

Problem 1)

5-34

Find SF using distortion energy and max shear

$$S_y = 400 \text{ MPa (60 kpsi)}$$

$$SF = \frac{S_y}{\sigma_1} = \text{Distortion}$$

$$= \frac{400 \text{ MPa}}{30.146}$$

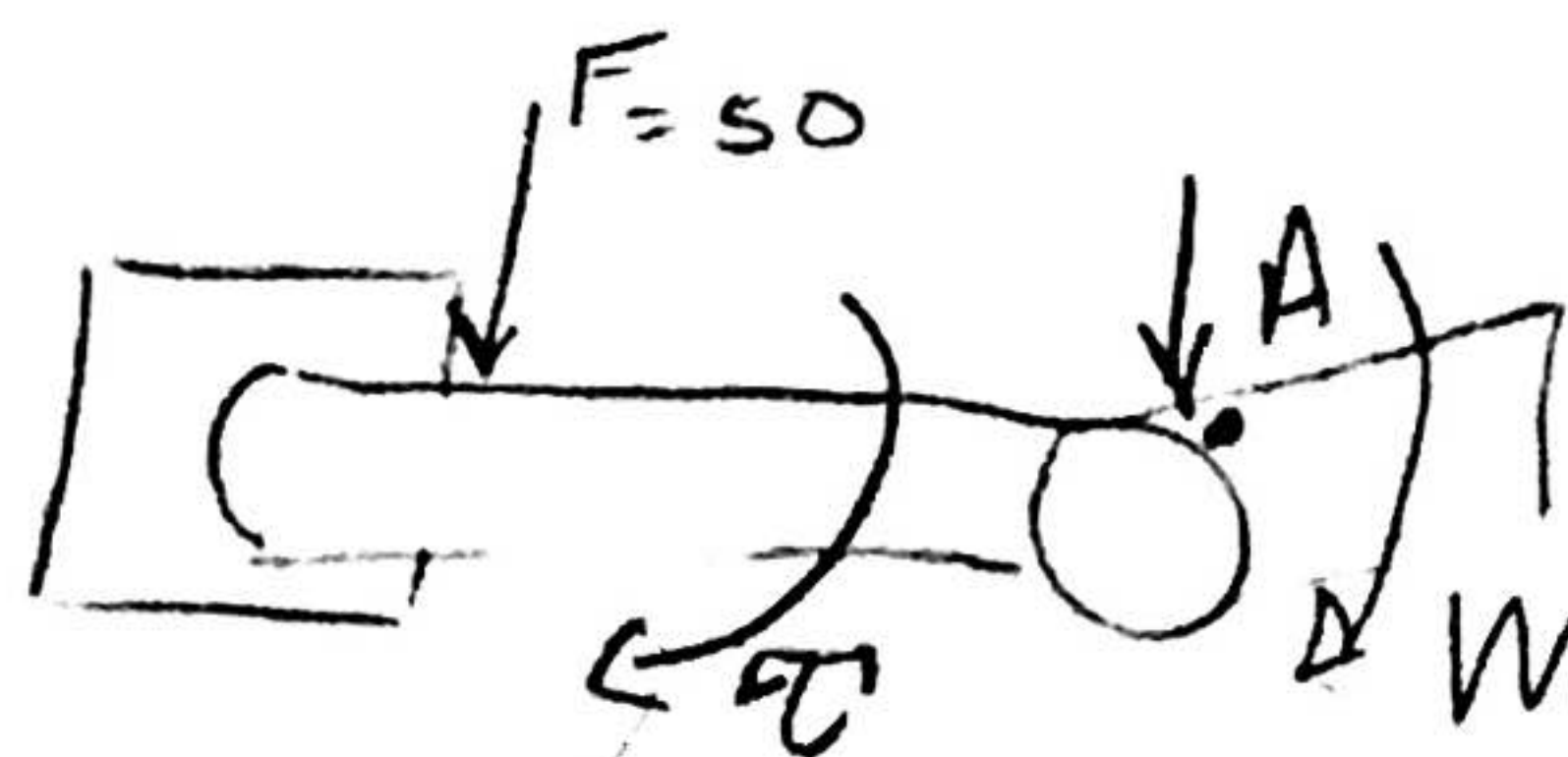
$$V = 30.146 \quad SF = 13.26$$

length (mm)

Row	a	l	a	t	h	F	OD	ID	F (ksi)
		100	400	10	20	50	20	14	706



$$M = (F)(a) = (50)(40) = 2000 \text{ N}\cdot\text{mm}$$



$$M = (50)(100) = 5000 \text{ N}\cdot\text{mm}$$

$$T = (50)(400) = 20,000 \text{ N}\cdot\text{mm}$$

$$\sigma_{max} = \frac{T \cdot r}{I} = \frac{20 \times 10^4}{11936} = 16.75 \text{ MPa}$$

$$I = \frac{\pi}{32} [d_o^4 - d_i^4] = \frac{\pi}{32} [20^4 - 14^4] = 11936 \text{ mm}^4$$

$$\sigma_{max} = \frac{m \cdot c}{I} = 8.38 \text{ MPa}$$

$$\sigma_{princ} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\frac{\sigma_x^2}{2} + \tau_{xy}^2}$$

$$I = \frac{\pi}{64} [d_o^4 - d_i^4] = 5968 \text{ mm}^4$$

$$= \frac{8.38}{2} \pm \sqrt{\frac{8.38^2}{2} + 16.75^2}$$

$$\sigma_1 = \sqrt{\sigma_1^2 - \sigma_3^2 + \tau_3^2}$$

$$\sigma_1 = 4.14 \pm 17.26 = 21.406 \text{ [MPa]}$$

$$= \sqrt{21.406^2 - 2(14.06)(13.07) + 13.07^2}$$

$$\sigma_2 = 0$$

$$\sigma_3 = -13.07 \text{ MPa}$$

Problem 1) Cont. (2)

$$N_{2max} = \frac{S_y}{\frac{\sigma_1 - \sigma_3}{2}} = \frac{S_y}{\frac{\sigma_1 - \sigma_3}{2}}$$

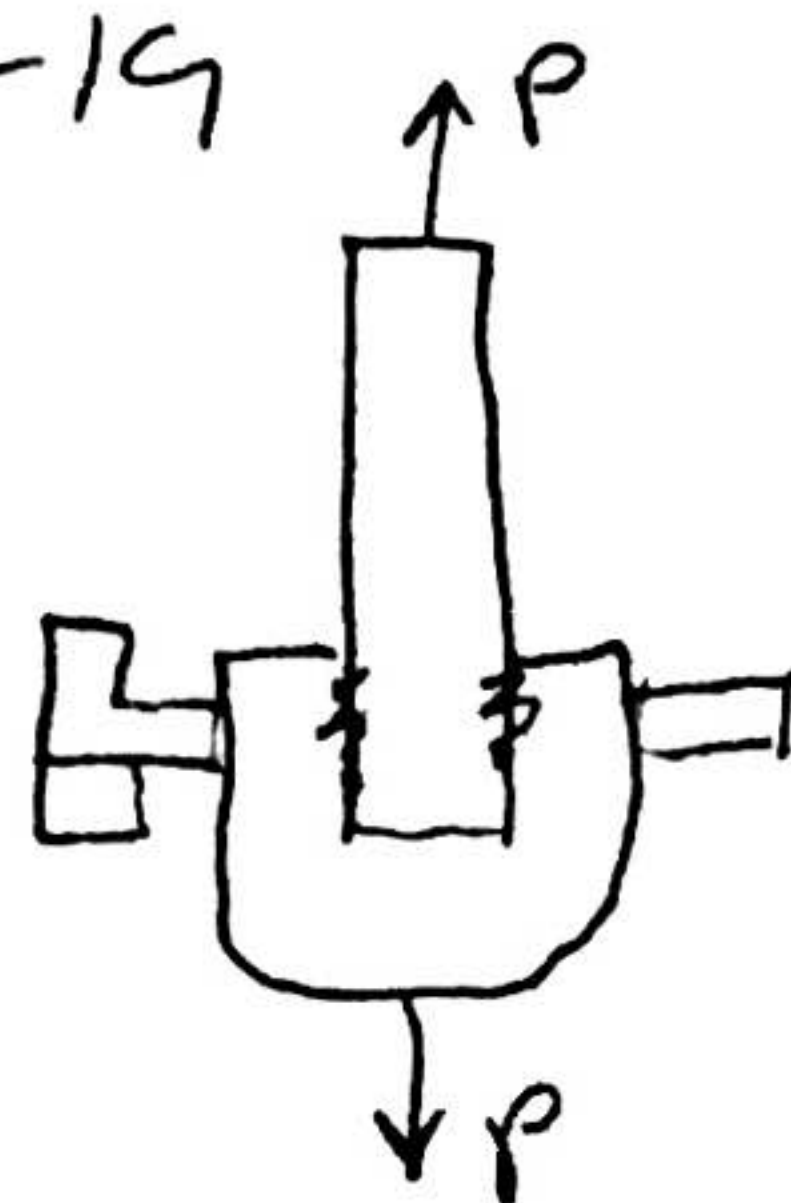
$$= \frac{S_y}{\frac{\sigma_1 - \sigma_3}{2}} = \frac{400}{21.45 - (-13.67)}$$

