INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

MECHANICAL ENGINEERING

COURSE DESCRIPTION FORM

Course Title	**FINITE ELEMENT METHODS**			
Course Code	**A60330**			
Regulation	**R15-JNTUH**			
Course Structure	Lectures	Tutorials	Practicals	Credits
	4	1	-	4
Course Coordinator	Prof. V. V. S. H. Prasad, Professor, Department of Mechanical Engineering			
Team of Instructors	Mr. C. Labesh Kumar, Assistant Professor.			

I. COURSE OVERVIEW:

The aim of this course is to introduce basic principles of Numerical methods and it is further extended to cover the application of finite element method by the inclusion of 1D bar elements truss elements beam elements 2D elements like CST, ring elements. Nowadays the principles of finite element method find wide applications in many engineering fields like mechanical engineering, aerospace, civil engineering, nuclear engineering, bio mechanics etc. The course deals with the Raleigh-ritz (PMPE) and galerkin approaches. The objective of the course is determined structural deformations strains element stress and heat transfer problems.

II. PREREQUISITE(S):

Level	Credits	Periods / Week	Prerequisites
UG	4	5	Mechanics of solids, Heat transfer.

III. MARKS DISTRIBUTION:

Sessional Marks (25)	University End Exam Marks	Total Marks
Continuous Assessment Tests (Midterm examinations): There shall be 2 midterm examinations. Each midterm examination consists of one objective paper, one subjective paper and one assignment. The objective paper is for 10 marks and subjective paper is for 10 marks, with duration of 1 hour 20 minutes (20 minutes for objective and 60 minutes for subjective paper). Objective paper is set for 20 bits of – multiple choice questions, fill-in the blanks, 10 marks. Subjective paper contains of 4 full questions (one from each unit) of which, the student has to answer 2 questions, each question carrying 5 marks. First midterm examination shall be conducted for 2.5 units of syllabus and second midterm examination shall be conducted for another 2.5 units. 5 marks are allocated for Assignment. First one assignment should be submitted before the conduct of the first mid, and the second one assignment should be submitted before the conduct of the second mid. The total marks secured by the student in each midterm examination are evaluated for 25 marks, and the average of the two midterm examinations shall be taken as the final marks secured by each candidate.	75	100

IV. EVALUATION SCHEME:

S. No.	Component	Duration	Marks
1	I Mid Examination	1 hour and 20 min	20
2	I Assignment		5
		TOTAL	**25**
3	II Mid Examination	1 hour and 20 min	20
4	II Assignment		5
		TOTAL	**25**
MID Examination marks to be considered as average of above 2 MID's TOTAL			
5	EXTERNAL Examination	3 hours	75
		GRAND TOTAL	**100**

V. COURSE OBJECTIVES:

The objectives of the course are to enable the student:

I. Introduction of Finite Element Method (FEM) which is one of the Numerical Methods with which solutions can be obtained for problems with complex geometries, material properties and boundary conditions.

II. Utility of FEM as Engineering solution tool to problems (both vector and scalar) involving various fields for Design Analysis and Optimization.

III. Development of Mathematical Model (Governed by Differential equations) for physical problems and concept of discretization of continuum.

IV. Ability to understand, to improve or refine the approximate solution by spending more computational effort by using higher interpolation continuities unlike expensive experimental methods / exact solutions

VI. COURSE OUTCOMES:

At the end of this course, the student shall have:

