Ref. No. : Ex/PG/ChE/T/128A/2018

M.E. CHEMICAL ENGINEERING FIRST YEAR SECOND SEMESTER - 2018

COMPUTATIONAL FLUID DYNAMICS

Time: Three hours **Full Marks: 100**

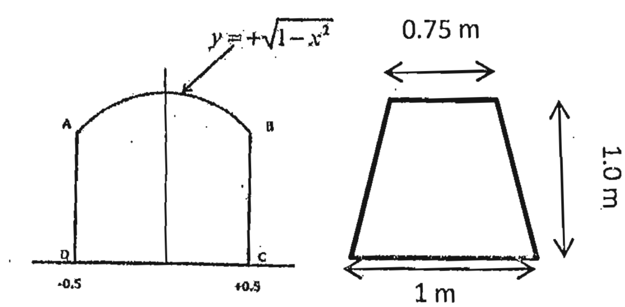
Answer any **FOUR** questions
Assume any missing data
Notations have usual significance
All parts of a question should be answered together and sequentially

1. A 40 cm thick plane wall has left surface temperature 200 K and right surface temperature 600 K. The volumetric heat generation rate in the wall is 5000 W/m^3. Use finite volume method to calculate temperatures at three equidistant internal nodes, and draw temperature profile in the wall. Also calculate heat flux at two boundaries.
   Thermal conductivity of material =0.5 W/m.K
   Density of the material = 1000 kg/m^3

   18+7=25

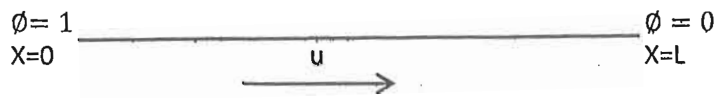
2. Consider a plane wall 30 cm thick and whose left surface temperature is 500 K and the heat flux at the right surface is 100W/m^2. Volumetric heat generation rate in the wall is 2000 W/m^3. Find temperatures at the mid plane, and at the right surface. Apply finite element Galerkin's weighted residual method to solve the problem and consider two elements of equal thickness for calculation. Plot temperature distribution on a graph paper. Thermal conductivity of the material = 1.0 W/m.K. 20+5=25

3. Draw grid lines on any one of the associated 2D figure by taking 3 X 3 internal grid points on computational plane. Show how transformation between physical plane and computational plane is done. Discuss advantages and disadvantages of solving field equations in physical domain and computational domain.



25

4. A property $\emptyset$ is transported by means of convection and diffusion through an one dimensional domain as shown in the figure.



The governing equations are:

$$\frac{d(\rho u \phi)}{dx} = \frac{d}{dx}\left(\Gamma \frac{d\phi}{dx}\right) \quad \text{and} \quad \frac{d(\rho u)}{dx} = 0$$

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

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

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

20+5=25

5. **Answer the following questions.**
   a) 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.
   b) Discuss importance of staggered grid formulation of fluid flow numerical scheme.
   c) Describe the method of generating external O-type, C-type and H-type grid over a streamline body.
   d) Discuss the difference between FDM, FVM and FEM method.
   e) Classify the following partial differential equations:

      i. $(1 - M^2)\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} = 0$

      ii. $\frac{\partial u}{\partial t} + \alpha \frac{\partial u}{\partial x} = 0$

      iii. $y\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$

      iv. $\frac{\partial u}{\partial t} - \alpha \frac{\partial^2 u}{\partial x^2} = 0$

      v. $\frac{\partial^2 u}{\partial t^2} - a^2 \frac{\partial^2 u}{\partial x^2} = 0$

5x5=25