$$N_{2max} = 11.45$$

Problem 2) 5-19

$S_{ypin} = 89.3 \text{ ksi}$

$S_{yclevis} = 35.5 \text{ ksi}$



Direct Shear

$$\tau = \frac{S_y}{\sigma'} = \frac{S_y}{\sqrt{3} \tau}$$

$$\tau = \frac{P}{2A} = \frac{P}{(2)(\frac{\pi d^2}{4})}$$

$$N = \frac{S_y}{\frac{\tau}{\sqrt{3}}} = 3 = \frac{S_y \cdot 2A}{\sqrt{3} P}$$

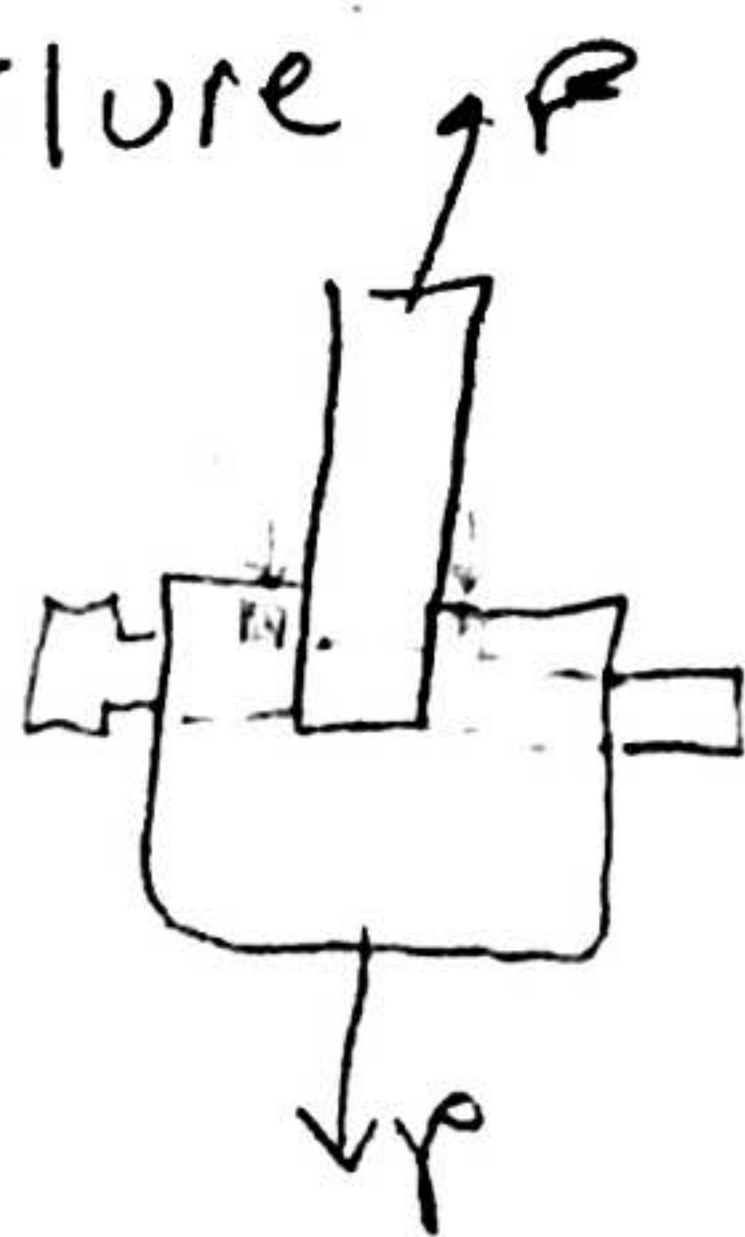
$$= \frac{S_y \cdot 2 \cdot \frac{\pi d^2}{4}}{\sqrt{3} P}$$

$$\sqrt{\frac{\sqrt{3} \cdot P \cdot 3 \cdot 4}{S_y \cdot 2 \cdot \pi}} = d$$

$$d = 2.19 \text{ in}$$

Bearing Failure

$$A = \frac{\pi d^2}{4}$$



$$\sigma' = \frac{P_{clevis}}{2A}$$

$$N = 3 = \frac{S_{yclevis}}{\sigma'} = \frac{S_{yclevis} \cdot 2A}{P}$$

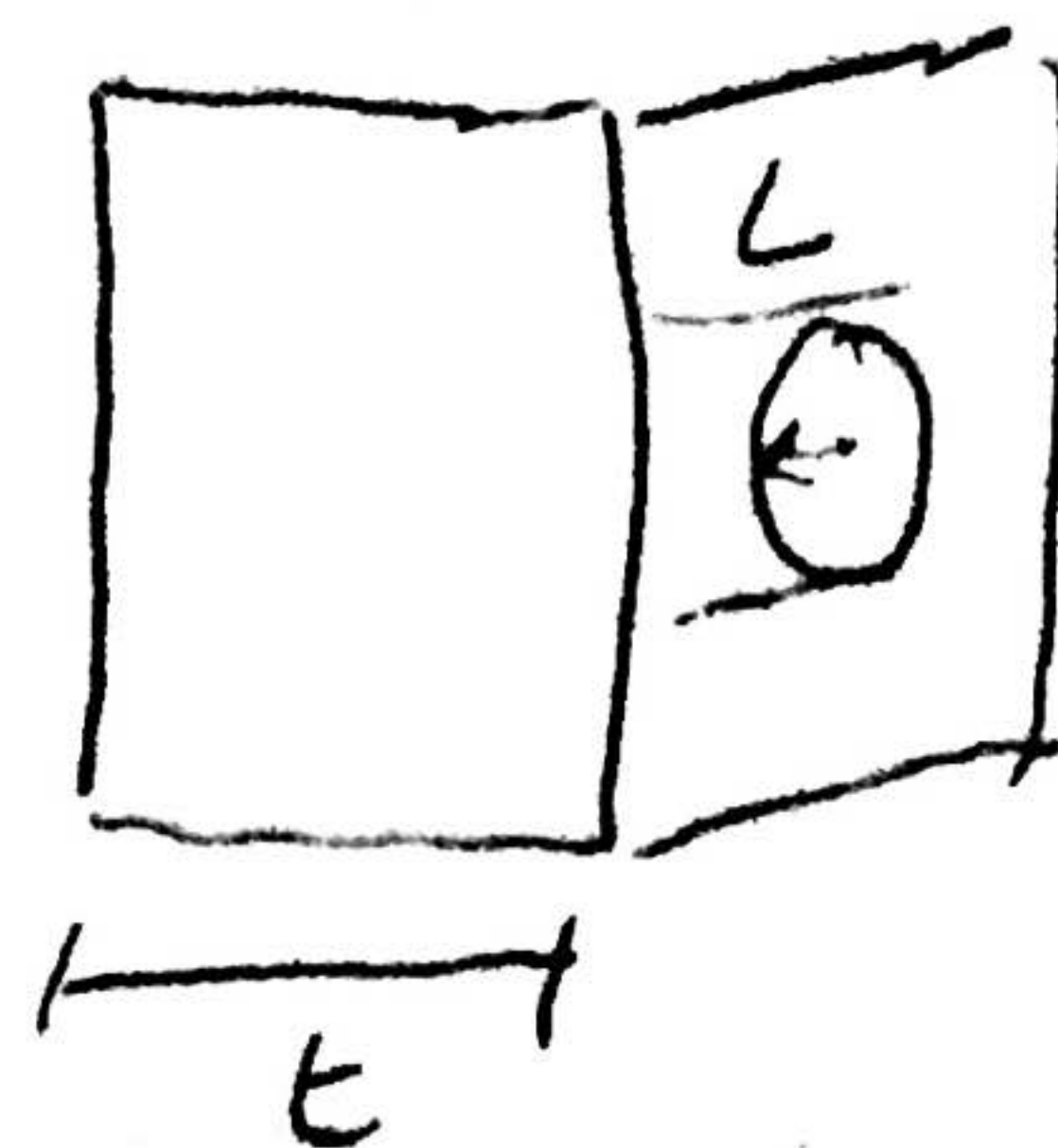
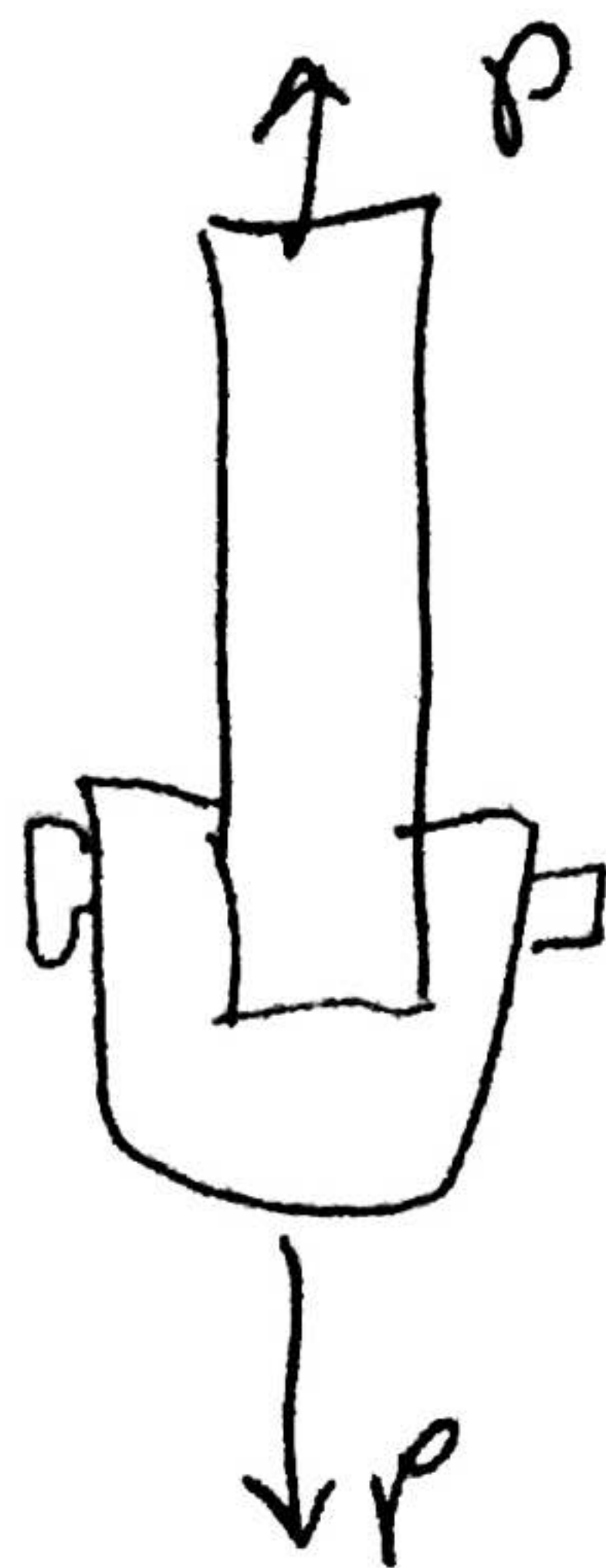
$$= \frac{S_y \cdot 2 \cdot d \cdot t}{P} = 3$$

