SEMESTER II

SLOT	COURSE CODE	COURSE NAME	MARKS		L-T-P	HOURS	CREDIT
			CIA	ESE			
A	222TCE100	ADVANCED NUMERICAL METHODS	40	60	3-0-0	3	3
B	222TCE103	FINITE ELEMENT METHOD	40	60	3-0-0	3	3
C	222ECEXXX	PROGRAM ELECTIVE 3	40	60	3-0-0	3	3
D	222ECEXXX	PROGRAM ELECTIVE 4	40	60	3-0-0	3	3
E	222EEXXXX/ 222ECEXXX	INDUSTRY/ INTERDISCIPLINARY ELECTIVE	40	60	3-0-0	3	3
S	222PCE100	MINI PROJECT	100	--	0-0-4	4	2
T	222LCE003	COMPUTATIONAL LAB	100	--	0-0-2	2	1
Total			**400**	**300**		**21**	**18**

Teaching Assistance: 6 hours

PROGRAM ELECTIVE 3

PROGRAM ELECTIVE 3						
SLOT	**SL NO**	**COURSE CODE**	**COURSE NAME**	**L-T-P**	**HOURS**	**CREDIT**
C	1	222ECE036	STRUCTURAL HEALTH MONITORING	3-0-0	3	3
	2	222ECE037	DESIGN OF BRIDGES	3-0-0	3	3
	3	222ECE038	STABILITY OF STRUCTURES	3-0-0	3	3
	4	222ECE039	THEORY OF PLATES AND SHELLS	3-0-0	3	3

PROGRAM ELECTIVE 4

PROGRAM ELECTIVE 4						
SLOT	**SL NO**	**COURSE CODE**	**COURSE NAME**	**L-T-P**	**HOURS**	**CREDIT**
D	1	222ECE042	ADVANCED COMPOSITE STRUCTURES	3-0-0	3	3
	2	222ECE043	DESIGN OF EARTHQUAKE RESISTANT STRUCTURES	3-0-0	3	3
	3	222ECE044	THEORY OF PLASTICITY	3-0-0	3	3
	4	222ECE045	ENGINEERING FRACTURE MECHANICS	3-0-0	3	3

INTERDISCILINARY ELECTIVE

INTERDISCILINARY ELECTIVE						
SLOT	**SL NO**	**COURSE CODE**	**COURSE NAME**	**L-T-P**	**HOURS**	**CREDIT**
E	1	222ECE096	NATURAL HAZARDS AND IMPACT MANAGEMENT	3-0-0	3	1
	2	222ECE097	MECHANICS OF COMPOSITE MATERIALS	3-0-0	3	2
	3	222ECE098	PROJECT EVALUATION AND MANAGEMENT	3-0-0	3	3

INDUSTRY ELECTIVE

SEMESTER II

Discipline:CIVIL ENGINEERING

Stream : CE4

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222TCE100	ADVANCED NUMERICAL METHODS	DISCIPLINE CORE 2	3	0	0	3

Preamble: For solving complex problems in mechanics and engineering, a post-graduate student must be well versed in numerical methods along with skills to apply them. This course equips the student with various numerical techniques that finds applications in civil engineering, across various streams (specialisations). Special focus is given to finite element method, explaining the relevance, versatility and fundamental concepts of this numerical tool.

Course Outcomes: After the completion of the course, the student will be able to

CO 1	Obtain the solution of simultaneous Linear system of equations
CO 2	Obtain the numerical solutions of ordinary differential equations
CO 3	Obtain the numerical solutions for solving boundary value problems of partial differential equations
CO 4	Describe the terminologies, applications or procedure of finite element method
CO 5	Describe or apply the concept of finite element method

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3			3			
CO 2	3			3			
CO 3	3			3			
CO 4	1		2	2	2	2	
CO 5	3			2	2	2	

(1-Weak, 2-Medium, 3- strong)

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	25
Analyse	25
Evaluate	5
Create	5

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 marks

Preparing a review article based on peer reviewed original publications (Minimum 10 publications shall be referred) : 15 marks

Course based task/Seminar/Data collection and interpretation : 15 marks

Test paper, 1 no. : 10 marks

Test paper shall include minimum 80% of the syllabus.

Note: Enough opportunity to explore the practical examples from specialization should be given to the students. One assignment/course project should be based on the coding or use of packages

End Semester Examination Pattern: 60 marks

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question Paper

QP CODE:

Reg No.:_______________

Name:___________________________ ___

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY FIRST SEMESTER M.TECH. DEGREE EXAMINATION, MONTH & YEAR

Course Code: XXXXXX

ADVANCED NUMERICAL METHODS

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer ***ALL*** questions; each question carries 5 marks)

1. Explain the procedure of solution of Tridiagonal systems
2. Explain single shooting method for solving Boundary value problems
3. Explain the parabolic and elliptic partial differential equations with examples
4. Explain any five practical applications of Finite element in the con
5. Explain Generalised coordinates and Natural coordinates in Finite Element analysis

PART B

(Answer ***any FIVE*** questions; each question carries 7 marks)

