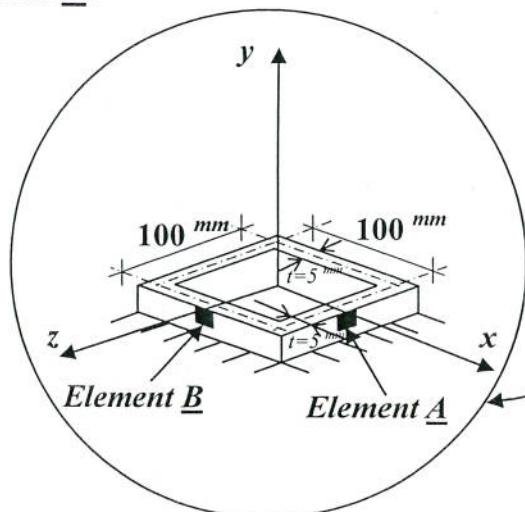
The section shown in the figure is subjected to a shear force ($V = 6.408 \text{ kN}$). Each bolt can resist a shear force of 2 kN . Determine:

1. The spacing of each bolt.
2. The shear center of the section.

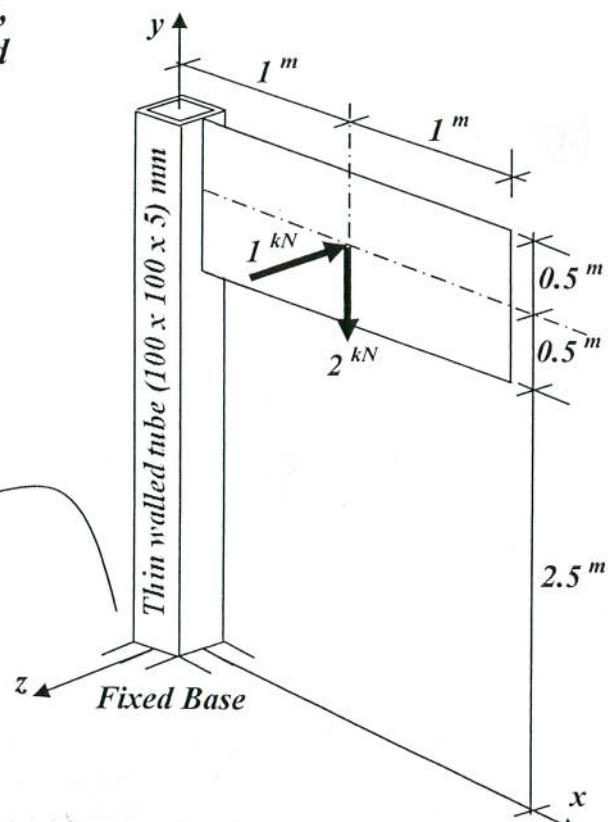


Q.5 (20 Marks)

For the sign board shown in the figure, find the state of stress at element A and element B.

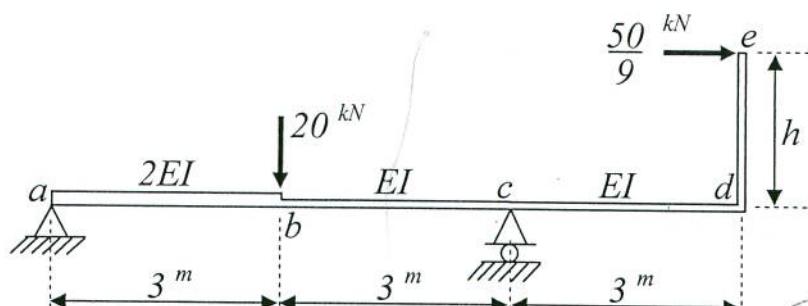


Section at Base



Q.6 (20 Marks)

For the figure shown, by using the moment area method, find the value of height (h) that make zero deflection at point (d).

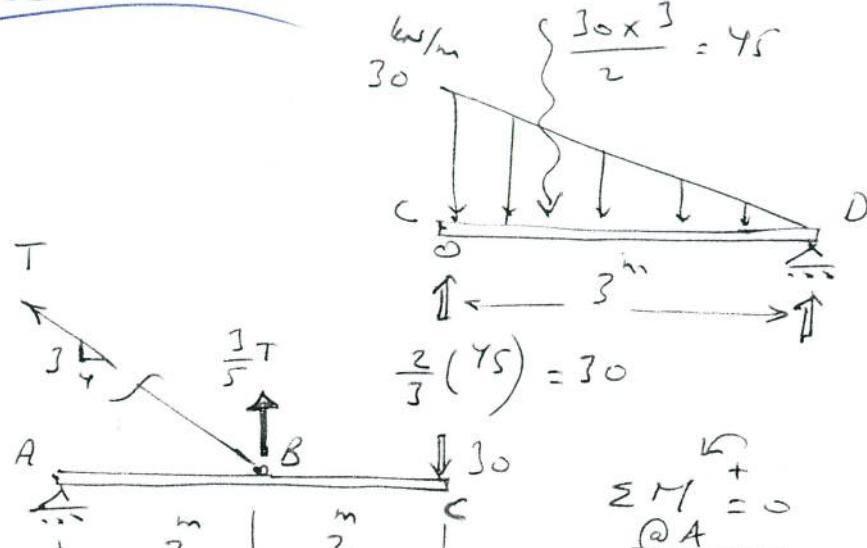


Good Luck

Cable

Q.1

(1)