$$d = \frac{3P}{S_y \cdot 2t} = \frac{3 \cdot 130}{35.5 \cdot 2 \cdot 2.5}$$

$$d = \frac{3P}{S_y \cdot 2t} = \frac{3 \cdot 130}{35.5 \cdot 2 \cdot 2.5}$$

will fail before pin

Problem 2) cont.



$$\frac{P}{2A} = \frac{P}{2 \cdot t \cdot L}$$

$$L = \frac{d}{2} + L'$$

$$\frac{P}{2A} = \frac{P}{2 \cdot t \cdot (\frac{d}{2} + L')}$$

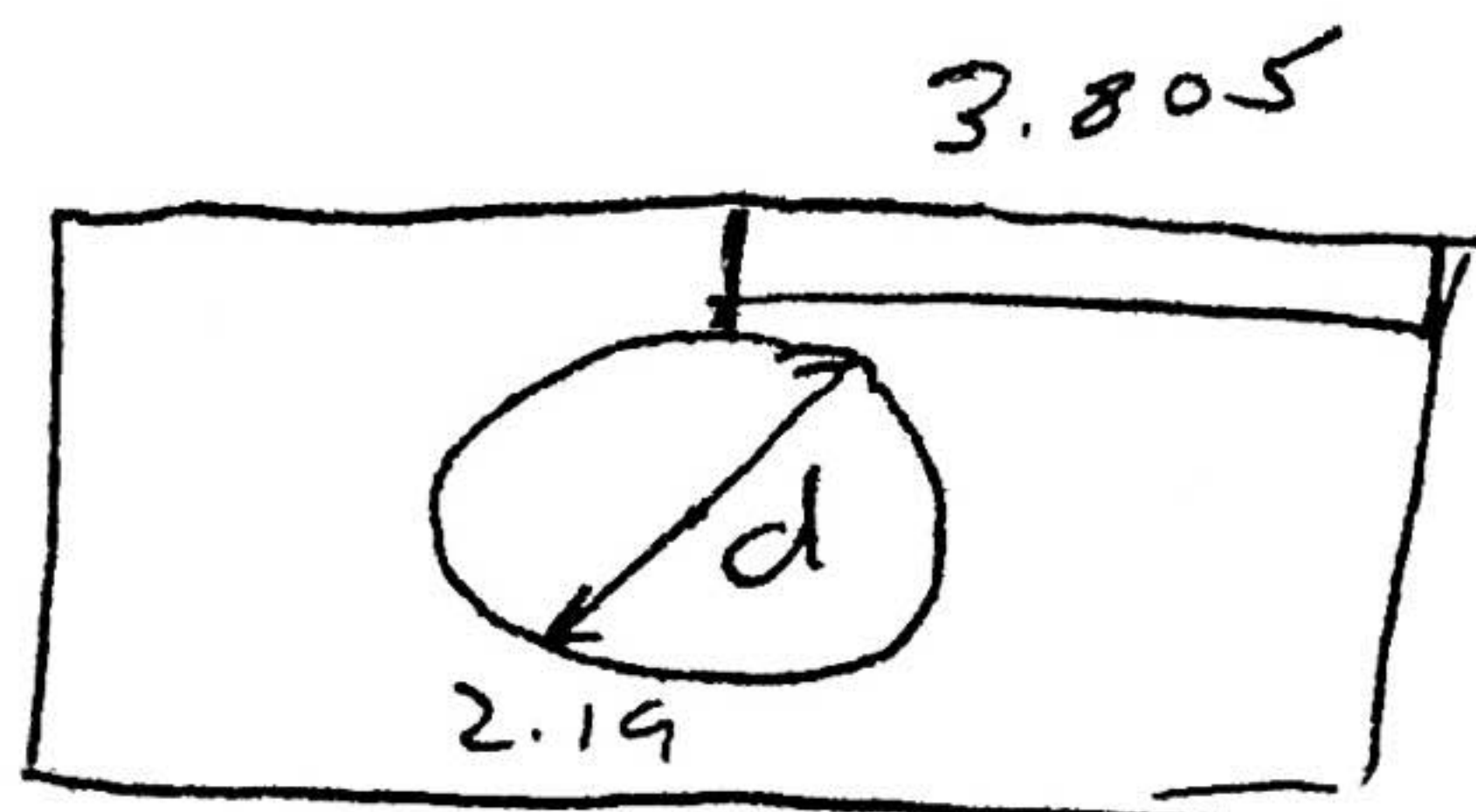
$$d = 2.19$$

$$N = 3 = \frac{\text{Sydney's} \cdot 2 \cdot t \cdot (L)}{\sqrt{3} \cdot P}$$

$$\frac{3 \cdot \sqrt{3} \cdot P}{2 \cdot t \cdot \text{Sydney's}} = L = \frac{d}{2} + L'$$

