$\sigma_x = 3\,MPa \quad \sigma_y = -2\,MPa \quad \tau_{xy} = -4\,MPa$

$\sigma_{méd.} = \frac{\sigma_x + \sigma_y}{2}$

$\sigma_{méd.} = \frac{3-2}{2}$

$\sigma_{méd.} = 0{,}5\,MPa$ (centro)

$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

$R = \sqrt{\left(\frac{3+2}{2}\right)^2 + (-4)^2}$

$\boxed{R = 4{,}717\,MPa}$

$A(3, -4)$

*

$\alpha = \operatorname{arctg}\left(\frac{4}{2{,}5}\right) - 40°$

$\alpha = 18°$

$\sigma_{x'} = 0{,}5 + 4{,}717 \cdot \cos 18°$

$\boxed{\sigma_{x'} = 4{,}986\,MPa}$

$\sigma_{y'} = 0{,}5 - 4{,}717 \cos 18°$

$\boxed{\sigma_{y'} = -3{,}986\,MPa}$

$\tau_{x'y'} = -4{,}717 \cdot \operatorname{sen} 18°$

$\boxed{\tau_{x'y'} = -1{,}457\,MPa}$

**

(2) a) $\sigma_x = 350\ MPa$ $\sigma_y = -200\ MPa$ $\tau_{xy} = 500\ MPa$

$$\sigma_{méd.} = \frac{\sigma_x + \sigma_y}{2}$$

$$\sigma_{méd.} = \frac{350 - 200}{2}$$

$\sigma_{méd.} = 75\ MPa$ (centro)

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$R = \sqrt{\left(\frac{350 - (-200)}{2}\right)^2 + (500)^2}$$

$\boxed{R = 570,64\ MPa}$

$A = (350, 500)$

$\sigma_1 = 75 + 570,64$

$\boxed{\sigma_1 = 645,64\ MPa}$

$\sigma_2 = 75 - 570,64$

$\boxed{\sigma_2 = 495,6\ MPa}$

$$tg(2\theta_p) = \frac{500}{275}$$

$tg(2\theta_p) = 1,8182$

$\boxed{\theta_{p_1} = 30,6°\ (anti\text{-}horário)}$

b) $\boxed{\tau_{máx\ plano} = R = 571\ MPa}$

$$\sigma_{méd.} = \frac{\sigma_x + \sigma_y}{2}$$

$$\sigma_{méd.} = \frac{350 - 200}{2}$$

$\boxed{\sigma_{méd.} = 75\ MPa}$

$$tg(2\theta_s) = \frac{275}{500} = 0,55$$

$\boxed{\theta_{s_1} = 14,4°\ (horário)}$

a) $\sigma_x = 45\,MPa$ $\quad \sigma_y = 30\,MPa$ $\quad \tau_{xy} = -50\,MPa$

$$\sigma_{méd.} = \frac{\sigma_x + \sigma_y}{2}$$

$$\sigma_{méd.} = \frac{45+30}{2}$$

$$\sigma_{méd.} = 37,5\,MPa \text{ (centro)}$$

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_x}{2}\right)^2 + \tau_{xy}^2}$$

