

# COURSE CONTENTS

## BACKGROUND: INTRODUCTION TO NUMERICAL METHODS

- ❖ OVERVIEW – BASIC INGREDIENTS OF THE FEM
- ❖ COMPARISON WITH ALTERNATIVE NUMERICAL METHODS

## BASIC CONCEPTS OF FEM – ONE-DIMENSIONAL PROBLEMS

- ✓ Axial deformations of a bar or one-dimensional heat transfer
- ✓ Strong and weak forms (variational and virtual work statements)
- ✓ Primary and secondary variables of the formulation
- ✓ Essential vs. natural boundary conditions
- ✓ Methods of approximations (weak-form Galerkin method)
- ✓ Finite element approximation functions (linear, quadratic, and cubic elements)
- ✓ Assembly of element equations
- ✓ Illustrative examples and discussion of results in light of physical response

## EXTENSION TO OF FEM TO TWO-DIMENSIONAL PROBLEMS

- ✓ Membrane and heat transfer-like problems in 2D
- ✓ Elements types (triangular and quadrilateral elements)
- ✓ Axisymmetric problems
- ✓ Discussions of representative field problems to understanding modeling issues

## EIGENVALUE AND TIME-DEPENDENT PROBLEMS

- ✓ Free vibration of elastic systems (natural frequencies, modal response, etc)
- ✓ Transient Analysis
- ✓ Time integration procedures
- ✓ Explicit dynamic integration

## NUMERICAL/COMPUTATIONAL ISSUES

- ✓ Subparametric, isoparametric, and superparametric formulations
- ✓ Numerical integration
- ✓ General modeling considerations

## PLANE ELASTICITY

- ✓ Governing equations of plane elasticity problems
- ✓ Elements types (triangular and quadrilateral elements)
- ✓ Incompatible modes
- ✓ Discussion of example problems to bring out modeling issues

## THREE-DIMENSIONAL PROBLEMS

- ✓ Heat transfer-type problems
- ✓ Elasticity problems
- ✓ Types of 3-D Finite elements (interpolation functions)

## INTRODUCTION TO NON-LINEAR PROBLEMS

- ✓ Geometric and material non-linearity
- ✓ Nonlinear formulation of a 2-D Model problem
- ✓ Solution algorithms for the solution of non-linear algebraic equations
- ✓ Derivation of tangent stiffness coefficients
- ✓ Convergence criteria

## NONLINEAR BENDING OF BEAMS

- ✓ Euler-Bernoulli beam theory
- ✓ Nonlinear finite element formulation of Euler-Bernoulli beam theory
- ✓ Tangent stiffness calculations
- ✓ Membrane locking
- ✓ Timoshenko beam theory and its finite element model
- ✓ Shear locking
- ✓ Numerical examples

## NONLINEAR BENDING OF PLATES

- ✓ Nonlinear finite element formulation of the first-order shear deformation (Mindlin) plate theory
- ✓ Tangent matrix coefficients
- ✓ Shear and membrane locking
- ✓ Numerical examples

## CONTINUUM FORMULATIONS

- ✓ Continuum equations
- ✓ Measures of stress and strain
- ✓ Total and Updated Lagrangian descriptions
- ✓ Degenerated thick shell element
- ✓ Applications

## FLOWS OF VISCOUS INCOMPRESSIBLE FLUIDS (NAVIER-STOKES EQUATIONS)

- ✓ Governing equations (Navier-Stokes Equations)
- ✓ Mixed finite element model (2D)
- ✓ Penalty finite element model (2D)
- ✓ Coupled fluid flow and heat transfer formulations
- ✓ Applications