$$\text{downward force at } D = \frac{30 \times 3}{2} = 45$$

$$\frac{2}{3}(45) = 30$$

$$\sum M @ A = 0$$

$$\frac{1}{5}T(2) - 30(4) = 0$$

$$\therefore T = \frac{120 \times 5}{6} = \underline{\underline{100 \text{ kN}}}$$

$$A_{sl} = \frac{\pi}{4}(30)^2 = 706.86 \text{ mm}^2$$

$$A_{el} = \frac{\pi}{4}(50^2 - 30^2) = 1256.64 \text{ mm}^2$$

$$A_{sl} E_{sl} = 706.86 \times 200 \times 10^3 = 141.372 \times 10^6 \text{ N}$$

$$A_{el} E_{el} = 1256.64 \times 70 \times 10^3 = 87.965 \times 10^6 \text{ N}$$

$$\sum AE = \underline{\underline{229.337 \times 10^6 \text{ N}}}$$

$$\Delta_{cable} = \frac{TL}{\sum AE} = \frac{100 \times 10 \times 2500}{229.337 \times 10^6} = \boxed{1.090 \text{ mm}}$$

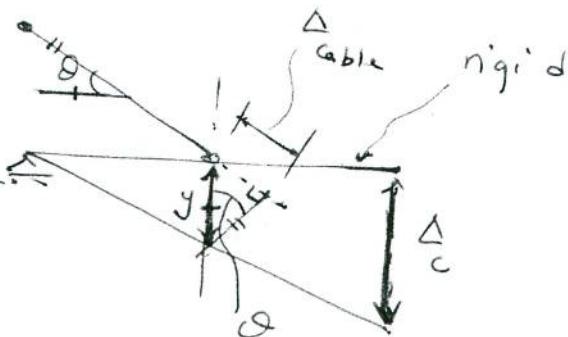
$$\sin \theta = \frac{\Delta_{cable}}{y}$$

$$\therefore y = \frac{\Delta_{cable}}{\sin \theta} = \frac{1.09}{(\frac{1}{5})}$$

$$\therefore y = 5.45 \text{ mm}$$

$$\frac{\Delta_c}{4} = \frac{y}{2} \Rightarrow \therefore$$

$$\boxed{\Delta_c = 2y = 3.633 \text{ mm}} \downarrow \text{ans.}$$



$$P_{st} = \frac{A_{st} E_{st}}{\sum A E} \times T$$

$$= \frac{141.372 \times 10^6}{229.337 \times 10^6} \times 100 = 61.644 \text{ kN}$$

$$P_{al} = \frac{A_{al} E_{al}}{\sum A E} \times T$$

$$= \frac{87.965 \times 10^6}{229.337 \times 10^6} \times 100 = 38.356 \text{ kN}$$

check $P_{st} + P_{al} = 61.644 + 38.356 = \underline{100 \text{ kN}}$

$$\therefore \sigma_{st} = \frac{P_{st}}{A_{st}} = \frac{61.644 \times 10^3}{702.86} = \underline{87.21 \text{ MPa}}$$

Ans.

$$\sigma_{al} = \frac{P_{al}}{A_{al}} = \frac{38.356 \times 10^3}{1256.64} = \underline{30.523 \text{ MPa}}$$

Ans.

(3)

Q.2

(A)

open rectangular section

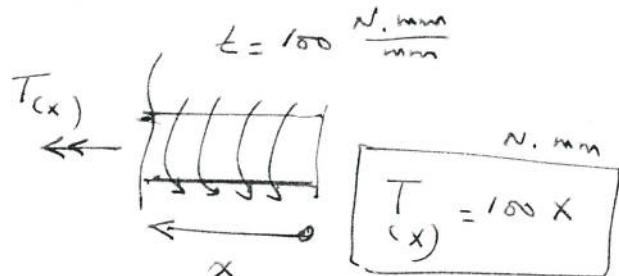
$$b = 300 \text{ mm}, c = 10 \text{ mm}$$

$$\frac{b}{c} = 30 \rightarrow \therefore \alpha = \beta = \frac{1}{3}$$

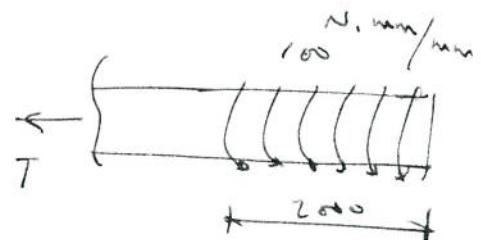
$$G = \frac{\epsilon}{2(1+\nu)} = \frac{200000}{2(1+0.21)} = 80000 \text{ MPa}$$