6. Solve the system of equations by Jacobi's iteration considering initial approximation as $[0.5, -0.5, 0.5]^T$

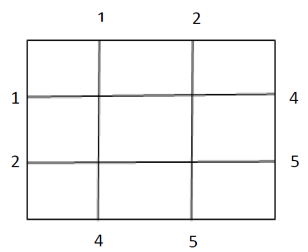
$$4x_1 + x_2 + x_3 = 2$$

$$x_1 + 5x_2 + 2x_3 = -6$$

$$x_1 + 2x_2 + 3x_3 = -4$$

7. Solve $y' = x^2 + y$ for y=0.1, given that $y(0)$=1 considering h=0.05 using (i) Eulers method and (ii) Runge Kutta method

8. Solve the equation $u_{xx} + u_{yy} = 0$ for the square mesh with boundary value as shown in figure



9. Solve $\left(\frac{\partial u}{\partial t}\right)=\left(\frac{\partial^2 u}{\partial x^2}\right)$ subject to the conditions $u(x,0)=\sin(\pi x)$ for $0 \le x \le 1$ $u(0, t)$=u(1, t)=0. Perform the computations of two levels taking h=1/3and t=1/36 using Crank Nicolson implicit scheme

10. Explain in detail the steps of finite element analysis

11. Explain forms of shape functions in finite element analysis

12. Explain the convergence criteria in finite element applications in detail

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Syllabus

Module 1 **(7 hours)**

Solutions of simultaneous Linear Systems of Equations- Solution of linear systems – Direct methods, Gauss-Jordan Method-Method of factorization- Solution of Tridiagonal Systems. Solution by matrix decomposition Iterative methods: Jacobi, Gauss-Siedel iteration for ordinary and sparse systems, Convergence of iterative solution schemes with examples.

Module 2 **(7 hours)**

Solving Ordinary Differential Equations- The Elementary Theory of Initial-Value Problems -Euler's Method- Higher-Order Taylor Methods. Runge-Kutta Method-Introduction to solution methods for differential algebraic equations- Single shooting method for solving ODE-BVPs.

Module 3 **(7 hours)**

Partial differential equations in two dimensions- Parabolic equations- Explicit finite difference method. Crank-Nicholson implicit method - Ellipse equations- Finite difference method-Problems with irregular boundaries.

Module 4 **(7 hours)**

Introduction to Finite Element Method – Historical Background — Mathematical Modeling of field problems in Engineering — Governing Equations — Discrete and continuous models — Boundary, Initial and Eigen Value problems– Basic concepts of the Finite Element Method- Displacement approach-Concept of Stiffness Matrix and Boundary Condition-- General procedure of FEA

Module5 **(7 hours)**

Concept of Finite Element Method- Concept of Nodes, elements, Generalised coordinates and Natural coordinates in FEA. Shape functions – Polynomials - Lagrangian and Hermitian Interpolation –- Compatibility - C0 and C1 elements - Convergence criteria - Conforming & nonconforming elements. Development of element matrices for one dimensional elements.

Text Books

1.Gupta,S.K. Numerical Methods for Engineers. Wiley Eastern, New Delhi, 1995.

2. Cook, RD. Concepts and Applications of Finite Element Analysis , Wiley.

Reference Books

1. Gilbert Strang, Linear Algebra and its Applications (4th Ed.), Wellesley Cambridge Press 2009
2. Gourdin, A. and M Boumhrat. Applied Numerical Methods.Prentice Hall India, New Delhi 2000
3. Chopra S.C. and Canale R.P. Numerical Methods for Engineers,McGraw Hill 2006
4. Krishnamoorthy C S, *Finite Element Analysis- Theory and Programming*, Tata McGraw Hill, New Delhi., 1994
5. Rao, SS. Finite Element Analysis, Elsevier Butterworth-Heinemann
6. Gerald and Wheatly*, Applied Numerical Analysis,* Pearson Education.
7. Rajasekharan S., *Numerical Methods in Science and Engineering,* S Chand & Company, 2003.
8. Bathe K J, *Finite Element Procedures in Engineering Analysis*, Prentice Hall, New Delhi. 1982
9. Chandrupatla T R and Belegundu A D, *Introduction to Finite Elements in Engineering*, Pearson Education, New Delhi 1998
10. Rajasekharan S, *Finite Element Analysis in Engineering Design*, Wheeler, New Delhi
11. Hutton D V, *Fundamentals of Finite Element Analysis*, Tata McGraw Hill Education Private Ltd, New Delhi

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CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222TCE103	**FINITE ELEMENT METHOD**	**PROGRAM CORE 3**	**3**	**0**	**0**	**3**

Preamble: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Develop approximate solution to boundary value problems in structural mechanics using method of weighted residuals and variational methods.
CO 2	Develop field approximations for various one- and two-dimensional finite elements.
CO 3	Formulate element equilibrium equations for 1D and 2D finite elements for solution of structural mechanics problems using energy principles.
CO 4	Understand the computational techniques for numerical integrations, large system of equation solvers etc. and apply the same for implementation of finite element method.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	2	3	3	3	3	1
CO 2	3	2	3	3	3	3	1
CO 3	3	2	3	3	3	3	1
CO 4	3	2	3	3	3	3	1

Assessment Pattern

Bloom's Category	Continuous Assessment test	End Semester Examination
Understand	10	15
Apply	10	15
Analyse	20	30
Evaluate	-	-
Create	-	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 40 marks Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

Model Question Paper

Max. Marks: 60
Duration: 2.5 Hours

PART A

Answer all questions; each question carries 5 marks

1. The stress components at a point in a body are given by

   $\sigma_x = 2xy^2z + 2x;\ \sigma_y = 5xyz + 3y;\ \sigma_z = x^2y + y^2z;\ \tau_{xy} = 0;\ \tau_{yz} = \tau_{xz} = 2xy^2z + 2xy$

   Check whether these stress components satisfy the conditions of equilibrium or not at the point (1,-1,2). If not, determine the suitable body force components required at this point so that the stress components satisfy equilibrium.