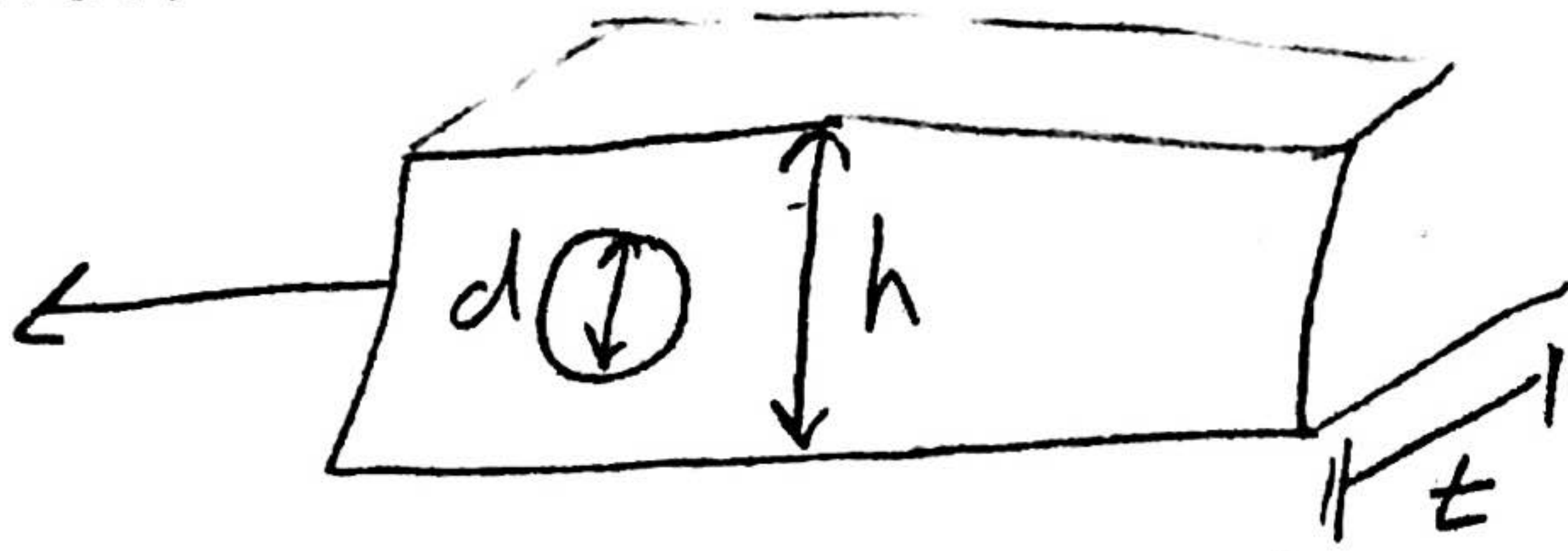
$$L' = \frac{3 \cdot \sqrt{3} \cdot P}{2 \cdot t \cdot \text{Sydney's}} - \frac{d}{2} = L' = 2.71 \text{ in}$$

$$L_{\text{from Leading edge}} = L' + \frac{d}{2} = 2.71 + \frac{2.19}{2} = 3.805$$



Problem 2) cont. (3)

Axial



$$P / 2a = \sigma$$
$$a = t \cdot (h - d)$$

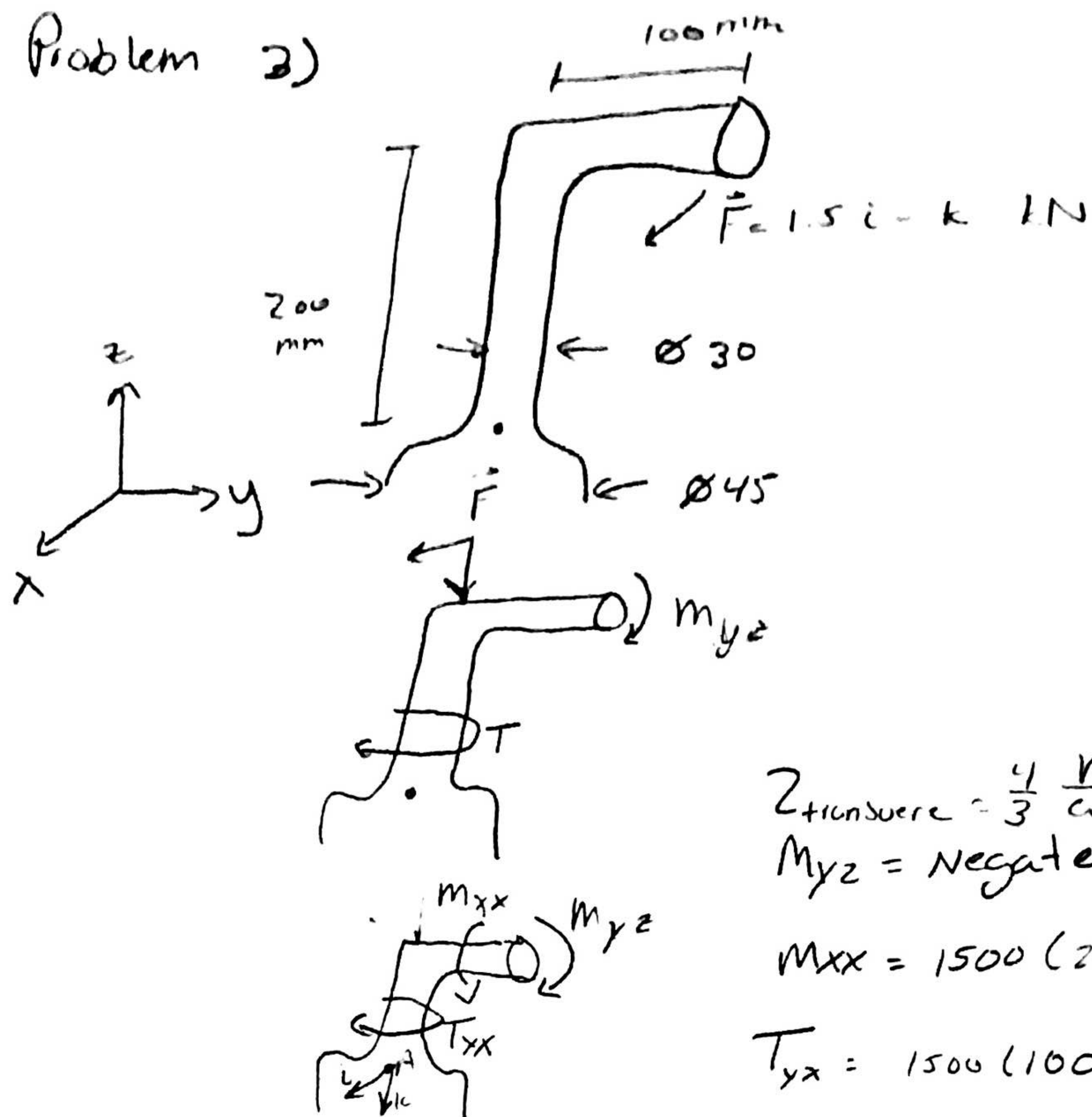
$$\frac{S_y \cdot 2a}{P} = 3$$

$$\frac{3 \cdot P}{2 S_y} = a = t \cdot (h - d)$$

$$\frac{3 \cdot P}{2 \cdot S_y \cdot t} + d = h = \frac{3 \cdot 130}{2 \cdot 35.5 \cdot 2.5} + 2.14 = h$$

$$\boxed{h = 4.387} \text{ material}$$

Problem 3)



$$Z_{transverse} = \frac{1}{3} \frac{V}{A} = 10 \text{ @ A}$$

$$M_{yz} = \text{Negative [Neutral Axis]}$$

$$M_{xx} = 1500(200) = 300 \text{ kN} \cdot \text{mm}$$

$$T_{yz} = 1500(100) = 150 \text{ kN} \cdot \text{mm}$$

$$\sigma_{xx} = \frac{m \cdot c}{I} = \frac{(300 \times 10^3) \cdot 15.64}{\pi (30^4)} = 113.17 \text{ MPa (compression)}$$

$$\tau_{yx} = \frac{T \cdot r}{J} = \left[\frac{150 \times 10^3 \cdot 15 \cdot 32}{\pi \cdot 30^4} \right] = 28.294 \text{ MPa}$$