$$\theta_c = \theta_{\text{free end}} = \theta_{c \rightarrow B} + \theta_{B \rightarrow A}$$

$$\begin{aligned}\theta_{c \rightarrow B} &= \int_0^{200} \frac{T(x) dx}{\beta b c^3 G} \\ &= \int_0^{200} \frac{(100x) dx}{\cancel{2} \times \cancel{300} \times (10) \times 80000} \\ &= \frac{1}{8 \times 10^7} \left[\frac{x^2}{2} \right]_0^{200} = 0.025 \text{ rad}\end{aligned}$$



$$\begin{aligned}\theta_{B \rightarrow A} &= \frac{TL}{\beta b c^3 G} \\ &= \frac{2 \times 10 \times 2000}{\cancel{2} \times \cancel{300} \times (10) \times 80000} \\ &= 0.05 \text{ rad}\end{aligned}$$



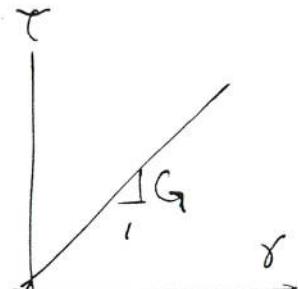
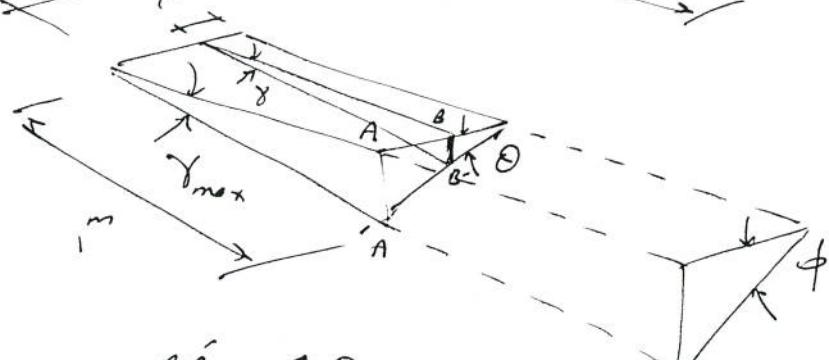
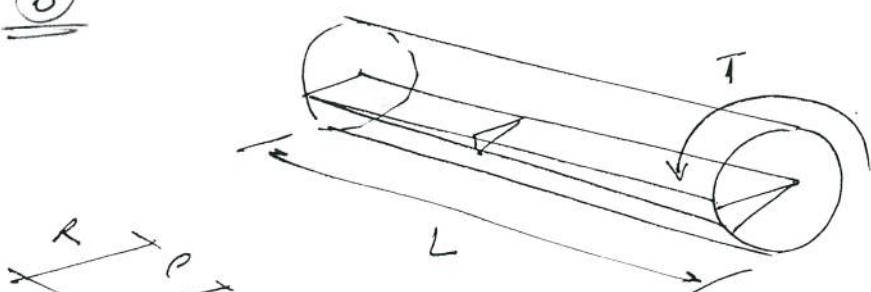
$$\begin{aligned}T &= 200000 \text{ N-mm} \\ &= 2 \times 10^5 \text{ N-mm}\end{aligned}$$

$$\begin{aligned}\therefore \theta_{\text{free end}} &= \theta_c = 0.025 + 0.05 = 0.075 \text{ rad} \\ &= 4.3 \text{ degrees}\end{aligned} \quad \left. \right\} \text{Ans.}$$

(7)

$$\tau_{\max} = \frac{T}{abc^2} = \frac{200000}{\frac{1}{3} \times 300 \times (10)^2} = \underline{\underline{20 \text{ MPa}}} \\ \underline{\underline{\text{Ans.}}}$$

(8)



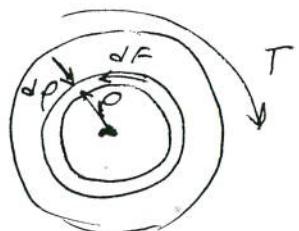
$$BB' = \rho \theta$$

$$\gamma = BB'$$

$$\therefore \gamma = \rho \theta$$

$$\frac{\tau}{\gamma} = G \Rightarrow \tau = \gamma G = \rho \theta G$$

$$T = \int dF \rho$$



$$T = \int \tau dA \rho$$

$$= \int_0^R G \rho \theta 2\pi \rho d\rho$$

$$= 2\pi G \theta \int_0^R \rho^3 d\rho = 2\pi G \theta \frac{R^4}{4}$$

$$T = \frac{\pi R^4}{2} G \theta = J G \theta$$

$$\therefore \theta = \frac{T}{JG} \Rightarrow \phi = \theta L$$

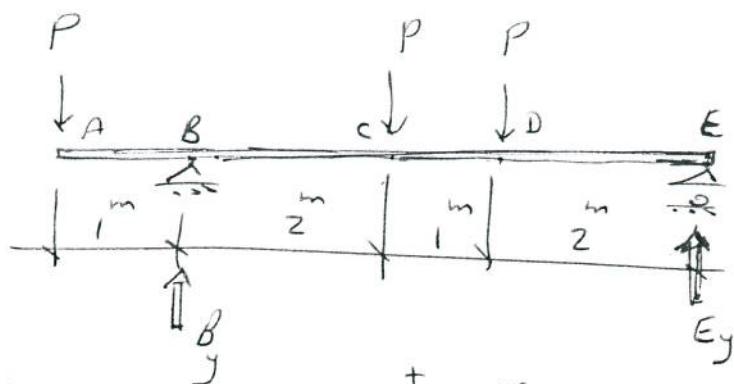
$$\therefore (\phi = \frac{TL}{JG})$$

$$\text{also, } \tau = G \rho \theta$$

$$\tau = G R \frac{I}{Jx} = \frac{TR}{Jx}$$

Q.3

(5)



