INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**FINITE ELEMENT METHODS**				
Course Code	AAE009				
Programme	B.Tech				
Semester	V	AE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	Mr. S.Devaraj, Assistant Professor				
Course Faculty	Mr. S.Devaraj, Assistant Professor Ms. CH.Ragha Leena, Assistant Professor				

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	AHS002	I	Linear Algebra and Ordinary Differential Equations	4
UG	AAE002	III	Theory of structures	4

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Finite Element Methods	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 modules and each module 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 module. 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
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Presentation on real-world problems
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	2	Seminar
PO 5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	1	Assignment

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Professional skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products	-	-
PSO 2	**Problem-solving Skills:** Imparted through simulation language skills and general purpose CAE packages to solve practical, design and analysis problems of components to complete the challenge of airworthiness for flight vehicles.	2	Lectures and Assignment
PSO 3	**Practical implementation and testing skills:** Providing different types of in house and training and industry practice to fabricate and test and develop the products with more innovative technologies	-	-
PSO 4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats.	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES :

The course should enable the students to:	
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
		CLO 5	Apply numerical methods for solving one dimensional bar problems

COs	Course Outcome	CLOs	Course Learning Outcome
CO 2	Derive elemental properties and shape functions for truss and beam elements and related 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.
		CLO 9	Apply the numerical methods for solving truss and beam problems
CO 3	Understand the concept deriving the elemental matrix and solving the basic problems of CST and axi-symmetric solids	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.
CO 5	Understand the concept of consistent and lumped mass models and slove the dynamic analysis of all types of elements.	CLO 16	Understand the concepts of mass and spring system and derive the equations for various structural problems
		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
AAE009.01	CLO 1	Describe the basic concepts of FEM and steps involved in it.	PO 1	3
AAE009.02	CLO 2	Understand the difference between the FEM and Other methods.	PO 1	3
AAE009.03	CLO 3	Understand the stress-strain relation for 2-D and their field problem.	PO 1	3
AAE009.04	CLO 4	Understand the concepts of shape functions for one dimensional and quadratic elements, stiffness matrix and boundary conditions	PO 1	3
AAE009.05	CLO 5	Apply numerical methods for solving one dimensional bar problems	PO 2, PO 5	2
AAE009.06	CLO 6	Derive the elemental property matrix for beam and bar elements.	PO 2	2
AAE009.07	CLO 7	Solve the equations of truss and beam elements	PO 2, PO 5	2
AAE009.08	CLO 8	Understand the concepts of shape functions for beam element.	PO 1	3
AAE009.09	CLO 9	Apply the numerical methods for solving truss and beam problems	PO 2, PO 5	2
AAE009.10	CLO 10	Derive the element stiffness matrices for triangular elements and axi- symmetric solids and estimate the load vector and stresses.	PO 2	2

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AAE009.11	CLO 11	Formulate simple and complex problems into finite elements and solve structural and thermal problems	PO 2, PO 5	2
AAE009.12	CLO 12	Understand the concept of CST and LST and their shape functions.	PO 1	3
AAE009.13	CLO 13	Understand the concepts of steady state heat transfer analysis for one dimensional slab, fin and thin plate.	PO 1	3
AAE009.14	CLO 14	Derive the stiffness matrix for for fin element.	PO 2	2
AAE009.15	CLO 15	Solve the steady state heat transfer problems for fin and composite slab.	PO 2, PO 5	2
AAE009.16	CLO 16	Understand the concepts of mass and spring system and derive the equations for various structural problems	PO 1, PO 2	3
AAE009.17	CLO 17	Understand the concept of dynamic analysis for all types of elements.	PO 1	3
AAE009.18	CLO 18	Calculate the mass matrices, Eigen values, Eigen vectors, natural frequency and mode shapes for dynamic problems.	PO 2, PO 5	2

3= High; 2 = Medium; 1 = Low

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

Course Outcomes (COs)	Program Outcomes (POs)			Program Specific Outcomes (PSOs)
	PO 1	PO 2	PO 5	PSO 2
CO 1	3	2	1	2
CO 2	3	2	1	2
CO 3	3	2	1	
CO 4	3	2	1	
CO 5	3	2	1	2

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

CLOs	Program Outcomes (POs)												Program Specific Outcomes (PSOs)			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CLO 1	3															
CLO 2	3															
CLO 3	3															
CLO 4	3															
CLO 5		2			1									2		
CLO 6		2														

