INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

MECHANICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**FINITE ELEMENT MODELLING**				
Course Code	AME014				
Programme	B. Tech				
Semester	VI	ME			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	Mrs. V. Prasanna, Assistant Professor, ME				
Course Faculty	Mrs. V. Prasanna, Assistant Professor, ME				

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. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AME002	II	Engineering Mechanics	4
UG	AME004	III	Mechanics of Solids	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Finite Element Modelling	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✘	Chalk & Talk	✔	Quiz	✔	Assignments	✘	MOOCs
✔	LCD / PPT	✔	Seminars	✘	Mini Project	✔	Videos
✘	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into five units and each unit carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each unit. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 1), with 25 marks for Continuous Internal Examination (CIE), 05 marks for Quiz/ Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	Theory		Total Marks
Type of Assessment	CIE Exam	Quiz / AAT	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration consisting of two parts. Part–A shall have five compulsory questions of one mark each. In part–B, four out of five questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz / Alternative Assessment Tool (AAT):

Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are be answered by choosing the correct answer from a given set of choices (commonly four). Marks shall be awarded considering the average of two quizzes for every course. The AAT may include seminars, assignments, term paper, open ended experiments, five minutes video.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO1	**Engineering Knowledge**: Capability to apply the knowledge of mathematics, science and engineering in the field of mechanical engineering.	**3**	Assignments
PO2	**Problem Analysis:** An ability to analyze complex engineering problems to arrive at relevant conclusion using knowledge of mathematics, science and engineering.	**2**	Assignments
PO3	**Design/development of solutions:** Competence to design a system, component or process to meet societal needs within realistic constraints.	**2**	Seminars
PO5	**Modern tool usage:** An ability to formulate solve complex engineering problem using modern engineering and information Technology tools.	**2**	Videos

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO1	**Professional Skills:** To produce engineering professional capable of synthesizing and analyzing mechanical systems including allied engineering streams.	**2**	Assignments
PSO2	**Problem solving skills**: An ability to adopt and integrate current technologies in the design and manufacturing domain to enhance the employability.	**3**	Seminars
PSO3	**Successful career and Entrepreneurship**: To build the nation, by imparting technological inputs and managerial skills to become technocrats.	**2**	Guest Lectures

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES (COs):

I	Introduce basic concepts of finite element methods including domain discretization, polynomial interpolation and application of boundary conditions.
II	Understand the theoretical basics of governing equations and convergence criteria of finite element method.
III	Develop of mathematical model for physical problems and concept of discretization of continuum
IV	Discuss the accurate Finite Element Solutions for the various field problems
V	Use the commercial Finite Element packages to build Finite Element models and solve a selected range of engineering problems

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Describe the concept of FEM and difference between the FEM with other methods and problems based on 1-D bar elements and shape functions.	CLO 1	Describe the basic concepts of FEM and steps involved in it.
		CLO 2	Understand the difference between the FEM and Other methods.
		CLO 3	Understand the stress-strain relation for 2-D and their field problem.
		CLO 4	Understand the concepts of shape functions for one dimensional and quadratic elements, stiffness matrix and boundary conditions
CO 2	Derive elemental properties and shape functions for truss and beam elements and related problems.	CLO 5	Apply numerical methods for solving one dimensional bar problems
		CLO 6	Derive the elemental property matrix for beam and bar elements.
		CLO 7	Solve the equations of truss and beam elements
		CLO 8	Understand the concepts of shape functions for beam element.
CO 3	Understand the concept deriving the elemental matrix and solving the basic problems of CST and axi-symmetric solids.	CLO 9	Apply the numerical methods for solving truss and beam problems
		CLO 10	Derive the element stiffness matrices for triangular elements and axi- symmetric solids and estimate the load vector and stresses.
		CLO 11	Formulate simple and complex problems into finite elements and solve structural and thermal problems
		CLO 12	Understand the concept of CST and LST and their shape functions.
CO 4	Explore the concept of steady state heat transfer in fin and composite slab.	CLO 13	Understand the concepts of steady state heat transfer analysis for one dimensional slab, fin and thin plate.
		CLO 14	Derive the stiffness matrix for for fin element.
		CLO 15	Solve the steady state heat transfer problems for fin and composite slab.
		CLO 16	Understand the concepts of mass and spring system and derive the equations for various structural problems
CO 5	Understand the concept of consistent and lumped mass models and slove the dynamic analysis of all types of elements.	CLO 17	Understand the concept of dynamic analysis for all types of elements.
		CLO 18	Calculate the mass matrices, Eigen values, Eigen vectors, natural frequency and mode shapes for dynamic problems.

X. COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AME014.01	CLO 1	Understand the numerical methods and development of mathematical models for physical system	PO 1	3
AME014.02	CLO 2	Identify mathematical model for solution of common engineering problems in the field of aeronautical, mechanical and civil	PO 1	3
AME014.03	CLO 3	Understand the concepts of shape functions for one dimensional and quadratic elements, stiffness matrix and boundary conditions	PO 1	3
AME014.04	CLO 4	Remember the steps involved in finite element methods while solving the model of physical problem	PO 2	2
AME014.05	CLO 5	Apply numerical methods for solving one dimensional bar problems	PO 2	2
AME014.06	CLO 6	Identify the mathematical models for two-dimensional, three-dimensional truss and beam elements	PO 2	2
AME014.07	CLO 7	Solve the equations of truss and beam elements	PO 2	1
AME014.08	CLO 8	Calculate stress strain and strain energy for common engineering problems	PO 3	1
AME014.09	CLO 9	Derive element matrix by different methods by applying basic laws in mechanics and integration by parts	PO 3	2
AME014.10	CLO 10	Demonstrate the ability to evaluate and interpret FEA analysis results for design and development purposes	PO 3	2
AME014.11	CLO 11	Formulate simple and complex problems into finite elements and solve structural and thermal problems	PO 1	3
AME014.12	CLO 12	Derive the element stiffness matrices for triangular elements and axisymmetric solids and estimate the load vector and stresses	PO 5	3
AME014.13	CLO 13	Understand the concepts of steady state heat transfer analysis for one dimensional slab, fin and thin plate	PO 5	3
AME014.14	CLO 14	Understand the concepts of mass and spring system and derive the equations for various structural problems	PO 1	3
AME014.15	CLO 15	Calculate the mass matrices; Eigen values Eigen vectors and natural frequency for dynamic problems	PO 5	2
AME014.16	CLO 16	Model multi-dimensional structural and heat transfer problems by using automatic and fully automatic software such as ANSYS, NISA, NASTRAN	PO 5	2
AME014.17	CLO 17	Understand the concept of dynamic analysis for all types of elements.	PO 1	3

AME014.18	CLO 18	Calculate the mass matrices, Eigen values, Eigen vectors, natural frequency and mode shapes for dynamic problems.	PO 2, PO 5	2

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XI. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES

Course Outcomes (COs)	Program Outcomes (POs)			
	PO 1	**PO 2**	**PO 4**	**PSO1**
CO 1	2	1		1
CO 2		2		
CO 3		1	1	1
CO 4	3			1
CO 5	1	2		1

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

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CLO 1	3												1		
CLO 2		2													
CLO 3	3												1		
CLO 4	3												1		
CLO 5		2													
CLO 6		2													
CLO 7		2													
CLO 8		2													
CLO 9				1											
CLO 10				1											
CLO 11		2											1		
CLO 12		2											1		
CLO 13	3														
CLO 14	3														

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CLO 15	3														
CLO 16	3												1		
CLO 17	3														
CLO 18		2			1									2	

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XIII. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO1,PO2, PO4, PSO1	SEE Exams	PO1, PO2, PO4, PSO1	Assignments	-	Seminars	PO1, PO2, PO4, PSO1
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	PO1, PO2, PO4, PS01						

XIV. ASSESSMENT METHODOLOGIES - INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✘	Assessment of Mini Projects by Experts		

XV. SYLLABUS

Unit-I	**INTRODUCTION TO FEM**
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 problem, 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 AND BEAMS**
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	**2-D ANALYSIS**
Finite element modeling of two-dimensional stress analysis with constant strain triangles and treatment of boundary conditions, estimation of load vector, stresses. Finite element modeling of axisymmetric solids subjected to axisymmetric loading with triangular elements, two-dimensional four node iso parametric elements.	
Unit-IV	**STEADY STATE HEAT TRANSFER ANALYSIS**
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 analysis: Dynamic equations, lumped and consistent mass matrices, Eigen values and Eigen vectors for a stepped bar, beam; 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.	