$$\sum M @ E = 0$$

$$B_y(s) - P(6) - P(3) - P(2) = 0$$

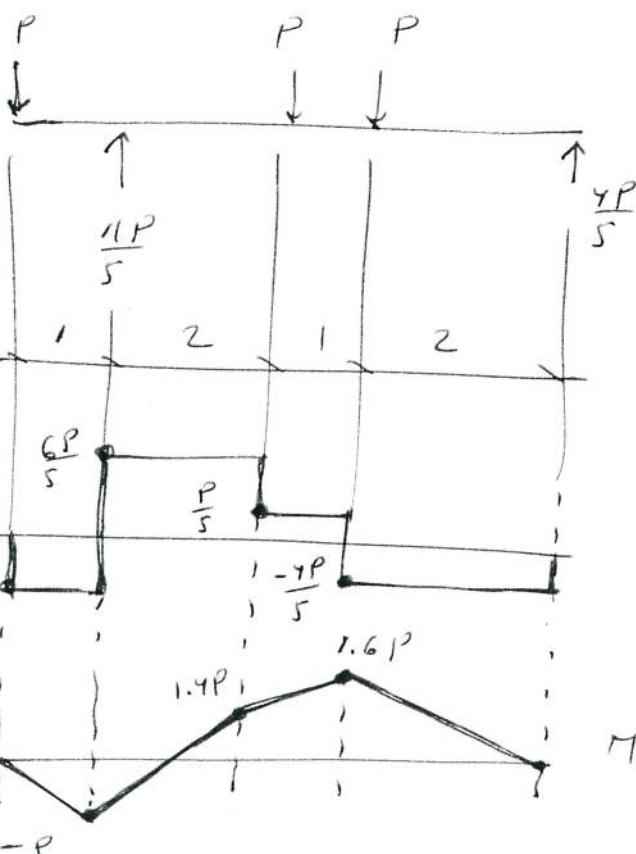
$$\therefore B_y = \boxed{\frac{11P}{5}}$$

$$\sum F_y = 0$$

$$F_y + B_y - 3P = 0$$

$$F_y = 3P - \frac{11P}{5}$$

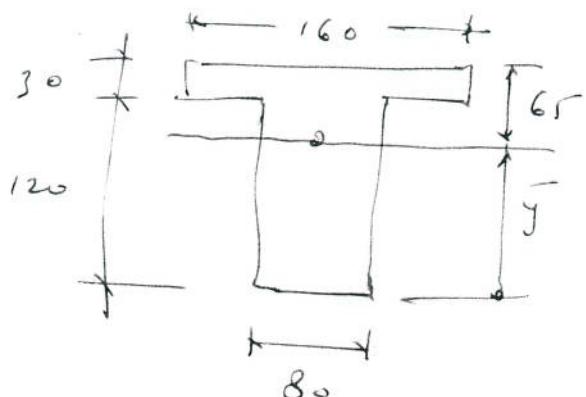
$$= \frac{15P}{5} - \frac{11P}{5} = \boxed{\frac{4P}{5}}$$



$$V-\text{diag.} \Rightarrow V_{\max} = \frac{6P}{5} \text{ kN}$$

$$M-\text{diag.} \Rightarrow \begin{cases} M_{\max}^+ = 1.6P \text{ kNm} \\ M_{\max}^- = P \text{ kNm} \end{cases}$$

(6)



$$\bar{y} = \frac{\Sigma Ay}{\Sigma A}$$

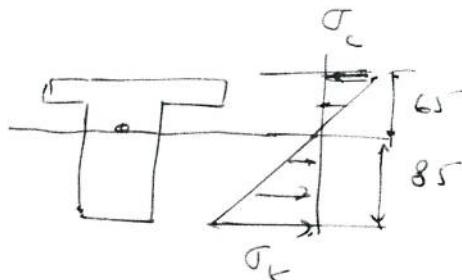
$$\bar{y} = \frac{(80 \times 120) 60 + (160 \times 30) 135}{80 \times 120 + 160 \times 30}$$

$$\therefore \bar{y} = \underline{85 \text{ mm}}$$

$$\frac{I}{N.A} = \frac{80(85)^3}{3} + \frac{160(65)^3}{3} - \frac{80(35)^3}{3} = \underline{\underline{29.88 \times 10^6 \text{ mm}^4}}$$

