Course Type	Course Code	Name of Course	L	T	P	Credits
DE	NMED513	Finite Element Method in Thermal Engineering	3	0	0	3

Course Objectives
Prerequisite: Basic knowledge of fluid mechanics and heat transfer are essential • FEM is going to be an indispensable numerical tool in the near future. The primary objective of this course is to acquaint the students with this powerful numerical method that enables them to solve simple as well as complex fluid dynamics and heat transfer problems with high accuracy. • To highlight the differences in FEM treatment of solid mechanics (Galerkin based) and fluid dynamics (Petrov-Galerkin based) problems.
Learning Outcomes
• The students will develop the ability to model steady/unsteady heat conduction as well as convection-diffusion problems using FEM. • Relative to the conventional FEM ways of generating the assembled matrix and vector, the students will learn a different approach of formulating the global matrix and vector that is very conducive to computer coding. • According to the present curriculum, this course will be offered simultaneously with Computational Fluid Dynamics where FDM and FVM are mostly covered. After this FEM course, the connections/differences among these three compteting numerical tools will be very clear to the students.

Unit No.	Topics to be Covered Lecture	Lecture Hours	Learning Outcomes
1	Concept of variational methods, concept of FEM, comparison with alternate methods such as, FDM and FVM	7L	This introductory module will enable the students to have the basic flavour of early numerical methods that were developed as a suitable substitute of the analytical approach
2	Strong and weak forms of a differential equation, Galerkin finite-element method, weight and shape functions, element connectivity and assembly	5L	After this module, the students will be able to generate the variational statement of a given PDE or ODE. Besides, they will be able to construct the basis functions and various arrays that aid in generating the global matrix and vector
3	Numerical integration, isoparametric elements, coordinate transformation, basic matrix equation solvers	6L	This foundation module will enable the students to evaluate the element level matrix and vector entries via Gauss quadrature. The strength of FEM for problems involving complex geometry will be more apparent. This module will also familiarize the students with the role of linear algebra in solving fluid dynamics problems via FEM

4	FEM discretization of unsteady equations, implicit and explicit methods, implementation of EBC, NBC and convective boundary conditions	5 L	The students will be familiar with the trapezoidal rule to discretize an unsteady term via FDM. They will also learn to implement the boundary conditions via use of various arrays discussed in module II
5	Matrix and vector formation for one- and two-dimensional heat conduction problems, treatment of one-dimensional convection-diffusion equation using linear and quadratic elements	7 L	This module implements for a single-degree-of-freedom problem, the theory discussed in the previous modules. The students will be able to completely formulate and discretize the Laplace/Poisson equations in single or two-dimensions and one-dimensional convection-diffusion equation
6	Limitations of Galerkin method for flow problems, upwinding, Petrov-Galerkin method, Navier-Stokes equations: properties and limitations, coupled versus segregated formulation of Navier-Stokes equations, connectivity and assembly for equations with multiple degrees-of-freedom	6 L	This module will highlight the inability of the Galerkin formulation to accurately predict a flow field and will also suggest the ways to modify the Galerkin approach. The students will be able to generate the global matrices for problems with multiple unknowns
7	Coupled formulation of steady Navier-Stokes equations in two-dimensions using collocated arrangement.	6 L	After this conclusive module, the students are expected to successfully discretize the Navier-Stokes equations of motion using coupled approach in two-dimensions
	Total	42 hrs	

Text books

1. An introduction to the finite element method, J. N. Reddy, Tata McGraw-Hill Edition, 4th Edition, 2019.

2. Finite element method for flow problems, J. Donea and A. Huerta, Wiley publication, 2003.

Reference books

1. The finite element method, T. J. R. Hughes, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, Dover Publications, 1st Revised Edition, 2000.

2. Fundamentals of the finite element method for heat and fluid flow, R. W. Lewis, P. Nithiarasu and K. N. Seetharamu, John Wiley & Sons, 2nd Edition, 2016.