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Subject Code:BME062

Roll No: | | | | | | | | | | | | | |

BTECH
(SEM. VI) THEORY EXAMINATION 2025-26
COMPUTATIONAL FLUID DYNAMICS

TIME: 3 HRS **M.MARKS: 70**

Note: Attempt all Sections. In case of any missing data; choose suitably.

SECTION A

1. Attempt *all* questions in brief. 02 x 7 = 14

Qno.	Question	CO	Level
a.	Define Computational Fluid Dynamics (CFD) and state its three principal branches of fluid mechanics it bridges.	1	K1
b.	Classify second-order partial differential equations based on the discriminant and give one physical example of each class.	1	K2
c.	Differentiate between explicit and implicit finite difference schemes with respect to stability and computational cost.	2	K2
d.	State the Courant–Friedrichs–Lewy (CFL) condition and explain its physical significance in transient CFD simulations.	2	K2
e.	What is the Jacobian of transformation in grid generation? Why is it required to be non-zero at every grid point?	3	K2
f.	List any four advantages of the Finite Volume Method (FVM) over the Finite Difference Method (FDM).	5	K2
g.	Define shape functions in the Finite Element Method and state any two essential properties they must satisfy.	4	K2

SECTION B

2. Attempt any *three* of the following: 07 x 3 = 21

Qno.	Question	CO	Level
a.	Derive the Navier–Stokes equations for an incompressible, viscous, Newtonian fluid in conservation form starting from Newton's second law of motion. Clearly state all the assumptions.	1	K3
b.	Using Taylor series expansion, derive the forward, backward, and central finite difference approximations for the first derivative.	2	K3
c.	Explain the von Neumann stability analysis of the FTCS (Forward Time, Central Space) scheme applied to the one-dimensional unsteady heat conduction equation.	2	K3
d.	Describe the concept of adaptive grid generation and elliptic grid generation techniques.	3	K2
e.	Explain the finite volume discretization of the general transport equation over a control volume. Derive the discretized form using the central difference scheme for a 1-D steady diffusion problem.	5	K3

SECTION C

3. Attempt any *one* part of the following: 07 x 1 = 07

Qno.	Question	CO	Level
a.	Starting from the Reynolds Transport Theorem, derive the continuity equation and the energy equation in both differential (non-conservation) and conservation forms. Highlight the physical meaning of each term.	1	K3

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b.	Discuss the mathematical classification of the quasi-linear second-order PDE $A \cdot \varphi_{xx} + B \cdot \varphi_{xy} + C \cdot \varphi_{yy} + D \cdot \varphi_x + E \cdot \varphi_y + F \cdot \varphi = G$ into elliptic, parabolic, and hyperbolic types. Provide one governing equation of fluid flow as an example of each class and explain the corresponding initial/boundary condition requirements.	1	K3

4. Attempt any *one* part of the following: 07 x 1 = 07

Qno.	Question	CO	Level
a.	Consider a one-dimensional steady-state heat conduction problem in a slab of length L = 1 m with thermal conductivity k = 50 W/m·K, subjected to boundary temperatures T(0) = 100 °C and T(L) = 500 °C, with a uniform heat generation q''' = 1000 kW/m³. Using the finite difference method with 5 equally-spaced nodes, set up the system of equations and solve for the nodal temperatures.	2	K3
b.	Derive the explicit and implicit (Crank–Nicolson) finite difference formulations for the one-dimensional unsteady heat conduction equation $\partial T/\partial t = \alpha \cdot \partial^2 T/\partial x^2$. Compare both schemes in terms of accuracy, stability, and computational effort.	2	K3

5. Attempt any *one* part of the following: 07 x 1 = 07

Qno.	Question	CO	Level
a.	Derive the transformation of the two-dimensional Laplace equation $\partial^2\varphi/\partial x^2 + \partial^2\varphi/\partial y^2 = 0$ from the physical (x, y) plane to the computational (ξ, η) plane. Express the result in terms of the metrics of transformation and the Jacobian.	3	K3
b.	Discuss the relative merits and limitations of algebraic grid generation, elliptic grid generation, and hyperbolic grid generation methods for complex geometries encountered in turbomachinery applications.	3	K2

6. Attempt any *one* part of the following: 07 x 1 = 07

Qno.	Question	CO	Level
a.	Derive the element stiffness matrix for a one-dimensional linear bar element used in steady-state heat conduction analysis using the Galerkin weighted residual method.	4	K3
b.	Explain the concept of isoparametric elements in the Finite Element Method. Derive the shape functions for a four-noded quadrilateral isoparametric element in natural coordinates (ξ, η).	4	K3

7. Attempt any *one* part of the following: 07 x 1 = 07

Qno.	Question	CO	Level
a.	Discuss the upwind, hybrid, and QUICK schemes used in the finite volume discretization of the convection–diffusion equation.	5	K3
b.	Describe the SIMPLE (Semi-Implicit Method for Pressure-Linked Equations) algorithm for solving incompressible Navier–Stokes equations on a staggered grid.	5	K3