from bending

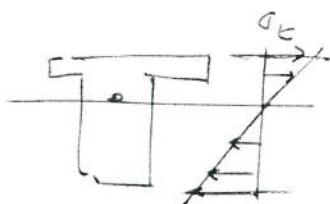
$$\textcircled{1} \quad M_{max}^+ = 1.6 P \text{ kNm}$$



$$\sigma_t = \frac{Mc}{I} \Rightarrow s_0 = \frac{1.6 P \times 10 \times 85}{29.88 \times 10^6} \rightarrow \therefore P = 17.58 \text{ kN}$$

$$\sigma_c = \frac{Mc}{I} \Rightarrow s_0 = \frac{1.6 P \times 10 \times 65}{29.88 \times 10^6} \rightarrow \therefore P = 22.98 \text{ kN}$$

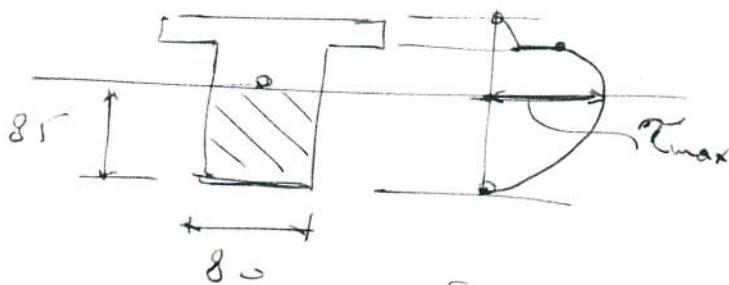
$$\textcircled{2} \quad M_{max}^- = P \text{ kNm}$$



$$\sigma_t = \frac{Mc}{I} \Rightarrow s_0 = \frac{P \times 10 \times 65}{29.88 \times 10^6} \rightarrow \therefore P = 36.78 \text{ kN}$$

$$\sigma_c = \frac{Mc}{I} \Rightarrow s_0 = \frac{P \times 10 \times 85}{29.88 \times 10^6} \rightarrow \therefore P = 28.12 \text{ kN}$$

(7)

from shear

$$\tau = \frac{VQ}{Ib} \Rightarrow \left\{ \begin{array}{l} M_f \\ \hline 6 = \frac{\frac{6P}{5} \times 10 \left[80 \times 85 \times \frac{85}{2} \right]}{29.88 \times 10 \times 80} \end{array} \right.$$

