UTTARANCHAL UNIVERSITY

(Established vide Uttaranchal University Act, 2012)
(Uttarakhand Act No. 11 of 2013)
Arcadia Grant, P.O. Chandanwari, Premnagar, Dehradun, Uttarakhand

Programme Name	**Pre-PhD Course Work**	Programme Code	23-40
Course Code	DSE704	Credit	3
Year/Sem	1/1	L-T-P	3-0-0
Course Name	Finite Element Method		

Objectives of the Course:

1. To learn basic principles of finite element analysis procedure.
2. To learn the theory and characteristics of finite elements that represent engineering structures.
3. To learn and apply finite element solutions to structural, thermal, dynamic problem to develop the knowledge and skills needed to effectively evaluate finite element analyses.

Unit-1:(Total Topics-15and Hrs-10)

Introduction and Direct Approach FEM

Concept of FEM, History, Packages, Range of applications, Steps in FEM, Approaches of FEM, Development of Elemental Equations for simple systems (i) Single dof problems-Spring Network, Hydraulic Network and Resistance Network (ii) Two dof problems- Plane Trusses and Frame structures; Assembly Procedure, Application of Boundary Conditions; Solver Technology: Linear direct solver, Iterative solvers, Eigen solver, Nonlinear equation solver.

Unit-2:(Total Topics-14and Hrs-10)

Galerkin's and Rayleigh-Ritz FEM for 1-D and Radially Symmetric Scalar Field Problems

Concept of Galerkin's and Raleigh-Ritz Mathematical Approaches, Governing Equation andBoundary Conditions for Heat Transfer-Rod and Fin, Solid Mechanics-Bar extension and Beambending; Fluid Dynamics-parallel wall flow; Electrostatics and Magnetostatic problems; WeakFormulation and Functional, Polynomial Approximation, Standard 1-D Shape Functions of C0 andC1 Continuity Elements, Derivation of Element Matrices and Vectors, Assembly, Imposition ofBoundary Conditions and Nodal Solution; Co-ordinate Transformation and Numerical Integration.Transient and Eigen Value Problems

Unit-3:(Total Topics-11and Hrs-10)

Galerkin's and Rayleigh-Ritz FEM for Plane (2-D) and Axisymmetric SINGLE VARIABLE Problems

Governing Equation and Boundary Conditions-Heat Transfer, Solid mechanics-Rod Torsion, Fluid Dynamics-Stream function and Velocity potential formulation, Electrostatics and Magnetostatic Problems, Weak Formulation and Functional, Polynomial Approximation, Standard 2- D Shape Functions of C0 Continuity Elements, Derivation of Element Matrices and Vectors, Assembly, Imposition of Boundary Conditions and Nodal Solution; Mapping and Numerical Integration; Transient and Eigen Value Problems.

Unit-4:(Total Topics-7and Hrs-10)

Galerkin's and Rayleigh-Ritz FEM for Plane (2-D) and Axisymmetric MULTI VARIABLE Problems

Governing equation and Boundary conditions- Stress Analysis and Fluid Flow AnalysisProblems: Weak Formulation and Functional, Polynomial Approximation, Derivation of ElementMatrices and Vectors, Assembly, Imposition of Boundary Conditions and Nodal Solution, Postprocessing of solutions

Course Outcomes (CO)

1. ME-104 (1)-CO1: Understand the concepts behind formulation methods in FEM.
2. ME -104 (1)-CO2: Identify the application and characteristics of FEA elements such as bars, beams, plane and iso-parametric elements.
3. ME -104 (1)-CO3: Develop element characteristic equation and generation of global equation.
4. ME -104 (1)-CO4: Able to apply suitable boundary conditions to a global equation for bars, trusses, beams, circular shafts, heat transfer, fluid flow, axi symmetric and dynamic problems and solve them displacements, stress and strains induced.

References:

1. Energy and Finite Element Methods in Structural Mechanics: I. H. Shames and C. L. Dym.
2. Concepts and Applications of Finite Element Analysis: R. D. Cook, D. S. Malkus and M. E Plesha.
3. The Finite Element Method Vol. I-II: O.C. Zienkiwicz and R.L. Taylor.
4. Finite Element Procedures: K. J. Bathe.
5. An Introduction to Finite Element Methods: J.N. Reddy.
6. Finite Element Methods in Engineering: S.S. Rao.

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Programme Name	**Pre-PhD Course Work**	Programme Code	23-40
Course Code	DSE704 (i)	Credit	3
Year/Sem	1/1	L-T-P	3-0-0
Course Name	Fracture Mechanics		

Objectives of the Course:

1. This course familiarizes the student with relevant fracture mechanics concepts, procedures for understanding materials behavior with respect to short and long fatigue cracks.
2. This course provides an understanding of various factors including metallurgical factors that control the fracture resistance of engineering alloys and that should help to develop a facility with the methods of predicting the failure of structural components.
3. Based on an understanding of the mechanisms controlling the strength and fracture resistance of structural materials, this course seeks to develop an appreciation of the procedures used to make rational choices in the selection of materials for structural applications.

