**Problem P5.2:** A 1 Mg container hangs from a 15 mm diameter steel cable. What is the stress in the cable?

**Approach:**
Find the cross–sectional area in terms of diameter using Equation (5.1). Calculate the tensile stress from Equation (5.2). Using the SI prefix "mega," 1 Mg = 1000 kg.

**Solution:**
Area:
\[ A = \frac{\pi}{4} (15 \text{ mm})^2 = 176.7 \text{ mm}^2 \]
\[ = 1.767 \times 10^{-4} \text{ m}^2 \]

Weight:
\[ w = (1000 \text{ kg}) \left( 9.81 \frac{\text{m}}{\text{s}^2} \right) = 9810 \frac{\text{kg} \cdot \text{m}}{\text{s}^2} = 9810 \text{ N} \]

Stress:
\[ \sigma = \frac{9810 \text{ N}}{1.1767 \times 10^{-4} \text{ m}^2} = 5.551 \times 10^7 \frac{\text{N}}{\text{m}^2} \]
\[ = 55.51 \text{ MPa} \]

**Discussion:**
This calculation neglects the weight of any hardware attaching the container to the cable. If the cable was wider, the stress would decrease since the force would be distributed across a larger cross-sectional area.
Problem P5.6: As a machinist presses the handles of the compound action bolt cutters, link $AB$ carries a 7.5-kN force. If the link has a 14×4-mm rectangular cross section, calculate the tensile stress within it.

![Figure P5.6](image)

**Approach:**
Calculate the tensile stress $\sigma = F/A$ with $F = 7.5$ kN = 7500 N and assume the cross sectional area of link $AB$ is constant.

**Solution:**
Cross–sectional area:

$$A = (14 \text{ mm}) (4 \text{ mm}) = 56 \text{ mm}^2 = 56 \times 10^{-6} \text{ m}^2$$

Tensile stress:

$$\sigma = \frac{F}{A} = \frac{7500 \text{ N}}{56 \times 10^{-6} \text{ m}^2} = 1.34 \times 10^8 \text{ Pa} = 134 \times 10^6 \text{ Pa} = 134 \text{ MPa}$$

![sigma.png](image)

**Discussion:**
If the link $AB$ were smaller, the tensile stress would be larger since the cross sectional area would be smaller. If the cross sectional area were to change across the link $AB$, the stress would be higher in the smaller sections and smaller in the larger sections.
Problem P5.9: An 8-mm-diameter aluminum rod has lines scribed on it which are exactly 10 cm apart. After a 2.11 kN force has been applied, the separation between the lines has increased to 10.006 cm. (a) Calculate the stress and strain in the rod. (b) To what total length has the rod stretched?

Approach:
Apply Equations (5.2) and (5.3) for tensile stress $\sigma = F/A$ and strain $\varepsilon = \Delta L/L$. The final length is $L_{\text{final}} = (1 + \varepsilon)L$.

Solution:
(a) Cross-sectional area:
$$A = \frac{\pi d^2}{4} = \frac{\pi (0.008 \text{ m})^2}{4} = 5.02 \times 10^{-5} \text{ m}^2$$

Tensile stress:
$$\sigma = \frac{F}{A} = \frac{2.11 \text{ kN}}{5.02 \times 10^{-5} \text{ m}^2} = \frac{2100 \text{ N}}{5.02 \times 10^{-5} \text{ m}^2} = 4.2 \times 10^7 \frac{\text{N}}{\text{m}^2} = 42 \times 10^6 \text{ Pa}$$

Strain (dimensionless):
$$\varepsilon = \frac{\Delta L}{L} = \frac{0.006 \text{ cm}}{10 \text{ cm}} = 6 \times 10^{-4}$$

(b) Length of the bar after the force has been applied:
$$\Delta L = \varepsilon L = (6 \times 10^{-4})(30 \text{ cm}) = 0.018 \text{ cm}$$

$$L_{\text{final}} = L + \Delta L = 30 \text{ cm} + 0.018 \text{ cm} = 30.018 \text{ cm}$$

Discussion:
The change in total length makes sense because it is three times the change in the length of one of the 10-cm segments. Since the rod stretches longer, then its diameter would decrease slightly according to Poisson’s contraction effect.
Problem P5.11: Determine the elastic modulus and the yield strength for the material having the stress–strain curve shown. Use the 0.2% offset method.

