Ex/PG/ChE/T/128A/2019

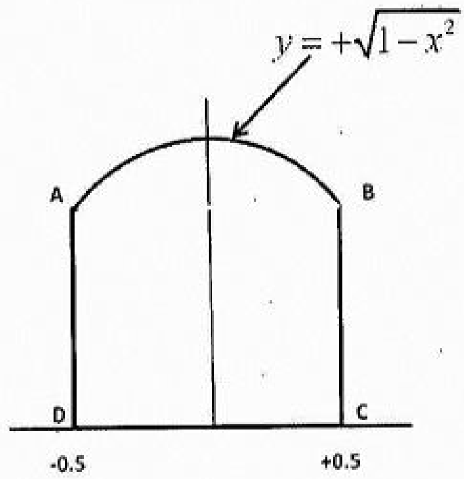
M.E. CHEMICAL ENGINEERING FIRST YEAR 2ND SEMESTER EXAMINATION - 2019

COMPUTATIONAL FLUID DYNAMICS

Time: three hour **Full marks: 100**

Answer any <u>four</u> questions
Assume any missing data
All questions carry equal marks
Symbols have usual significance

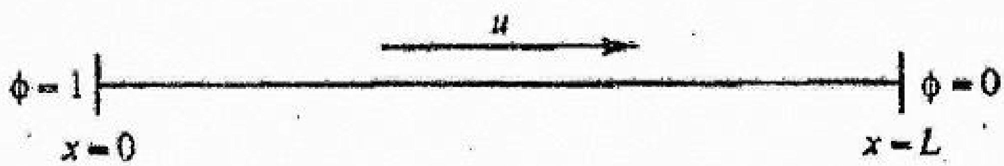
1. Draw grid lines on the associated 2D figure by taking 3 X 3 = 9 inner nodes and required boundary nodes. Show how transformation between physical and computational plane is done. Discuss advantages and disadvantages of solving field equations in physical plane and computational plane.



2. A plane wall 40 cm thick has both surface temperatures 200 K. The volumetric heat generation rate in the wall is 1000 W/m^3. Use finite volume method to predict temperature distribution in the wall. Take four cells of equal length for formulation. Compare the results with analytical solution. Data : k = 0.5 W/m.K and density = 2000 kg/m^3.

3. 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 temperature distribution in the wall applying Finite element method. Compare the result with analytical solution.

4. A property ϕ is transported by means of convection and diffusion trough 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, $\rho = 1.0$ kg/m^3, $\Gamma = 0.1$ kg/m/s, and $u = 0.1$ m/s.

5. For a 1-D convection diffusion problem, formulate a solution scheme based on finite volume upwind method. Using this method solve following 1-D convection diffusion problem by taking three equidistant nodes.

The governing equations are:

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

With continuity equation,

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

Data: L = 1 m, ρ = 1.0 kg/m3, Γ = 0.1 kg/m/s, and u = 3 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.