Unit-1(Total Topics-12 and Hrs-14)

Introduction: Modes of loading, Crack growth and fracture mechanismsNeed for fracture mechanics, Linear elastic fracture mechanics and elastic plastic fracture mechanics.

Energy Release Rate : Surface Energy, Resistance, Griffith Theory of fracture, Extension of Griffith Theory by Irwin and Orowan, R-Curve, Pop-in phenomena, Crack branching. Necessary and sufficient conditions for fracture.

Unit-2(Total Topics-7and Hrs-12)

Crack - Tip Stress and Displacement Fields: Airy's stress function, Westergaard's approach, Generalized **Westergaard's** approach, William's Eigen function approach, Multi-parameter stress field equations, **Influence** of **the** T-stress and higher order terms, Role of photoelasticity on the development of stress field equations in fracture **mechanics**.

Unit-3 (Total Topics-5and Hrs-12)

Stress Intensity Factor: Equivalence between SIF andG**,** Variousmethods for evaluating Stress Intensity Factors.

Crack Tip Plastic Zone: Modeling plastic zone at the crack-tip, Irwin and Dugdale models.

Unit-4(Total Topics-10and Hrs-12)

Fracture Toughness Testing: Qualitative toughness testing, KICtesting, K–R curve testing, JIC measurements, J-R curve testing, CTOD testing.

Micromechanics of Fracture: Cohesive strength of solids, Cleavage fracture, Intergranular fracture, Ductile fracture, Crack detection methods.

Course Outcomes (CO)

1. ME-104 (2) -CO1: Explain the basic concepts of fracture mechanics for both linear elastic and elastic-plastic regimes.
2. ME -104 (2) -CO2: Describe the fracture mechanics characterization of fatigue crack growth sustained load fracture and dynamic crack growth.
3. ME -104 (2) -CO3: Identify various fracture mechanisms and explain the influence of material behavior on fracture mechanics characterization of crack growth.
4. ME -104 (1) -CO4: Identify initiation and growth of fatigue crack.

References:

1. Elementary Engineering Fracture Mechanics: D. Broek.
2. Elements of Fracture Mechanics: Prashant Kumar.
3. Fracture Mechanics - Fundamentals and Applications: T. L. Anderson.
4. Introduction to Fracture Mechanics: Kare Hellan.

5. Fracture Mechanics- With an Introduction to Micromechanics: Dietmar Gross and Thomas Seelig.
6. Fracture Mechanics- An Introduction: E.E. Gdoutos.

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Programme Name	**Pre-PhD Course Work**	Programme Code	23-40
Course Code	DSE704 (ii)	Credit	3
Year/Sem	1/1	L-T-P	3-0-0
Course Name	Computational Fluid Dynamics		

Objectives of the Course:

1. Study the governing equations of fluid dynamics.
2. Learn how to formulate and solve Euler's equation of motion.
3. Become skilled at Representation of Functions on Computer
4. Solve computational problems related to fluid flows.

Unit1-1(Total Topics-14and Hrs-14)

Basic ideas of CFD: Introduction to CFD, role of CFD and its applications, future of CFD.

Governing equations (GE's) of Fluid dynamics*:* Modeling of flow, control volume concept, substantial derivative, physical meaning of the divergence of velocity. Continuity equation, momentum equation, energy equation and its conservation form. Equations for viscous flow (Navier-Stokes equations), equations for inviscid flow (Euler equation). Different forms of GE's, initial and boundary conditions.

Unit-2(Total Topics-10and Hrs-12)

FVM for Diffusion Problems: FVM for 1D steady state diffusion, 2D steady state diffusion, 3d steady state diffusion. Solution of discretised equations- TDMA scheme for 2D and 3D flows.

FVM for Convection-Diffusion Problems: FVM for 1D steady state convection-diffusion, Central differencing scheme, Conservativeness, Boundedness, Transportiveness, Upward differencing scheme, Hybrid differencing scheme for 2D and 3D convection-diffusion, Power-law scheme, QUICK scheme.

Unit-3(Total Topics-9and Hrs-12)

Solution Algorithm for Pressure-velocity Coupling in Steady Flows: Concept of staggered grid, SIMPLE, SIMPLER, SIMPLEC, PISO algorithm.

FVM for Unsteady Flows: 1D unsteady heat conduction (Explicit, Crank-Nicolson, fully implicit schemes), Implicit mecthods for 2D and 3D problems, Discretization of transient convection-diffusion problems, solution procedure for transient unsteady flow calculations (transient SIMPLE, transient PISO algorithms).

Unit-4(Total Topics-10and Hrs-12)

Grid Generation: General transformation of the equations. Metices and Jacobians. Types of grids- structured and unstructured grids, grid generation methods- algebraic, differential and hybrid methods. Coordinate stretching, boundary-fitted coordinate systems. Elliptic and hyperbolic grid generation methods, orthogonal grid generation for Navier-Stokes equations, Multi-block grid generation.

Latest development in CFD techniques and newer applications.

