MEEN 644 – Numerical Heat Transfer and Fluid Flow
Spring 2019
Homework # 4

Name ______________________________________

Instructor: N. K. Anand

Due Date: March 21, 2019 Maximum points: 100

A viscous fluid (Water) is trapped in a square 2-D cavity of dimension 0.1m by 0.1m. Both top and bottom walls are pulled to the right at a uniform velocity.

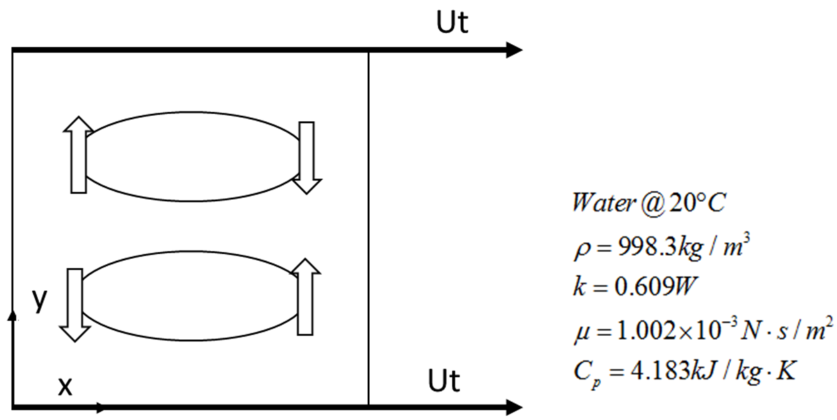

Figure 1. HW#4 Lid-Driven Cavity Problem

Write a finite volume-based computer program to predict the 2-D steady laminar flow field for Re = 400. Solve the velocity and pressure fields by linking them through the SIMPLE algorithm in a staggered grid. Represent solution to the one-dimensional convection-diffusion problem using the power law scheme.

1) In order to verify your code for symmetry, make calculations using 5 x 5 uniformly sized control volumes (CVs). Declare convergence when (R_U & $R_V < 10^{-6}$) and ($R_P < 10^{-5}$). Print your velocity and pressure fields up to 5 decimal places. (E.g. 9.12345e-6) **(60 points)**
2) With left and right plates pulled upwards at constant velocity at Re = 400, calculate velocity and pressure fields using 8x8, 16x16, 32x32, 64x64, and 128x128 CVs.
   a) Plot the centerline U and V velocities for each case (For centerline U, plot @ x=0.1m while for centerline V, plot @y = 0.1m). **(20 Points)**
   b) Compare your solutions of 128x128 CV case with the benchmark solution of Roy et al. (2015) on Table 4 and Table 5. (**20 Points)**

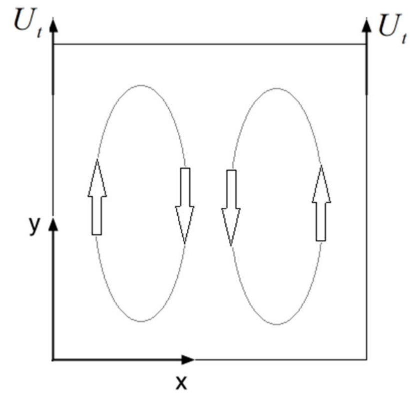

Figure 2 Problem (1), Checking for symmetry

Definition of Residuals:

$$R_U = \frac{\sum_{node}\left|a_e u_e - \sum a_{nb}u_{nb} - b_u - A_e\left(P_P - P_E\right)\right|}{\sum_{node}\left|a_e u_e\right|}$$

$$R_V = \frac{\sum_{node}\left|a_n v_n - \sum a_{nb}v_{nb} - b_v - A_n\left(P_P - P_N\right)\right|}{\sum_{node}\left|a_n v_n\right|}$$

$$R_P = \frac{\sum_{node}\left|\left(\rho_w u_w - \rho_e u_e\right)dy + \left(\rho_s u_s - \rho_n u_n\right)dx\right|}{\rho u_{ref} L_{ref}}$$

$$R_T = \frac{\sum_{node}\left|a_P T_P - \sum a_{nb}T_{nb} - b_T\right|}{\sum_{node}\left|a_P T_P\right|}$$

Notes:

i. For this homework, you do not need to calculate the temperature residual, since you will not solve energy equation.

ii. For Reynolds number and calculation for R_P, use cavity height as characteristic length L_{ref} and top velocity U_t as reference velocity u_{ref}.

iii. For the second part, nondimensionalize centerline velocities by dividing your result by u_{ref}.

Reference

Pratanu Roy, N. K. Anand, Diego Donzis, A Parallel Multigrid Finite-Volume Solver on Collocated Grid for Incompressible Navier-Stokes Equations, *Numerical Heat Transfer, Par B: Fundamentals,* **67(5)**, 2015