MEEN 644- Numerical Heat Transfer and Fluid Flow
Spring 2018

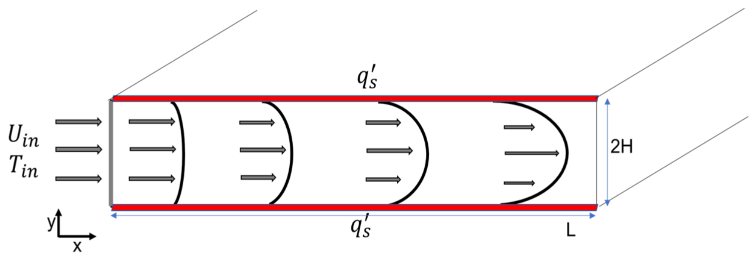
Homework 5

Name____

Instructor: N. K. Anand

Due Date: April 15, 2019

Maximum Points: 100



$\rho = 988.3$ kg/m3
$k = 0.609$ W / m · K
$\mu = 1.002\text{x}10^{-3}$ N · s/m^3
$C_p = 4.183\ kJ/kgK$

Consider an incompressible laminar flow between two infinite parallel plates. Flow enters at constant velocity U_{in} and constant heat flux q'_s of 500 W/m^2 is applied to each wall. Height of channel 2H and length of channel L are 0.02 m and 2.0 m, respectively. Constant velocity U_{in} and temperature T_{in} of 25 C is set as inlet condition. Reynold number is defined as $\text{Re} = \rho U_{in}(2H)/\mu$.

(1) Specify your boundary condition for U, V, P, and T (10 Points).

(2) Write a finite volume method code to predict velocity, pressure and temperature profiles for Re = 100. Employ Power Law scheme to represent a solution to 1-D convection diffusion equation. Use the SIMPLE algorithm to link velocity and pressure fields. Use 10 uniformly sized CVs in X-direction and 5 uniformly sized CVs in Y- direction (10 X 5). Declare convergence at R_u, R_v R_p and $R_T < 10^{-6}$ (50 Points).

(3) Run your program with 10x5 grid and tabulate U, $(P-P_0)$ and T fields to check for symmetry. P_0 is pressure at outlet. (10 Points).

(4) Use 180 X 54 grid to solve for U, V, P, and T (30 Points).
(a) Plot U/U_{in} along the centerline of the channel (as function of x).
(b) Plot U, V, and T profile at x = 0.8 m as function of y.
(c) Plot Nusselt number as function of stream-wise distance X from the channel entrance.

Definition of Residuals:

$$\mathrm{R_u} = \frac{\sum_{node}\left|a_p u_p - \sum a_{nb} u_{nb} - b_u - A_U(P_{i,j} - P_{i+1,j})\right|}{\sum_{node}\left|a_p u_p\right|}$$

$$\mathrm{R_v} = \frac{\sum_{node}\left|a_p v_p - \sum a_{nb} v_{nb} - b_v - A_V(P_{i,j} - P_{i,j+1})\right|}{\sum_{node}\left|a_p V_p\right|}$$

$$\mathrm{R_p} = \frac{\sum_{node}\left|(\rho_w u_w - \rho_e u_e)dy + (\rho_s v_s - \rho_n v_n)dx\ \right|}{\rho u_{ref} L_{ref}}$$

$$\mathrm{R}_T = \frac{\sum_{node}\left|a_p T_p - \sum a_{nb} T_{nb} - b_T\right|}{\sum_{node}\left|a_p T_p\right|}$$

Reference

1. Patankar, S. V., and D. Brian Spalding. "A calculation procedure for heat, mass and momentum transfer in three-dimensional parabolic flows. *"International Journal of Heat and Mass Transfer* **15.10** (1972): 1787-1806.

2. Shah, R. K., and A. L. London. "Laminar Flow Forced Convection in Ducts: a Source Book for Compact Heat Exchanger Analytical Data, Supplement. 1." (1978).