MEN 102
Exam 2
Fall 2005

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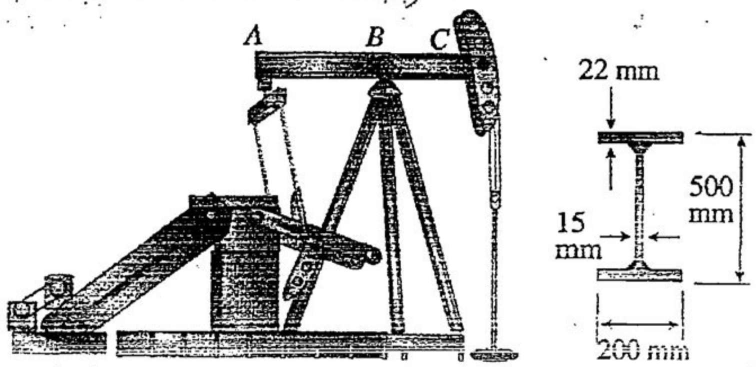
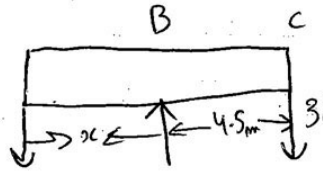
1) (15 pts) The horizontal beam ABC of an oil-well pump has the cross section shown in the figure. If the vertical pumping force acting at end C is 38 kN, and if the distance from the line of action of that force to point B is 4.5 m, calculate the maximum bending stress in the beam due to the pumping force.





$\Sigma F_y = 0: \; B_y - 38 - A_y = 0$ (1)

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$\Sigma M_A = 0: \; B_y(x) - 38(4.5 + x) = 0$ (2)

$\Sigma M_B = 0: \; -38(4.5) + A_y(x) = 0$ (3)

in (2): $B_y(x) - 171 - 38x = 0$

$\Leftrightarrow x(B_y - 38) = 171 \Leftrightarrow \boxed{x = \frac{171}{B_y - 38}}$

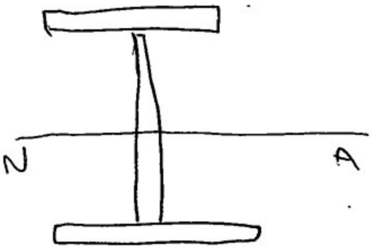
replace in (3): $-38(4.5) + A_y\left(\frac{171}{B_y - 38}\right) = 0$

$\Leftrightarrow -171(B_y - 38) + A_y \times 171 = 0$

$\Leftrightarrow -171 B_y + 171 A_y = -6498$

$B_y - A_y = 38$ (1)

$$\sigma_{max} = \frac{Mc}{I}$$



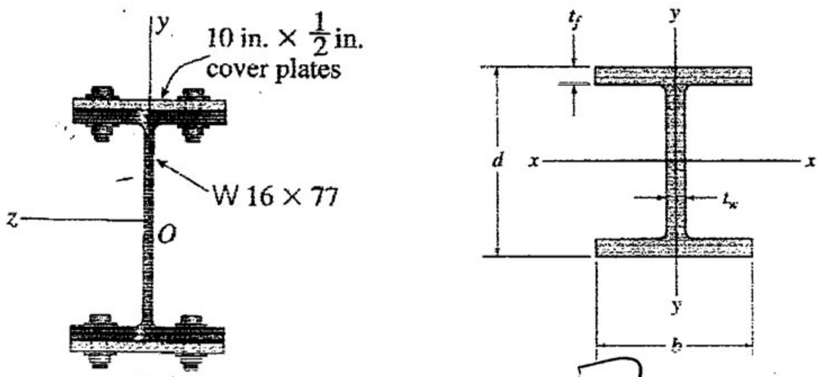
$c = \cancel{500\,mm}\ 250\,mm + 22\,m = 272\,mm$

$\boxed{c = 0.272\,m}$ X

$$I = 2\left[\frac{1}{12}(0.2)(0.022)^3 + (0.2)(0.022)(0.261)^2\right] + \left[\frac{1}{12}(0.015)(0.456)^3\right]$$

$$\Leftrightarrow \boxed{I = 7.183\times10^{-4}}$$ X

2) (15 pts) A steel beam is built up from a $W16\times77$ wide-flange beam and two $10\,in \times 1/2\,in$ cover plates (as shown in the left part of the figure below). The allowable load in shear on each bolt is $2.8\,kip$. Determine the required bolt spacing s in the longitudinal direction if the shear force is $V = 40\,kip$. For a $W16\times77$ section (as shown in the right part of the figure below), we have $d=16.52\,in,\ t_w=0.455\,in,\ b=10.295\,in,\ t_f=0.985\,in,\ I_{xx}=1110\,in^4,\ I_{yy}=138\,in^4$.



$$s = \frac{V}{q} \qquad q = \frac{VQ}{I}$$

$V = 40\,kip$

$$\cancel{I = \sqrt{(1110)^2 + (138)^2} = 1118.5}$$

$$\cancel{Q = y'A} \qquad I = \sqrt{I_{xx}^2 + I_{yy}^2 + I_{zz}^2}$$

$$I = 2\left[\frac{1}{12}(10.295)(0.985)^3 + (10.295)(0.985)(7.7675)^2\right] + \left[\frac{1}{12}(0.455)(14.55)^3\right] = 1342.07$$

$$1342.07 = \sqrt{(1110)^2 + (138)^2 + I_{zz}^2}$$

$$\cancel{1801271.85 =}$$

$$\boxed{I_{zz} = 741.638}$$

$$Q = y'A' = 10 \times \frac{1}{2} \times 7.7675 = 38.83$$

$$q = \frac{VQ}{I_{zz}} = \frac{40 \times 38.83}{741.63} = 2.09$$

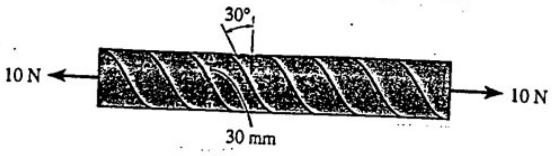
$$\boxed{q = 2.09} \quad X$$

$$S = \frac{V}{q} = \frac{2.8}{2.09} = 1.336 \text{ in}$$

$$\boxed{S = 1.336 \text{ in}} \quad X$$

3) (20pts)

A paper tube is formed by rolling a paper strip in a spiral and then gluing the edges together as shown. Determine the shear stress acting along the seam, which is at 30° from the vertical, when the tube is subjected to an axial force of 10 N. The paper is 1 mm thick and the tube has an outer diameter of 30 mm.



$\sigma_x = 10N \qquad \sigma_y = 0 \qquad \cancel{\tau_{xy} = \alpha}$

$$\tan 2\theta_s = \frac{-(\sigma_x - \sigma_y)/2}{\tau_{xy}} =$$

$$\tan 2(30) = \frac{-(10-0)/2}{\tau_{xy}}$$

$$\Leftrightarrow \quad 1.73 = \frac{-5}{\tau_{xy}}$$

$$\boxed{\tau_{xy} = -2.88}$$