C BYREGOWDA INSTITUTE OF TECHNOLOGY
(Approved by AICTE, New Delhi, Recognized by Govt. of Karnataka & Affiliated to VTU, Belagavi.)
KOLAR – SRINIVASAPUR ROAD, KOLAR – 563101, KARNATAKA.
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Department of Mechanical Engineering

Course File

Course Name	FINITE ELEMENT METHODS
Course Code	18ME61
Academic Year	2022-23
Course Co-ordinator	SANDEEP S N

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COURSE DETAILS

1.1 Preliminary Information

Course Name	FINITE ELEMENT METHODS
Course Code	18ME61
Academic Year	2022-23
Semester	VI
Course Co-ordinator	SANDEEP S N

1.1.1 Course Objectives:

1. To learn basic principles of finite element analysis procedure.
2. To learn the theory and characteristics of finite elements that represent engineering structures.
3. To learn and apply finite element solutions to structural, thermal, dynamic problem to develop the knowledge and skills needed to effectively evaluate finite element analyses.

1.1.2 Internal assessment (IA) marks:

1. There shall be a maximum of 40 for CIE marks.
2. The internal assessment marks shall be based on the average of three tests plus the assignment mark (Max. 10 marks).

1.1.3 Eligibility for passing

For a pass in the subject, the candidate shall secure minimum of 40% of the maximum marks prescribed in the university examination and 40% of marks in the aggregate inclusive of the internal assessment mark.

Sl. No.	Evaluation Type	Maximum Marks	Minimum passing marks
1	CIE	40	16
2	SEE	60	24

1.1.4 The Program Educational Objectives (PEOs)

PEO1: Graduates will utilize their engineering expertise and critical thinking skills to excel in diverse technical roles within industry, academia, or as innovative entrepreneurs.

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PEO2: Graduates will actively participate in lifelong learning and professional development, pursuing continuing education in mechanical engineering or related fields.

PEO3: Graduates will demonstrate effective communication skills, strong teamwork abilities, leadership qualities, and a commitment to ethical conduct.

1.1.5 Program Outcomes (PO's)

The graduates of the Mechanical Engineering department will have the ability

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
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.
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 considerations.
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.
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.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multi-disciplinary environments.

12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

1.1.6 Program Specific Outcomes (PSO's)

By the completion of Mechanical Engineering program, graduates are able to

PSO1: Graduates will be able to utilize engineering principles and tools in the design, production, and analysis of mechanical systems.

PSO2: Graduates will be proficient in using modern technical tools to solve complex mechanical engineering problems.

1.2 Course Contents

FINITE ELEMENT METHODS			
Subject Code	**18ME61**	**I.A. Marks**	**40**
Hours / Week	**05**	**Exam Hours**	**03**
Total Hours	**50**	**Exam Marks**	**60**
CREDITS 04			

Module No.	**Contents**	**Teaching Hour**
1	**Introduction to Finite Element Method:** General steps of the finite element method. Engineering applications of finite element method. Advantages of the Finite Element Method. **Boundary conditions:** Homogeneous and non-homogeneous for structural, heat transfer and fluid flow problems. Potential energy method, Rayleigh Ritz method, Galerkin's method, Displacement method of finite element formulation. Convergence criteria, Discretisation process, Types of elements: 1D, 2D and 3D, Node numbering, Location of nodes. Strain- displacement relations, Stress-strain relations, Plain stress and Plain strain conditions, temperature effects. **Interpolation models:** Simplex, complex and multiplex elements, linear interpolation polynomials in terms of global coordinates 1D, 2D, 3D Simplex Elements.	**10**
2	**Introduction to the stiffness (Displacement) method:** Introduction, Derivation of stiffness matrix, Derivation of stiffness matrix for a spring element, Assembly the total stiffness matrix by superposition. One-Dimensional Elements-Analysis of Bars and Trusses, Linear interpolation polynomials in terms of local coordinate's for1D, 2Delements. Higher order interpolation functions for 1D quadratic and cubic elements in natural coordinates, Constant strain triangle, Four-Nodded Tetrahedral Element (TET 4), Eight-Nodded Hexahedral Element (HEXA 3 8), 2D iso-parametric element, Lagrange interpolation functions. **Numerical integration:** Gaussian quadrature one point, two point formulae, 2D integrals. Force terms: Body force, traction force and point loads, Numerical Problems: Solution for displacement, stress and strain in 1D straight bars, stepped bars and tapered bars using elimination approach and penalty approach, Analysis of trusses.	**10**
3	**Beams and Shafts:** Boundary conditions, Load vector, Hermite shape functions, Beam stiffness matrix based on Euler-Bernoulli beam theory, Examples on cantilever beams, propped cantilever beams, Numerical problems on simply supported, fixed straight and stepped beams using direct stiffness method with concentrated and uniformly distributed load. **Torsion of Shafts:** Finite element formulation of shafts, determination of stress and twists in circular shafts.	**10**
4	**Heat Transfer:** Basic equations of heat transfer: Energy balance equation, Rate equation: conduction, convection, radiation, 1D finite element formulation using vibration method, Problems with temperature gradient and heat fluxes, heat transfer in composite sections, straight fins. **Fluid Flow:** Flow through a porous medium, Flow through pipes of uniform and stepped sections, Flow through hydraulic net works.	**10**
5	**Axi-symmetric Solid Elements:** Derivation of stiffness matrix of axisymmetric bodies with triangular elements, Numerical solution of axisymmetric triangular element(s) subjected to surface forces, point loads, angular velocity, pressure vessels. **Dynamic Considerations:** Formulation for point mass and distributed masses, Consistent element mass matrix of one dimensional bar element, truss element, axisymmetric triangular element, quadrilateral element, beam element. Lumped mass matrix of bar element, truss element, Evaluation of eigen values and eigen vectors, Applications to bars, stepped bars, and beams.	**10**