1. An understanding of Numerical Methods and development of mathematical models for physical system using principle of minimum potential energy / principle of Virtual Work
2. A generalized procedure FEM comprising element attributes, types, different types of boundary conditions and interpolation functions for 1D
3. An understanding about thermal stress and initial stress in the structural problems.
4. Application of FEM to simple bars, Trusses, Beams, for determining displacement / stresses induced / initial strain problems
5. Development of LST/CST triangular 2D elements for structural problems and thermal problems.
6. Determination of strain displacement matrix for ring elements/axis-symmetric elements applied to pressure vessels and shrink fit shaft assemblies.
7. Introduction of numerical integration for quadrilateral/isoperimetric boundary elements for gauss quadrature integration to determine strain displacement matrix.
8. Application of Jacobin matrix for 2D elements
9. Introduction of 3D tertrahydran elements and determination of Jacobin partial strain matrix.
10. Development of conductance matrix for conduction, convective heat transfer for 1D elements 2D fin elements.
11. Estimation of eigen values and eigen vectors for steeped bar and beam elements for dynamic analysis
12. FEM as a tool for Design Validation of complex physical Engineering Applications.

VII. HOW COURSE OUTCOMES ARE ASSESSED:

Program Outcomes		Level	Proficiency assessed by
PO1	**Engineering knowledge**: Capability to apply the knowledge of Mathematics, Science and Engineering in the field of Mechanical Engineering.	H	Assignments, Mid-term, End Exams
PO2	**Problem analysis**: An ability to analyze complex engineering problems to arrive at relevant conclusions using knowledge of Mathematics, Science and Engineering.	H	Design Lab on Ansys
PO3	**Design/development of solutions**: Competence to design a system, com ponent or process to meet societal needs within realistic constraints.	S	Guest Lectures
PO4	**Conduct investigations of complex problems**: To design and conduct research oriented experiments as well as to analyze and implement data using research methodologies.	H	--
PO5	**Modern tool usage**: An ability to formulate, solve complex engineering problems using modern engineering and Information Technology tools.	S	--
PO6	**The engineer and society**: To utilize the Engineering practices, Techniq ues, skills to meet needs of the health, safety, legal, cultural and societal issues.	S	Assignments, Mid-term, End Exams
PO7	**Environment and sustainability**: To understand impact of Engineering solutions in the societal context and demonstrate the knowledge for sustainable development.	H	Assignments, Mid-term, End Exams
PO8	**Ethics**: An understanding and Implementation of professional and Ethical responsibilities.	H	--
PO9	**Individual and teamwork**: To function as an effective individual and as a member or leader in Multi-disciplinary environment and adopt in diverse teams.	H	Guest Lectures
PO10	**Communication**: An ability to assimilate, comprehends, communicate, give and receive instructions to present effectively with engineering community and society.	S	Assignments, Mid-term, End Exams
PO11	**Project management and finance**: An ability to provide leadership in managing complex engineering projects at Multidisciplinary environme nt and to become a professional engineer.	H	Guest Lectures
PO12	**Life-long learning**: Recognition of the need and an ability to engage in life-long learning to keep abreast with technological changes.	S	Design Lab on Ansys

S = Supportive **H = Highly Related** **N = None**

VIII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes		Level	Proficiency assessed by
PSO1	**Professional Skills:** To produce engineering professional capable of synt hesizing and analyzing mechanical systems including allied engineering s treams.	H	Guest Lectures
PSO2	**Design/Analysis:** An ability to adopt and integrate current technologies in the design and manufacturing domain to enhance the employability.	S	Assignments, Mid-term, End Exams
PSO3	**Successful Career and Entrepreneurship:** To build the nation, by imparting technological inputs and managerial skills to become Technocrat.	H	Design Lab on Ansys

N-None **S-Supportive** **H- Highly Related**

IX. SYLLABUS:

UNIT -I
Introduction to FEM for solving field problems. Basic equations of elasticity, Stress – Strain and strain - displacement relations for 2D-3D elastic problems. Boundary conditions
One Dimensional problems : Finite element modeling coordinates and shape functions. Assembly of Global stiffness matrix and load vector. Finite element equations - Quadratic shape functions
UNIT –II
Analysis of Trusses
Stiffness matrix for plane Truss Elements, stress calculations and problems.

Analysis of beams: Element stiffness matrix for two nodes, two degrees of freedom per node beam element and simple problems.