Stress concentration

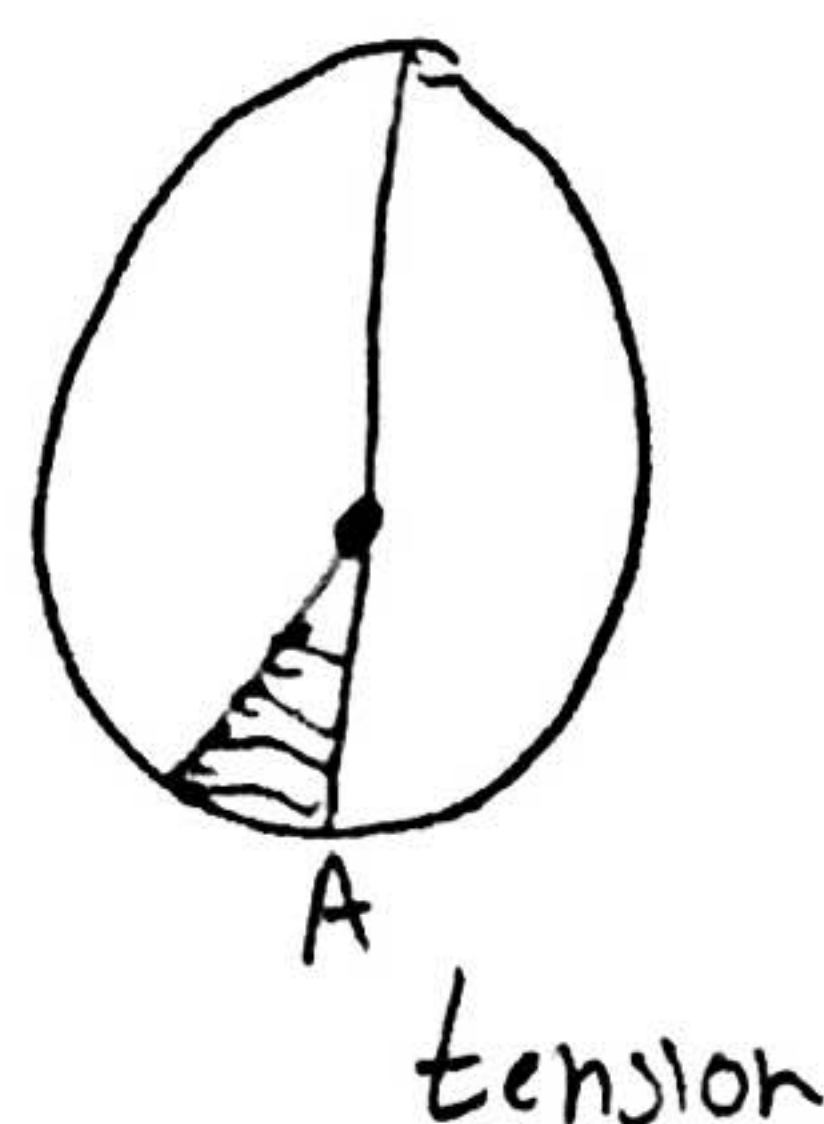
From charts

$$k_{\text{moment}} = 1.45$$

$$k_{\text{torsion}} = 1.29$$

$$\sigma_{xx} = 1.45 \cdot 113.17 = 164.106 \text{ MPa}$$

$$\tau_{yx} = 1.29 \cdot 28.294 = 36.5 \text{ MPa}$$



$$\tau_{\max} = \frac{\sigma_x}{2} \pm \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_{yx}^2}$$

$$82.053 \pm 89.805$$

[MPa]

$$\sigma_1 = 171.855$$

$$\sigma_2 = 0$$

$$\sigma_3 = -7.752$$

$$N = \frac{S_y}{\sigma_1} = \frac{325 \text{ MPa}}{175.859} = 1.848$$

$$\sigma_1' = \sqrt{\sigma_1^2 + \sigma_3^2 + \sigma_2^2} = 175.859 \text{ MPa}$$

5-48

100 kg = m
 65 cm = dia drive wheels
 70 cm = track width
 1 m rollers
 min height
 Alloy = Aluminum
 Shaft = Steel
 min deflection = 1 mm

Point A most likely to Fail

$$y(x) = \frac{F}{3EI} \left[za^3 - \frac{a^4}{2} - \frac{1}{6} a^6 \right]$$

$$\tau_{xx} = \frac{m \cdot c}{I}$$

$$\tau_p = \frac{\tau_{xx}}{2} \pm \sqrt{\tau_{xx}^2 + \tau_{xz}^2}$$

$$F_{total} = 125 \cdot 9.81 = 1225 [N]$$

$$F_{wheel} = \frac{F_t}{2}$$

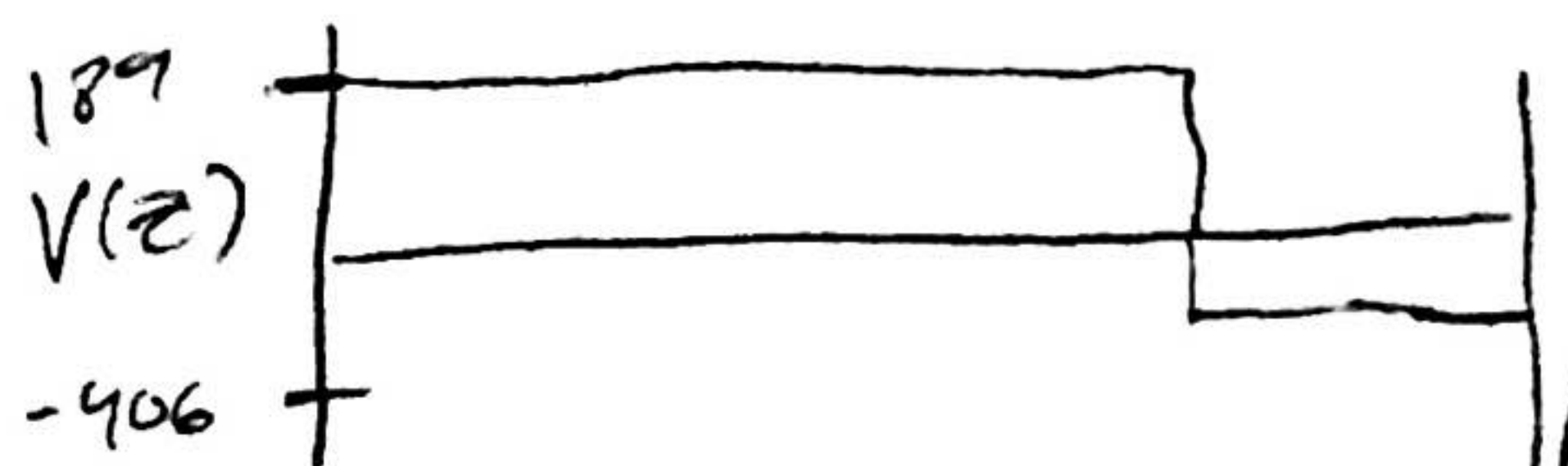
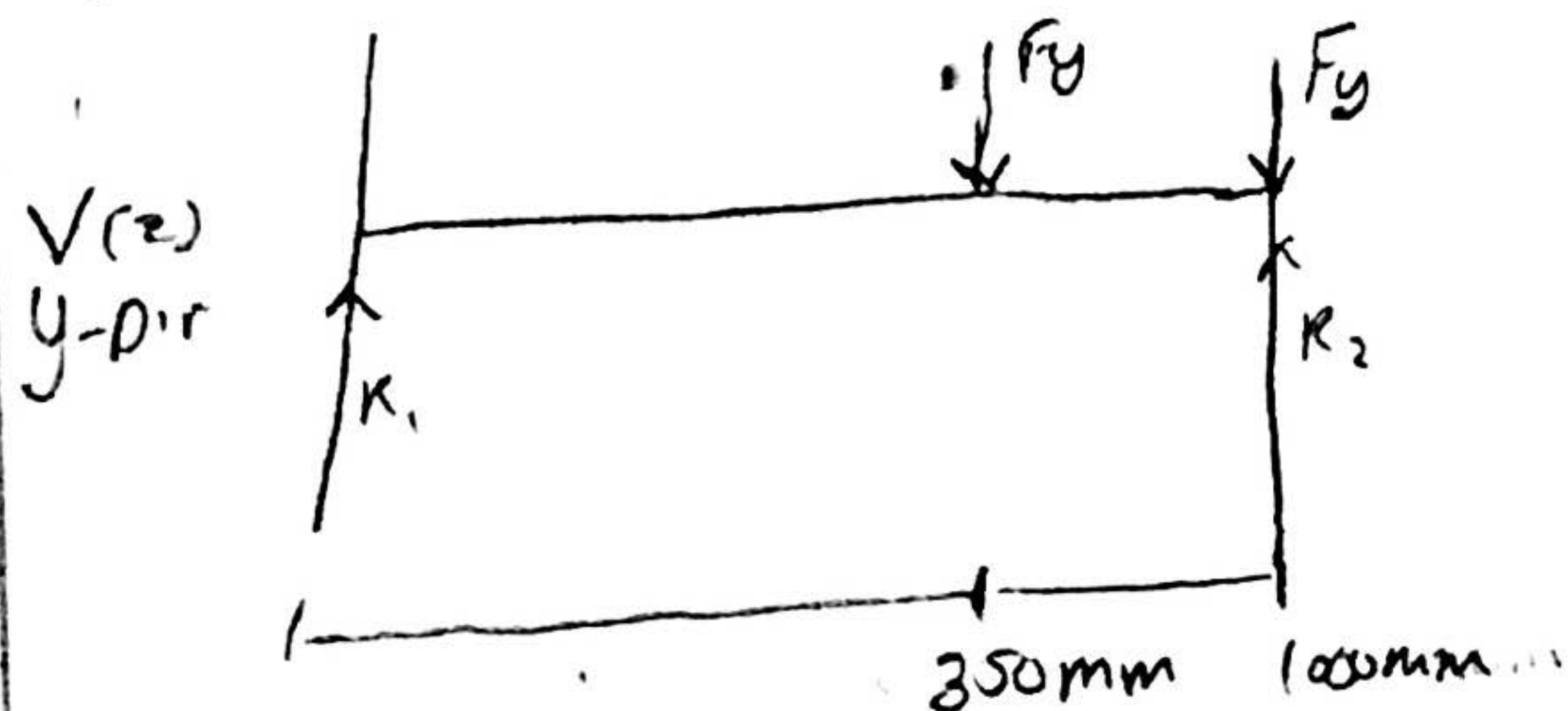
$$F_{shaft} = \frac{F_{wheel}}{2} = \frac{F_{total}}{4}$$

