# INSTITUTE OF AERONAUTICAL ENGINEERING

**(Autonomous)**

Dundigal, Hyderabad -500 043

## MECHANICALENGINEERING

## COURSE DESCRIPTOR

| | | | | | |
|---|---|---|---|---|---|
| **Course Title** | **ADVANCED FINITE ELEMENT ANALYSIS** | | | | |
| **Course Code** | **BCCB11** | | | | |
| **Programme** | M. Tech | | | | |
| **Semester** | II | | | | |
| **Course Type** | Core | | | | |
| **Regulation** | IARE - R18 | | | | |
| **Course Structure** | **Theory** | | | **Practical** | |
| | **Lectures** | **Tutorials** | **Credits** | **Laboratory** | **Credits** |
| | 3 | - | 3 | 3 | 2 |
| **Chief Coordinator** | **Dr. P Srinivasa Rao, Professor** | | | | |
| **Course Faculty** | **Dr. P Srinivasa Rao, Professor** | | | | |

## I. COURSE OVERVIEW:

The course is aimed at students from all engineering majors. Advanced Finite Element Analysis covers the fundamental practices common to all engineering majors in making and reporting basic finite element Analysis and their use in designing high precision items. Advanced Finite Element Analysis covers the fundamental practices common to all engineering majors in making and reporting basic finite element Analysis and using these analysis for obtaining an approximate solution of ordinary and partial differential equations. Students will learn about the finite element Analysis process and commonly used finite element method as well as statistical analysis and standard uncertainty analysis methods. The learning process will be enhanced by completing assignments using mathematical software.

## II. COURSE PRE-REQUISITES:

| Level | Course Code | Semester | Prerequisites | Credits |
|---|---|---|---|---|
| UG | AME014 | VI | FINITE ELEMENT MODELLING | 4 |

## III. MARKSDISTRIBUTION:

| Subject | SEE Examination | CIA Examination | Total Marks |
|---|---|---|---|
| **Advanced Finite Element Analysis** | 70 Marks | 30 Marks | 100 |

## IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ✔ | LCD / PPT | ✔ | Seminars | ✔ | Videos | ✔ | MOOCs |
| ✘ | 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 $8^{th}$ and $16^{th}$ 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 and MOOCs.

## VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

| Program Outcomes (POs) | | Strength | Proficiency assessed by |
|---|---|---|---|
| PO 1 | Apply advanced level knowledge, techniques, skills and modern tools in the field of computer aided engineering to critically assess the emerging technological issues. | 3 | Presentation on real-world problems |
| PO 2 | Have abilities and capabilities in developing and applying computer software and hardware to mechanical design and manufacturing fields. | 2 | Seminar |
| PO 3 | Conduct experimental and/or analytical study and analyzing results with modern mathematical / scientific methods and use of software tools. | 2 | Assignments |
| PO 4 | Function on multidisciplinary environments by working cooperatively, creatively and responsibly as a member of a team. | 2 | Seminar |
| PO 5 | Write and present a substantial technical report / document. | 1 | Seminar |
| PO 6 | Independently carry out research / investigation and development work to solve practical problems | 2 | Assignments |
| PO 7 | Design and validate technological solutions to defined problems and recognize the need to engage in lifelong learning through continuing education. | 1 | Assignments |

**3 = High; 2 = Medium; 1 = Low**

## VII. COURSE OBJECTIVES (COs):

| The course should enable the students to: | |
|---|---|
| I | Comprehensive understanding of Finite element methods and its application to the engineering problems. |
| II | Apply the fundamental and advanced finite element methods to the complex structural problems |
| III | Design, identify and adopt the suitable FE Methods |

