ASSIGNMENTS FOR MEEG 4103 Machine Element Design
TR 9:30 a.m. -10:50 a.m. Spring 2009
4103-001 LEC 9897 Machine Element Design
4103H-001 LEC 10315 HNRS Machine Element Design

Text: *Shigley’s Mechanical Engineering Design, Eighth Edition*

Supplies: Calculator, engineering paper, mechanical pencil, eraser, *transparent* 6-in. plastic ruler, and compass or template for drawing circles.

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Part A

**Chapter 3**
3-3a, 3-3b, 3-4, 3-8, 3-11, 3-13, 3-25b, 3-25d, 3-29, 3-38, 3-55

**Chapter 4**
4-13, 4-16, 4-18, 4-20, 4-21

4S-1. A Gerber beam (*Gerberbalken*) with total length $4L$ has a hinge connection at $C$ and constant flexural rigidity $EI$ in its segments $ABC$ and $CDE$. This beam is supported and loaded with a concentrated moment $M_0 \phi$ at $D$ as shown in Fig. 4S-1. Determine (a) the slopes $\theta_B$, $\theta_D$, and $\theta_E$ at $B$, $D$, and $E$, respectively; (b) the slope $(\theta_C)_l$ just to the left of $C$; (c) the slope $(\theta_C)_r$ just to the right of $C$; (d) the deflection $y_C$ at $C$; (e) the deflection $y_D$ at $D$.

**Fig. 4S-1** A Gerber beam

\[
\theta_B = \frac{M_0L}{8EI} \phi \quad \theta_D = \frac{5M_0L}{16EI} \phi \quad \theta_E = \frac{M_0L}{16EI} \phi \\
(\theta_C)_l = \frac{3M_0L}{8EI} \phi \quad (\theta_C)_r = \frac{M_0L}{16EI} \phi \\
y_C = \frac{7M_0L^2}{24EI} \downarrow \quad y_D = \frac{7M_0L^2}{48EI} \downarrow
\]

**Chapter 5**
5-1, 5-3, 5-14, 5-25, 5-26

5S-1 Derive the strain energy per unit volume
\[
u = \frac{1}{2E} \left[ \sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\nu(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1) \right]
\]

5S-2 Derive the strain energy in *volume change* per unit volume
\[
u_e = \frac{1-2\nu}{6E} \left[ \sigma_1^2 + \sigma_2^2 + \sigma_3^2 + 2(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1) \right]
\]
5S-3 Derive the strain energy in distortion per unit volume

\[ u_d = \frac{1 + \nu}{3E} \left[ \frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2} \right] \]

5S-4 Using principal axes, derive von Mises stress for yielding

\[ \sigma' = \frac{1}{\sqrt{2}} \left[ (\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \right]^{1/2} \geq s_y \]

5S-5 Using non-principal axes and eigenvalues of the stress matrix at a point in 3D, derive von Mises stress for yielding

\[ \sigma' = \frac{1}{\sqrt{2}} \left[ (\sigma_e - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_e)^2 + 6(\tau_{yx}^2 + \tau_{yz}^2 + \tau_{zx}^2) \right]^{1/2} \]

5S-6 Derive the traction vector formula

\[ t_i = \sigma_j n_j \]

5S-7 Using the traction vector formula, derive the octahedral normal stress

\[ \sigma_{\text{oct}} = \frac{1}{3}(\sigma_1 + \sigma_2 + \sigma_3) \]

5S-8 Using the traction vector formula, derive the octahedral shear stress

\[ \tau_{\text{oct}} = \frac{1}{3} \left[ (\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \right]^{1/2} \]

5S-9 Describe the octahedral-shear-stress theory and use it to verify that this theory is equivalent to the distortion-energy theory.

5H-1 Let \( \sigma' = s_y \) in Eq. (5-13) so that we have a quadratic equation in \( \sigma_a \) and \( \sigma_b \) as follows:

\[ \sigma_a^2 - \sigma_a \sigma_b + \sigma_b^2 = s_y^2 \]

Using matrix algebra and rotation of axis for a symmetric matrix, identify and graph this quadratic equation. Compare your graph with that in Figure 5-9.