1.3 Literature referred for the Course

Book Type	Code	*Title & Author*	Publication Information		
			Edition	Publisher	Year
Text Books	T1	**A first course in the finite element method,** ,by Logan, D. L.	6th Edition	Cengage Learning	2016
	T2	**Finite element method in engineering** by Rao, S. S.	5th Edition	Pergaman Int. Library of Science,	2010
	T3	**Finite element method** by Thyagaraj N R et.al.	1st Edition	Sunstar Publications	2018
Reference Books	R1	**"Finite Element Method"- by** J.N.Reddy, **Finite Elements Procedures**, by Bathe K. J.	International Edition	McGraw - Hill.PHI.	
	R2	**"Concepts and Application of Finite Elements Analysis"-**by Cook R. D., et al.	4th Edition	Wiley & Sons	2003

2. COURSE PLAN

2.1 Course Outcome:

Subject: FINITE ELEMENT METHODS
Subject Code: 18ME61

CO1	Identify the application and characteristics of FEA elements such as bars, beams, plane and iso-parametric elements.
CO2	Develop element characteristic equation and generation of global equation.
CO3	Formulate the Finite Element model for beams and shafts subjected to various loading conditions.
CO4	Develop element characteristic equations and generation of global equations for heat transfer and fluid flow problems.
CO5	Apply suitable boundary conditions to a global equation for axi-symmetric and dynamic problems.

2.2 CO Attainment:

2.2.1: Internal Attainment

Microsoft Excel - FEM CO-ATTAINMENT.xlsx

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Faculty Name	SANDEEP S N		BRANCH	MECHANICAL ENGINEERING		SUBJECT	FINITE ELEMENT METHODS			
Course	BE	SEM	6	SUB. CODE	18ME61	TOTAL NO. OF STUDENTS	7	YEAR	2022-23	

Attainment for CO

TEST 1

Main Questions		1			2			3			4		
Sub Questions		a	b	c	a	b		a	b		a		
Mapped CO		CO1	CO1	CO1	CO1	CO1		CO1	CO1		CO1		
Max. Marks		9	8	8	10	15		5	20		25		
Sl. No.	USN												
1	1CK19ME002										25		
2	1CK19ME009		2										
3	1CK20ME001					7		4	18				
4	1CK20ME002					15		5	12				
5	1CK20ME003	6	4	4				5	10				
6	1CK20ME004												
7	1CK21ME401				9	15		4					

TEST 2

Main Questions		1			2			3			4		
Sub Questions		a	b		a			a	b		a	b	
Mapped CO		CO2	CO2		CO2			CO3	CO3		CO3	CO3	
Max. Marks		10	15		25			10	15		10	15	
Sl. No.	USN												
1	1CK19ME002				23				10				
2	1CK19ME009	9	1										
3	1CK20ME001				15				12				
4	1CK20ME002				8							9	
5	1CK20ME003	10	13					10	7				
6	1CK20ME004												
7	1CK21ME401	5	9									9	