2. What are conforming and non-conforming elements? Briefly explain the convergence characteristics of both.

3. Starting from the Hermitian shape functions develop the consistent load vector for a two node 1D beam element subjected to a uniformly distributed of intensity w covering full span.

4. Evaluate the following integrals using two point Gauss quadrature.

(i) $\int_{-1}^{1}\int_{-1}^{1} xy\, dxdy$

(ii) $\int_{1}^{3} \frac{dx}{(x^4+1)^{1/2}}$

5. Write short notes on:
   (i) Shear locking (ii) Storage schemes in FEA

PART B

Answer any five questions; each question carries 7 marks

6. Using modified Galerkin method obtain an approximate solution of the following boundary value problem

$$2u''(x) + 3u(x) = 0, \qquad 1 < x < 3$$

$u(1) = 1$ Essential boundary condition

$u'(3) = 1$ Natural boundary condition

Assume a quadratic polynomial satisfying the essential boundary condition as a trial solution.

7. A two-member truss is loaded as shown in Fig.2. The area of cross section of each element is 500 mm² and E = 200 GPa. Compute the displacement components at node 3, reactions at supports and member stresses

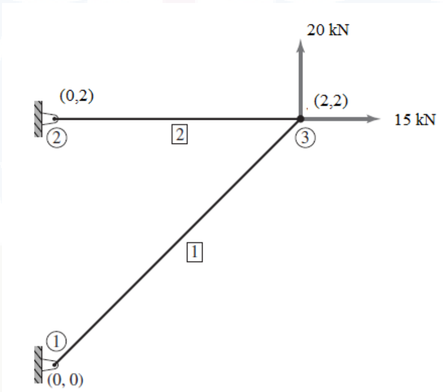


Fig. 2

8. The nodal displacement components (in mm units) of a triangular element from the finite element analysis of a thin plate is shown in Fig.3. Develop appropriate approximations for the u and v fields within the element in terms of area coordinates .

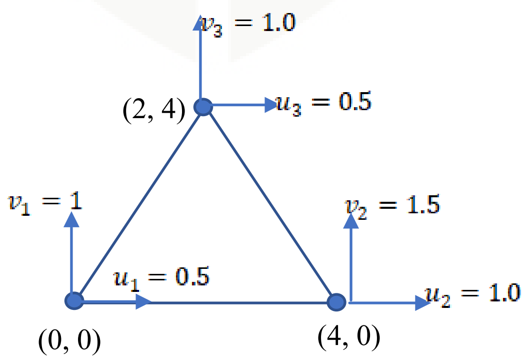


Fig.3.

9. (i) Differentiate between Lagrangian and Hermitian interpolation. (2 marks)

(ii) Compute the consistent nodal load vector when a surface traction of uniform intensity w N/m length acts normal to the edge containing nodes with coordinates (4,0) and (2,4) of the triangular element shown in Fig.3.

(5 marks)

10. Develop the FE formulation for an isoparametric 4 node quadratic element for solution of 2D elasticity problems.

11. Develop the Finite element formulation for a Resinner-Mindlin plate element.

12. Write short notes on:

(i) Spurious energy modes. (4 marks)

(ii) Frontal solver in FEA. (3 marks)

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Module I: Classical approximate solution of boundary value problems & Introduction to FEA**	
1.1	Idealization of physical problems & mathematical modelling;	1
1.2	Basic equations of elasticity: Equilibrium, traction boundary conditions, Strain – Displacement relations — Constitutive relations; 2D idealization – Plane stress & Plane strain conditions	1
1.3	Approximate solution of boundary value problems – method of least squares,	1
1.4	Approximate solution of BVP-Weighted residual methods-structural mechanics applications.	2
1.5	Approximate solution of BVP -Variational approach (Rayleigh-Ritz method)- structural mechanics applications.	2
1.6	Introduction to Finite Element Method – History of development – Advantages – Disadvantages - General description of the method.	1
2	**Module II: Review of direct stiffness method & field approximations in FEA**	
2.1	Direct stiffness method – Review of basic concepts of matrix displacement analysis – formulation element stiffness matrices and load vectors for truss & beam	2