Course Outcomes (CO)

1. ME-104 (3) -CO1: Understand mathematical characteristics of partial differential equations.
2. ME -104 (3) -CO2: Explain how to classify and computationally solve Euler and Navier-Stokes equations.
3. ME -104 (3) -CO3: Make use of the concepts like accuracy, stability, and consistency of numerical methods for the governing equations.
4. ME -104 (3) -CO4: Identify and implement numerical techniques for space and time integration of partial differential equations.
5. ME-104 (3) -CO5: Acquire basic skills on programming of numerical methods used to solve the

Governing equations.

References:

1. "An Introduction to Computational Fluid Dynamics: the Finite Volume Method", H.K Versteeg and W. Malalasekara, 2nd edition, Pearson Education, England, 2007.
2. "Computational Fluid Dynamics for Engineers" B. Andersson & others, 1st edition, Cambridge University Press, U.K., 2012.
3. "Computational Fluid Flow and Heat Transfer" (2nd edition), K. Muralidhar and T. Sundararajan, NarosaPublishing, 2004.
4. "Numerical Heat Transfer and Fluid Flow", S.V. Patankar, McGraw-Hill, New York, 1980.
5. "Principles of Computational Fluid Dynamics", P. Wesseling, Springer-Verlag.
6. "Computational Techniques for Fluid Dynamics Volume I & II" (2nd edition), C.A.J. Fletcher, Springer-Verlag, 1991.
7. "Computational Fluid Mechanics and Heat Transfer" (2nd edition), J.C. Tannehill, D.A. Anderson and R.H. Pletcher, Taylor and Francis, 1997.
8. "Numerical Computation of Internal and External Flows" (Vols. I & II), C. Hirsch, Wiley International, 1988.
9. "Computational Fluid Dynamics for Engineers" (Vols. I & II), K. Hoffmann and S. T. Chiang, Engineering Education System, 1993.

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Programme Name	**Pre-Ph.D. Course Work**	Programme Code	23-40
Course Code	DSE704 (iii)	Credit	3
Year/Sem	1/1	L-T-P	3-0-0
Course Name	Mechanical Behaviour of Materials		

Objectives of the Course:

1. The description of the physical mechanisms and/or mechanical behavior of monocrystals and polycrystals under elastic & plastic deformation.
2. The different mechanisms of material failures (fracture, fatigue and creep) and their relationship with the different types of stress.

UNIT I (Total Topics-12 and Hrs-10)

Introduction, overview of the subject and fundamentals of the atomic structure and types of bonding in different classes of materials and its relation to the physical and mechanical properties.

Elasticity - Analysis of stress, State of stress at a point, Normal and shear stress components, Stress components on an arbitrary plane, Principal stresses, Plane stress & amp; Plane strain, Generalized Hooke's law, Atomic equivalent of Hooke's law, Elastic behavior of anisotropic and isotropic materials.

UNIT II(Total Topics- 14 and Hrs-10)

Plastic deformation in single & amp; polycrystalline, semi crystalline materials, strengthening mechanisms in solids, Work hardening, Solid solution strengthening, Grain boundary strengthening, Particle hardening, High temperature deformation of amorphous; crystalline materials, Mechanical testing- A review, Common states of stress in real life, Tension, Indentation, Compression, Torsion, Bending.

UNIT- III (Total Topics- 9 and Hrs- 10)

Fracture of solids/Fracture mechanics - Linear elastic stress field in cracked bodies – Crack deformation modes, - Singular stress field and displacement fields, Stress intensity factor solutions - Crack growth based on energy balance - Griffith's criterion for brittle fracture - Strain energy release rate, Stress intensity factor equivalence - Crack stability, R curves.

UNIT-IV (Total Topics-7 and Hrs- 10)

J integral concepts – Critical stress intensity factor fracture criterion -Fracture criterion - Experimental determination of fracture toughness (K_{IC})- Non-linear fracture - Toughening mechanisms (in ceramics).

Creep, mechanisms of creep, Creep of pure metals, solid solutions, MMCs, Creep of ceramics and polymers, creep asymmetry. Super plasticity in materials.

Course Outcomes (CO)

1. ME-104 (8) -CO1: Eexplain the fundamentals of various properties of materials and their application for engineering design.
2. ME -104 (8) -CO2: Understand the different strengthening mechanism and plastic deformation process of the single crystal and amorphous materials.
3. ME -104 (8) -CO3: Recognize the type of fracture in different materials and analysis of different crack growth.
4. ME -104 (8) -CO4: understand the different parameters involve in the plastic deformation of the materials.
5. ME -104 (8) -CO5: Analyse the fatigue failure in different engineering materials and the mode of failures and their classification.

Reference Books

1. Mechanical Behavior of Materials, Engineering methods for Deformation, Fracture and Fatigue, 4th Edition. Norman E. Dowling
2. Mechanical Behavior of Materials, 2nd Edition. Marc Meyers and Krishan Chawla
3. Mechanical Behavior of Materials, 2nd Edition, Thomas H. Courtney