## VIII. COURSE OUTCOMES (COs):

| COs | Course Outcome | CLOs | Course Learning Outcome |
|---|---|---|---|
| CO1 | Upon completion of this course, the students can able to understand different mathematical Techniques used in FEM analysis | CLO 1 | To perform complete FE formulations for engineering analysis |
| | | CLO 2 | To write codes for a finite element model |
| | | CLO 3 | To use commercial FEA software to solve engineering problems |
| CO2 | Understand the concepts of Nodes and elements | CLO 4 | To perform complete FE formulations for engineering analysis |
| | | CLO 5 | To write codes for a finite element model |

| | | | |
|---|---|---|---|
| | | CLO6 | To use commercial FEA software to solve engineering problems |
| CO3 | Understand use of FEA in Structural and thermal problem | CLO 7 | To apply finite element methods in design engineering components or systems |
| | | CLO 8 | To apply finite element methods in design engineering components or systems |
| | | CLO 9 | To apply finite element methods in design engineering components or systems |
| CO4 | Understand the application of FEA in heat transfer problem | CLO 10 | To apply finite element methods in design engineering components or systems |
| | | CLO 11 | To apply finite element methods in design engineering components or systems |
| | | CLO 12 | To apply finite element methods in design engineering components or systems |
| CO5 | Learn how to do analysis learn the various concepts and types of analysis and finite element modeling techniques | CLO 13 | To apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis |
| | | CLO 14 | To apply finite element methods in design engineering components or systems |
| | | CLO 15 | To apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis |

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## IX. 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 |
|---|---|---|---|---|
| BCC201.01 | CLO 1 | To perform complete FE formulations for engineering analysis | PO 1 | 3 |
| BCC201.02 | CLO 2 | To write codes for a finite element model | PO 1 | 3 |
| BCC201.03 | CLO 3 | To use commercial FEA software to solve engineering problems | PO 1,PO 2 | 3 |
| BCC201.04 | CLO 4 | To perform complete FE formulations for engineering analysis | PO 1,PO 2 | 2 |
| BCC201.05 | CLO 5 | To write codes for a finite element model | PO 2 | 2 |
| BCC201.06 | CLO 6 | To use commercial FEA software to solve engineering problems | PO 1,PO 2,PO 3 | 2 |
| BCC201.07 | CLO 7 | To apply finite element methods in design engineering components or systems | PO 2 | 1 |
| BCC201.08 | CLO 8 | To apply finite element methods in design engineering components or systems | PO 2, PO 3 | 1 |
| BCC201.09 | CLO 9 | To apply finite element methods in design engineering components or systems | PO 2 | 2 |
| BCC201.10 | CLO 10 | To apply finite element methods in design engineering components or systems | PO 1,PO 2 | 2 |
| BCC201.11 | CLO 11 | To apply finite element methods in design engineering components or systems | PO 1,PO 2,PO 3 | 3 |

| | | | | |
|---|---|---|---|---|
| BCC201.12 | CLO 12 | To apply finite element methods in design engineering components or systems | PO 3, PO 6 | 3 |
| BCC201.13 | CLO 13 | To apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis | PO 2, PO 6 | 3 |
| BCC201.14 | CLO 14 | To apply finite element methods in design engineering components or systems | PO 3,PO 2 | 3 |
| BCC201.15 | CLO 15 | To apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis | PO 3, PO 6 | 1 |

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## X. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

| (COs) | Program Outcomes (POs) | | | | | | |
|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 |
| CO 1 | 3 | 2 | | | | | |
| CO 2 | 3 | 2 | | | | | |
| CO 3 | | 3 | 2 | | | | |
| CO 4 | | | 2 | | 2 | | |
| CO 5 | | 1 | 3 | | | | |