Assume W tracks BAR at 15°

$$\vec{F} = \frac{1225 \sin(15^\circ)}{4} \hat{i} - \frac{1225 \cos(15^\circ)}{4} \hat{j}$$

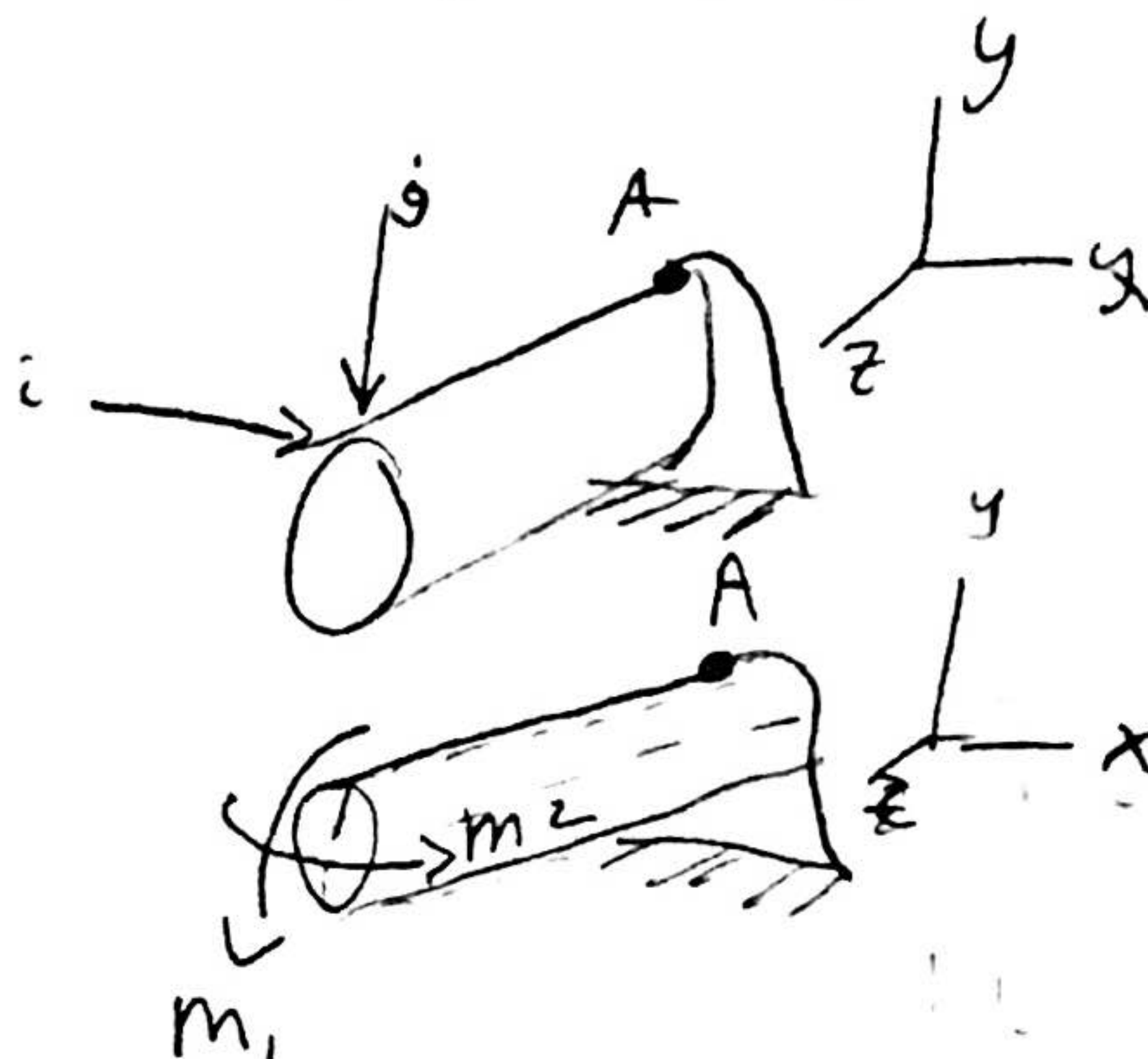
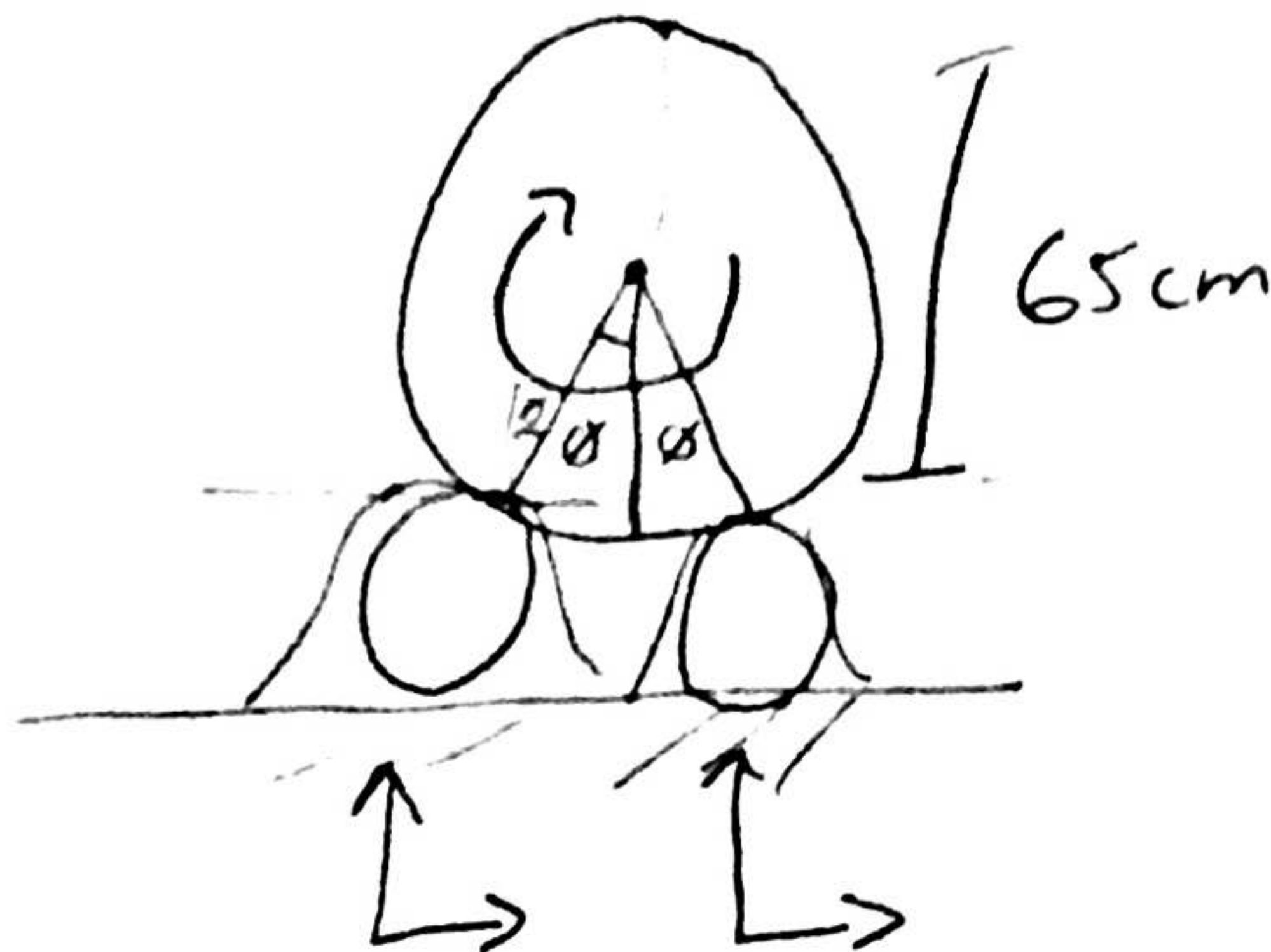
$$F_x = 79.26 [N]$$

$$F_y = 295.81 [N]$$



Worst case scenario

125 kg ripper at the edge.