CLOs	Program Outcomes (POs)												Program Specific Outcomes (PSOs)			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CLO 7		2			1											
CLO 8	3															
CLO 9		2			1									2		
CLO 10		2														
CLO 11		2			1											
CLO 12	3															
CLO 13	3															
CLO 14		2														
CLO 15		2			1											
CLO 16	3	2														
CLO 17	3															
CLO 18		2			1									2		

3 = High; 2 = Medium; 1 = Low

XIII. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO1, PO2, PO5, PSO2	SEE Exams	PO1, PO2, PO5, PSO2	Assignments	PO5, PSO2	Seminars	PO1, PO2, PO5, PSO2
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	PO1, PO2, PO5, PSO2						

XIV. ASSESSMENT METHODOLOGIES - INDIRECT

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

XV. SYLLABUS

Unit-I	INTRODUCTION
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 Problem: 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 AND BEAMS**
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	CONTINUUM ELEMENTS
Finite element modeling of two dimensional stress analysis with constant strain triangles and treatment of boundary conditions. Estimation of load vector and stresses. 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**
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**
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:	
1. Tirupathi. R. Chandrapatla, Ashok D. Belegundu, "Introduction to Finite Elements in Engineering", Printice Hall India, 3rd Edition, 2003. 2. Rao. S.S., "Finite Element Methods in Engineering," Butterworth and Heinemann, 2001. 3. Reddy J.N., "An Introduction to Finite Element Method", McGraw Hill, 2000.	
Reference Books:	
1. Krishnamurthy, C.S., "Finite Element Analysis", Tata McGraw Hill, 2000. 2. K. J. Bathe, E. L. Wilson, "Numerical Methods in Finite Elements Analysis", Prentice Hall of India, 1985. 3. Robert D Cook, David S Malkus, Michael E Plesha, "Concepts and Applications of Finite Element Analysis", 4th edition, John Wiley and Sons, Inc., 2003. 4. Larry J Segerlind, "Applied Finite Element Analysis", 2nd Edition, John Wiley and Sons, Inc. 1984.	

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	T2 : 1.1-1.5
3-5	Stress and Equilibrium. Boundary conditions. Strain - displacement relations.	CLO 3	T1 : 1.4-1.6; T2:1.13-1.14
6-7	One Dimensional Problems: Finite element modeling coordinates	CLO 5	T1 : 3.1-3.4, T2:6.2-6.4
7-8	Shape functions, Quadratic shape functions.	CLO 4	T1:3.9; T2:6.5
9-11	Assembly of Global stiffness matrix and load vector.	CLO 2	T1 : 3.6 R4:4.3
12-13	Finite element equations – Treatment of boundary conditions	CLO 4	T1:3.8 R2:6.4
14-16	Analysis of Trusses: Stiffness matrix for plane Truss Elements	CLO 6, CLO 9	T1: 4.2
17-19	Shape functions, stress-strain calculations and their problems	CLO 7, CLO 8	T1:4.2 R1:7.3
20-22	Analysis of beams: Element stiffness matrix for two noded, two degrees of freedom per node beam element	CLO 6, CLO 9	T1:8.1-8.5
23-25	Finite element modeling of two dimensional stress analysis with constant strain triangles	CLO 10	T1:9.1-9.3 T2:13.3

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
26-29	Treatment of boundary conditions. Estimation of load vector and stresses.	CLO 11	T1:9.2 T2:13.4
30-31	Finite element concept of CST and LST	CLO 12	T1:6.1-6.2
32-34	Axi-symmetric solids subjected to Axi-symmetric loading with triangular elements	CLO 10	T1:6.3 T2:13.6
35-36	Two dimensional four noded isoparametric elements, Problems	CLO 11	T1:7.1-7.3 T2:14.6
37-38	Steady state Heat Transfer Analysis	CLO 13	T1:10.1-10.2
39-41	One dimensional analysis of slab	CLO 15	T1:10.2 T2:17.12
42-44	Fin and two dimensional analysis of thin plate	CLO 14, CLO 15	T1:10.2 R3:5.8
45-47	Analysis of a uniform shaft subjected to torsion.	CLO 15	T1:10.3
48-51	Finite element-formulation to 3D problems in stress analysis	CLO 16	T3:11.2
52-55	Derive the mass matrix for all elements	CLO 17	T1:12.1-12.2
56-61	Evaluation of Eigen values and Eigen Vectors for a stepped bar, truss	CLO 18	T1:11.3 T2:16.13
62-64	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 / Guest Lectures	PO 1	PSO 2
2	Encourage students to perform analysis on composite materials using FEM applications	Projects	PO 5	PSO 2
3	Encourage students to solve real time applications and prepare towards competitive examinations.	NPTEL	PO 2	PSO 2

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