**3 = High; 2 = Medium; 1 = Low**

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

| Course Learning Outcomes (CLOs) | Program Outcomes (POs) | | | | | | |
|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 |
| CLO 1 | 3 | | | | | | |
| CLO 2 | 3 | | | | | | |
| CLO 3 | 3 | 3 | | | | | |
| CLO 4 | 3 | 2 | | | | | |
| CLO 5 | | 2 | | | | | |
| CLO 6 | 2 | 2 | 2 | | | | |
| CLO 7 | | 1 | | | | | |
| CLO 8 | | 1 | 1 | | | | |
| CLO 9 | | 2 | | | | | |
| **Course** | | | | | | | |

| Learning Outcomes (CLOs) | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 |
|---|---|---|---|---|---|---|---|
| CLO 10 | 2 | 2 | | | | | |
| CLO 12 | | | 3 | | | 3 | |
| CLO 13 | | 3 | | | | 3 | |
| CLO 14 | | 3 | 3 | | | | |
| CLO 15 | | | 1 | | | 1 | |

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## XII. ASSESSMENT METHODOLOGIES–DIRECT

| | | | | | |
|---|---|---|---|---|---|
| CIE Exams | PO1, PO3, PO5 | SEE Exams | PO1, PO3, PO5 | Seminar and Term Paper | PO1, PO2, PO3, PO5 |
| Viva | - | Mini Project | - | Laboratory Practices | - |

## XIII. ASSESSMENT METHODOLOGIES-INDIRECT

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

## XIV. SYLLABUS

| UNIT-I | FINITE ELEMENT METHODS – A REVIEW | Classes:09 |
|---|---|---|
| Governing differential equations of one – and two dimensional problems, Library of one dimensional and two dimensional elements; Gauss Quadrature and iso parametric elements- Stress calculation and Gauss points convergence requirements and patch test. | | |
| **UNIT-II** | **BENDING OF PLATES AND SHELLS** | **Classes: 09** |
| Bending of plates and shells- Finite element formulations of plates and shell elements – Thin and thick plates – Conforming and non conforming elements –C0 and C1 continuity elements –Shell elements as de generate 3D stress elements and Applications | | |
| **UNIT-III** | **THREE DIMENSIONAL SOLIDS** | **Classes: 09** |
| Introduction- Tetrahedral elements hexahedron elements Linear and Higher order elements- Elements with curved surfaces. | | |
| **UNIT-IV** | **SPECIALPURPOSE ELEMENTS** | **Classes: 09** |
| Crack tip elements- Transition elements – Finite strip elements – Strip element method – Method of infinite domains – node less elements | | |
| **UNIT-V** | **NON LINEAR ANALYSIS** | **Classes: 09** |
| Introduction to non linear analysis Material Non linearity and non linearity –plasticity creep viscoplasticity Non Linear constitutive problem in solid mechanics- Various yield considerations – solution procedures and direct Iteration method Newton Rapson method and modified newton rapson method , application in any one manufacturing process | | |
| **Text Books:** | | |
| 1. Robert D. Cook David S. Malkus, Michel E. Plesha Robert J. Whitt Concepts and applications of Finite element analysis John Whiley & Sons,<br>2. O.C. Zienkowitz, ―The Finite Element Method in Engineering Science‖, McGraw-Hill, | | |

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| 1st Edition, 2013 |
| **Reference Books:** |
| 1. Bathe .K. J, ―Finite Element procedures, Printicehall , 2006.<br>2. S. S. Rao, ―The Finite Element Methods in Engineering, Elsevier, 4th Edition, 2013.<br>3. J. N. Reddy, ―An Introduction to Finite Element Methods, McGraw-Hill, 1st Edition, 2013. |