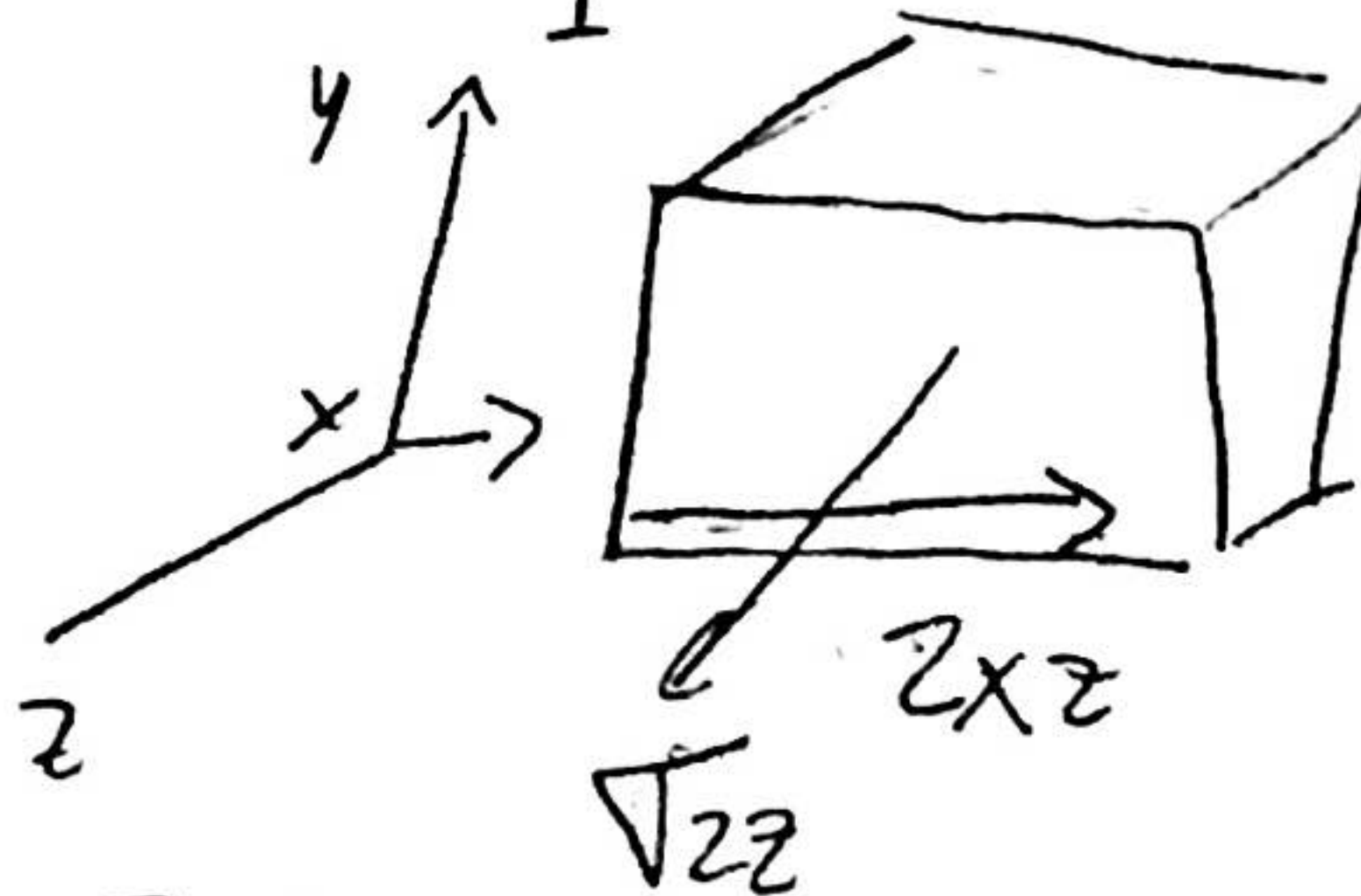


$M_2 = 0$ A is on Neutral Axis

$$\text{Transverse Shear} = \frac{4}{3} \frac{V}{a}$$

$$\tau_{zx} = \frac{4}{3} \frac{V}{a}$$

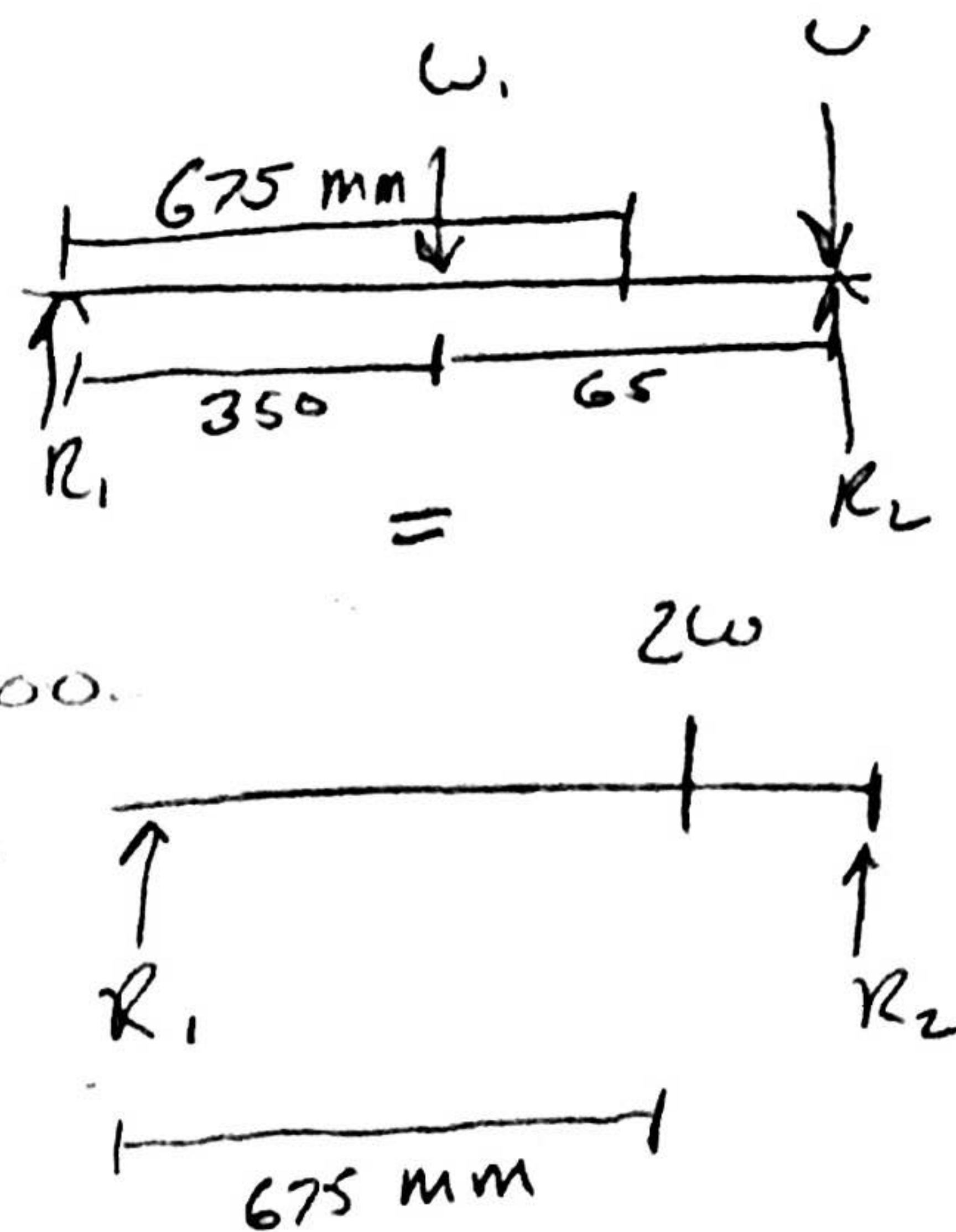
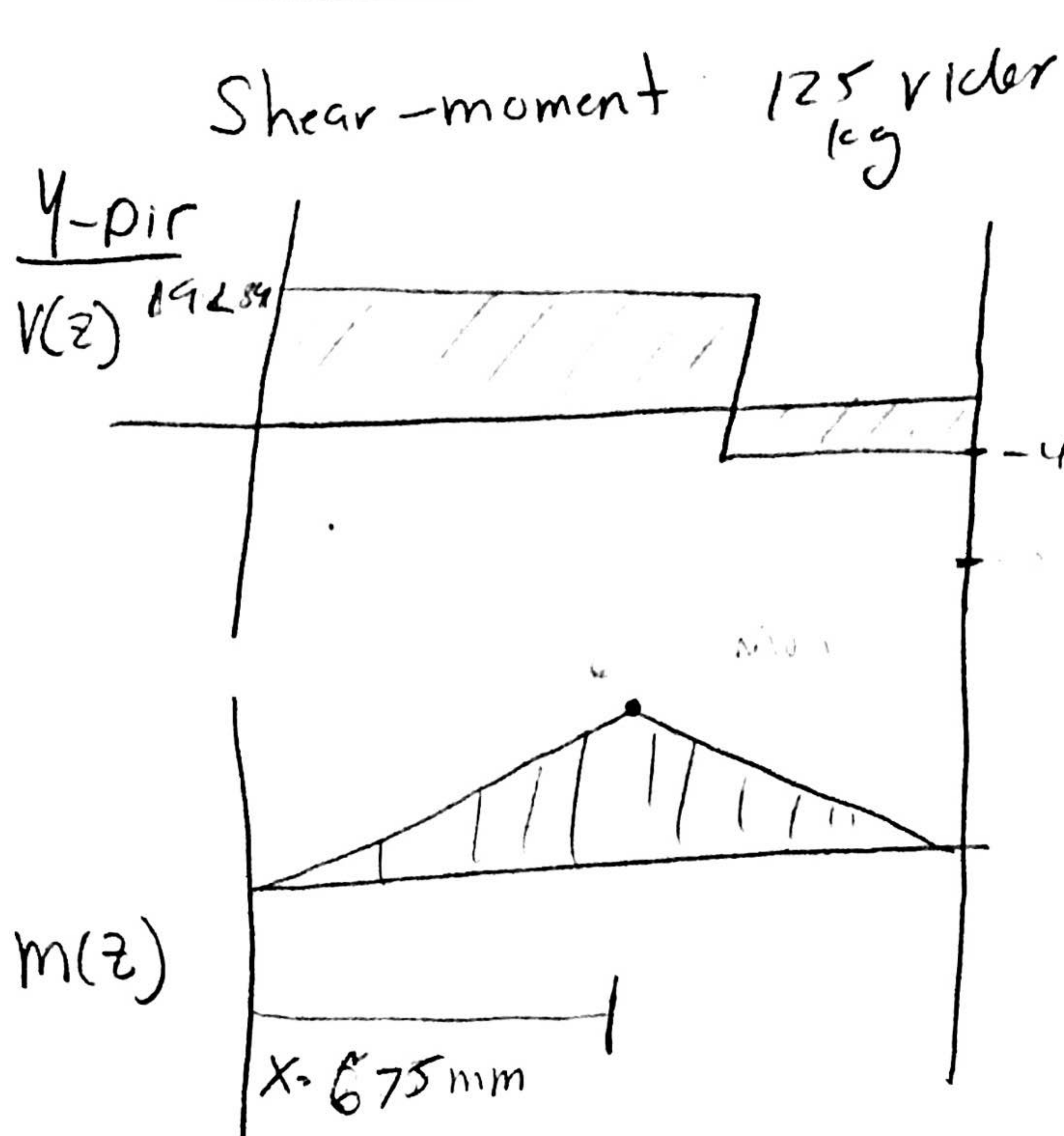
$$\tau_{zz} = \frac{m \cdot c}{I}$$



$$\sum F_y = R_1 + R_2 = 2 F_y$$

$$\sum M_{R_1} = F_y(350) + F_y(650) - R_2(1000) = 0$$

$$R_1 = 192.27 \quad R_2 = 399.34 [N]$$



$$y(x) = 1000 = \frac{F}{3EI} \left[2a^3 - \frac{a^4}{1000} - la^2 \right]$$

$$1000 \text{ mm} = \frac{(F)}{3EI} \left[2 \cdot 675^3 - \frac{675^4}{1000} - 1000 \cdot 675^2 \right]$$

$$EI = 9.49 \times 10^9$$

$$I = \frac{9.49 \times 10^9}{71.1 \times 10^3 \text{ MPa}} = 133.3 \times 10^3 \text{ mm}^4$$

$$E = 71.1 \text{ GPa}$$

$$N = \frac{S_y}{\sigma'} \quad \sigma' = \sqrt{\sigma_x^2 + \tau_{xy}^2 - \sigma_x \sigma_y + 3\tau_{xy}^2}$$

$$2 = \frac{179 \text{ MPa}}{\sigma'}$$

$$\text{AL 2024} \quad \sigma' = 89.5 \text{ MPa}$$

$$\sigma' = \sqrt{\frac{m \cdot c}{I} - 3\left(\frac{4}{3}\right)\frac{V^2}{a^2}}$$

$$\sigma' = \sqrt{\frac{m \cdot c}{133 \times 10^3} - 2 \cdot \left(\frac{V^2}{a^2}\right)}$$

Type ~~40~~ steel 1040 Hot rolled

$$N = 2 = \frac{483}{\sigma'}_1$$

$$d_i = \sqrt{\frac{2 \cdot F \cdot \sqrt{3} \cdot 4}{483 \cdot \pi \cdot 52}} = 1.911$$

$$d_o = 40.594 \text{ m}$$

$$M_{\max} = 12,690 \text{ N}\cdot\text{mm}$$

$$\frac{M \cdot c}{I} = \sigma_{xx}$$

