Objective: The primary objective of this assignment is to become familiar with some relevant static problems associated with common engineering analysis and construction practices. Specific goals:

- Learn how to calculate normal stress, strain and deformations in a bar carrying an axial force (uniaxial problem).
- Learn how to apply safety factors to the design of bars carrying an axial force.
- Practice conversion of units.

Reading assignment:

- Study the handout on elastic stress analysis (section 4.6 and 4.7 in Introduction to Engineering Analysis by K.D. Hagen, download from electronic reserve.)
- Read Ch.s 3 and 4 in Structures: or why things don’t fall down, by J.E. Gordon (on 2-hour reserve at Carlson for ME104Q)
- Read Cotterell/Kamminga: Ch. 3, Stress and strength, Deformation and strain, Stress-strain relationship (pp 65-72), but skip material related to shear stress.

Homework Assignment: Problem sets that you turn in must be clear, legible, and well organized. Write your name and problem set on all pages you turn in. Please write only on one side of the sheet, and use standard 8"x11" sheets. All problems in the problem set should be labeled, and all pages must be stapled together. No torn, folded or unlabeled pages, please!

In the following problems, use the analysis procedure consisting of (1) problem statement, (2) diagram, (3) assumptions, (4) governing equations, (5) calculations, (6) solution check. Diagrams must be clear, concise, uncrowded, with clearly marked symbols such as forces, dimensions, etc. (use different color pens if you prefer).

Problem 1
A solid rod of stainless steel (E = 190 GPa) is 50 cm in length and has a 4 mm x 4 mm cross section. The rod is subjected to an axial tensile force of 8 kN. Find the normal stress, strain, and axial deformation.

Problem 2
An 8-m-high granite column sustains an axial compressive load of 500 kN. If the column shortens 0.12 mm under the load, what is the diameter of the column? For granite, E = 70 GPa.

Problem 3
A plastic (E = 3 GPa) tube with an outside and inside diameter of 6 cm and 5.4 cm, respectively, is subjected to an axial compressive force of 12 kN. If the tube is 25 cm long, how much does the tube shorten under the load?

Problem 4
A rod of aluminum 6061-T6 has a square cross section measuring 0.25 in x 0.25 in. Using the yield stress as the failure stress, find the maximum tensile load that the rod can sustain for a factor of safety of 1.5. The yield stress of aluminum 6061-T6 is 240 MPa.
**Problem 5**
A concrete column with a diameter of 60 cm supports a portion of a highway overpass. Using the ultimate stress as the failure stress, what is the maximum compressive load that the column can carry for a factor of safety of 1.25? For the ultimate stress of concrete, use 40 MPa.

**Problem 6**
A tensile test is conducted on a steel specimen with a diameter of 8.0 mm and a test length of 6.0 cm. The data is shown in the table. Plot the stress- strain diagram, and find the approximate value of the modulus of elasticity for the steel.

<table>
<thead>
<tr>
<th>Load (kN)</th>
<th>Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td>0.0119</td>
</tr>
<tr>
<td>5.0</td>
<td>0.0303</td>
</tr>
<tr>
<td>10.0</td>
<td>0.0585</td>
</tr>
<tr>
<td>15.0</td>
<td>0.0895</td>
</tr>
<tr>
<td>20.0</td>
<td>0.122</td>
</tr>
<tr>
<td>25.0</td>
<td>0.145</td>
</tr>
</tbody>
</table>
1

\[ E = 190 \text{ GPa} = 1.9 \times 10^9 \text{ Pa} \]

\[ L = 50 \text{ cm} = 0.5 \text{ m} \]

\[ A = \frac{Y_{\text{min}} \times Y_{\text{max}}}{4 \times 10^{-3} \text{ m} \times 4 \times 10^{-3} \text{ m}} \]

\[ P = 8 \text{ kN} = 8 \times 10^3 \text{ N} \]

\[ \text{Strain} = \frac{6 \times \sigma E}{P} = \frac{F_B D}{A} \]

\[ \Delta = \frac{P L}{E A} = \frac{6 L}{E} \]

\[ \text{Strain} = \frac{\Delta}{L} = \frac{6 \times 6^3}{L} \]

\[ \Delta = 1.32 \text{ mm} \]

\[ \Delta = \frac{P L}{E A} \rightarrow A = \frac{P L}{E \Delta} = \pi r^2 \]

\[ \Delta = \frac{P L}{E A} \rightarrow A = \frac{P L}{E \Delta} = \pi r^2 \]

\[ r = \sqrt{\frac{5000 \times 10^3 (8)}{(7 \times 10^3) (12 \times 10^{-4}) \pi}} \]

\[ r = 38.9 \Rightarrow r = 38.93 \text{ cm} \]

\[ d = 77.9 \text{ cm} \]