Text Books:

1. Tirupathi K., Chandrapatla, Ashok D. Belagundu, ―Introduction to Finite Elements in Engineering, 1st Edition, 2013.
2. S. S. Rao, ―The Finite Element Methods in Engineering, Elsevier, 4th Edition, 2013.
3. J. N. Reddy, ―An Introduction to Finite Element Methods, McGraw-Hill, 1st Edition, 2013.

Reference Books:

1. Alavala, ―Finite Element Methods‖, TMH, 1st Edition, 2012.
2. O.C. Zienkowitz, ―The Finite Element Method in Engineering Science‖, McGraw-Hill, 1st Edition, 2013.
3. Robert Cook, ―Concepts and Applications of Finite Element Analysis‖, Wiley, 1st Edition, 2013.
4. S. Md. Jalaludeen, ―Introduction of Finite Element Analysis‖, Anuradha publications, 1st Edition, 2010.

XVI. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1-2	Introduction to Finite Element Method for solving field problems	CLO 1	T1:1.4 R1:1.2
3-5	Stress and Equilibrium. Boundary conditions. Strain - displacement relations	CLO 1	T1:1.5 R1:2.4
6-7	One Dimensional Problems: Finite element modeling coordinates	CLO 2	T1:2.5 R1:2.5
7-8	Shape functions, Quadratic shape functions	CLO 3	T1:2.5 R1:2.6
9-11	Assembly of Global stiffness matrix and load vector	CLO 4	T1:22.7
12-13	Finite element equations – Treatment of boundary conditions	CLO 4	T1:6.3 R1:5.3
14-16	Analysis of Trusses: Stiffness matrix for plane Truss Elements stress calculations and problems	CLO 5	T1:6.6 R1:5.3.6
17-19	Analysis of beams: Element stiffness matrix for two noded, two degrees of freedom per node beam element	CLO 6	R1:6.2
20-22	Finite element modeling of two-dimensional stress analysis with constant strain triangles	CLO 7	T1:7.5 R1:6.3
23-25	Treatment of boundary conditions. Estimation of load vector and stresses	CLO 8	T1:8.5 R1:6.8
26-30	Finite element modeling of Axisymmetric solids	CLO 9	T1:12.2 R1:13.1
31-33	Axisymmetric solids subjected to Axisymmetric loading with triangular elements	CLO 10	T1:12.3 R1:13.2
33-34	Two dimensional four noded isoparametric elements, Problems	CLO 11	T1:12.10 R1:13.7
35-38	Steady state Heat Transfer Analysis One dimensional analysis of slab	CLO 12	T1:11.2 R1:10.2

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
38-40	Fin and two-dimensional analysis of thin plate Analysis of a uniform shaft subjected to torsion	CLO 13	T1:11.5 R1:10.3
40-43	Evaluation of Eigen values and Eigen Vectors for a stepped bar, truss	CLO 14	T1:11.12 R1:11.9
44-46	Finite element-formulation to 3D problems in stress analysis convergence requirements, mesh generation	CLO 15	T1:11.8 R1:11.5
47-49	Finite element-formulation to 3D problems in stress analysis	CLO 16	T1:9.9
50-53	Derive the mass matrix for all elements	CLO 17	T1:12.1-12.2
54-56	Evaluation of Eigen values and Eigen Vectors for a stepped bar, truss	CLO 18	T1:11.3 T2:16.13
57-59	Techniques such as semi-automatic and fully automatic use of software such as ANSYS, NISA, NASTRAN	CLO 18	T1:12.3 R1:11.3

XVII. GAPS IN THE SYLLABUS - TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S NO	Description	Proposed actions	Relevance with POs	Relevance with PSOs
1	Gain information about space frames used in the modeling of car body and bicycle frames.	Seminars	PO 1, PO 2	PSO 3
2	Encourage students to perform analysis on composite materials using FEM applications.	Guest Lectures	PO 1, PO 3, PO 5	PSO 2

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