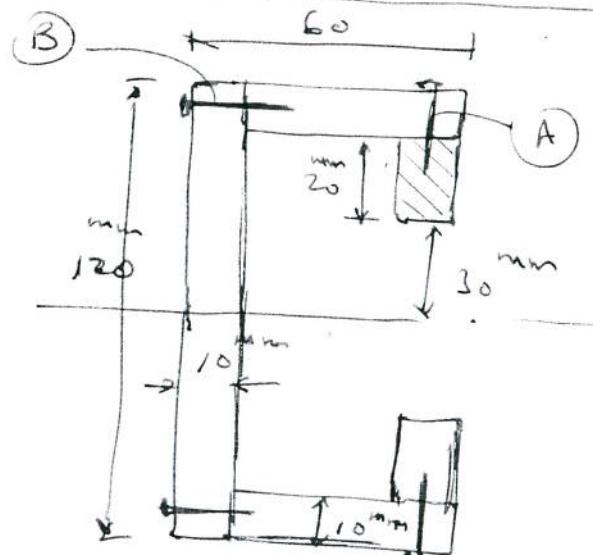
$$\therefore P = 41.36 \text{ kN}$$

\therefore Safe $P = 17.58 \text{ kN}$ Ans

Q. 7

$$I = \frac{60(120)^3}{12} - \frac{10(60)^3}{12} - \frac{40(100)^3}{12}$$

$$I = 5.1267 \times 10^6 \text{ mm}^4$$

for bolts Type A

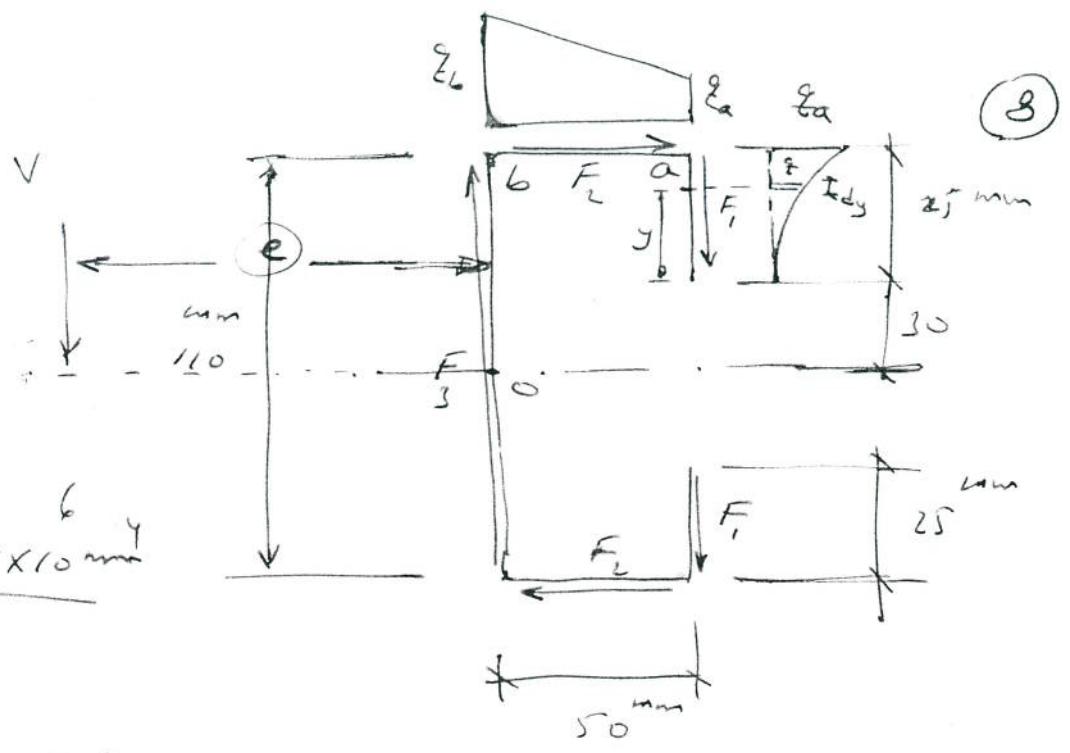
$$q = \frac{VQ}{I} = \frac{V}{I} [10 \times 20 \times 40] = \frac{8000 V}{I}$$

$$S = \frac{F}{q} = \frac{2000}{\frac{8000 \times 6408}{5.1267 \times 10^6}} = 200 \text{ mm}$$

for bolts Type B

$$q = \frac{VQ}{I} = \frac{V}{I} [10 \times 20 \times 70 + 10 \times 50 \times 55] = \frac{35500 V}{I}$$

$$S = \frac{F}{q} = \frac{2000}{\frac{35500 \times 6408}{5.1267 \times 10^6}} = 45 \text{ mm}$$



$$I = 5.1267 \times 10^6 \text{ mm}^4$$

$$\sum M_{@O} = 0$$

$$V \times e = F_2(110) + 2F_1(50) \rightarrow ①$$

$$F_1 = \int_0^{25} e \, dy = \int_0^{25} \frac{VQ}{I} \times dy = \frac{V}{I} \int_0^{25} ty \left(\frac{y}{2} + 30\right) dy$$

$$F_1 = \frac{tV}{I} \int_0^{25} \left(\frac{y^2}{2} + 30y\right) dy = \frac{tV}{I} \int_0^{25} \left(\frac{(25)^3}{6} + 15(25)^2\right) dy$$

$$F_1 = 119.792 \times 10^6 \frac{V}{I}$$

$$F_2 = \frac{e_a + e_b}{2} \times 50 = 25 \left(e_a + e_b \right)$$

$$e_a = \frac{VQ}{I} = \frac{V}{I} \left[25 \times 10 \times \left(30 + \frac{25}{2} \right) \right] = 10625 \frac{V}{I}$$

$$e_b = \frac{VQ}{I} = \frac{V}{I} \left[25 \times 10 \times \left(30 + \frac{25}{2} \right) + 50 \times 10 \times \frac{110}{2} \right] = 38125 \frac{V}{I}$$

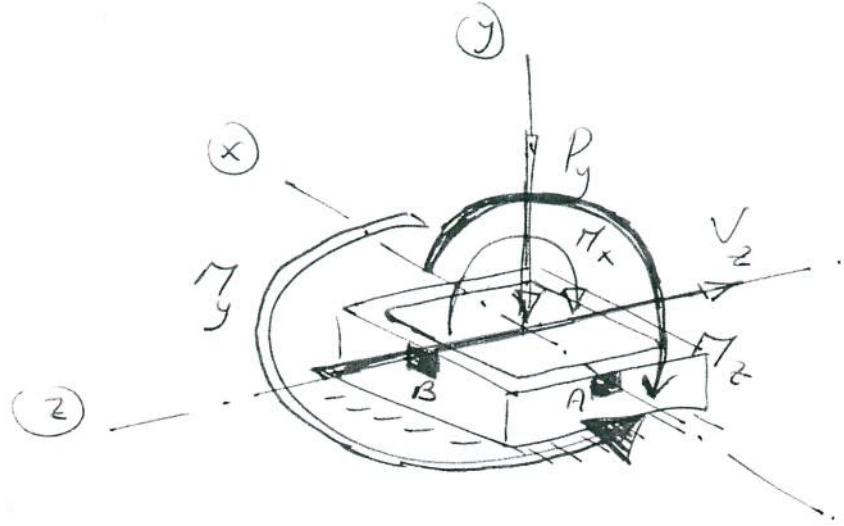
$$\therefore F_2 = 1.21875 \times 10^6 \frac{V}{I}$$

$$\therefore V \times e = 110 \times 1.21875 \times 10^6 \frac{V}{I} + 100 \times 119.792 \times 10^6 \frac{V}{I}$$

