1. (30%) A steel countershaft ($E = 30 \times 10^6$ psi) with roller bearings at $O$ and $B$ is in equilibrium as shown, where $T_1 = 9T_2$. Taking the bearings as simple supports, determine (a) the deflection $y_C$ at $C$, (b) the minimum shaft diameter $d_{\text{min}}$ needed, using $\frac{1}{8}$-in. increments, if the slope at either bearing should not exceed $0.05^\circ$, (c) the value of $y_C$ when the shaft diameter is $d_{\text{min}}$.

![Fig. P1](image)

2. (20%) Using the traction vector formula

$$t_i = \sigma_{ji} n_j$$

derive the octahedral normal stress $\sigma_{\text{oct}}$ and the octahedral shear stress $\tau_{\text{oct}}$ in terms of the principal stresses: $\sigma_1, \sigma_2, \sigma_3$. Include pertinent sketches in the derivation.

3. (20%) Describe the octahedral-shear-stress theory and show that this theory gives the same equivalent stress ($\sigma'$) for yielding as that given in the distortion energy theory.

4. (30%) A bar of AISI 1040 hot-rolled steel has a minimum yield strength in tension and compression of 42 kpsi. Using the distortion-energy and maximum-shear-stress theories, computing the von Mises stress, drawing the stress element, and drawing Mohr’s circle diagrams, determine the factor of safety $n$ for the following plane stress states:

(a) $\sigma_x = 30$ kpsi, $\tau_{xy} = -8$ kpsi
(b) $\sigma_x = -24$ kpsi, $\sigma_y = -12$ kpsi, $\tau_{xy} = -8$ kpsi
(c) $\sigma_x = 12$ kpsi, $\sigma_y = 28$ kpsi, $\tau_{xy} = 6$ kpsi