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Bharatiya Vidya Bhavan's

Sardar Patel College of Engineering

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B.Tech. (~~Thermal~~ Mech), Sem-VII **B.Tech. in Mechanical Engineering**

COMPUTATIONAL FLUID MECHANICS

Max. Marks: 100 (BTM-708) **Duration: 4 Hours**

Instructions:

- Answer any **FIVE** from seven questions.
- Answers to all sub questions should be grouped together
- Make suitable assumption if needed with proper reasoning
- Figures on right in square bracket shows maximum marks for a particular sub-question.
- Figure on the extreme right shows **course outcome number** and **module number** respectively as per the syllabus of the course.

1. Consider steady state heat conduction with heat generation. Both face A and B are maintained at constant temperatures. Data: Wall thickness L = 2cm, Constant thermal conductivity k = 5 W/m^2.K, T_A = T_B=100°C, Volumetric heat generation q = 500 kW/m^3. **[20]** 1,6 &3

(a) Write the governing equation in both differential and integral form and mathematically represent appropriate boundary condition.

(b) Discretize the computational domain in 5 equal parts and write finite volume based nodal equation.

(c) Find nodal temperature by a direct method and compare it with a converged iterative solution.

2. A. List the different methods for discretization of governing equations. Explain any two of them in detail with proper illustration. **[10]** 2,4

B. Solve the following system of equations **[10]** 2,2

$$5x_1 + 2x_2 + x_3 = 12$$
$$x_1 + 4x_2 + 2x_3 = 15$$
$$x_1 + 2x_2 + 5x_3 = 20$$

using Gauss-Seidel method and compare the result with Jordon iterative method with 4 iterative solution and comment on the nature of solution.

3. A. Explain the relevance and significance of upwinding? How does it differ from central difference scheme? Explain both clearly. **[10[** 3,6

B. A long square cross section steel ingot of size 40cm at red hot temperature of 500°C is suddenly brought into blowing air 20°C with heat transfer coefficient 80 W/m^{2}K. To study the temporal evolution of temperature by neglecting any radiation if present, **[10[** 2,5

(i) show the computational domain with proper reasoning.

(ii) write the governing equation with initial and boundary condition.

(iii) write numerical model to calculate domain temperature using ADI scheme.

(iv) assuming minimum mesh size=12 cells and considering stability restriction imposed by explicit scheme, show time evolution of temperature for minimum 5 time steps in tabular form.

(Take thermal diffusivity α for the material as 10^{-5} m^2/s).

4. A. Explain turbulence phenomena and its characteristic features? **[10]** 3,7

B. What is the need of turbulence models? Classify them and list important features of at least two models. **[05]**

C. What is the effect of turbulence on heat transfer? Explain **[05]**

5. A. Explain Crank-Nicolson differencing to solve problems governed by parabolic equations. **[10]** 1,4

B. An insulated copper rod of length 1 m has initial temperature profile in degree Celsius is given by, $T(x, 0) = 5x^2+4x+20$. **[10]**

At $t = 0$. one end of the rod is brought in contact with 100°C and other end to 0°C. Use finite volume method for discretization and calculate the temperature across the rod after 4 time step where each time step may be assumed to be of 0.01s or any suitable time step to ensure the stability of solution.

6. A. Discuss the complexities associated with numerical modeling of flow problems. **[10]** 2,4

B. 'For incompressible flow problem, the continuity equation is a pressure equation.' Prove this statement in context to SIMPLE algorithm. **[10]**

7. A. Consider steady state heat diffusion in two dimension, **[10]** 1,5

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}=0$$

The boundary condition is given by:

$T(x,y)\, at\, x=0\, is\, 40°C, \quad and \quad T(x,y)\, at\, x=2m\, is\, 60°C$

$T(x,y)\, at\, y=0\, is\, 40°C, \quad and \quad T(x,y)\, at\, y=2m\, is\, 200°C$

Obtain the temperature profile T(x,y), considering 5 node in each direction and solving by line by line method for one vertical sweep.

B. Discuss convergence and stability issues associated with one dimensional uncoupled transient convection-diffusion heat transfer under central difference interpolation of convective terms. **[10]** 1,3