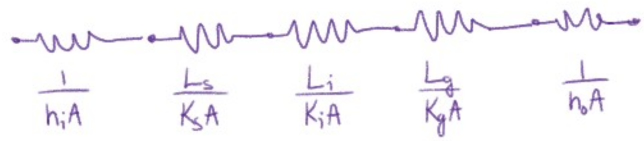
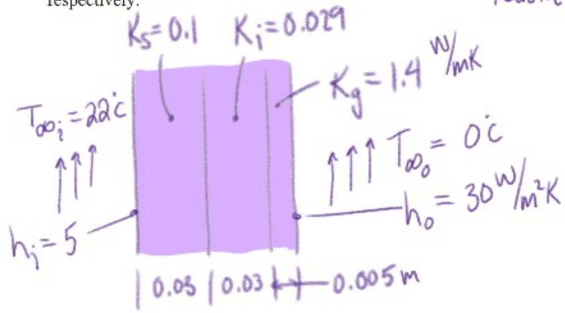
HW3

Tuesday, September 19, 2023   9:52 PM

Chapter3:
Problems: 4, 17, 34, 41 and 54

3.4 A dormitory at a large university, built 50 years ago, has exterior walls constructed of L_s = 30-mm-thick sheathing with a thermal conductivity of k_s = 0.1 W/m · K. To reduce heat losses in the winter, the university decides to encapsulate the entire dormitory by applying an L_i = 30-mm-thick layer of extruded insulation characterized by k_i = 0.029 W/m · K to the exterior of the original sheathing. The extruded insulation is, in turn, covered with an L_g = 5-mm-thick architectural glass with k_g = 1.4 W/m · K. Determine the heat flux through the original and retrofitted walls when the interior and exterior air temperatures are $T_{\infty,i}$ = 22°C and $T_{\infty,o}$ = 0°C, respectively. The inner and outer convection heat transfer coefficients are h_i = 5 W/m² · K and h_o = 30 W/m² · K, respectively.





Retrofit

$$q'' = \frac{\Delta T}{\Sigma R_{tot}} = \frac{q}{A} = \frac{T_{\infty o} - T_{\infty i}}{\frac{1}{A}\left(\frac{1}{h_i} + \frac{L_s}{K_s} + \frac{L_i}{K_i} + \frac{L_g}{K_g} + \frac{1}{h_o}\right)}$$

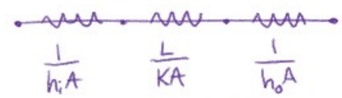
$$q/A \qquad q'' = \frac{22-0}{1/5 + 0.03/0.1 + 0.03/0.029 + 0.005/1.4 + 1/30} = 14.0 \text{ W/m}^2$$

Original

$$q'' = \frac{22-0}{1/5 + 0.03/0.1 + 1/30} = 41.25 \text{ W/m}^2$$

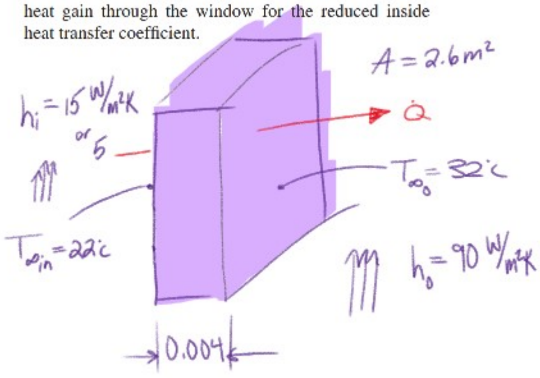
3.17 The t = 4-mm-thick glass windows of an automobile have a surface area of A = 2.6 m². The outside temperature is $T_{\infty,o}$ = 32°C while the passenger compartment is maintained at $T_{\infty,i}$ = 22°C. The convection heat transfer coefficient on the exterior window surface is h_o = 90 W/m² · K. Determine the heat gain through the windows when the interior convection heat transfer coefficient is h_i = 15 W/m² · K. By controlling the airflow in the passenger compartment the interior heat transfer coefficient can be reduced to h_i = 5 W/m² · K without sacrificing passenger comfort. Determine the heat gain through the window for the reduced inside heat transfer coefficient.

$$\dot{Q} = \frac{\Delta T}{R_{tot}}$$

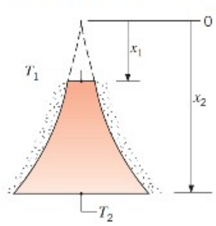


$$\dot{Q} = \frac{T_{\infty o} - T_{\infty i}}{\frac{1}{A}\left(\frac{1}{h_i} + \frac{L}{K} + \frac{1}{h_o}\right)}$$

$$= \frac{(32)-(22)}{(2.6)\left(\frac{1}{15} + \frac{0.004}{1.4} + \frac{1}{90}\right)} = 47.7 \text{ W/m}^2$$



3.34 A truncated solid cone is of circular cross section, and its diameter is related to the axial coordinate by an expression of the form $D = ax^{3/2}$, where $a = 2.0\ m^{-1/2}$.



