INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTION FORM

Course Title	**FINITE ELEMENT METHODS**			
Course Code	**A60330**			
Regulation	**R15 - JNTUH**			
Course Structure	Lectures	Tutorials	Practicals	Credits
	4	-	-	4
Course Coordinator	Mr. G. S. D Madhav, Asst. Professor, Dept of AE			
Team of Instructors	Ms Y Shwetha, Asst. Professor, Dept of AE Mr. G. S. D Madhav, Asst. Professor, Dept of AE			

I. COURSE OVERVIEW:

The Finite Element Method (FEM) is widely used in industry for analyzing and modeling structures and continua, whose physical behavior is described by ordinary and partial differential equations. The FEM is particularly useful for engineering problems that are too complicated to be solved by classical analytical methods. The main objective of this course is to introduce the mathematical concepts of the Finite Element Method for obtaining an approximate solution of ordinary and partial differential equations. In this course you will attend lectures on the fundamentals of the Finite Element Method. The learning process will be enhanced by completing assignments using mathematical software. You will also be introduced to a commercial Finite Element software package

II. PREREQUISITE(S):

Level	Credits	Periods / Week	Prerequisites
UG	4	5	Mathematics, Engineering Mechanics, Mechanics of solids, Thermodynamics

III. MARKS DISTRIBUTION:

Sessional Marks (25)	University End Exam Marks	Total Marks
Continuous Assessment Tests (Midterm examinations): **Mid Semester Test** There shall be two midterm examinations. Each midterm examination consists of subjective type and objective type tests. The subjective test is for 10 marks of 60 minutes duration. Subjective test of shall contain 4 questions; the student has to answer 2 questions, each carrying 5 marks. The objective type test is for 10 marks of 20 minutes duration. It consists of 10 Multiple choice and 10 objective type questions, the student has to answer all the questions and each carries half mark. First midterm examination shall be conducted for the first two and half units of syllabus and second midterm examination shall be conducted for the remaining portion	75	100

IV. EVALUATION SCHEME:

S. No	Component	Duration	Marks
1.	I Mid Examination	80 minutes	20
2.	I Assignment	-	5
3.	II Mid Examination	80 minutes	20
4.	II Assignment	-	5
5.	External Examination	3 hours	75

V. COURSE OBJECTIVES:

The Course objectives will enable the student to

I. Introduce basic aspects of finite element technology, including domain discretization, polynomial interpolation, and application of 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 for physical problems and concept of discretization of continuum.

IV. 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 the semester Course will enable the student to

1. Identify mathematical model for solution of common engineering problems.
2. Understand the selection of element types for various applications of engineering problems.
3. Formulate simple problems into finite elements and Solve structural, thermal problems.
4. Use professional-level finite element software to solve engineering problems in Solid mechanics, fluid mechanics and heat transfer.
5. Understand the use of the basic finite elements for structural applications using truss, beam, frame, and plane elements
6. Understand the Numerical Methods and development of mathematical models for physical system.
7. Derive element matrix equation by different methods by applying basic laws in mechanics and integration by parts.
8. Use the FEM to simple bars, Trusses, Beams, Solids of Revolutions, Frequency analysis and Heat Transfer.
9. Model multi-dimensional heat transfer problems using ANSYS
10. Demonstrate the ability to evaluate and interpret FEA analysis results for design and evaluation purposes
11. Develop a basic understanding of the limitations of the FE method and understand the possible error sources in its use.
12. Solve the mass matrices and understand the importance of Eigen value problems.
13. Analyze three dimensional stress analysis and convergence techniques using software's.
14. Understand mesh generation techniques of different analysis software's such as ANSYS, NASTRAN.