$$R = \sqrt{\left(\frac{45-30}{2}\right) + (-50)^2}$$

$$\boxed{R = 50,56\,MPa}$$

$$\boxed{A(45, -50)}$$

*

$$\sigma_1 = 37,5 + 50,56$$

$$\boxed{\sigma_1 = 88,06\,MPa}$$

$$\sigma_2 = -50,56 + 37,5$$

$$\boxed{\sigma_2 = -13,06\,MPa}$$

$$tg(2\theta_p) = \frac{50}{7,5}$$

$$tg(2\theta_p) = 6,667$$

$$\theta_{p_1} = 40,7^\circ \text{ (anti-horário)}$$

**

b) $\tau_{máx\,plano} = R = 50,6\,MPa$

$$\sigma_{méd.} = \frac{\sigma_x + \sigma_y}{2}$$

$$\sigma_{méd.} = \frac{45+30}{2}$$

$$\boxed{\sigma_{méd.} = 37,5\,MPa}$$

$$tg(2\theta_s) = \frac{7,5}{50}$$

$$tg(2\theta_s) = 0,15$$

$$\theta_{s_1} = 4,27^\circ \text{ (horário)}$$

***

④ $\zeta + \Sigma M_D = 0$

$-500 \cdot 1,25 + 2,5 F_C = 0$

$\boxed{F_C = 250N}$

$\uparrow + \Sigma F_y = 0$

$250 - 200 \times 1,5 + V = 0$

$\boxed{V = 50N}$

$\zeta + \Sigma M = 0$

$M - (200 \times 1,5) \cdot 0,75 - 250 \cdot 1,5 = 0$

$\boxed{M = 150 N.m}$

$\sigma_D = \frac{M_y}{I} = \frac{150 \cdot 0,025}{\frac{0,1 \cdot 0,2^3}{12}}$

$\boxed{\sigma_D = 56,25 kPa\ (T)}$

$\tau_D = \frac{VQ_D}{Ib}$

$\tau_D = \frac{50 \cdot (0,0625 \cdot 0,075 \cdot 0,1)}{\left(\frac{0,1 \times 0,2^3}{12}\right) \cdot (0,1)}$

$\boxed{\tau_D = 3,516 kPa}$

$\sigma_x = 56,25 kPa \qquad \sigma_y = 0 kPa \qquad \tau_{xy} = -3,516 kPa$

$\sigma_{méd} = \frac{\sigma_x + \sigma_y}{2}$

$\sigma_{méd} = \frac{56,25 + 0}{2}$

$\sigma_{méd} = 28,125 kPa$ (centro)

$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

$R = \sqrt{\left(\frac{56,25 - 0}{2}\right)^2 + (-3,516)^2}$

$\boxed{R = 28,344 kPa}$

$\phi = \text{tg}^{-1}\left(\frac{3,516}{28,125}\right)$

$\boxed{\phi = 7,126°}$

$\theta = 180° - 120° - 7,126°$

$\boxed{\theta = 52,874°}$

$\sigma_{x'} = 28,125 - 28,344 \cos(52,874)$

$\boxed{\sigma_{x'} = 11 kPa}$

$\tau_{x'y'} = -28,344 \text{sen}(52,874°)$

$\boxed{\tau_{x'y'} = -22,6 kPa}$

$N_z = 25 \cdot (4/5)$ $\quad V_y = 25 \cdot (3/5)$ $\quad M_x = 15 \cdot 0,4$

$N_z = 20\,kN$ $\quad V_y = 15\,kN$ $\quad M_x = 6\,kN \cdot m$

$$\sigma_A = \frac{N_z}{A} + \frac{M_x y_A}{I_x}$$

$$\sigma_A = \frac{20 \times 10^3}{0,08 \cdot 0,16} + \frac{(6 \times 10^3) \cdot 0,040}{\left(\frac{0,080 \times 0,160^3}{12}\right)}$$

$\sigma_A = 10,35\,MPa$ (T)

$$\tau_A = \frac{V_y Q_A}{I_x t}$$

$$\tau_A = \frac{(15 \times 10^3) \cdot (0,060 \cdot 0,080 \cdot 0,040)}{\left(\frac{0,080 \cdot 0,160^3}{12}\right)(0,08)}$$

$\tau_A = 1,32\,MPa$

$\sigma_x = 10,35\,MPa$ $\quad \sigma_y = 0\,MPa$ $\quad \tau_{xy} = -1,32\,MPa$

$$\sigma_{méd.} = \frac{\sigma_x + \sigma_y}{2}$$

$$\sigma_{méd} = \frac{10,35 + 0}{2}$$

$\sigma_{méd.} = 5,175\,MPa$ (centro)

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$R = \sqrt{\left(\frac{10,35 - 0}{2}\right)^2 + (-1,32)^2}$$

$R = 5,34\,MPa$

$\sigma_1 = 5,175 + 5,34$ $\quad \sigma_2 = 5,175 - 5,34$

$\sigma_1 = 10,52\,MPa$ $\quad \sigma_2 = -0,165\,MPa$

(6) $\sigma_x = 90$ MPa $\quad \sigma_y = -80$ MPa $\quad \tau_{xy} = 40$ MPa

*

$$\sigma_{méd.} = \frac{\sigma_x + \sigma_y}{2}$$

$$\sigma_{méd.} = \frac{90 - 80}{2}$$

$\boxed{\sigma_{méd.} = 5 \text{ MPa} \text{ (centro)}}$

$$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$R = \sqrt{\left(\frac{90 - (-80)}{2}\right)^2 + (40)^2}$$