2

\[ \downarrow \text{700 kN} \]

\[ L = 8 \text{ m} \]

\[ P = 500 \times 10^3 \text{ N} \]

\[ \Delta = 0.12 \text{ mm} = 1.2 \times 10^{-4} \text{ m} \]

\[ E = 70 \text{ GPa} = 7 \times 10^9 \text{ Pa} \]

3

\[ E = 3 \text{ GPa} = 3 \times 10^9 \text{ Pa} \]

\[ d_1 = 0.06 \text{ m} \]

\[ d_2 = 0.054 \text{ m} \]

\[ A = \pi \left( \left( \frac{d_1}{2} \right)^2 - \left( \frac{d_2}{2} \right)^2 \right) = 1.71 \times 10^{-4} (\pi) \text{ m}^2 \]

\[ P = 1.2 \times 10^4 \text{ N} \]

\[ L = 2.5 \text{ m} \]

\[ \Delta = \frac{P L}{A E} = \frac{(1.2 \times 10^4)(0.25)}{(1.71 \times 10^{-4}) \pi (3 \times 10^9)} = 0.0186 \]

\[ \Delta = 1.86 \text{ mm} \]

12 kN
4) \[ \sigma_y = 240 \text{ MPa} \]
\[ \text{F.S.} = 1.5 \]
\[ \frac{\sigma_y}{\text{F.S.}} = 1.5 \quad \Rightarrow \quad \sigma_{\text{applied}} = \frac{\sigma_y}{1.5} = 160 \text{ MPa} \]
\[ A = (0.25 \text{ in.})^2 = 0.0625 \text{ in.}^2 \]
\[ \sigma_{\text{applied}} = \frac{F_{\text{max}}}{A} \quad \Rightarrow \quad F_{\text{max}} = \sigma_{\text{applied}} A \]
\[ \text{S.I.} \quad F_{\text{max}} = (160 \times 10^6 \text{ Pa})(0.0625 \text{ in.}^2)(0.0384 \text{ m/in.})^2 = 6.45 \text{ kN} \]
\[ \text{U.S.} \quad F_{\text{max}} = (160 \times 10^6 \text{ Pa})(0.0625 \text{ in.}^2)(1.45 \times 10^4 \text{ psi/Pa}) = 1.45 \text{ kips} \]

5) \[ D = 60 \text{ cm} = 0.6 \text{ m} \quad \sigma_u = 40 \text{ MPa} \]
\[ \text{F.S.} = 1.25 \]
\[ \frac{\sigma_u}{\text{F.S.}} = 1.25 \quad \Rightarrow \quad \sigma_{\text{applied}} = \frac{\sigma_u}{1.25} = 40 \text{ MPa} \]
\[ \sigma_{\text{applied}} = 32 \text{ MPa} \quad A = \frac{\pi}{4} D^2 = \frac{\pi}{4} (0.6 \text{ m})^2 \]
\[ \sigma_{\text{applied}} = \frac{F_{\text{max}}}{A} \quad \Rightarrow \quad F_{\text{max}} = \sigma_{\text{applied}} A \]
\[ F_{\text{max}} = (32 \times 10^6 \text{ Pa}) \left[ \frac{\pi}{4} (0.6 \text{ m})^2 \right] \]
\[ F_{\text{max}} = 9.05 \text{ MN} \]
6) 

\[ D [m] = 8.00 \times 10^{-3} \quad A [m^2] = 5.03 \times 10^{-5} \quad L [m] = 6.00 \times 10^{-2} \]

<table>
<thead>
<tr>
<th>Load [N]</th>
<th>Deformation [m]</th>
<th>Strain [mm/mm]</th>
<th>Stress [Pa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.00E+03</td>
<td>1.19E-05</td>
<td>1.98E-04</td>
<td>3.98E+07</td>
</tr>
<tr>
<td>5.00E+03</td>
<td>3.03E-05</td>
<td>5.05E-04</td>
<td>9.95E+07</td>
</tr>
<tr>
<td>1.00E+04</td>
<td>5.85E-05</td>
<td>9.75E-04</td>
<td>1.99E+08</td>
</tr>
<tr>
<td>1.50E+04</td>
<td>8.95E-05</td>
<td>1.49E-03</td>
<td>2.98E+08</td>
</tr>
<tr>
<td>2.00E+04</td>
<td>1.22E-04</td>
<td>2.03E-03</td>
<td>3.98E+08</td>
</tr>
<tr>
<td>2.50E+04</td>
<td>1.45E-04</td>
<td>2.42E-03</td>
<td>4.97E+08</td>
</tr>
</tbody>
</table>

**Steel Stress vs. Strain**

\[ y = 2.0143 \times 10^1x \]

\[ R^2 = 9.9829 \times 10^{-1} \]

Young's Modulus is the slope of the curve

\[ E = 201.4 \text{ GPa} \]