	elements	
2.2	Coordinate transformations, global assembly, global equilibrium solution, estimation of element forces.	2
2.3	Field approximation in FEA: Polynomial approximations - Convergence & Compatibility requirements	1
2.4	Polynomial approximation for 1D & 2D fields in global coordinates; continuity requirements.	1
2.5	1D & 2D Field approximation using Lagrange polynomials	1
2.6	Area coordinates and field approximation for CST & LST elements	1
2.7	Shape functions for serendipity elements	1
3	**Module III: Formulation of element equations**	
3.1	Development of equilibrium equations for finite elements– using principle of virtual work	1
3.2	Formulation of element equations (including consistent load vector) for 1D bar element for modelling axial behaviour.	1
3.3	Formulation of element equations (including consistent load vector) for 1D beam (Euler-Bernoulli) element for modelling flexural behaviour	2
3.4	Formulation of element equations (including consistent load vector) for CST element for modelling plane stress/strain problems	2
3.5	Formulation of LST & 4 node quadrilateral elements for modelling plane stress/strain problems	1
4	**Module IV: Isoparametric formulations & Numerical Integrations**	
4.1	Geometric approximation – concept of mapping – Isoparametric, sub-parametric and super-parametric mapping. Isoparametric Mapping/formulations for 1D line elements	2
4.2	Isoparametric mapping for planar bilinear elements; formulation of element equations for four node isoparametric quadrilateral element	2
4.3	Restrictions in mapping	1
4.4	Numerical integrations – introduction to Newton-Cotes and Gauss quadrature - Gauss quadrature formulae for 1D integration	2
4.5	Gauss quadrature formulae for 2D	1
5	**Module V: Plate elements, Storage & solution schemes for large system of equations**	
5.1	Introduction to plate bending – Kirchoff and Mindlin plate theories	2
5.2	FE formulations for Kirchoff and Mindlin Plate elements;	2
5.3	Shear locking, reduced and selective reduced integrations; Spurious energy modes;	1
5.4	Global assembly of element equations; Storage schemes in FEA – Banded and Skyline storage; Calculation of semi-band width – node numbering for optimal bandwidth	2
5.5	Solution schemes in FEA – Frontal solver; Discussion of modelling and analysis using recent commercial finite	1

	element software packages	

Reference Books

1. *Cook R D et al., Concepts and Applications of Finite Element Analysis, John Wiley & Sons, Singapore.*
2. *Logan D L, A First Course in Element Method,* Thomson, 2007.
3. *M. Asghar Bhatti, Fundamentals of Finite Element Analysis and Applications, John Wiley &Sons NewJersy, U.S.*
4. *J.N. Reddy, An Introduction to Finite Element Method, Tata McGraw Hill Publishing Company Ltd., New Delhi.*
5. *Hutton D V, Fundamentals of Finite Element Analysis, Tata McGraw Hill Education Private Ltd. New Delhi.*
6. *Krishnamoorthy C S, Finite Element Analysis- Theory and Programming, Tata McGraw Hill, New Delhi*
7. *Rajasekharan S, Finite Element Analysis in Engineering Design, Wheeler, New Delhi*
8. *Chandrupatla T R and Belegundu A D, Introduction to Finite Elements in Engineering, Pearson Education, New Delhi*
9. *Bathe K J, Finite Element Procedures in Engineering Analysis, Prentice Hall, New Delhi*
10. *Zienkiewicz O C and Taylor R W., Finite Element Method, Elsevier Butterworth-Heinemann, UK*

COURSE CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222PCE100	MINI PROJECT	PROJECT	0	0	4	2

Mini project can help to strengthen the understanding of student's fundamentals through application of theoretical concepts and to boost their skills and widen the horizon of their thinking. The ultimate aim of an engineering student is to resolve a problem by applying theoretical knowledge. Doing more projects increases problem solving skills.

The introduction of mini projects ensures preparedness of students to undertake dissertation. Students should identify a topic of interest in consultation with PG Programme Coordinator that should lead to their dissertation/research project. Demonstrate the novelty of the project through the results and outputs.The progress of the mini project is evaluated based on three reviews, two interim reviews and a final review. A report is required at the end of the semester.

Evaluation Committee - Programme Coordinator, One Senior Professor and Guide.

Sl. No	Type of evaluations	Mark	Evaluation criteria
1	Interim evaluation 1	20	
2	Interim evaluation 2	20	
3	Final evaluation by a Committee	35	Will be evaluating the level of completion and demonstration of functionality/ specifications, clarity of presentation, oral examination, work knowledge and involvement
4	Report	15	the committee will be evaluating for the technical content, adequacy of references, templates followed and permitted plagiarism level(not more than 25%)
5	Supervisor/Guide	10	
	Total Marks	100	

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222LCE003	**COMPUTATIONAL LAB**	**LABORATORY**	**0**	**0**	**2**	**1**

Preamble: The course is intended to provide the students with an ability to model, analyse and interpret results by analysing and design various structural elements/whole structure using software packages such as SAP2000, ETABS, STAAD, ANSYS,ABAQUS, MATLAB, MATHCAD, MATHEMATICA, MS-EXCEL, MIDAS CIVIL, CSI BRIDGE, TEKLA, AUTOCAD, REVIT and. It also encompasses to develop a firm foundation for research and practice in StructuralEngineering. It also enables students to familiarize with industry standards projects with the help of cutting-edge technology and software available in the field at presentto have no gap between academia and industry. All design and detailing shall be done as per the latest BIS, IRC and other relevant Codes of Practice.