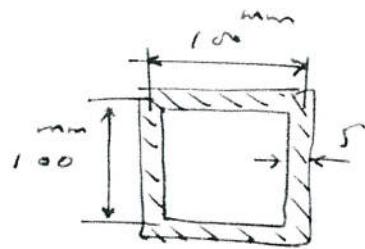
$$\therefore e = 28.486 \text{ mm} \approx \underline{\underline{28.5 \text{ mm}}}$$

Q.5

(9)



$$\begin{aligned} V_z &= 1 \text{ kN} \rightarrow \left\{ \begin{array}{l} M_x = 1 \times 3 = 3 \text{ kNm} \\ M_y = T = 1 \times 1 = 1 \text{ kNm} \\ M_z = 2 \times 1 = 2 \text{ kNm} \end{array} \right. \\ P_y &= 2 \text{ kN} \\ V_x &= 0 \end{aligned}$$

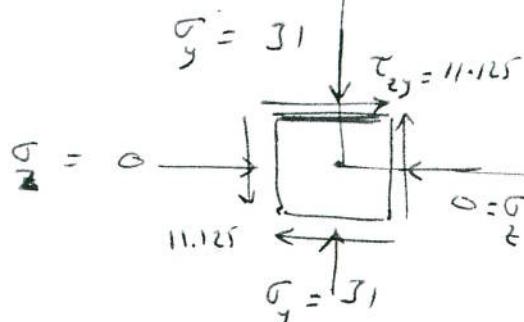


$$\begin{aligned} A &= 100 \times 4 \times 5 = 2000 \text{ mm}^2 \\ I_x &= I_z = \frac{s(100)^3}{12} \times 2 + 2 \{ 100 \times 5 \times 50^2 \} \\ &= 3.3333 \times 10^6 \text{ mm}^4 = \boxed{\frac{10}{3} \times 10^6 \text{ mm}^4} \end{aligned}$$

for Element A

$$\sigma_y = \frac{-P_y}{A} - \frac{M_z c_x}{I_z} = \frac{-2000}{2000} - \frac{2 \times 10 \times 50}{\frac{10}{3} \times 10^6} = -1 - 30 = \boxed{-31 \text{ MPa}}_{\text{comp}}$$

$$\tau_{zy} = \frac{V_z Q}{I_x b} + \frac{T}{2 A c} = \frac{1 \times 10 \times [100 \times 5 \times 50 + 2 \times 50 \times 5 \times 10]}{\frac{10}{3} \times 10^6 \times 10} + \frac{1 \times 10}{2 \times 100 \times 5 \times 5} = 1.125 + 10 = 11.125 \text{ MPa}$$



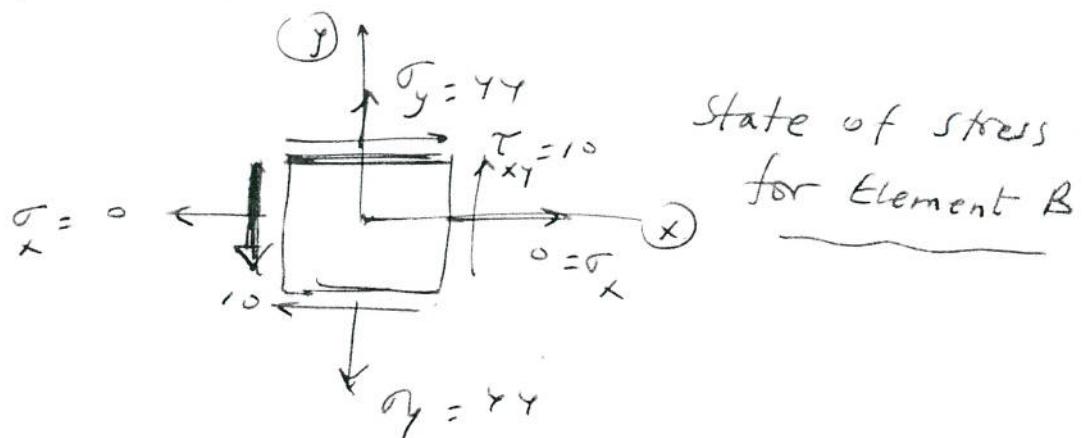
State of stress for
Element A

(10)

for Element B

$$\sigma_y = \frac{-P_y}{A} + \frac{M_x C_z}{I_x} = \frac{-2000}{2000} + \frac{3 \times 10 \times 50}{\frac{10}{3} \times 100} \\ = -1 + 45 = \underline{\underline{\underline{44 \text{ MPa}}}} \text{ Tension}$$

$$\tau_{xy} = \frac{\tau}{I_b} + \frac{T}{2A_e t} = 10 \text{ MPa}$$



Q. 6 final

By using the Method
of moment area,

evaluate
the height
(h) that
make zero
deflection
at point d.

