Exam Date & Time: 30-Nov-2023 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

VII SEMESTER B.TECH END SEMESTER EXAMINATIONS, NOV 2023

Computational Fluid Dynamics [MME 4049]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates:
Answer ALL questions
Missing data if any, may be suitably assumed

1) A) Derive the general governing differential equation for Energy conservation by considering suitable flow model. (5)

B) Describe the characteristics of Elliptic, Parabolic and Hyperbolic PDEs with examples. (3)

C) What is meant by total derivative? Provide two practical examples. (2)

2) A) A 200 mm long fin having uniform circular cross section of 25 mm diameter is fitted to an engine head at temperature 385 °C. Thermal conductivity of the fin material is 45 W/(m.K). It is exposed to ambient convective air having convective heat transfer coefficient of 22 $W/m^2.K$. The average bulk temperature of the cooling air is 32 °C. The fin can be treated as slender with negligible heat transfer from the open-end face of the fin. Assuming steady one-dimensional heat transfer, discretize the domain using finite difference approach, considering minimum three internal grids. Solve for temperature distribution in unknown grids using Gauss-Seidel method for 3 iterations or 5% error. Compare the numerical solution with exact solution at any one location along the length of the fin. (5)

B) Enumerate the relative advantages and limitations of solving a transient unsteady heat transfer problem using Euler's Explicit, Crank-Nicholson's Semi Implicit and Pure Implicit Schemes. (3)

C) Derive the second order accurate difference equation for mixed derivative. (2)

3) A) A large plate of thickness L = 2 cm, with constant thermal conductivity k = 0.5 W/m.K and uniform heat generation q = 1000 $k.W/m^3$. The faces A and B are at temperatures of 120 °C and 220 °C respectively. Assuming that the temperature gradients are significant only along the thickness direction of the plate. Discretize the domain using Finite Volume Method, evaluate the steady state temperature distribution along the thickness in minimum 3 interior grids. Solve using TDMA and compare the numerical result with the analytical solution using the following relation. (5)

$$T = \left[\frac{T_B - T_A}{L} + \frac{q}{2k}(L - x)\right]x + T_A$$

B) Derive the discretized equation from general transport equation for steady two-dimensional diffusion using the Finite Volume Method in the following form. (3)

$a_P T_P = a_E T_E + a_W T_W + a_N T_N + a_S T_S + b.$

C) Explain the need for negative slope linearization in finite volume method. (2)

4)

A) Warm brine solution having density of 1200 kg/m^3 is flowing in a pipe of diameter 35 mm. It enters the pipe with a temperature of 98 °C. The velocity at inlet is 1.25 m/s which can be assumed to remain constant along the pipe length. The diffusive flux (Γ) through the pipe can also be assumed to be constant at 815 kg/(m.s), The length of the pipe is 960 mm. Solution leaves the pipe at a temperature of 28 °C. Apply the Upwind differencing scheme (UDS) to formulate system of algebraic equations for minimum four equally spaced control volumes. Solve using TDMA. (5)

B) Conduct the error analysis for the convection-diffusion problem solved in Question 4A, Compare the numerical solution with analytical solution at each grid location. Comment and suitability of scheme adopted. (3)

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

C) Describe the role of convective flux to diffusive flux ratio in assessing various differencing methods for high flow velocities. (2)

5) Derive the pressure correction equation for convection dominated diffusion flow. Explain with a neat flow diagram SIMPLE algorithm of Patankar & Spalding. (5)

A)

B) What is checkerboard pressure field problem? Explain the remedy for resolving it. (3)

C) Explain the following with examples a) Inlet Velocity Boundary Condition; b) Inlet Pressure Boundary Condition. (2)

-----End-----