22MEHO207	ADVANCED COMPUTATIONAL FLUID DYNAMICS (CFD)					
PREREQUISITES		**CATEGORY**	**L**	**T**	**P**	**C**
Knowledge of undergraduate heat transfer and fluid mechanics, basic computational fluid dynamics		**PE**	**3**	**0**	**0**	**3**

COURSE OBJECTIVES:

1. The primary objective of the course is to teach fundamentals of computational method for solving non-linear partial differential equations (PDE) primarily in complex geometry. The emphasis of the course is to teach CFD techniques for solving incompressible and compressible N-S equation in primitive variables, grid generation in complex geometry, transformation of N-S equation in curvilinear coordinate system and introduction to turbulence modelling.

UNIT I	INTRODUCTION	9	0	0	9

Brief introduction of boundary layer flow, incompressible and compressible flows, finite difference and finite volume method, example of parabolic and hyperbolic systems and time discretization technique, explicit and implicit methods, upwind and central difference schemes, stability, dissipation and dispersion errors

UNIT II	SOLUTION OF SIMULTANEOUS EQUATIONS	9	0	0	9

Point iterative/block iterative methods, Gauss-Seidel iteration (concept of central coefficient and residue, SOR), CGS, Bi-CGSTAB and GMRES (m) matrix solvers, different acceleration techniques.

UNIT III	INCOMPRESSIBLE FLOW	9	0	0	9

Higher order upwind schemes: second order convective schemes, QUICK. Solution of NS equations: Solution of incompressible N-S equation (Explicit time stepping, Semi–explicit time stepping). SMAC method for staggered grid: Predictor - Corrector step, discretization of N-S and continuity equations, Pressure correction Poisson’s equation, boundary conditions (no-slip, moving wall, slip boundary and inflow conditions), outflow (zero gradient/Orlanski) boundary conditions for unsteady flows, algorithm for the SMAC method, stability considerations for SMAC method.

UNIT IV	FDE IN COMPLEX GEOMETRIES	9	0	0	9

Transformation of governing equation in ξ η– plane, transformation of Laplace equation, introduction to geometrical parameters and the accuracy of the solution, basic facts about transformation, grid transformation on complex geometries. N-S equations in transformed plane, matrices and Jacobians

UNIT V	COMPRESSIBLE FLOW	9	0	0	9

N-S and energy equations, properties of Euler equation, linearization. Solution of Euler equation: Explicit and implicit treatment such as Lax-Wendroff, MacCormark, Beam and Warming schemes, Upwind schemes for Euler equation: Steger and Warming, Van Leer's flux splitting, Roe's approximate Riemann solver, TVD schemes. Solution of N-S equations: MacCormack, Jameson algorithm in finite volume formulation and transformed coordinate system.

TOTAL(45L) : 45 PERIODS

TEXT BOOKS:

1. Computational Fluid Flow and Heat Transfer, Second Edition by K. Muralidhar, T. Sundararajan (Narosa), 2011.
2. Computational Fluid Dynamics by Chung T. J., Cambridge University Press, 2003.
3. Computational Fluid Dynamics by Tapan K. Sengupta, University Press, 2005.
4. Numerical Computation of Internal and External Flows by Hirch C., Elesvier 2007.

REFERENCES:

1. K. J. Bathe, Finite Element Procedures, Prentice-Hall of India Private Limited, New Delhi, 1996
2. J. C. Simo and T. J. R. Hughes, Computational Inelasticity, Springer-Verlag New York, Inc., New York, 1998

3.	Cook and Robert Davis etal, “Concepts and Applications of Finite Element Analysis”, 4th Edition, John Wiley and Sons, 2001.
4.	Segerlind L.J, “Applied Finite Element Analysis”, 2nd Edition, John Wiley, 1984.
5.	O. C. Zienkiewicz and R. L. Taylor, Finite Element Method: Volume 2 Solid Mechanics, Fifth Edition, Butterworth-Heinemann, Oxford,

COURSE OUTCOMES: Upon completion of this course, the students will be able to:		**Bloom Taxonomy Mapped**
CO1	Understand and be able to numerically solve the incompressible and compressible flows.	Understand
CO2	Solve computational problems related to iterative methods.	Evaluate
CO3	Solve the problems related to incompressible fluid flow.	Evaluate
CO4	Interpret the knowledge, capability of analyzing and solving FDE in complex geometries problem.	Apply
CO5	Solve the problems related to compressible fluid flow.	Evaluate

COURSE ARTICULATION MATRIX

COs/POs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	1	1	2	0	0	0	0	0	0	0	2	2	0
CO2	2	2	1	3	2	0	0	0	0	0	0	0	2	2	0
CO3	2	2	1	3	2	0	0	0	0	0	0	0	2	2	0
CO4	2	2	1	1	2	0	0	0	0	0	0	0	2	2	0
CO5	2	2	1	3	2	0	0	0	0	0	0	0	2	2	0
Avg	**2**	**2**	**1**	**2.2**	**2**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**2**	**0**

3/2/1 – indicates strength of correlation (3 – high, 2- medium, 1- low)