Assume
 Z_{xx} is negligible

$$\sigma'_{xx} = \sqrt{\sigma_x^2 + 3\tau_{xz}^2} =$$

$$\sigma'_{xx} = \sigma = \frac{m \cdot c}{I} = \frac{m \cdot r}{I} = 89.5 \text{ MPa}$$

$$r = 176.8 \text{ mm}$$

$$d_o = 353.7 \text{ mm}$$

$$I = \frac{\pi}{64} (353.7^4 - d_i^4)$$

$$d_i = \sqrt[4]{-\frac{64}{\pi} I + d_o^4}$$

$$d = 17.95 \text{ mm}$$

$$= 20.00 \text{ mm}$$

Shaft dia 1040 Hot rolled

$$N = 2 = \frac{S_y}{\sigma'}_1 = \frac{524}{\sigma'}_1$$

$$\sigma' = 262 = \sigma_{xx}$$

$$d = \left(\frac{129600(2)}{\pi \cdot 262} \right)^{\frac{1}{3}} = 6.803 \text{ mm} = 7 \text{ mm}$$

$$\sigma_{xx} = \frac{m \cdot c}{I} = \frac{129600 \cdot \frac{d}{2}}{\frac{\pi}{4} d^4} = \frac{129600(2)}{\pi d^3}$$

Spec:

Outer diameter = 20 mm
Inner diameter = 7 mm

$$SF_{\text{roller}} = 1.068$$

$$SF_{\text{bearing}} = \text{Bearing}$$

125 kg rider

$$AL = 2040$$

Steel = 1040 Hot Rolled

$$V(x)_{\text{max}} = 400$$

Direct Shear

$$N = \frac{S_y}{\sigma'} = \frac{584}{\sigma'} = 87.32 \quad \sigma' = \frac{400}{\frac{\sqrt{3}}{2} \cdot \frac{\pi}{4} \cdot 7^2} = \frac{400}{\frac{\sqrt{3}}{2} \cdot \frac{\pi}{4} \cdot 7^2}$$

$$I = \frac{\pi}{64} [d_o^4 - d_i^4]$$

$$7736.122 = \frac{\pi}{64} [20^4 - 7^4]$$

$$SF = 1.068 \text{ For roller}$$

$$SF = 4.44 \text{ For Bearing}$$

100 kg rider

$$M_{\text{max}} = 103,936 \text{ N}\cdot\text{mm}$$

$$\sigma' = 134.35 \text{ MPa}$$

$$N = \frac{179}{134.35} = 1.33$$