UNIT -III
Finite element modeling of two dimensional stress analysis with constant strain triangles and treatment of boundary conditions. Estimation of load Vector, stresss.
Finite element modeling of Ax symmetric solids subjected to Axi symmetric loading with triangular elements
Two dimensional four noded iso parametric elements

UNIT – IV

Steady state Heat Transfer Analysis: 1-D Heat conduction of slab,– 1D fin elements – 2D heat conduction - analysis of thin plates –Analysis of a uniform shaft subjected to torsion- problems.

UNIT -V
Dynamic Analysis: Dynamic equations – Lumped and consistent mass matrices – Eigen Values and Eigen Vectors for a stepped bar, truss –
Finite element-formulation to 3D problems in stress analysis, convergence requirements, mesh generation, techniques such as semi automatic AND fully automatic use of software such as ANSYS, NISA, NASTRAN etc.

TEXT BOOKS:

T1. The finite element methods in Engineering – S.S. Rao – Elsevier – 4th edition
T2. Introduction to finite elements in engineering – Tirupathi K. Chandrupatla and Ashok D. Belagundu.

REFERENCES:

R1. Finite Element Methods/ Alavala/TMH

R2. An Introduction to Finite Element Methods – J. N. Reddy – Mc Grawhill

R3. The Finite element method in engineering science – O.C. Zienkowitz, Mc Grawhill.

R4. Concepts and applications of finite element analysis – Robert Cook – Wiley

R5. Introduction of Finite Element Analysis – S.Md.Jalaludeen – Anuradha publications

X. COURSE PLAN:

The course plan is meant as a guideline. There may probably be changes.

Lecture No.	Course Learning Outcomes	Topics to be covered	Reference
1-5	Recognize the need for FEM and applications. Prepare Flow chart for FEM	**Introduction to FEM:** basic concepts, historical back ground, application of FEM, general description,	T1 – 4- Ex 1.1 T1 – 10 Table 1.1
6	Interpret Results with other methods	comparison of FEM with other methods	R5 – 3.2
7-10	Review of Mechanics of Solids fundamentals. Compare problem formulation of by PMPE	Basic equations of elasticity, Stress – Strain and strain - displacement relations.	R1 – 1.5
11-13	Distinguish between RR method and Weighted Residual Methods	Finite element modeling coordinates and shape functions	R5 – 3.4.1 – Ex 3.1 & 3.2
14-17	Sketch 1-D bar element. Develop interpolation model. Setup intrinsic co-ordinate System	Stiffness equations for a axial bar element in local co-ordinates using Potential Energy approach and Virtual energy principle	R1 – 3.1 & 3.7
18-21	Develop FEM equations Assemble [K] Matrix	Finite element modeling coordinates and shape functions	R1 – 3.1 & 3.7
22-23	Review of Matrix Algebra Manipulate the Boundary Conditions	Assembly of Global stiffness matrix and load vector -	R1 – 3.6
24-26	Select the Quadratic Shape Function for [K] Matrix and Compare above	Quadratic shape functions - properties of stiffness matrix.	R1 – 3.8
27	Construct [K] matrix for Truss Element Extend [K] for 3-D Truss Element	Stiffness equations for a truss bar element oriented in 2D plane Finite Element Analysis of Trusses	R1 – 4.1 & 4.3
28	Practice Node numbering and Analysis Stresses	– Finite Element Analysis of Trusses –	R1 – Ex – 4.1
29	Evaluate Stresses for Different Loading Conditions	Plane Truss and Space Truss elements. problems	R1 – Ex – 4.2
30 - 32	Synthesize the Beam Identify the D.O.F Develop the Shape Function Determine [K] Matrix	**Analysis of beams:** Element stiffness matrix – degress of freedom	R1 –5.1 & 5.4, T – 9.3
33 - 34	Assemble [K] [d] = [F] Apply Different Loads Construct SF & BM plots Evaluate the Bending Stress	Load vector – Problems.	R1 – 5.5 & 5.7
36 - 37	Determine Strain Matrix in CST	**2-D problems:** CST - Stiffness matrix and load vector	R1 – 8.1, 8.3, 8.5