$\boxed{R = 93{,}94 \text{ MPa}}$ **

$\sigma_1 = 5 + 93{,}94$

$\boxed{\sigma_1 = 98{,}94 \text{ MPa}}$

$\sigma_2 = 5 - 93{,}94$

$\boxed{\sigma_2 = -88{,}94 \text{ MPa}}$

$\boxed{\sigma_{máx.} = 98{,}94 \text{ MPa}}$ $\boxed{\sigma_{int.} = -88{,}94 \text{ MPa}}$ $\boxed{\sigma_{mín.} = -100 \text{ MPa}}$

$$\tau_{máx\ abs.} = \frac{\sigma_{máx} - \sigma_{mín}}{2}$$

***

$$\tau_{máx\ abs.} = \frac{98{,}94 - (-100)}{2}$$

$\boxed{\tau_{máx\ abs.} = 99{,}47 \text{ MPa}}$

$\sigma_x = 0$ MPa $\sigma_y = 0$ MPa $\tau_{xy} = 5$ MPa ✗

$\sigma_{med.} = \frac{\sigma_x + \sigma_y}{2}$

$\sigma_{med} = 0$ MPa (centro)

$R = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

$R = \sqrt{\left(\frac{0-0}{2}\right)^2 + (5)^2}$

$\boxed{R = 5 \text{ MPa}}$ ✗✗

$\sigma_1 = 0 + 5$

$\boxed{\sigma_1 = 5 \text{ MPa}}$

$\sigma_2 = 0 - 5$

$\boxed{\sigma_2 = -5 \text{ MPa}}$

$\boxed{\sigma_{máx} = 7 \text{ MPa}}$

$\boxed{\sigma_{int} = 5 \text{ MPa}}$

$\boxed{\sigma_{mín} = -5 \text{ MPa}}$

$\tau_{máx\ abs} = \frac{\sigma_{máx} - \sigma_{mín}}{2}$ ✗✗✗

$\tau_{máx\ abs} = \frac{7 - (-5)}{2}$

$\boxed{\tau_{máx\ abs} = 6 \text{ MPa}}$

(8) $\sigma_x = 40\ MPa$ $\sigma_y = -40\ MPa$ $\tau_{xy} = 0\ MPa$

Plano X-Y

~~$\sigma_{méd} = 0\ MPa$~~

$$\sigma_{méd} = \frac{\sigma_x + \sigma_y}{2}$$

$$\sigma_{méd} = \frac{40 - 40}{2}$$

$$\boxed{\sigma_{méd} = 0\ MPa}$$

$$\tau_{máx} = \frac{\sigma_{máx} - \sigma_{mín}}{2}$$

$$\tau_{máx} = \frac{40 - (-40)}{2}$$

$$\boxed{\tau_{máx} = 40\ MPa}$$

Plano Y-Z

$\sigma_y = -40\ MPa$ $\sigma_z = -40\ MPa$ $\tau_{xy} = 0\ MPa$

$$\sigma_{méd} = \frac{\sigma_y + \sigma_z}{2}$$

$$\sigma_{méd} = \frac{-40 - 40}{2}$$

$$\boxed{\sigma_{méd} = -40\ MPa}$$

$$\tau_{máx} = \frac{\sigma_{máx} - \sigma_{mín}}{2}$$

$$\tau_{máx} = \frac{-40 - (-40)}{2}$$

$$\boxed{\tau''_{máx} = 0\ MPa}$$

Plano X-Z

$\sigma_x = 40\ MPa$ $\sigma_z = -40\ MPa$ $\tau_{xz} = 0\ MPa$

$$\sigma_{méd} = \frac{\sigma_x + \sigma_z}{2}$$

$$\sigma_{méd} = \frac{40 + (-40)}{2}$$

$$\boxed{\sigma_{méd} = 0\ MPa}$$

$$\tau_{máx} = \frac{\sigma_{máx} - \sigma_{mín}}{2}$$

$$\tau_{máx} = \frac{40 - (-40)}{2}$$

$$\boxed{\tau_{máx} = 40\ MPa}$$