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
PO2	**Problem analysis**: An ability to analyze complex engineering problems to arrive at relevant conclusions using knowledge of Mathematics, Science and Engineering.	H	Assignments
PO3	**Design/development of solutions**: Competence to design a system, com ponent or process to meet societal needs within realistic constraints.	H	Micro Projects
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	Micro Projects
PO5	**Modern tool usage**: An ability to formulate, solve complex engineering problems using modern engineering and Information Technology tools.	H	Certification
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.	-	
PO7	**Environment and sustainability**: To understand impact of Engineering solutions in the societal context and demonstrate the knowledge for sustainable development.	-	
PO8	**Ethics**: An understanding and Implementation of professional and Ethical responsibilities.	-	
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.	-	
PO10	**Communication**: An ability to assimilate, comprehends, communicate, give and receive instructions to present effectively with engineering community and society.	-	
PO11	**Project management and finance**: An ability to provide leadership in managing complex engineering projects at Multidisciplinary environm ent and to become a professional engineer.	S	Assignments
PO12	**Life-long learning**: Recognition of the need and an ability to engage in life-long learning to keep abreast with technological changes.	-	

S = Supportive **H = Highly Related**

VIII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes		Level	Proficiency assessed by
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	H	Assignments
PO 2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	H	Assignments
PO 3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental	S	Mini Project
PO 4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	S	Open ended experiments /

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IX. SYLLABUS:

UNIT -I

Introduction to Finite Element Method for solving field problems. Stress and Equilibrium. Boundary conditions. Strain - displacement relations. Stress-strain relations for 2-D and3-D elastic problems.

One Dimensional Problems : Finite element modeling coordinates and shape functions. Assembly of Global stiffness matrix and load vector. Finite element equations – Treatment of boundary conditions, 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 noded, 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 Axi-symmetric solids subjected to Axi-symmetric loading with triangular elements.Two dimensional four noded isoparametric elements and problems.

UNIT – IV

Steady state Heat Transfer Analysis: one dimensional analysis of slab, fin and two dimensional analysis of thin plate. Analysis of a uniform shaft subjected to torsion.

UNIT -V

Dynamic Analysis: Formulation of finite element model, element –Mass matrices, evaluation of Eigen values and Eigen Vectors for a stepped bar, truss.

Finite element-formulation to 3D problems in stress analysis, convergence requirements, mesh eneration, 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 R. Chandrupatla and Ashok D. Belegundu.

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 – 2.1
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
14-17	Sketch 1-D bar element. Develop interpolation model. Setup intrinsic	Stiffness equations for a axial bar element in local co-ordinates using	R1 – 3.1 & 3.7

Lecture No.	Course Learning Outcomes	Topics to be covered	Reference
	co-ordinate System	Potential Energy approach and Virtual energy principle	
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 –4.1
29	Evaluate Stresses for Different Loading Conditions	Plane Truss and Space Truss elements. problems	R1 –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 Point Out for naming on CST	2-D problems: CST - Stiffness matrix and load vector	R1 – 8.1, 8.3, 8.5
38	Need for Isoparametric Element, Boundary Element Representation	Isoparametric element representation	T1 – 4.9 R1 – 9.1
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 isoparametric 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 & 11.2
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 15.3
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- 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	Eigen Values and Eigen Vectors	R1 13.5
56	Interpret the mode shape	mode shapes	R1 - 13.1
57	Predict “ω” for bars	modal analysis for bars	R1- 13.1

Lecture No.	Course Learning Outcomes	Topics to be covered	Reference
58-59	Predict "ω" for beams	modal analysis for beams	R1- 13.7
60-62	Analyze the mode shapes	convergence requirements – Problems	R1- 13.1
63-65	Express in terms of Area / Length	Problems on stepped bar	R1 - 13.1
66-67	Express in terms of MI/E	Problems on beams	R1 - 13.1
68-69	Summarize the Dynamic Analysis	Problems with different loading conditions	R1- 13.8

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

Course Objectives	Program Outcomes												Program Specific Outcomes			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
I	H	H											H			
II												H		H		
III		H												S		
IV	H			H									H			

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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	PSO4
1	H												H			
2	H		H											H		
3		H		S	S							S				
4														H		
5		H		H								S	H			
6					H									H		H
7		H														
8	H			S								S	H			
9		H													H	
10				H												H
11			H		H							S		H		
12		H											H			
13	H														H	
14				H												

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