Ref. No.: Ex/ME/5/T/323G/2025

BACHELOR OF ENGINEERING (MECHANICAL ENGG) 3rd YR 2nd SEMESTER EXAM 2025

NUMERICAL HEAT TRANSFER

Time: Three Hours **Full Marks: 100**

Answer any FIVE Questions..
All the parts of a question must be answered together.
Assume any relevant data if necessary, with suitable justifications.
Symbols used in this question paper carry their usual meanings.

1. (i) Write down the complete Navier-Stokes Equations and Scalar Transport Equations. Explain the importance and necessity of numerical methods for solving these complex equations in practical engineering applications.

   (ii) Write down the Taylor Series Expansion and systematically formulate the basic expressions for Forward, Backward, and Central differencing schemes. Indicate their respective orders of truncation errors and discuss the implications for numerical accuracy. **[20]**

2. With a neat, well-labeled sketch and using a straightforward diffusion equation as an example, thoroughly discuss all the essential steps involved in the finite volume method of discretization. Include the process of grid generation, control volume integration, and the formulation of the algebraic system of equations. **[20]**

3. Using the technique of numerical heat transfer, solve a source-free heat conduction problem consisting of an insulated rod of length 0.5m with a uniform cross-sectional area of 10×10^{-3} m^2. The rod ends are maintained at constant temperatures of 100°C and 500°C, respectively. Calculate the steady-state temperature distribution in the rod when its thermal conductivity is equal to 1000 W/m.K. Finally, graphically present the computed results indicating both numerical and exact solutions. **[20]**

4. Consider steady-state one-dimensional heat conduction in a cylindrical fin of uniform cross-sectional area A. The base is maintained at a temperature of 100°C, and the end is insulated. The fin is exposed to an ambient temperature of 20°C. Using the finite volume method with five equally spaced control volumes, calculate the temperature distribution along the fin and compare your numerical solution with the analytical solution. Given: L = 1 m, $hP/(kA) = 25/m^2$. **[20]**

5. (i) What are the essential properties that a discretization scheme should possess for physically realistic solutions? Explain in detail the concepts of conservativeness, boundedness, and transportiveness, and why each is critical for numerical stability and accuracy.

   (ii) Comprehensively compare the central differencing, upwind, and hybrid discretization schemes for convection-diffusion problems. Discuss their relative advantages and limitations. **[20]**

6. (i) With suitable sketches, explain the concept of a staggered grid in computational fluid dynamics. Discuss its advantages over collocated grids and explain how it helps avoid the 'checker-board' pressure field problem.
   (ii) How does the accuracy of the finite volume method change with grid refinement? **[20]**

7. (i) What are the full forms of SIMPLE and SIMPLER algorithms? Explain the relative merits and demerits of the SIMPLE and SIMPLER algorithms.

   (ii) Write down the SIMPLE algorithm along with a flow chart. **[20]**

8. (i) Differentiate FVM with other CFD Methods, such as FDM, FEM.

   (ii) Explain the systematic approach to transform a one-dimensional governing equation to address two-dimensional and three-dimensional problems. Derive and present the general equation form that can effectively cover all directional problems in computational heat transfer and fluid flow. **[20]**