3 Laminar Internal Flows - l14 to l20

1. Show that the axial velocity profle in a fully developed flow in an annulus is given by

$$\frac{u}{\overline{u}} = \frac{2}{A}\left[1 - (\frac{r}{r_o})^2 + B \ln(\frac{r}{r_o})\right]$$

whrer $B = ((r^*)^2 - 1)/\ln r^*$, A = 1 + $(r^*)^2$ - B and $r^* = r_i/r_o$. Hence show that the maximum velocity will occur at $(r_m^*)^2 = 0.5B$ and $f\,Re = 16\,(1-(r^*)^2)/A$

2. Determine Fully-Developed Pressure drop per unit length (N / m^3) of the following ducts. In each case $Re_{D_{th}} = 500$. Take $\rho = 1000$ kg / m^3, $\mu = 8 \times 10^{-4}$ kg/m-s. (Hint: Wherever possible, use solns given in the class. Else, evaluate from series solutions.)

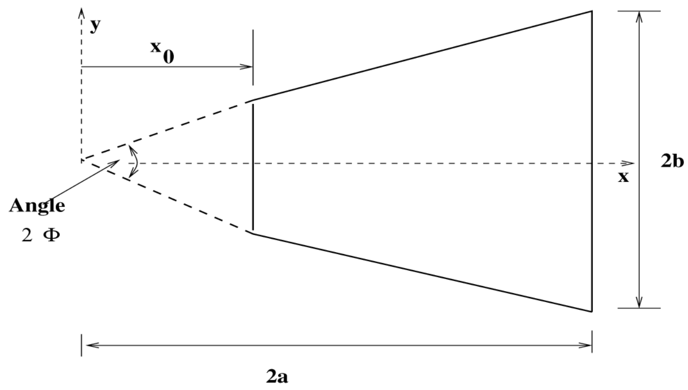

Figure 5: Duct of Rhombic cross-section

(a) Rectangular duct: (b = 1 cm, a = 4 cm)

(b) Annulus (r_i = 1 cm, r_o = 2.2 cm)

(c) Annular Sector Duct (r_i = 1 cm, r_o = 2.2 cm, θ_0 = 60 degrees)

(d) Equilateral Triangle: (a = 2 cm)

(e) Equilateral Triangle with Rounded Radius: (a = 2 cm, r / a = 0.1)

3. Using Kantarovich method, derive analytic expression for $(f\ Re)_{D_h} = F\,(x_0, b/a, \Phi)$ for the duct shown in figure 5.

4. Write a general computer program for predicting $(f\,Re)_{D_h}$ and Nu_{D_h} in ducts of arbitrary cross section using the method described in lectures 16 and 18.

5. Using the computer program developed in the previous problem, calculate $(f\ Re)_{D_h}$ and Nu_{D_h} for the duct shown in figure 5.

6. Consider FD flow and heat transfer between two parallel plates. Include effect of viscous dissipation. Constant wall heat flux q_w is applied at both surfaces. Show that $(f\ Re)_{D_h} = 24$ and

$$Nu_{D_h} = \frac{140}{17 + 108\,Br} \qquad \text{where} \quad Br \equiv \frac{\mu\,\overline{u}^2}{q_w\,D_h}$$

7. A heat exchanger is to be designed to cool lubricating oil ($\rho = 785 kg/m^3$, k = 0.12 W / m-K, $\nu = 0.0247\, m^2/hr$ and Cp = 2 kJ / kg - K) from 60 C to 40 C. The oil velocity is 0.75 m / s and the tube surface temperature is 27 C. Calculate the required tube (dia 6 mm) length.

8. Water at 35 C enters a tube (2.5 cm ID) with a velocity 1.25 m/s. The tube wall temperature is constant at 95 C. Calculate the tube-length necessary to raise water temperature by 45 C. Also calculate pumping power. Use a) Dittus-Boelter correlation b) Expression for Nu derived from universal law.

9. Liquid mercury flows through a long tube (2.5 cm dia) with a velocity 1 m/s. Calcualte h for constant wall heat flux (ρ = 13264 kg / m^3, Cp = 0.1365 kJ/kg-K, k = 11.5 W/m-K, $\mu = 9 \times 10^{-4}$ N-s/m^2

10. Consider flow of air (Pr = 0.7) between two parallel plates 1 m wide and 2.5 cm apart. The top plate receives heat flux q_{top} = 650 W/m^2 whereas the bottom plate is insulated. If Re_{D_h} = 500 and air enters the passage with $T_{in} = 32^0$C, calculate and plot variations of $T_{w,top}$ and $T_{w,bottom}$ till $x^+ = 0.1$ (Hint: Use results of slide 4, l19).

11. Consider flow of air in a passage formed by two parallel plates W = 1 m wide, L = 1.4 m long and separated by distance 3 mm. Heat flux at both the plates varies as

$$q_w = 950 + 2500 \sin\left(\frac{\pi\, x}{L}\right) \qquad \left(\frac{W}{m^2}\right)$$

The air inlet temperature is 50^0C and system pressure is 7 bar. If the air mass flux is 250 kg/m^2-hr, calculate and plot variation of T_b, T_w and Nu_x with axial distance x (m). Evaluate properties at 100^0C.