EX/PG/ChE/T/128A/2017

M. E. CHEMICAL ENGINEERING FIRST YEAR SECOND SEMESTER-2017

COMPUTATIONAL FLUID DYNAMICS Time: three hour Full marks: 100

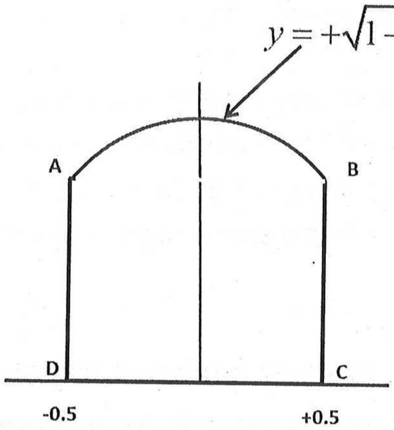
Answer any four questions
Assume any missing data
All questions carry equal marks
Symbols have usual significance

1. A plane wall 60 cm thick has left surface temperatures is 500 K and right surface temperature is 300 K. The volumetric heat generation rate in the wall is 3000 W/m^3. Use finite volume method to calculate temperatures at 15 cm, 30 cm, and 45 cm distances from the left surface. Take four cells of equal length for formulation. Compare the results with analytical solution. Data : k = 0.5 W/m.K and density = 1000 kg/m^3.

2. Consider a plane wall of thickness 40 cm whose left surface is at 700 K and right surface is at 900 K. The thermal conductivity of the material is 1.0 W/m.K. Find mid-plane temperature of the wall applying Finite element method. Compare the result with analytical solution.

3. In a 1.0 m long pressure tube a compressible fluid is enclosed at a pressure of 20 bar. Suddenly one end of the tube is opened to atmosphere causing pressure and velocity transients in the tube. Develop an algorithm based on finite difference method and pressure-velocity coupling technique to predict pressures and velocities at different nodes in the tube as a function of time. For numerical formulation take five cells of equal length in the tube.

4. Draw grid lines on the associated 2D figure by taking 3 X 3 = 9 cells. Show how transformation between physical and computational plane is done. Discuss advantages and disadvantages of solving field equations in physical plane and computational plane.



5. A property ϕ is transported by means of convection and diffusion through one dimensional domain as shown in the following figure.

The governing equations are:

$$\frac{d}{dx}(\rho u \phi) = \frac{d}{dx}\left(\Gamma \frac{d\phi}{dx}\right)$$

And

$$\frac{d(\rho u)}{dx} = 0$$

Use finite volume central difference scheme and three equidistant internal nodes to find out distribution of ϕ and compare the computational results with analytical solution given as,

$$\frac{\phi - \phi_0}{\phi_L - \phi_0} = \frac{\exp(\rho u x/\Gamma) - 1}{\exp(\rho u L/\Gamma) - 1}$$

Data: L = 1 m, ρ = 1.0 kg/m³, Γ = 0.1 kg/m/s, and u = 0.1 m/s.

6. (a) Describe the method of generating external O-type, C-type and H-type grid over a streamline body.

(b) Consider flow of fluid between two parallel flat plates. It is desired to generate more number of grid points near the walls to calculate velocity distribution more accurately, and less number of grid points in the core region. Describe the method for smooth transition of grid spacing (grid stretching) in the flow field.

(c) Discuss importance of staggered grid formulation of fluid flow numerical scheme.

(d) Discuss the difference between FDM, FVM and FEM method