Given: $\sigma_x = 9$ MPa, $\sigma_y = 19$ MPa, $\tau_{xy} = 8$ MPa (CW)

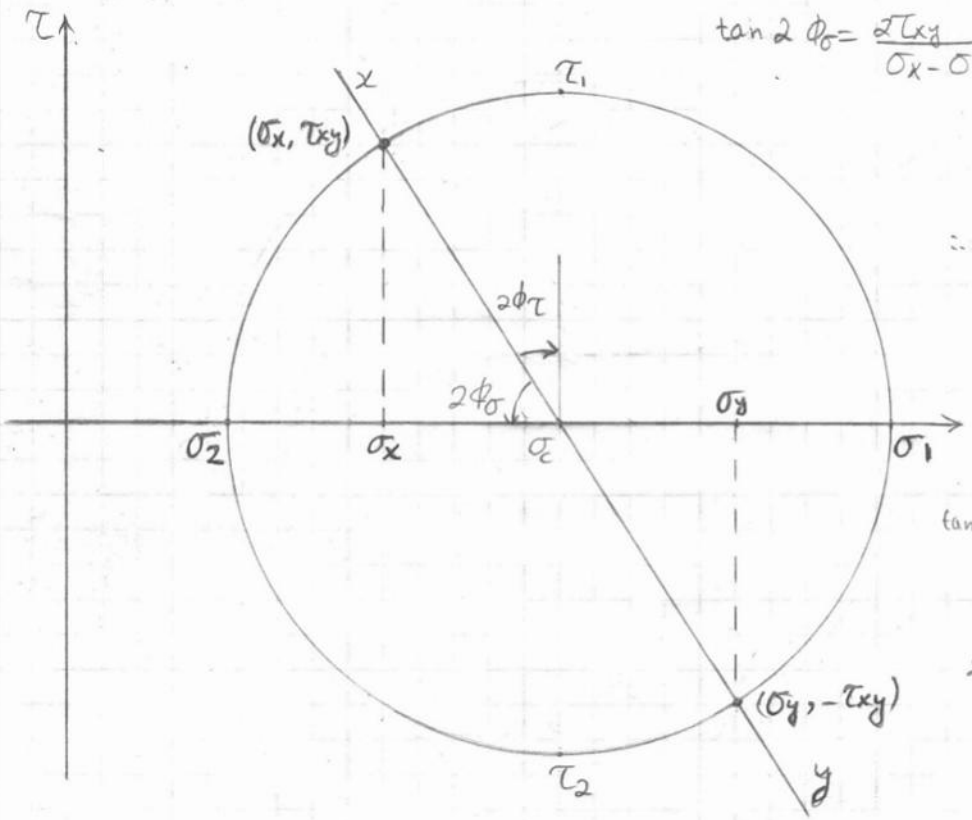
Solution:

$$\sigma_c = \frac{\sigma_x + \sigma_y}{2} = \frac{9+19}{2} = 14 \text{ MPa}$$

$$\tau_1, \tau_2 = \pm\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = \pm\sqrt{\left(\frac{9-19}{2}\right)^2 + 8^2} = \pm 9.43 \text{ MPa}$$

$$\therefore \underline{\tau_1 = 9.43 \text{ MPa}} \quad \underline{\tau_2 = -9.43 \text{ MPa}}$$

$$\underline{\sigma_1 = \sigma_c + \tau_1 = 23.43 \text{ MPa}} \qquad \underline{\sigma_2 = \sigma_c + \tau_2 = 4.57 \text{ MPa}}$$



$$\tan 2\phi_\sigma = \frac{2\tau_{xy}}{\sigma_x - \sigma_y} = \frac{2(8)}{9-19} = -\frac{8}{5}$$

$$\therefore 2\phi_\sigma = -58^\circ, 122^\circ$$

$$\phi_\sigma = -29^\circ$$

$$\tan 2\phi_\tau = -\frac{\sigma_x - \sigma_y}{2\tau_{xy}} = +\frac{5}{8}$$

$$2\phi_\tau = 32^\circ, -148^\circ$$

$$\phi_\tau = 16^\circ$$