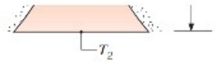
The sides are well insulated, while the top surface of

$$D = 2x^{3/2}$$

$$A = \frac{\pi D^2}{4} = \pi x^3$$

a) $$\dot{Q} = -KA\frac{dT}{dx} = -K\pi x^3 \frac{dT}{dx}$$

$$\frac{-\dot{Q}}{K\pi}\int_{x_1}^{x} x^{-3}\,dx = \int_{T_1}^{T} dT$$



The sides are well insulated, while the top surface of the cone at x_1 is maintained at T_1 and the bottom surface at x_2 is maintained at T_2.

(a) Obtain an expression for the temperature distribution $T(x)$.

(b) What is the rate of heat transfer across the cone if it is constructed of pure aluminum with $x_1 = 0.080$ m, $T_1 = 100°C$, $x_2 = 0.240$ m, and $T_2 = 20°C$?

$$-\frac{\dot{Q}}{K\pi}\int_{x_1}^{x} x^{-3}\,dx = \int_{T_1}^{T} dT$$

$$\frac{\dot{Q}}{K\pi}\,\frac{x^{-2}}{2}\Big|_{x_1}^{x} = T\Big|_{T_1}^{T}$$

$$\frac{\dot{Q}}{2\pi K}\left(\frac{1}{x^2}-\frac{1}{x_1^2}\right) = (T - T_1)$$

$$\boxed{T(x) = \frac{\dot{Q}}{2\pi K}\left(\frac{1}{x^2}-\frac{1}{x_1^2}\right) + T_1}$$

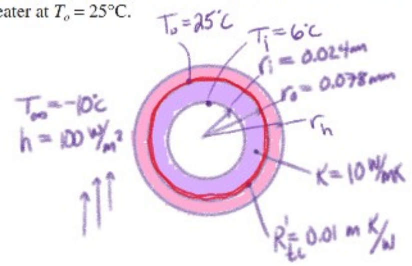
b) $$\dot{Q} = \frac{2\pi K(T_2 - T_1)}{\frac{1}{x_2^2} - \frac{1}{x_1^2}}$$

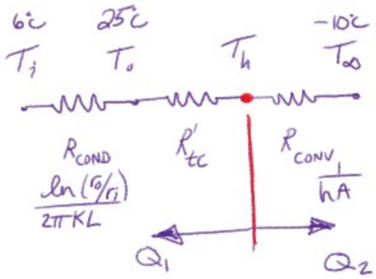
$$= \frac{2\pi(240)(20-100)}{\frac{1}{(0.24)^2} - \frac{1}{(0.08)^2}} = 868.6\text{ W}$$

Al @ 20 to 100 °C = 293–373 K

↳ $K \approx 240$ W/mK

3.41 A thin electrical heater is wrapped around the outer surface of a long cylindrical tube whose inner surface is maintained at a temperature of 6°C. The tube wall has inner and outer radii of 24 and 78 mm, respectively, and a thermal conductivity of 10 W/m · K. The thermal contact resistance between the heater and the outer surface of the tube (per unit length of the tube) is $R'_{t,c} = 0.01$ m · K/W. The outer surface of the heater is exposed to a fluid with $T_\infty = -10°C$ and a convection coefficient of $h = 100$ W/m² · K. Determine the heater power per unit length of tube required to maintain the heater at $T_o = 25°C$.





Why is no thickness given for heater?

$$\dot{Q} = \frac{2\pi KL(T_1 - T_2)}{\ln(r_2/r_1)}$$

$$\dot{Q} = \frac{\Delta T}{\Sigma R}$$

$$R = \frac{\ln(r_2/r_1)}{2\pi KL}$$

$$Q_{tot} = Q_1 + Q_2 = \frac{(T_o - T_i)}{R_{COND} + R'_{tc}} + \frac{(T_o - T_\infty)}{R_{CONV}}$$

$$Q_{tot} = \frac{(25)-(6)}{\frac{\ln\left(\frac{0.078}{0.024}\right)}{2\pi(10)\cancel{L}} + 0.01} + \frac{(25)-(-10)}{\frac{1}{(100)2\pi(r_?)\cancel{L}}}$$

?

THIS IS PER UNIT LENGTH SO "$\cancel{L}$" IS TAKEN OUT OF EQUATIONS

$\dot{Q}_{tot} =$

3.54 A spherical tank for storing liquid oxygen is to be made from stainless steel of 0.75-m outer diameter and 6-mm wall thickness. The boiling point and latent heat of vaporization of liquid oxygen are 90 K and 213 kJ/kg, respectively. The tank is to be installed in a large compartment whose temperature is to be maintained at 240 K. Design a thermal insulation system that will maintain oxygen losses due to boiling below 1 kg/day.