Lecture No.	Course Learning Outcomes	Topics to be covered	Reference
	Point Out for naming on CST		Ex – 8.1 – 8.4
38	Need for Isoparametric Element, Boundary Element Representation	Isoparametric element representation.	T1 – 4.9 R1 – 9.1 & 9.5
39	Quadrilateral Element representation Indentify nodes and Shape Functions	Shape functions	R1 – 9.5
40	Indentify nodes and Shape Functions	Nodes and shape functions	R1 – 9.5 T1 – 3.6
41 – 42	Explain Jacobian and Inverse Jacobian of above	Two dimensional four noded is oparametric elements.	T1 – 4.9 R1 – 10.2
43	Need for Numerical Integration Formulate 1P, 2P, 3P, 4P Numerical Integration Methods	Numerical integration	T1 – 4.10
44 - 45	Explain Polar Co-ordinates and Applications Develop [B] Matrix	Finite element modelling of Axisymmetric solids subjected to Axisymmetric loading with triangular elements.	R1 – 11.1 & 11.6 Ex – 11.1 & 11.2
46 - 47	**Introduction** of 3D – element and Estimate [B] Matrix	3-D problems – Tetrahedran element	R1 – 12.1 & 12.2
48-49	Formulate 1-D Scalar Problem for conduction Explain Heat Flux Fix Boundary Conditions	**Steady state heat transfer analysis:** 1-D Heat conduction – 1D fin **elements**	R1 15.1 R1 Ex 15.1 R1 15.3 R1 Ex 15.2
50	Compare 1D & 2D Problems	2D heat conduction - analysis of thin plates.	R1 15.3
51	Predict Uniform shaft subjected to torsion	Uniform shaft subjected to torsion - problems.	R1 Ex 15.3
52-53	Outline Dynamic Analysis Develop from First Principle the Governing Equation	**Dynamic Analysis:** Dynamic equations	R1 13.1
54	Compare and contrast between two types of masses	Lumped and consistent mass matrices	R1 13.2
55	Outline the standard procedure for Eigen Value / Eigen Vector Problems (Characteristics Equations)	Eigen Values and Eigen Vectors	R1 13.5
56	Interpret the mode shape	mode shapes	R1 Ex 13.1
57	Predict “ω” for bars	modal analysis for bars	R1 13.1
58-59	Predict “ω” for beams	modal analysis for beams	R1 13.7
60-62	Analyze the mode shapes	convergence requirements – Problems	R1 Ex 13.1
63-65	Express in terms of Area / Length	Problems on stepped bar	R1 Ex 13.1
66-67	Express in terms of MI/E	Problems on beams	R1 Ex 13.1
68-69	Summarize the Dynamic Analysis	Problems with different loading conditions	R1 Ex 13.8

XI. MAPPING COURSE OBJECTIVES LEADING TO ACHIEVEMENT OF THE PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Course Objectives	Program outcomes												Program Specific Outcomes		
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
I	H						S								H
II			S	H		H				S	S	H	H		
III		H	S		H		H	H	H					H	
IV							H								

S=Supportive **H=Highly Related**

XII. MAPPING COURSE OUTCOMES LEADING TO ACHIEVEMENT OF THE PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Course Outcomes	Program Outcomes												Program Specific Outcomes		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
1	S	H					H								H
2			H							H				H	
3				S		S			S			H	H		
4			H		S			H			H				
5															
6						H									
7						S									
8								H							
9						S								H	
10															
11		S										S			
12										H					S

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Prepared by
Mr. C. Labesh Kumar, Assistant Professor.
Prof. V.V. S. H. Prasad, Professor.

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