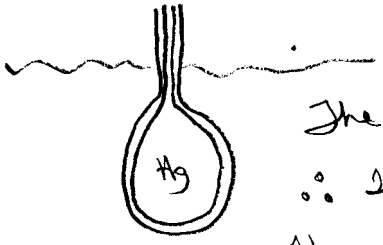
ENGINEERING 2C3 Assignment #4 Solution

1. [Serway Chapter 19 Question 6, pg 544]
Explain why a column of mercury in a thermometer first descends slightly and then rises when placed in hot water.



The hot water expands the glass first.
∴ the volume of the bulb increases ∴ Hg level ↓.
Then the Hg heats up and expands. ∴ Hg level ↑.

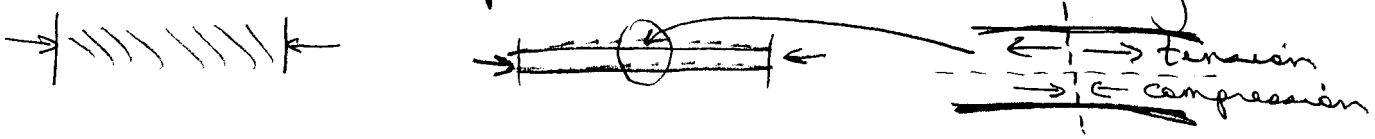
2. [Serway Chapter 19 Problem 18, pg 545]
A concrete walk is poured on a day when the temperature is 20 °C in such a way that the ends are unable to move.
   a. What is the stress in the cement on a hot day of 50 °C?
   b. Does the concrete fracture? Take Young's modulus for concrete to be 7.0×10^6 N/m^2 and the tensile strength to be 2×10^6 N/m^2.

$Y \frac{\Delta L}{L} = F/A$, $\frac{\Delta L}{L} = \alpha \Delta T = 12 \times 10^{-6} \times 30$
$= 0.36 \times 10^{-3}$

∴ F/A = stress $= 7 \times 10^6 \times 0.36 \times 10^{-3}$
$= 2.52 \times 10^3$ N/m^2 << tensile strength of 2×10^6 N/m^2

∴ Does not fracture

Note:
The load is compression but consider the tendency to buckle:



3. [Serway Chapter 19 Problem 20, pg 545]
The New River Gorge Bridge in West Virginia is a steel arch bridge 518 m in length. How much does its length change between temperature extremes of -20.0 °C and 35.0 °C?

$\Delta L = \alpha L \Delta T = 11 \times 10^{-6} \times 518 \times 55 = 0.313$ m.

4. [Serway Chapter 19 Problem 22, pg 546]
A steel rod undergoes a stretching force of 500 N. Its cross sectional area is 2.00 cm^2. Find the change in temperature that would elongate the rod by the same amount produced by the 500-N force. *(Hint: Refer to Tables 12.1 and 19.2.)*

$\frac{F}{A} = \frac{500\ N}{2\times10^{-4}\ m^2} = 2.5\times10^6\ N/m^2$

$Y = 20\times10^{10}\ N/m^2$

$\therefore \frac{\Delta l}{l} = \frac{F/A}{Y} = \frac{2.5\times10^6}{20\times10^{10}} = 1.25\times10^{-5}$

Since $\frac{\Delta l}{l} = \alpha\Delta T$, $\Delta T = \frac{\Delta l}{l\alpha} = \frac{1.25\times10^{-5}}{11\times10^{-6}} = 1.136^\circ C$

5. [Serway Chapter 19 Problem 42, pg 547]
At 25.0 m below the surface of the sea (density = 1025 kg/m^3), where the temperature is 5.00 °C, a diver exhales an air bubble having a volume of 1.00 cm^3. If the surface temperature of the sea is 20.0 °C, what is the volume of the bubble right before it breaks the surface?

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$P_1 = P_A + \rho g \times 25m.$

$V_1 = 1\ cm^3$

$T_1 = 5+273.15 = 278.15\ K$

$P_2 = P_A$

$V_2 = ?$

$T_2 = 20+273.15 = 293.15$

$\therefore V_2 = \frac{P_1V_1}{T_1}\cdot\frac{T_2}{P_2} = \left\{\frac{1.00\ cm^3 \times \left(101\times10^3\ Pa + 1025\ kg/m^3 \times 9.8\ m/s^2 \times 25\right)}{101\times10^3\ Pa}\right\} \times \frac{293.15}{278.15} = 2.62\ cm^3$

6. [Serway Chapter 19 Problem 45, pg 547]
The tire on a bicycle is filled with air to a gauge pressure of 550 kPa at 20 °C. What is the gauge pressure in the tire after a ride on a hot day when the tire air temperature is 40 °C? (Assume constant volume and a constant atmospheric pressure of 101 kPa.)

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$,

$P_1 = 550+101\ kPa = 651\ kPa$

$P_2 = ?$

$T_1 = 20+273.15 = 293.15\ K$

$T_2 = 40+273.15 = 313.15\ K$

$\therefore P_2 = P_1\frac{T_2}{T_1} = 651 \times \frac{313.15}{293.15} = 695.414$

$= 594.4\ kPa$ gauge