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NOIDA INSTITUTE OF ENGINEERING AND TECHNOLOGY, GREATER NOIDA
(An Autonomous Institute Affiliated to AKTU, Lucknow)

M.Tech

SEM: II - THEORY EXAMINATION (2024 - 2025)

Subject: Computational Fluid Dynamics

Time: 3 Hours

Max. Marks: 70

General Instructions:

IMP: Verify that you have received the question paper with the correct course, code, branch etc.

1. This Question paper comprises of **three Sections -A, B, & C**. It consists of Multiple Choice Questions (MCQ's) & Subjective type questions.
2. Maximum marks for each question are indicated on right -hand side of each question.
3. Illustrate your answers with neat sketches wherever necessary.
4. Assume suitable data if necessary.
5. Preferably, write the answers in sequential order.
6. No sheet should be left blank. Any written material after a blank sheet will not be evaluated/checked.

SECTION-A

15

1. Attempt all parts:-

- | | | |
|------|--|---|
| 1-a. | Which method is commonly used for solving time-dependent problems in CFD?
(CO1, K1) | 1 |
| | (a) Finite difference method | |
| | (b) Finite element method | |
| | (c) Finite volume method | |
| | (d) Spectral method | |
| 1-b. | What is the primary focus of elliptic equations in numerical methods? (CO2, K1) | 1 |
| | (a) They describe equilibrium or steady-state behavior | |
| | (b) They model transient phenomena | |
| | (c) They capture wave-like behavior | |
| | (d) They exhibit parabolic flow characteristics | |
| 1-c. | What is the primary objective of the upwind scheme in finite volume methods? (CO3, K1) | 1 |
| | (a) To capture the direction of flow accurately by considering upstream values | |
| | (b) To minimize computational cost | |
| | (c) To simplify boundary conditions | |
| | (d) To improve numerical stability | |
| 1-d. | How does matrix inversion contribute to the solution of finite difference equations in computational fluid dynamics simulations? (CO4, K1) | 1 |

- (a) By providing a direct method to solve linear systems of equations
 - (b) By minimizing computational errors during discretization
 - (c) By improving the accuracy of the solution
 - (d) By reducing the memory footprint of the numerical simulation
- 1-e. What is the primary purpose of using a variable time step method in CFD simulations? (CO5, K1) 1
- (a) To adaptively adjust the time step size based on solution dynamics
 - (b) To reduce computational cost by using a fixed time step
 - (c) To improve convergence of iterative solvers
 - (d) To model fluid flow with varying Reynolds numbers

2. Attempt all parts:-

- 2.a. Describe the role of momentum equations in CFD simulations. (CO1, K2) 2
- 2.b. What are Neumann boundary conditions, and how do they differ from Dirichlet boundary conditions? (CO2, K1) 2
- 2.c. Define the term "upwind scheme" in the context of finite volume methods. (CO3, K1) 2
- 2.d. Explain the significance of the ADI method in handling time-dependent problems in computational fluid dynamics. (CO4, K2) 2
- 2.e. Define phase change problems in Computational Fluid Dynamics (CFD). (CO5, K1) 2

SECTION-B

20

3. Answer any five of the following:-

- 3-a. Discuss the challenges associated with solving conservation equations numerically in CFD simulations and potential strategies to overcome them. (CO1, K2) 4
- 3-b. Explain how the conservation equations are applied in practical engineering simulations and their role in optimizing design processes. (CO1, K2) 4
- 3-c. Discuss the key steps involved in solving elliptic equations numerically and the challenges associated with their solution. (CO2, K2) 4
- 3-d. Explain the role of relaxation factors in iterative solution methods and how they affect solution convergence and stability. (CO2, K2) 4
- 3-e. Describe the process of matrix inversion methods and their application in solving finite difference equations. (CO3, K2) 4
- 3-f. How does the operator splitting method simplify the solution of complex partial differential equations in computational fluid dynamics? (CO4, K2) 4
- 3.g. Discuss the role of enthalpy in CFD simulations and its significance in phase change problems. (CO5, K2) 4

SECTION-C

35

4. Answer any one of the following:-

- 4-a. Analyze the importance of the convective form of equations in CFD, explaining its 7

- relevance in capturing advection-dominated flow phenomena and its implications for numerical solution methods. (CO1, K4)
- 4-b. Analyze the importance of conservation equations in studying unsteady flow phenomena, discussing their relevance in applications such as transient flow simulations and dynamic response analysis. (CO1, K4) 7
5. Answer any one of the following:-
- 5-a. Describe the finite volume method in detail, including its formulation, discretization techniques, and applications in solving partial differential equations for fluid flow problems. (CO2, K2) 7
- 5-b. Evaluate the advantages and disadvantages of explicit and implicit time integration schemes in numerical simulations, considering factors such as stability, accuracy, and computational cost. (CO2, K4) 7
6. Answer any one of the following:-
- 6-a. Describe the applications of the Fast Fourier Transform (FFT) in computational fluid dynamics simulations. Discuss how FFT is used to accelerate numerical calculations, analyze spatial and temporal data, and solve partial differential equations. Provide examples illustrating the application of FFT in numerical simulations. (CO3, K3) 7
- 6-b. Explain the different approaches for handling moving boundaries in numerical simulations and their advantages and disadvantages. Discuss techniques such as Arbitrary Lagrangian-Eulerian (ALE) method, dynamic mesh adaptation, and immersed boundary method. Provide examples demonstrating the application of these approaches in computational fluid dynamics simulations. (CO3, K3) 7
7. Answer any one of the following:-
- 7-a. Describe the process of solving finite difference equations using iterative methods and how they differ from direct methods in computational fluid dynamics simulations. Provide examples and applications. (CO4, K3) 7
- 7-b. Discuss the iterative process involved in solving finite difference equations using the Successive Over-Relaxation (SOR) method. Explain how relaxation parameters are chosen and their impact on convergence. (CO4, K3) 7
8. Answer any one of the following:-
- 8-a. Explain the process of phase change modeling in CFD simulations, including the mathematical formulations used to represent phase change phenomena, such as evaporation, condensation, and solidification. Discuss the challenges and limitations of phase change modeling and propose techniques to improve accuracy and efficiency. (CO5, K3) 7
- 8-b. Compare and contrast the Rayleigh-Ritz and Galerkin methods in terms of their mathematical formulations, convergence properties, and computational efficiency. Discuss the advantages and disadvantages of each method in the context of solving complex fluid flow problems. (CO5, K3) 7