

Homework 22.0

Carefully review chapter 22 lecture slides and, if time allows, read textbook sections of Askeland 22.1 - 22.4 and give an honor statement confirming the reading

Homework 22.1

Calculate the increase in temperature for 100 g of samples of the following when 1000 J of heat is supplied to the following materials at 25°C: (a) Al; (b) Cu; (c) Al₂O₃. The specific heat (mass heat capacity) is 0.90, 0.38, and 0.84 J/(K•g), respectively

(a) For Al, specific heat (mass heat capacity) $C_{p_m} = 0.90 \text{ J}/(\text{K}\cdot\text{g})$

$$\Delta T = \dots = 11.1 \text{ K}$$

(b) For Cu, specific heat (mass heat capacity) $C_{p_m} = 0.38 \text{ J}/(\text{K}\cdot\text{g})$

$$\Delta T = \dots = 26.3 \text{ K}$$

(c) For Al₂O₃, specific heat (mass heat capacity) $C_{p_m} = 0.84 \text{ J}/(\text{K}\cdot\text{g})$

$$\Delta T = \dots = 11.9 \text{ K}$$

Homework 22.2

A 100 g aluminum sample is heated to 300°C and then quenched into 1500 cc water at 25°C. Calculate the water/Al equilibrium temperature after reaching the system's thermal equilibrium. Assume no heat loss from the system and specific heat for Al and H₂O is 0.90 and 4.18 J/(K•g), respectively.

Suppose the system equilibrium temperature is T ,

The heat loss for Al should equal to heat gain for water, i.e.,

$$Q_{Al} = -Q_{H_2O}$$

$$100 \text{ g} \times 0.90 \frac{\text{J}}{\text{K} \cdot \text{g}} \cdot (300 - T) \text{K} = 1500 \text{ g} \times 4.18 \frac{\text{J}}{\text{K} \cdot \text{g}} \cdot (T - 25) \text{K}$$

$$\dots = \dots$$

$$T = 28.9^\circ\text{C}$$

Homework 22.3

A 1 m long soda-lime glass rod is produced at 1325°C. Determine its length after cooling to 25°C. Specify the assumptions made. Knowing soda-lime glass CTE is $9 \times 10^{-6}/^{\circ}\text{C}$ at RT.

Assume constant CTE between 25 and 1325°C.

$$L = 1 \text{ m} (1 + \alpha \Delta T) = 1 \text{ m} \times [1 + (9 \times 10^{-6}/^{\circ}\text{C}) (1325^{\circ}\text{C} - 25^{\circ}\text{C})] = \mathbf{0.988 \text{ m}}$$

Homework 22.4

A thick nickel part is coated with thin SiC film to inhibit high temperature corrosion of Ni. If no residual stress at 25°C, please determine the stress developed in the SiC coating when the part is heated to 225°C. Knowing CTE for Ni and SiC is $13 \times 10^{-6}/^{\circ}\text{C}$ and $4.3 \times 10^{-6}/^{\circ}\text{C}$, respectively, and elastic modulus for SiC is 420 GPa.

Thermal stress is due to the difference in CTE between Ni and SiC:

$$\Delta\alpha = 13 \times 10^{-6} - 4.3 \times 10^{-6} = \dots = 8.7 \times 10^{-6} \frac{1}{^{\circ}\text{C}}$$

Thermal stress in SiC:

$$\sigma_{thermal} = E \Delta\alpha \Delta T = 420 \times 10^9 \times 8.7 \times 10^{-6} \times 200 = 7.31 \times 10^8 \text{ Pa}$$

Homework 22.5

Temperature for a 0.5 m long copper rod is maintained at 200°C at one end and 0°C at the other end. Knowing copper has a thermal conductivity of 400 W/(m·K),

(1) Please calculate the heat flow per unit area per unit time through the copper rod.

(2) If the copper rod has diameter of 1 cm, please calculate the total heat flow in 1 hour.

(1) Absolute value for heat flux through the copper rod:

$$q = \frac{160,000 \text{ W}}{1 \text{ m}^2} = 160,000 \frac{\text{J}}{\text{m}^2 \cdot \text{s}}$$

160 kJ per m² per s

(2) Total heat flow in 1 hour

$$Q = q \cdot A \cdot t = \dots = 4.52 \times 10^4 \text{ J} = 45.2 \text{ kJ}$$