MME 9710a Assignment # 5

Date Given: November 27, 2015 Date Due: December 7, 2015

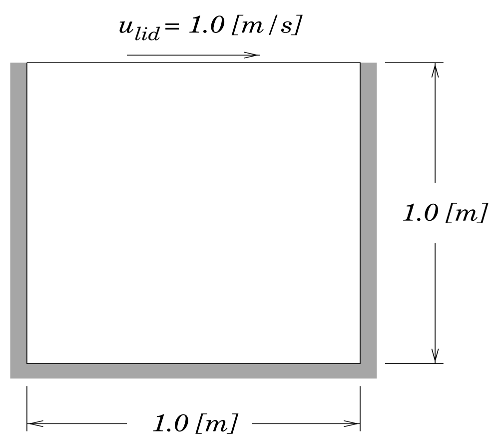
This assignment is intended to give you experience using a two–dimensional finite–volume CFD code. The source code required for this assignment is supplied to you. The source code is available in the Resources section of the course website.

The following code modifications are necessary before the assignment can be completed:

- Complete the subroutine *hoconv.f* so that CDS and QUICK can be used for modelling advection. UDS has been implemented implicitly, so the task is to compute the deferred corrections `DCCE(I,J), DCCN(I,J)` and then include them appropriately in the energy and momentum equations.
- Modify the subroutines *srcu.f* and *srcv.f* to add the buoyancy force in the u– and v–momentum equations. Use the Boussinesq approximation in your implementation. Assume that the gravity vector points down at an angle θ from vertical. Show your implementation details.

Problems

1. Laminar flow in a lid–driven cavity. The model geometry is given in the figure below, which shows the orientation and the dimensions. Start with 30×30



equal–sized control–volumes to model the geometry, and refine the grid until you achieve convergence to better than 2%. Impose the appropriate boundary conditions on the edges of the computational domain. For this case, it is essential to extrapolate the pressure to all walls. To fix the pressure level, set the pressure to zero in the (approximate) center of the domain.

The fluid properties are ρ=1 [kg/m^3], C_p=1 [$J/kg \cdot K$], k= 1 [$W/m \cdot K$], and μ= 0.001 [$kg/m \cdot s$], yielding a Reynolds number $Re = U_{lid}L/\mu$= 1000. Compute solutions using the UDS and CDS schemes. Plot the velocity vectors and pressure contours and discuss the resulting flow field, i.e. recirculation zones, how pressure alters velocity, etc.. Compare your results from the two schemes to those of Ghia *et al.* (1982).

2. Natural convection in a horizontal enclosure heated from below. Consider an enclosure has a width W=0.07 $[m]$ and height H=0.014 $[m]$ (aspect ratio W/H= 5). The lower wall is maintained at T_H= 360 $[K]$ and the upper wall is maintained at T_C= 300 $[K]$). The short end–walls of the enclosure are adiabatic. The fluid inside the enclosure is air with properties: ρ=1.1614 $[kg/m^3]$, C_p=1007 $[J/kg{\cdot}K]$, k= 0.0263 $[W/m \cdot K]$, μ= 1.846 $\times 10^{-5}$ $[kg/m \cdot s]$, β= 0.00333 $[K^{-1}]$. Model the enclosure using 90 $\times$ 18 equal–sized control–volumes. Set the appropriate boundary conditions for T, P, U, V on all of the walls and set the pressure level to zero at the (approximate) center of the enclosure.

   Solve the problem to steady state using the QUICK scheme for convection and plot the velocity vectors and isotherms. Assume a time–step size of Δt= 0.5 $[s]$ and do one internal iteration per time step. Calculate the non–dimensional heat flow across the cavity using:

$$Nu = \frac{q_{tot}\ H}{A_{wall}\ \Delta T\ k}$$

   and plot your result as a function of angle, where $\theta = 0$, 10, 20 and 30 degrees, as measured from the horizontal. Prove that your solution is converged by computing the heat in at the bottom wall to the heat out at the top wall. Briefly discuss the flow and temperature fields.

3. Natural convection in a vertical channel. Consider two vertical plates of height L and separation S. The plates are maintaned at a constant temperature of 40 $[^oC]$ and the ambient supply air temperature is 20 $[^oC]$. The properties of air are the same as those used for problem 2. Use a 40 $\times$ 40 grid and impose appropriate boundary conditions on T, P, U, V on the walls and at the inlet and outlet of the channel formed by the heated plates. Use the QUICK scheme for convection.

   Solve the problem to steady–state for $L = 0.1$ $[m]$ and S= 0.005, 0.01 and 0.015 $[m]$. Plot sample results of the temperature, velocity and pressure fields. Report your results for overall heat transfer on a plot of $\overline{Nu}_S$ verses Ra_S, where:

$$\overline{Nu}_S = \left(\frac{q/A}{T_s - T_\infty}\right)\frac{S}{k}, \qquad Ra_S = \frac{g\beta(T_s - T_\infty)S^3}{\alpha\nu}$$

   Compare your results to a textbook correlation (Eg. Incropera & DeWitt). Briefly discuss your results.