22 November 2021

CHE 260 – Thermodynamics and Heat Transfer

Quiz 2 – 2021

You have 60 minutes to do the following three problems. You may use the aid sheet provided and any type of non-communicating calculator.

1) A rectangular forced air heating duct is suspended from the ceiling of a basement whose air and walls are at a temperature of $T_\infty = T_{sur}$ = 5°C. The duct is 15 m long, and its cross section is 350 mm x 200 mm.
   a) For an uninsulated duct whose average surface temperature is 50°C, estimate the rate of heat loss from the duct. The surface emissivity and convection coefficient are ε=0.5 and h=4 W/m^2 K, respectively.
   b) If heated air enters the duct at 58°C and a velocity of 4 m/s and the heat loss corresponds to the result of part (a), what is the outlet temperature? The density and specific heat of the air may be assumed to be ρ =1.10 kg/m^3 and c_p= 1008 J/kg K, respectively.

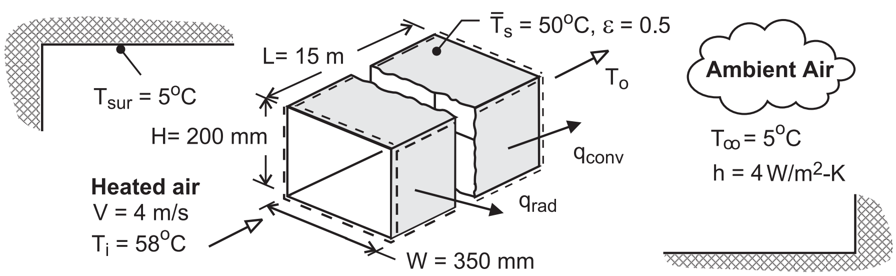

Figure 1

(30 Marks)

2) A 2-mm-diameter electrical wire is insulated by a 2-mm-thick rubberized sheath (k = 0.13 W/m K), and the wire/sheath interface is characterized by a thermal contact resistance (for a unit interface area) of R_c = 3 x 10^{-4} m^2 K/W. The convection heat transfer coefficient at the outer surface of the sheath is 10 W/m^{2}K, and the temperature of the ambient air is 20°C. If the temperature of the insulation may not exceed 50°C, what is the maximum allowable electrical power that may be dissipated per unit length of the conductor? What is the temperature at the wire surface?

(35 Marks)

3) Both ends of a U-shaped, 0.6-cm diameter, copper rod (k=396 W/mK) are welded to a vertical wall as shown in the accompanying sketch. The temperature of the wall is maintained at 93°C. The total length of the rod is 0.6 m, and it is exposed to air at 38°C. The convection heat transfer coefficient on the surface of the rod is h=34 W/m^{2}K.
   a) Calculate the temperature of the midpoint of the rod.
   b) What will the rate of heat transfer from the rod be?

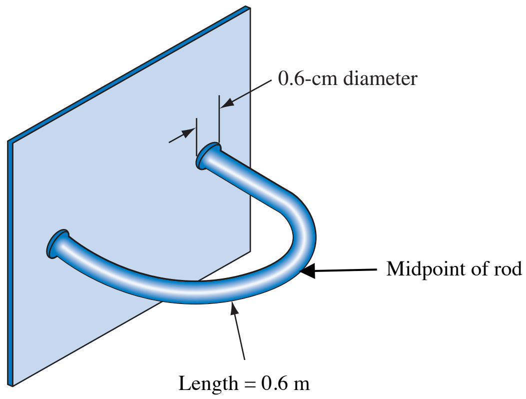

Figure 2

(35 Marks)

Aid sheet

$\dot{m} = \rho A \boldsymbol{V}$

$$\dot{Q}_{conduction} = -kA\frac{dT}{dx}$$

$$\dot{Q}_{convection} = hA(T_s - T_\infty)$$

$$\dot{Q}_{radiation} = \varepsilon\sigma A(T_s^4 - T_{surr}^4)$$

$\sigma = 5.67 \times 10^{-8}$ W/m^{2}K^4

$$\dot{Q} = \frac{T_2 - T_1}{R_{total}}$$

$$R_{convection} = \frac{1}{hA}$$

$$R_{wall} = \frac{L}{kA}$$

$$R_{radiation} = \frac{1}{h_{rad}A}$$

$$h_{rad} = \varepsilon\sigma(T_s^2 + T_{surr}^2)(T_s + T_{surr})$$

$$R_{cylinder} = \frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi Lk}$$

$$R_{sphere} = \frac{r_2 - r_1}{4\pi k r_1 r_2}$$

$$R_c = \frac{\Delta T_{interface}}{\dot{Q}/A}$$

$$a = \sqrt{\frac{hP}{kA_c}}$$

For infinitely long fin

$$\frac{T(x) - T_\infty}{T_b - T_\infty} = \exp(-ax)$$

$$\dot{Q}_{fin,long} = \sqrt{hPkA_c}(T_b - T_\infty)$$

$$\eta_{fin,long} = \frac{1}{aL}$$

For insulated tip fin

$$\frac{T(x) - T_\infty}{T_b - T_\infty} = \frac{\cosh\,[a(L-x)]}{\cosh\,(aL)}$$

$$\dot{Q}_{fin,ins} = \sqrt{hPkA_c}(T_b - T_\infty)\tanh(aL)$$

$$\eta_{fin,ins} = \frac{\tanh\,(aL)}{aL}$$