Course Outcomes: After the completion of the course on Computational Lab, the student will be able to:

CO 1	Model structural elements/ whole structures using finite element packages.
CO 2	Analyse and design structural elements/ whole structures using finite element packages.
CO 3	Interpret results from finite element analysis packages.
CO 4	Draw structural details using AutoCAD.
CO 5	Write design reports.
CO 6	Develop bar bending schedule and bill of quantities from the structural drawings.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	2	3	3	2	2	2	1
CO 2	2	3	3	2	2	2	1
CO 3	3	3	3	3	2	2	1
CO 4	2	3	3	2	2	2	1
CO 5	2	3	3	2	2	2	3
CO 6	2	3	3	2	2	2	3

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	100	–	–

Continuous Internal Evaluation Pattern:

The laboratory courses will be having only Continuous Internal Evaluation and carries 100 marks. Final assessment shall be done by two examiners; one examiner will be a senior faculty from the same department.

Syllabus and Course Plan

Concrete Structures

Analysis, design and detailing of a G + 10 residential building – Analysis, design and detailing of an overhead circular and rectangular water tanks with staging – Analysis, design and detailing of a ribbed slab floor system–Analysis, design and detailing of shear walls –Application of strut-and-tie method to design and detail various RC elements and junctions – Develop a spreadsheet for generation of interaction curves for RC rectangular columns– Design of slab bridge.

Steel Structures

Design of Steel Industrial Building –Design of Steel Multi-storey Building.

List of Experiments

Expt. No.	Title	Hours Allotted
1	Analysis, design and detailing of a G + 10 residential building without shear wall.	2
2	Analysis, design and detailing of an overhead circular water tank with staging.	2
3	Analysis, design and detailing of an overhead rectangular water tank with staging using LSM and IS 1893(Part 2)	2
4	Analysis, design and detailing of a ribbed slab floor system.	2
5	Analysis, design and detailing of a G + 10 residential building with shear wall.	2
6	Using strut-and-tie method, design and detail various RC elements and beam-column joints.	2
7	Develop a spreadsheet for generation of interaction curves for RC rectangular columns.	2
8	Design and detail a simply supported slab bridge of spans less than or equal to 6 m.	2
9	Design and detail a Multi-storey Steel Building.	2
10	Design and detail a Steel industrial building.	2
11	Design and detail a single span, straight RC Slab bridge.	2

Reference Books/Resources:

1. Manuals of SAP2000, ETABS, STAAD, ANYSYS, MATLAB, MATHCAD, MATHEMATICA, MS-EXCEL, MIDAS CIVIL, CSI BRIDGE, TEKLA, AUTOCAD, REVIT and ABAQUS.
2. IS 456:2000, "PLAIN AND REINFORCED CONCRETE - CODE OF PRACTICE", Bureau of Indian Standards New Delhi.
3. IS800:2007, "GENERAL CONSTRUCTION IN STEEL - CODE OF PRACTICE", Bureau of Indian Standards New Delhi.
4. IS 3370 (Part 1 to 4), "Concrete Structures for Retaining Aqueous Liquids - Code of Practice", Bureau of Indian Standards New Delhi.
5. IS 1893 (Part 1 to 6), "Criteria for Earthquake Resistant Design of Structures", Bureau of Indian Standards New Delhi.
6. IRC:112-2020,"Code of Practice for Concrete Road Bridges", Indian Roads CongressNew Delhi.
7. V. L. Shah and S. R. Karve,"Illustrated Design of Reinforced Concrete Buildings", Assorted Editorial.

SEMESTER II

PROGRAM ELECTIVE III

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222ECE036	STRUCTURAL HEALTH MONITORING	PROGRAMME ELECTIVE 3	3	0	0	3

Preamble: This subject is taught to impart knowledge about the Structural Health Monitoring Concepts.Diagnosis the distress in the structure by understanding the causes and factors.Assess the health of structure using static field methods and dynamic field tests.Suggest repairs and rehabilitation measures of the structure

Course Outcomes: The COs shown are only indicative. For each course, there can be 4 to 6 COs.

After the completion of the course the student will be able to

CO 1	Know the causes of Distress in structures, factors effecting structural health, need of regular maintenance of structures
CO 2	Understand the concept of structural health monitoring and various methods applied for monitoring of structures and structural safety
CO 3	Understand the importance of structural audit and Assessment of Health Structure, Collapse and Investigation, Investigation Management, SHM Procedures
CO 4	Know The Importance of Static field testing, Types of Static Tests, Simulation and Loading Methods, sensor systems and hardware requirements, Static Response Measurement
CO 5	Understand the Dynamic Field testing, stress History Data, Dynamic Response Methods, Hardware for Remote Data Acquisition systems, Remote Structural Health Monitoring.
CO 6	Introduction to Repairs and Rehabilitations of Structures impedance (EMI) technique, Adaptations of EMI technique

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	3	-	-	-	1	-	-
CO 2	-	-	-	1	2	-	-
CO 3	3	-	-	1	2	-	-
CO 4	-	-	-	-	1	-	-
CO 5	-	-	-	-	1	-	-
CO 6	-	2	-	-	2	-	-

Assessment Pattern

Bloom's Category	Continuous Assessment test	End Semester Examination
Remember	10	15
Understand	20	30
Apply	10	15
Create		

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 40 marks Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

Test paper, 1 no. : 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall includeminimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the University. There will be two parts;Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful inthe testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluationand understanding of the students), with 1 question from each module, having 5 marks foreach question. Students shall answer all questions. Part B contains 7 questions (suchquestions shall be useful in the testing of overall achievement and maturity of the students ina course, through long answer questions relating to theoretical/practical knowledge,derivations, problem solving and quantitative evaluation), with minimum one question fromeach module of which student shall answer any five. Each question can carry 7 marks. Totalduration of the examination will be 150 minutes.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State the factors affecting Health of Structures

2.Write short notes on division of maintenance.

