1) Given a straight round bar made from steel alloy with Young’s modulus (E) of 207GPa and yield strength (σ𝑦) of 400MPa.
   a) What is the axial strain at yielding? (hint: the answer is close to 0.002mm/mm)
   b) If a strain gage was used to measure the axial strain to be 0.001mm/mm, can the axial stress be determined? If not, why not? If so, what is the axial normal stress?
   c) If a strain gage was used to measure the axial strain to be 0.003mm/mm, can the axial stress be determined? If not, why not? If so, what is the axial normal stress?

2) A cylindrical metal specimen having an original diameter of 12.8mm (0.505in) and a gage length of 50 mm (~2.0 in) is pulled in tension until fracture occurs. The diameter at the point of fracture is 7.2 mm and the fractured gage length is 74.3 mm. Calculate the ductility in terms of both percent reduction in area (%RA) and percent elongation (%EL).

3) The following stress-strain curve is from 2024-T351 aluminum alloy. If a straight bar made of 2024-T351 aluminum had a length of 100mm before loading, what would the length of the bar be with the following:
   a) 200 MPa axial load applied.
   b) Loaded to 200 MPa, and then the load is removed.
   c) 400 MPa axial load applied.
   d) Loaded to 400 MPa, and then the load is removed.

4) Using equation 6-18 in the textbook (RB: tensile strength = 500HB).
   a) What does HB refer to in this equation?
   b) Using this equation, what is the hardness of steel with tensile strength of 560MPa?
   c) Can this equation be used to determine the tensile strength of brass if its hardness was measured to be 120 HB? If not, why not? If so, what would the tensile strength be?

5) In words, what is ductility? What is toughness? Would you expect a material with high ductility to also have high toughness? Explain why/why not.
Given: metal tensile bar, \( D_0 = 12.8 \text{ mm} \), \( L_0 = 50 \text{ mm} \), pulled in tension until fracture

\[ D_{\text{fract}} = 7.2 \text{ mm} \quad L_{\text{fract}} = 74.3 \text{ mm} \]

Determine: ductility in terms of \( \% \text{EL} \) and \( \% \text{RA} \)

SOLN: \( \% \text{EL} = \frac{L_{\text{fract}} - L_0}{L_0} \times 100\% \)

\[ = \frac{74.3 \text{ mm} - 50 \text{ mm}}{50 \text{ mm}} \times 100\% \]

\( \% \text{EL} = 48.6\% \) (very ductile)

\( \% \text{RA} = \frac{A_0 - A_{\text{fract}}}{A_0} \times 100\% \)

\[ A_0 = \frac{\pi}{4} D_0^2 = \frac{\pi}{4} (12.8 \text{ mm})^2 \]

\[ A_0 = 128.7 \text{ mm}^2 \]

\[ A_{\text{fract}} = \frac{\pi}{4} D_{\text{fract}}^2 = \frac{\pi}{4} (7.2 \text{ mm})^2 \]

\[ A_{\text{fract}} = 40.72 \text{ mm}^2 \]

\( \% \text{RA} = \frac{(128.7 - 40.72) \text{ mm}^2}{128.7 \text{ mm}^2} \times 100\% \)

\( \% \text{RA} = 68.4\% \) (very ductile)
Given: Straight round steel bar, \( E = 207 \text{ GPa} \)
\( \sigma_{YS} = 400 \text{ MPa} \)

(a) Find: axial strain at yielding

\[ E = \frac{\sigma}{E} \]

Assume the \( \sigma - \varepsilon \) relationship is linear up until \( \sigma = \sigma_{YS} \)

\[ E = \frac{\sigma_{YS}}{E} = \frac{400 \text{ MPa}}{207,000 \text{ MPa}} = 0.0019 \text{ m/m} \]

(b) If \( E_{axial} = 0.001 \text{ m/m} \) can the axial stress be determined?

Ans: Yes since the material has not yielded.

\[ \sigma = E \varepsilon = 207 \text{ GPa} (0.001 \text{ m/m}) = 207 \text{ MPa} \]

(c) If \( E_{axial} = 0.003 \text{ m/m} \), can axial stress be determined?

Ans: No, not from the information given. For this steel if \( \varepsilon > 0.001 \text{ m/m} \), yielding will occur and Hooke's law (\( E = \varepsilon / \varepsilon \)) is not valid.
3) Given: $\sigma$-$\varepsilon$ curve (attached) for 2024-T351 long bar of 2024-T351, 100 mm long before testing

How long will it be:

a) with 200 MPa axial load

Assume: $E = 69$ GPa

From $\sigma$-$\varepsilon$ curve, $\sigma_{ys} = 350$ MPa

Since applied stress will not cause yield:

$$\varepsilon = \frac{\sigma}{E} = \frac{350 \text{ MPa}}{69,000 \text{ MPa}} = 0.0051 \text{ in./in.}$$

$$\varepsilon = \frac{l - l_0}{l_0} = 0.0051 \text{ in./in.}$$

$$l = l_0 \varepsilon + l_0 = l_0 (1 + \varepsilon)$$

$$l = 100 \text{ mm} (1 + 0.0051) = 100.51 \text{ mm}$$

(Assume $l_0 = 100.00 \text{ mm}$)

b) Loaded to 200 MPa, then unloaded.

Ans: Since the material did not yield, it will return to its original length (100 mm)

c) Loaded to 400 MPa

The material has yielded so Hooke’s law is not valid. From $\sigma$-$\varepsilon$ curve:

at $\sigma = 400$ MPa, $\varepsilon = 0.03$ in./in.

$$l = l_0 (1 + \varepsilon) = 100 \text{ mm} (1 + 0.03) = 103 \text{ mm}$$
d) Loaded to 400 MPa, then unload

Unloaded strain (from σ-ε curve) is about 0.022 deg

\[ l = l_0 (1 + \varepsilon) = 100 \text{ mm} (1 + 0.022) = 102.2 \text{ mm} \]