TEST 3

Main Questions		1			2			3			4							
Sub Questions		a	b	c	a	b	c	a	b	c	a	b	c					
Mapped CO		CO5	CO5		CO5			CO4			CO4			CO1	CO2	CO3	CO4	CO5
Max. Marks		15	10		25			25			25			50	25	25	25	25
Sl. No.	USN																	
1	1CK19ME002	15	10								20			25	23	10	20	25
2	1CK19ME009	2	10								20			2	10	0	20	12
3	1CK20ME001	15	9								22			29	15	12	22	24
4	1CK20ME002	15	10								25			32	8	9	25	25
5	1CK20ME003	6	10								25			29	23	17	25	16
6	1CK20ME004													AB	AB	AB	AB	AB
7	1CK21ME401	14									22			28	14	9	22	14
													ΣCOt	145	93	57	134	116
													ΣCOt (Reduction)	87	56	34	80	69.6

Threshold Values for Attainment Calculation						
Attainment level	3	%	2	%	1	%
Internal Assessment	>=	70	>=	60	>=	50

Reduction Factor 3/5

CO	CO1	CO2	CO3	CO4	CO5
ΣCO	180	90	90	90	90
ΣCOt	87	56	34	80	70
%	48	62	38	89	77
Attainment Level	0	2	0	3	3

The Average Internal Attainment Level Is "1.6"

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2.2.2: AQSM Attainment

Assignment		A1	A2	AVG
	Max Marks	10	10	10
Sl. No.	USN			
1	1CK19ME002	10	10	10
2	1CK19ME009	10	10	10
3	1CK20ME001	10	10	10
4	1CK20ME002	10	10	10
5	1CK20ME003	10	10	10
6	1CK20ME004	AB	AB	AB
7	1CK21ME401	10	10	10

Threshold Values for Attainment Calculation						
Attainment level	3	%	2	%	1	%
AQSM Assessment	>=	70	>=	60	>=	50

The AQSM Attainment Level is "3"

2.2.3 SEE Attainment:

Sl. No.	USN	Name	SEE Marks (60)
1	1CK18ME002	AKASH M	39
2	1CK18ME009	GURUKIRAN A	11
3	1CK20ME001	ESHWAR RAJ	21
4	1CK20ME002	NANDISH K V	42
5	1CK20ME003	SAMREEN TAJ	38
6	1CK20ME004	VEDANTH SINGH K T	X
7	1CK21ME401	SATISHA N	37

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Subject Name	No of students appeared for SEE	Class Average Marks in SEE	Number of Students scoring above class average in SEE	Percentage of students scored above class average in SEE	Attainment level (AL)
Finite Element Analysis (18ME61)	6	31	4	66.67 %	3

If percentage of students scored above class Average in SEE>=60% Attainment level is 3

Else if <60% but >=50% Attainment level is 2

Else if <50% but >=40% Attainment level is 1

Else Attainment level is 0

2.2.4 Overall CO Attainment:

CO	Internal Attainment	AQSM Attainment	CEE Attainment	SEE attainment	Overall CO Course attainment
CO1	0	3	0.75	3	2.1
CO2	2	3	2.25	3	2.7
CO3	0	3	0.75	3	2.1
CO4	3	3	3	3	3
CO5	3	3	3	3	3
			Average Attainment =		**2.58**

CEE attainment = 0.75 * Internal attainment + 0.25 * AQSM attainment

Overall CO Course attainment = 0.6 * SEE attainment + 0.4 * CEE attainment

2.3 Mapping of COs with POs and PSOs:

COs	POs												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	3	3										1	2	
CO2	3	3										1	2	
CO3	3	2	2									1	2	
CO4	3	3	2									1	2	
CO5	2	2	2									1	2	
Average	**2.8**	**2.6**	**2**									**1**	**2**	

2.4 CO/PO/PSO Attainment

COs	POs												PSOs	
	1	2	3	4	5	6	7	8	9	10	11	12	1	2
CO1	2.1	2.1										0.7	1.4	
CO2	2.7	2.7										0.9	1.8	
CO3	2.1	1.4	1.4									0.7	1.4	
CO4	3	3	2									1	2	
CO5	2	3	2									1	2	
Average	**2.4**	**2.4**	**1.4**									**0.9**	**1.7**	

PO attainment can be computed for a batch using the below formula.

PO/PSO attainment = (CO attainment * CO-PO Mapping)/Max correlation strength