Ref. No.: Ex/PG/AuE/PC/T/111/2025

M.E. AUTOMOBILE ENGINEERING FIRST YEAR FIRST SEMESTER-2025

Subject: COMPUTATIONAL METHODS IN ENGINEERING

Time: 3 hours **Full Marks: 100**

(ANSWER ANY FIVE QUESTIONS)

Q.1 (a) Write differential form of mass, momentum and energy conservation equations in case of 3-D Cartesian coordinate system. Describe each of the terms. (6)

(b) Find a general form of the above equations considering ϕ as dependent variable, Γ as diffusion coefficient, and S as volumetric source term. Present these variables in tabular form for the mass, momentum and energy conservations. (6)

(c) State the reasons behind consideration of computational methods in solving above equations. (2)

(d) Write different computational/numerical methods to discretize above governing equations. Explain discretization concept for one of these methods briefly. (3+3)

Q.2 (a) Derive 1-D steady state heat conduction equation with a volumetric heat source considering the generalized governing equation and stating all necessary assumptions. (6)

(b) Discretize the 1-D steady heat conduction equation including source term based on finite volume method (FVM) stating all necessary assumptions. (10)

(c) State the four basic rules of discretization. (4)

Q.3 (a) Explain the necessary consideration for a property at interface between two control volumes in case of finite volume method (FVM). (5)

(b) Write 1-D unsteady state heat conduction equation with a volumetric heat source. Discretize it based on finite volume method (FVM) stating all necessary assumptions. (12)

(c) Explain schematically explicit, Crank-Nicolson, and fully implicit methods. (3)

Q.4 (a) Derive a criterion for time step (Δt) in case of explicit scheme. (5)

(b) Discuss on different types of boundary conditions and the methods to incorporate these boundary conditions in simulation. (5)

(c) Consider a1-D heat conduction situation with $S = 2$ and $k = 1$ everywhere. If four grid points at $x = 0, 1, 2, 3$ are used to span the domain of length 3, write the four discretization equations (use Practice B geometry). Solve the equations based on TDMA if $T = 25$ at $x = 0, 3$. (8)

(d) What is line-by-line TDMA (2)

Q.5 (a) What is staggered grid. (2)

(b) State the reasons behind consideration of staggered grid in predicting velocity and pressure fields. (4)

(c) Write name of the schemes to discretize convection and diffusion terms. (2)

(d) Write 1-D steady state problem includes only convection and diffusion terms following the generalize governing equation. Hence, find exact solution of the equation if $\phi = \phi_0$ at $x = 0$ and $\phi = \phi_L$ at $x = L$. (8)

(e) Explain the power law scheme schematically. (4)

Q.6 Explain the SIMPLE algorithm along with necessary discretized equations and discretization. (20)

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Q.7 (a) Derive the second-order accurate central difference finite difference approximations at the point (i,j) of the following expression: (10)

$$\frac{\partial^2 u}{\partial x^2} + y\frac{\partial^2 u}{\partial y^2} - e^{xy}$$

where u(x, y) is the dependent variable and, (x, y) are the independent variables, respectively.

(b) Employing the Crank-Nicolson method, discretize the following convection-diffusion equation at any point (*i,j*): (10)

$$\frac{\partial c}{\partial t} + u\frac{\partial c}{\partial x} + v\frac{\partial c}{\partial y} = D\left(\frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2}\right)$$

where, $c(x, y, t), u(x, y, t), v(x, y, t)$ are variables, and *D* is the diffusion constant, respectively.

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