Approach:
Draw a straight line along the curve near $\varepsilon = 0$, and read values of stress and strain to determine the slope $E$. To find the yield strength, draw a line with slope $E$ starting from the coordinates $\sigma = 0$ and $\varepsilon = 0.2\%$. That line intersects the curve at the 0.2% yield strength.

Solution:
Elastic modulus:
$$E = \frac{\sigma}{\varepsilon} = \frac{440 \text{ psi}}{0.25\%} = \frac{440 \text{ psi}}{0.0025} = 176,000 \text{ psi}$$
$$E = 176 \text{ ksi}$$
Yield strength:
The offset line intersects the stress–strain curve at 1040 psi. 
$$S_Y = 1.04 \text{ ksi}$$

Discussion:
This approach assumes the relation between $\sigma$ and $\varepsilon$ is nearly straight for small strains up to about 0.2%. At the yield point, the material deformation will leave a permanent strain of 0.002 (0.2%) when it is at zero stress. This is an approximation of the yield stress that can be used when more exact methods such as testing are not available.
Problem P5.14: A circular rod of length 25 cm and diameter 8 mm is made of grade 1045 steel, (a) Calculate the stress and strain in the rod, and its extension, when it is subjected to 5 kN of tension, (b) At what force would the rod begin to yield? (c) By what amount would the rod have to be stretched beyond its original length in order to yield?

Approach:
Calculate the tensile stress \( \sigma = F/A \), and strain \( \varepsilon = \sigma/E \) using the elastic modulus value \( E = 207 \text{ GPa} \) for steel from Table 5.2. The yield strength is \( S_y = 414 \text{ MPa} \) from Table 5.3 and the rod begins to yield when \( \sigma = S_y \). The elongation of the bolt is \( \Delta L = \varepsilon L \).

Solution:
(a) Cross–sectional area:
\[
A = \frac{\pi d^2}{4} = \frac{\pi (0.008 \text{ m})^2}{4} = 5.027 \times 10^{-5} \text{ m}^2
\]
Tensile stress:
\[
\sigma = \frac{F}{A} = \frac{5000 \text{ N}}{5.027 \times 10^{-5} \text{ m}^2} = 9.95 \times 10^7 \text{ Pa} = 99.5 \times 10^6 \text{ Pa}
\]
\( \sigma = 99.5 \text{ MPa} \)

Strain:
\[
\varepsilon = \frac{\sigma}{E} = \frac{99.5 \times 10^6 \text{ Pa}}{207 \times 10^9 \text{ Pa}} = 4.81 \times 10^{-4}
\]
\( \varepsilon = 4.81 \times 10^{-4} \)

Elongation:
\[
\Delta L = \varepsilon L = (4.81 \times 10^{-4})(25 \text{ cm}) = 0.012 \text{ cm} = 1.2 \times 10^{-4} \text{ m} = 120 \times 10^{-6} \text{ m}
\]
\( \Delta L = 120 \mu\text{m} \)

(b) The rod begins to yield when the force has magnitude:
\[
F = \sigma A = S_y A = (414 \times 10^6 \text{ Pa})(5.027 \times 10^{-5} \text{ m}^2) = 2.08 \times 10^4 \text{ N}
\]
\( F = 20.8 \text{ kN} \)

(c) The rod begins to yield when it has been stretched by amount:
\[
\varepsilon = \frac{\sigma}{S_y} = \frac{414 \times 10^6 \text{ Pa}}{207 \times 10^9 \text{ Pa}} = 2 \times 10^{-3}
\]
\( \varepsilon = 2 \times 10^{-3} \)
\[
\Delta L = \varepsilon L = (2 \times 10^{-3})(25 \text{ cm}) = 0.05 \text{ cm} = 5 \times 10^{-4} \text{ m} = 500 \times 10^{-6} \text{ m}
\]
\( \Delta L = 500 \mu\text{m} \)

Discussion:
This small actual elongation makes sense because of the size and material of the rod. If the rod was smaller in diameter, then the stress, strain, and elongation would all be larger.