3.Define distress

4.Name different types of distress

5. What do you mean by deterioration? Explain themechanism of deterioration in concrete structures?

6. Discuss in detail various construction stage defects & their preventive measures?

7. Explain preventive maintenance of structures? Explainthem in detail

8. Write the different reasons for development of cracksdue to errors in design and detailing. Give preventivemeasures.

Course Outcome 2 (CO2)

1. Define the concept of health monitoring of structures

2. Explain the working system of components of structural health monitoring in detail.

3. Explain Active and Passive Smart Materials

4. What are SHM Technologies? Explain briefly.

5. Enumerate the dynamic response analysis using Laser Doppler Vibrometer

6. What are the challenges in Implementation of SHM

Course Outcome 3(CO3):

1. What are the importance and need of Non-Destructive Testing
2. Basic Methods for NDT of Concrete Structures. Explain
3. What are quality control tests
4. Explain fundamental principle of partial destructive tests
5. Visual Inspection Test
6. Schmidt Rebound Hammer Test

Course Outcome 4 (CO4):

1. Explain the different Types of Static Tests in detail.
2. Discuss Simulation and Loading Methods in staticstructural health monitoring.
3. Explain the role of sensor systems in static structuralhealth monitoring.
4. What are the functions of hardware tools in staticstructural health monitoring?
5. Explain about Static Response Measurement Remember
6. Explain long-Term static structural health monitoring?
7. What is seismic structural health monitoring?
8. Write short notes on intelligent structural healthmonitoring?
9. List out the applications of structural health monitoring in post-earth quake controls.
10. What are smart material and explain their applications in structural health monitoring

Course Outcome 5 (CO5):

1. Explain the application and Adaptations of EMItechnique in structural health monitoring.

2.Write a short notes on data based techniques invibration based structural health monitoring.

3. Define and explain in detail about electro–mechanicalimpedance (EMI) technique

4. Explain the procedure for Adaptations of EMItechnique.

5. Name the types of Dynamic Field Test

6. What is vibration based structural health monitoring.

7. State the different forms of Dynamic ResponseMethods

8. What is Dynamic Response Method remember

9. Name different types of sensors used in structuralhealth monitoring

10. Define epoxy resins.

Course Outcome 6 (CO6):

1. Define repair in a structure

2.Discuss the method of underpinning in detail.

3. Discuss the various types of blanket repair techniques.

4. Enumerate the different methods available for repairsof concrete works. Discuss the any one in detail.

Model Question Paper

Time 2.5 hrs Maximum: 60marks

PART A

Answer all questions; each question carries 5 marks

1. What is the structural health monitoring? Explain scope of structural health monitoring?

2. Explain the role of piezoelectric sensors in structural health monitoring

3. Fundamental Principle of Partial Destructive Tests

4. What are the pros and cons of static structural healthmonitoring system

5.Explain about Electrical-Mechanical Impedance (EMI) Method?

PART B

Answer any five questions; each question carries 7 marks

6. What is distress? Give its classification.

7. Explain the Role of Smart Materials in Structural Health Monitoring System and Discuss aboutActive and Passive Smart Materials?

8. Explain in detail assessment of a health of a structure by NDT's equipment.

9.Describe the procedure of behavioral test and its importance.

10.Explain stress history data of dynamic field testing

11.Enumerate the different methods available for repairsof concrete works. Discuss the any one in detail.

12.Explain the Process of Guniting in Detail With Figure.

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Introduction to Structural Health Monitoring**:	
1.1	Definition of Structural Health Monitoring SHM – Principle and Organization of a SHM System – SHM versus NDE – Advantages of SHM - Factors affecting Health of Structures	2hr
1.2	Repair and Rehabilitation - Facets of Maintenance – importance of Maintenance	1hr
1.3	Various aspects of Inspection - Assessment procedure for evaluating a damaged structure – causes of deterioration	1.5hr
2	**Structural Health Monitoring :**	
2.1	Concepts, Various Measures, Structural Safety in Alteration	1hr
2.2	Active and Passive Smart Materials – SHM Technologies – Piezoelectric Sensors – Magneto strictive Sensors – Optical Fibre Sensors	2hr
2.3	Dynamic Response Analysis using Laser Doppler Vibrometer – Challenges in Implementation of SHM	1hr
3	**Structural Audit :**	
3.1	Assessment of Health of Structure- Assessment by NDT equipment‘s	1hr
3.2	Introduction to NDT – Importance and Need of Non-Destructive Testing – Basic Methods for NDT of Concrete Structures – Testing of Concrete – Quality Control Tests	2hr
3.3	Partial Destructive Tests – Fundamental Principle – Equipment –General Procedure - Visual Inspection Test-Schmidt Rebound Hammer Test	2hr
3.4	Collapse and Investigation Management, SHM Procedures	1hr
4	**Static Field Testing :**	
4.1	Types of Static Tests, Static Testing- Static field testing-types of static tests loading methods	2hr
4.2	Behavioral/ Diagnostic tests - Proof tests -Static response measurement – strain gauges, LVDTs, dial gauges	2hr
4.3	Case study	2hr
5	**Dynamic Field Testing and rehabilitation:**	
5.1	Types of dynamic tests - Stress history data -Dynamic load allowance tests Ambient vibration tests – Forced Vibration Method - Dynamic response methods - Impact hammer testing- Shaker testing - Periodic and continuous monitoring	3hr
5.2	Introduction to Repairs and Rehabilitations of Structures:	3hr

