UTPA THE UNIVERSITY OF TEXAS-PAN AMERICAN™ MECHANICAL ENGINEERING DEPARTMENT

Assignment: _____

Name: _____

Date: ____/____/_____

HW#6 → 8.6 (5e), 8.13 (5e), 8.23a (5e), 8.32 (5e), 8.40 (5e), 8.62 (5e)

Hydrodynamic Considerations

8.5 For fully developed laminar flow through a parallel-plate channel, the x-momentum equation has the form $\mu\left(\frac{d^2u}{dy^2}\right) = \frac{dp}{dx} = \text{constant}$

The purpose of this problem is to develop expressions for the velocity distribution and pressure gradient analogous to those for the circular tube in Section 8.1.

(a) Show that the velocity profile, $u(y)$, is parabolic and of the form

$$u(y) = \frac{3}{2}u_m\left[1 - \frac{y^2}{(a/2)^2}\right]$$

where u_m is the mean velocity

$$u_m = -\frac{a^2}{12\mu}\left(\frac{dp}{dx}\right)$$

and $-dp/dx = \Delta p/L$, where Δp is the pressure drop across the channel of length L.

(b) Write an expression defining the friction factor, f, using the hydraulic diameter D_h as the characteristic length. What is the hydraulic diameter for the parallel-plate channel?

(c) The friction factor is estimated from the expression $f = C/Re_{D_h}$, where C depends upon the flow cross section, as shown in Table 8.1. What is the coefficient C for the parallel-plate channel?

(d) Air flow in a parallel-plate channel with a separation of 5 mm and a length of 200 mm experiences a pressure drop of $\Delta p = 3.75\ \text{N/m}^2$. Calculate the mean velocity and the Reynolds number for air at atmospheric pressure and 300 K. Is the assumption of fully developed flow reasonable for this application? If not, what is the effect on the estimate for u_m?

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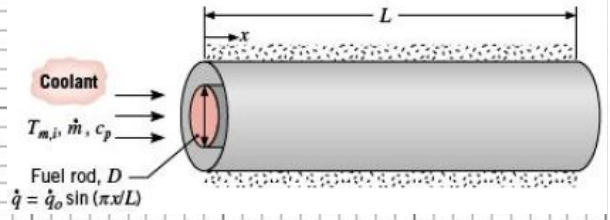
Thermal Entry Length and Energy Balance Considerations

8.13 Consider a cylindrical nuclear fuel rod of length L and diameter D that is encased in a concentric tube. Pressurized water flows through the annular region between the rod and the tube at a rate $\dot{m}$, and the outer surface of the tube is well insulated. Heat generation occurs within the fuel rod, and the volumetric generation rate is known to vary sinusoidally with distance along the rod. That is, $\dot{q}(x) = \dot{q}_o \sin(\pi x/L)$, where $\dot{q}_o$ (W/m^3) is a constant. A uniform convection coefficient h may be assumed to exist between the surface of the rod and the water.

(a) Obtain expressions for the local heat flux $q''(x)$ and the total heat transfer q from the fuel rod to the water.

(b) Obtain an expression for the variation of the mean temperature $T_m(x)$ of the water with distance x along the tube.

(c) Obtain an expression for the variation of the rod surface temperature $T_s(x)$ with distance x along the tube. Develop an expression for the x location at which this temperature is maximized.



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Heat Transfer Correlations: Circular Tubes

8.22 Engine oil is heated by flowing through a circular tube of diameter $D = 50\,\text{mm}$ and length $L = 25\,\text{m}$ and whose surface is maintained at 150°C.

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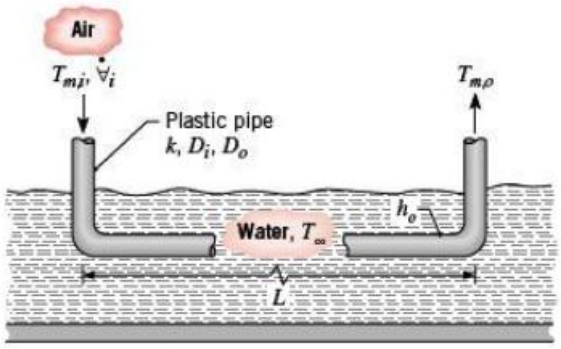
8.31 To cool a summer home without using a vapor-compression refrigeration cycle, air is routed through a plastic pipe ($k = 0.15\ \text{W/m} \cdot \text{K}$, $D_i = 0.15\ \text{m}$, $D_o = 0.17\ \text{m}$) that is submerged in an adjoining body of water. The water temperature is nominally at $T_\infty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



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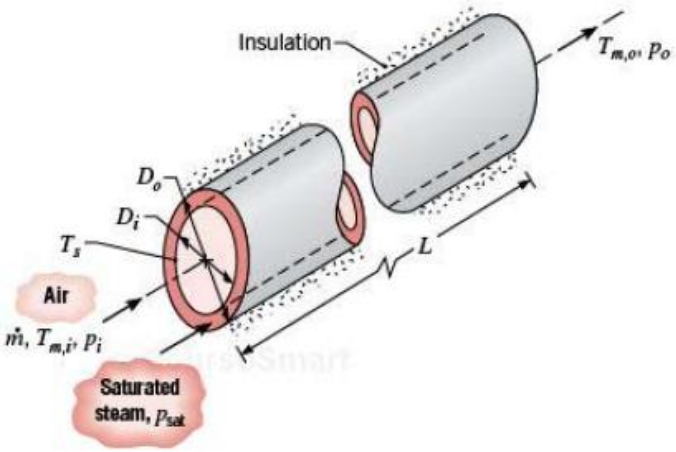
8.38 An air heater for an industrial application consists of an insulated, concentric tube annulus, for which air flows through a thin-walled inner tube. Saturated steam flows through the outer annulus, and condensation of the steam maintains a uniform temperature T_s on the tube surface.

Consider conditions for which air enters a 50-mm-diameter tube at a pressure of 5 atm, a temperature of $T_{m,i} = 17°C$, and a flow rate of $\dot{m} = 0.03$ kg/s, while saturated steam at 2.455 bars condenses on the outer surface of the tube. If the length of the annulus is $L = 5$ m, what are the outlet temperature $T_{m,o}$ and pressure p_o of the air? What is the mass rate at which condensate leaves the annulus?



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8.60 A thin-walled tube with a diameter of 6 mm and length of 20 m is used to carry exhaust gas from a smoke stack to the laboratory in a nearby building for analysis. The gas enters the tube at 200°C and with a mass flow rate of 0.003 kg/s. Autumn winds at a temperature of 15°C blow directly across the tube at a velocity of 5 m/s. Assume the thermophysical properties of the exhaust gas are those of air.

(a) Estimate the average heat transfer coefficient for the exhaust gas flowing inside the tube.

(b) Estimate the heat transfer coefficient for the air flowing across the outside of the tube.

(c) Estimate the overall heat transfer coefficient U and the temperature of the exhaust gas when it reaches the laboratory.