DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

ME704: Computational Methods in Thermal & Fluid Engineering **Autumn 2023**

Assignment # 6: FDM-based Solution for 1D & 2D Convection Instructor: Prof. Atul Sharma

Date Posted: 12th Oct. (Thursday) **Due Date: 20th Oct. (Friday, Midnight 12)**

VIVA on: 25th October, Wednesday, 04:30-06:30 PM, F-24, Mech. Engg. Dept.

ONLINE SUBMISSION THROUGH MOODLE ONLY (No late submission allowed): Submit **separate** files for the (a) filled-in answer sheet (this doc file—converted into a pdf file **rollno.pdf**), and (b) all the computer programs (name of the files should be **rollno-p1.m** and **rollno-p2.m**).

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1. **Steady State formulation-based 1-D Heat Convection:** Consider one-dimensional, steady-state convection in a domain of length L=1. The fluid has a density ρ =1, diffusion coefficient Γ =0.02 and a velocity of u=1. The value of convected variable is φ =0 at x=0 and φ =1 at x=1. Develop a program (**rollno-p1.m**) having an option to use FOU or CD scheme to obtain φ at various interior grid points. Compute the φ distribution for a grid size of (a) 11 × 11 grids and (b) 41 × 41 grids for both the convection scheme. Considering the analytical solution, presented in the lecture slides, draw an overlap plot for both the schemes as well as analytical solution for φ as a function of x. Note: You have to use an underrelaxation factor to obtain the result for the CD scheme on 11 × 11 grid size.

2. **Explicit Method-based Solution of 2D unsteady state heat convection:** Consider a 2D Cartesian computational x-y domain of non-dimensional size ***L=6 unit*** and ***H=1 unit***, for heat convection with a prescribed velocity field. This corresponds to a slug flow (***u=1, v=0***) of a fluid in a channel; subjected to a non-dimensional temperature of ***θ=1*** at the inlet and ***θ=0*** at the walls. At the outlet, fully developed Neumann BC is used. The initial condition for the non-dimensional temperature of the fluid is ***θ=0***.

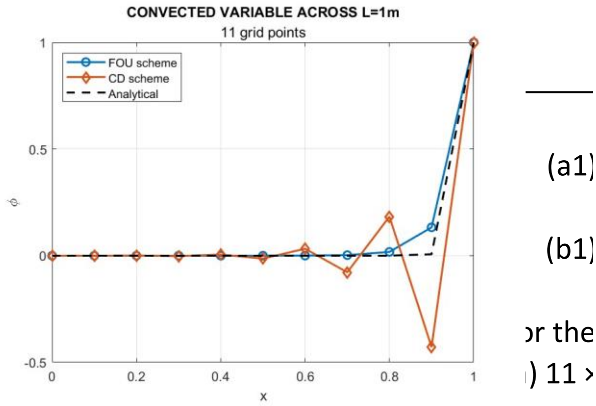
   Using the non-dimensional variables, develop a computer program "**rollno-p2.m**" for the above problem, run the code for two different advection schemes: (a) FOU and (b) CD; at *Re=10* and *Pr=1 (you can take any value of thermo-physical properties to obtain the given Re and Pr)*. Take the maximum number of grid points in x-and y-direction as *imax=42* and *jmax=22,* respectively; and the steady state convergence criteria as 0.0001. Report the results as

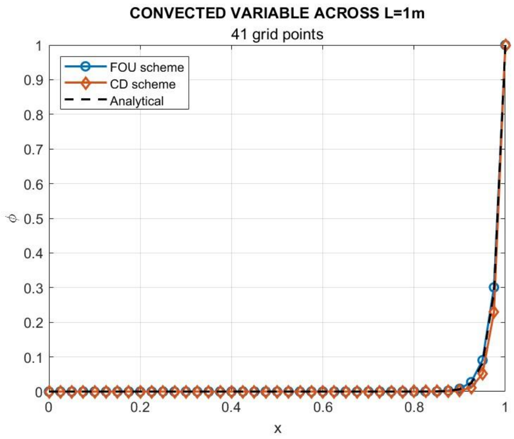
   i. Plot and discuss the steady state temperature contours for the different advection schemes (2 figures).

   ii. Plot and discuss the temperature profile, ***θ (Y)***, at different axial locations (***X=x/H=1, 2, 3* and *5***), for the different advection schemes (2 figures).

Answer Sheet

Problem # 1: Steady State formulation-based 1-D Heat Convection: draw an overlap plot for both the schemes as well as analytical solution for φ as a function of x (2 figures).





(a1)

(b1)

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Discussion on the Fig. 6.1: Write your answer, limited inside this text box only

we can see unphysical oscillations in CD scheme for Pe > 2 and while applying gauss sidel method, we have to use and underrelaxation factor in order to make sure solution converges (non diagonally dominant matrix for CD scheme). We implemented steady state solution and we see at higher grid refining, CD solution is accurate than FOU scheme solution.

Problem # 2: 2. Explicit Method-based Solution of 2D unsteady state heat convection:

a) Plot and discuss the steady state temperature contours for the different advection schemes (2 figures).

b) Plot and discuss the temperature profile, ***θ (Y)***, at different axial locations (***X=x/H=1, 2, 3* and *5***), for the different advection schemes (2 figures).

(a1)

(b1)