	Repair of Structure – Common types of Repairs – Repair in Concrete Structures – Repairs in Under Water Structures – Guniting– Shot Create – Underpinning. Strengthening of Structures – Strengthening Methods – Retrofitting– Jacketing.	
5.3	Case Studies(Site Visits) electro mechanical impedance (EMI) technique, adaptations of EMI technique	1hr

Reference Books

1. Hua-Peng Chen, Structural Health Monitoring of Large Civil Engineering Structures ,John Wiley & Sons Ltd, Year: 2018

2. Douglas E Adams, Health Monitoring of Structural Materials and Component - Methods with Applications, John Wiley and Sons, 2007.

3. Bhattacharjee, Concrete Structures Repair Rehabilitation and Retrofitting, CBS; first edition (2019).

4. J. P. Ou, H. Li and Z. D. Duan, Taylor, Structural Health Monitoring and Intelligent Infrastructure, Vol1, and Francis Group, London, UK, 2006

5. Victor Giurglutiu, Structural Health Monitoring with Wafer Active Sensors, Academic Press Inc, 2007

6. Daniel Balageas, Claus Peter Fritzen, Alfredo Güemes, Structural Health Monitoring,John Wiley and Sons, 2006

7. Fu-Kuo, Chang Structural Health Monitoring: Current Status and Perspectives CRC Press; 1 edition (24 April 1998)

8. Structural Health Monitoring of Civil Infrastructure System, Vistasp M. Karbhari and Farhad Ansari, Wood Head Publishing Limited, Cambridge, 2009.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222ECE037	**DESIGN OF BRIDGES**	**PROGRAMME ELECTIVE 3**	**3**	**0**	**0**	**3**

Preamble: The course aims to provide a basic understanding of the concepts and design of both concrete and steel bridges as per the latest Indian Road Congress (IRC) and Indian Railway Standard (IRS) specifications. The student is expected to independently plan, analyse, design, and detail various types and components of bridges after completion of this course. The students will be exposed through field visits (whenever feasible) to real-life bridge design and construction practices.

Course Outcomes: After the completion of the course on Design of Bridges, the student will be able to

CO 1	Review bridge specifications as per current IRC and IRS standards for bridges.
CO 2	Design and detail slab and T beam bridges.
CO 3	Design and detail box culvert and Prestressed Concrete bridges.
CO 4	Design and detail plate girder and composite bridges
CO 5	Design elastomeric bearings in bridges.
CO 6	Analyse substructures and foundations in bridges.

Mapping of course outcomes with program outcomes

	PO 1	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**
CO 1	3	3	3	3	2	2	1
CO 2	3	3	3	3	2	2	1
CO 3	3	3	3	3	2	2	1
CO 4	3	3	3	3	2	2	1
CO 5	3	3	3	3	2	2	1
CO 6	3	3	3	3	2	2	1

Assessment Pattern

Bloom's Category	**Continuous Evaluation (Marks)**	**End Semester Examination(Marks)**
Remember	10	15
Understand	10	15
Apply	15	25
Analyse	5	5
Evaluate	–	–
Create	–	–

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): 15 marks

Course based task/Seminar/Data collection and interpretation: 15 marks

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question Paper

C

PART A

(Answer *ALL* questions)

1. What are impact factors? How these factors vary with respect to the type of loading, span, and type of bridge?
2. List the live loads to be considered in the design of road bridges?
3. Explain the effective width procedure for finding moments due to concentrated loads acting on one-way slabs.
4. Explain Courbon's method of finding reaction factors in a T beam girder bridge using an example.
5. Sketch a single cell box culvert and mark the components.

PART B

(Answer Any *FIVE* questions only)

6. (a) Explain the classification of bridges with sketches.
   (b) Explain the importance of site investigation in bridge engineering.

12. Design an interior cross girder for a T beam bridge for the following data: Effective span = 16 m, Live load – IRC Class 70R tracked; Materials – M25 concrete and Fe 415 steel; spacing of cross girders 5 m c/c; width of carriage way 7.5m; thickness of wearing coat = 80 mm; kerbs on either side = 600 mm wide × 300 mm deep; width of main girder = 300 mm; width of cross girder = 300 mm; spacing of main girders = 2.5 m c/c. Sketch reinforcement details.

