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MAE 3440: HW #9

Due March 25, 2020

1. Water enters a tube at 27°C with a flow rate of 450 kg/h. The heat transfer from the tube wall to the fluid is given as q_s' (W/m)= ax, where the coefficient a is 20 W/m^2 and x (m) is the axial distance from the tube entrance.

   (a) Beginning with a properly defined differential control volume in the tube, derive an expression for the temperature distribution $T_m(x)$ of the water.

   (b) What is the mean outlet temperature of the water for a heated section of 30 m long?

   (c) Sketch the mean fluid temperature, $T_m(x)$, and the tube wall temperature, $T_s(x)$, as a function of distance along the tube for fully developed and developing flow conditions.

   (d) What value of a uniform wall heat flux, q_s'' (instead of $q_s' = ax$), would provide the same fluid outlet temperature as that determined in part (b)? For this type of heating, repeat part (c).

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2. SAE 30 oil ($k = 0.15$ W/m-K) is heated by flowing through a circular tube of diameter $D = 50$ mm and length $L = 25$ m and whose surface is maintained at 150°C. If the flow rate and inlet temperature of the oil are 0.5 kg/s and 20°C, what is the outlet temperature $T_{m,o}$? What is the total heat transfer rate q for the tube?

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3. To cool a summer home without using a vapor-compression refrigeration cycle, air is routed through a plastic pipe ($k = 0.15$ W/m-K, $D_i = 0.15$ m, $D_o = 0.17$ m) that is submerged in an adjoining body of water. The water temperature is nominally at $T_\infty = 17°$C, and a convection coefficient of $h_o = 1500$ W/m^2-K is maintained at the outer surface of the pipe. If air from the home enters the pipe at a temperature of $T_{m,i} = 29°$C and a volumetric flow rate of $V_i = 0.025$ m^3/s, what pipe length is needed to provide a discharge temperature of $T_{m,o} = 21°$C?

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4. Air at 4×10^{-4} kg/s and 27°C enters a triangular duct that is 20 mm on a side and 2 m long. The duct surface is maintained at 100°C. Assuming fully developed flow throughout the duct, determine the air outlet temperature.