## XV. COURSE PLAN:

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

| Lecture No | Topic Outcomes | Topics to be covered | Reference |
|---|---|---|---|
| 1-2 | To perform complete FE formulations for engineering analysis | Introduction of finite element methods | T1:3.1<br>R1:3.1 |
| 3-7 | To write codes for a finite element model | Introduction of finite element methods , Governing differential equations of one – and two dimensional problems, | T1:3.2.5<br>R1:3.3.4 |
| 8-10 | To use commercial FEA software to solve engineering problems | Library of one dimensional and two dimensional elements | T1:3.1.5<br>R1:3.1.3 |
| 11-14 | To perform complete FE formulations for engineering analysis | Gauss Quadrature and iso parametric elements - Stress calculation a | T1:9.1<br>R1:5.1 |
| 15-16 | To write codes for a finite element model | Stress calculation and Gauss points convergence requirements and patch test | T1:9.2.1<br>R1:5.2.3 |
| 17-20 | To use commercial FEA software to solve engineering problems | Introduction of Bending of plates and shells- Finite element formulations of plates and shell elements | T1:9.4.2<br>R1:5.3 |
| 21-23 | To apply finite element methods in design engineering components or systems | Thin and thick plates , Conforming and non conforming elements | R2:9.16<br>R2:27.5 |
| 24-26 | To apply finite element methods in design engineering components or systems | Conforming and non conforming elements , C0 and C1 continuity elements | R2:9.16.12<br>R2:27.1 |
| 27-28 | To apply finite element methods in design engineering components or systems | Shell elements as de generate 3D stress elements | R2:9.64<br>R2:30.2 |
| 29-30 | To apply finite element methods in design engineering components or systems | Applications and problems on | R2:9.55<br>R1:29.3 |
| 31-32 | To apply finite element methods in design engineering components or systems | Introduction to THREE DIMENSIONAL SOLIDS | T1:7.1.1<br>R1:4.6 |
| 33-34 | To apply finite element methods in design engineering components or systems | Tetrahedral elements hexahedron elements | T1:7.1<br>R1:3.6.1 |
| 35-36 | To apply the knowledge of FEM for stress analysis, | Linear and Higher order elements | T1:7.1.1<br>R1:4.6 |

| Lecture No | Topic Outcomes | Topics to be covered | Reference |
|---|---|---|---|
| | model analysis, heat transfer analysis and flow analysis | | |
| 37 | To apply finite element methods in design engineering components or systems | Elements with curved surfaces | T1:7.2<br>R1:4.2 |
| 38 | To apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis | Introduction to SPECIALPURPOSE ELEMENTS | T1:8.3<br>R2:6.5 |
| 39 | To apply finite element methods in design engineering components or systems | Type of elements , Crack tip elements | T1:8.7<br>R1:4.8.12 |
| 40-41 | To apply finite element methods in design engineering components or systems | Transition elements and Finite strip elements | T1:8.4<br>R1:4.5 |
| 42 | To apply finite element methods in design engineering components or systems | Introduction to type of methods , Strip element method | T1:8.9<br>R1:4.8.15 |
| 43-44 | To apply finite element methods in design engineering components or systems | Method of infinite domains – node less elements | T1:8.6<br>R1:4.8.15 |
| 45-47 | To apply finite element methods in design engineering components or systems | Introduction to non linear analysis , Material Non linearity | T1:8.1<br>R1:4.8.6 |
| 48-49 | To apply finite element methods in design engineering components or systems | Non linearity plasticity, creep viscoplasticity | T1:7.4<br>R1:4.4 |
| 50-52 | To apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis | Non Linear constitutive problem in solid mechanics- Various yield considerations – solution procedures | T1:7.4.2<br>R1:4.4.1 |
| 53-55 | To apply finite element methods in design engineering components or systems | direct Iteration method Newton Rapson method | T1:7.4.4<br>R1:4.4.2 |
| 56-57 | To apply the knowledge of FEM for stress analysis, model analysis, heat transfer analysis and flow analysis | modified newton rapson method , application in any one manufacturing process. | T1:7.3<br>R1:4.3 |

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

| S NO | Description | Proposed Actions | Relevance with POs |
|---|---|---|---|
| 1 | To improve standards and analyze the concepts. | Seminars / Guest Lectures / NPTEL | PO 1, PO 2, PO 3 |
| 2 | Encourage students to solve real time applications and prepare towards competitive examinations. | Seminars / Guest Lectures / NPTEL | PO 2, PO 5 |

**Prepared by:**

**Dr. P Srinivasa Rao, Professor**

**HOD, MECHANICAL ENGINEERING**