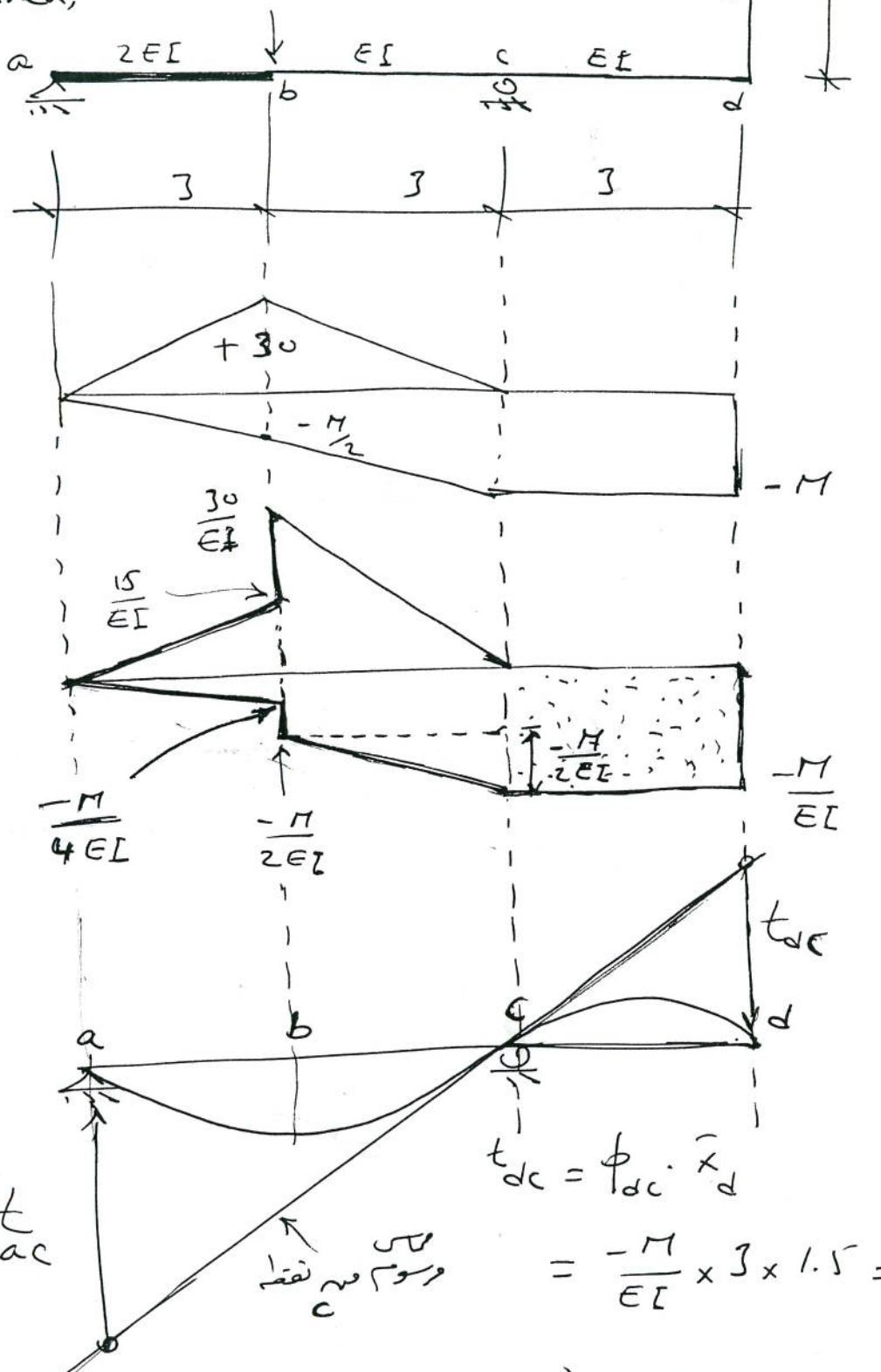
$\frac{50}{9}$

$\frac{50}{9}$

\rightarrow

e

(11)



$$t_{dc} = \phi_{dc} \cdot \bar{x}_d$$

$$= -\frac{M}{EI} \times 3 \times 1.5 = -\frac{4.5M}{EI}$$

$$t_{ac} = \phi_{ac} \cdot \bar{x}_a = \left(\frac{30}{EI} \times \frac{3}{2} \right) 4 + \left(\frac{15}{EI} \times \frac{3}{2} \right) 2 - \left(\frac{M}{4EI} \times \frac{3}{2} \right) 2$$

$$-\left(\frac{M}{2EI} \times 3 \right) \times 4.5 - \left(\frac{M}{2EI} \times \frac{3}{2} \right) 5 = \frac{225}{EI} - \frac{11.25M}{EI}$$

$$\frac{|t_{dc}|}{3} = \frac{|t_{ac}|}{6} \rightarrow t_{dc} = \frac{1}{2} t_{ac} \rightarrow \frac{4.5M}{EI} = \frac{112.5}{EI} - \frac{5.625M}{EI}$$

$$\therefore M = 11.11 \rightarrow 11.11 = \frac{50}{9} h \Rightarrow \therefore h = 2 \text{ m}$$