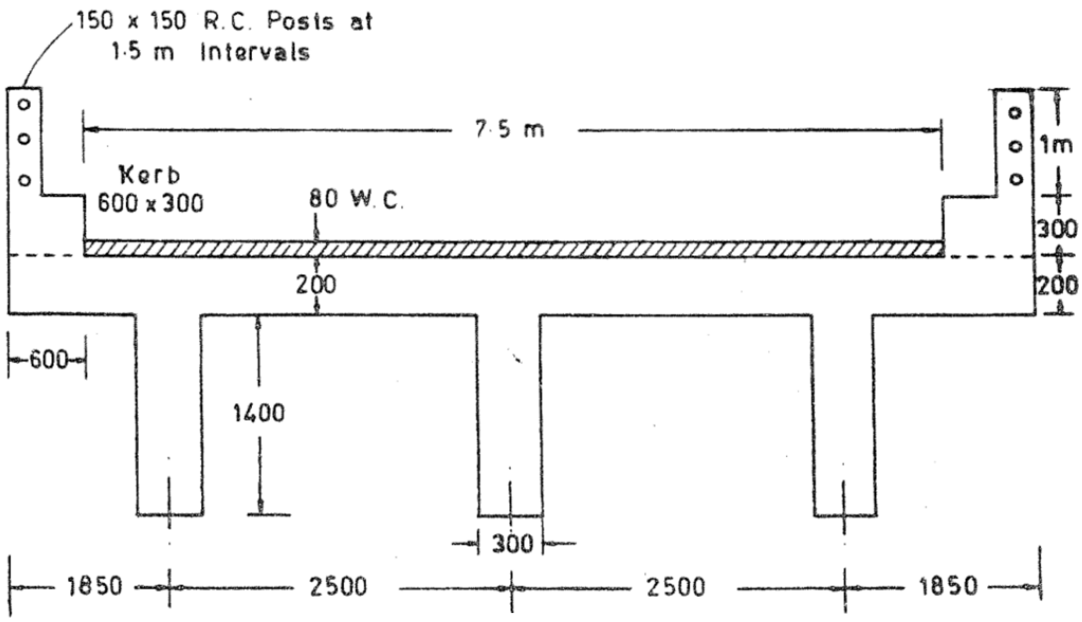
13. Design an interior longitudinal girder of a post tensioned prestressed concrete T beam bridge with the following data: Effective span = 24 m; Width of carriageway = 7.5 m; Kerbs 600 mm wide on either side; Spacing of main girders = 2 m; Spacing of cross girders = 4 m; Loading is IRC Class 70R tracked vehicle; Adopt M50 concrete and high tensile steel strands of 7 ply – 15.2 mm diameter with ultimate strength of 1800 MPa. Use Fe 415 grade steel for supplementary reinforcements. Assume loss ratio = 0.85.

14. Design a welded deck type plate girder bridge for a BG track to suit the following data: Effective span = 40 m; Dead load of track = 10 kN/m; Equivalent uniformly distributed load for bending moment calculations/track = 3498 kN; Equivalent uniformly distributed load for shear force calculations/track = 3815 kN. Take CDA = 0.324. Use plates of Fe410 grade.
15. Design an elastomeric bearing as per IRC 83 Part 2:2018 with the following data.

    Maximum vertical design force = 1009 kN

Minimum vertical design force = 666 kN
Horizontal force along span direction = 10.39 kN
Horizontal force along width direction = 41.56 kN
Resultant of all horizontal forces = 42.84 kN
Relative displacement in the direction of dimension '*a*' = 3.77 mm
Relative displacement in the direction of dimension '*b*' = 1.88 mm
Angle of rotation across the width 'a' of bearing = 0.00381
Angle of rotation across the length 'b' of bearing = 0.001
Adopt an elastomeric bearing (based on International Standards) of dimension 250 mm(*a*) × 400 mm(*b*)
Yield strength of steel laminate = 500 MPa

16. Design the main girder of a steel-concrete composite bridge as per relevant IRC standards to cover a span of 36m and for a three-lane carriage way. Use IRC- Class A loading.
17. Find out the distribution coefficient for the outer and central girder having the same moment of inertia as shown in the figure below, when single lane of class AA tracked loading is placed on the deck with maximum eccentricity. The distance between centre lines of bearing of the deck is 16 meters.



All dimensions are in mm.

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Syllabus

Module 1

Introduction to bridges: Importance of site investigation–Classification and components of bridges–Review of road (IRC) and railway (IRS) bridge specifications.

Module 2

Slab and T Beam Bridges: Loads on slabs, Effective width method–Design of straight and skew slab bridges as per relevant IRC loads–Design of interior panel of deck slab, Pigeauds curves–Distribution of loads on Girders – Courbon's method–Design of T beam bridges (up to three girders only) as per relevant IRC loads.

Module 3

Box culvert and Prestressed Concrete Bridges: Box culvert bridges–General aspects–Design of box culvert bridges (single cell) as per relevant IRC loads–Pre-stressed Concrete Bridges: Design of single span bridges–Introduction to various forms-Slab bridges-girder bridges-box girder bridges.

Module 4

Steel and Composite bridges: Design of plate girder (bolted and welded connection)–Design of Composite bridge (RCC slab over steel girder)–Theory-Load carrying action of folded plates.

Module 5

Bearings, substructures, and foundations in bridges: Design of elastomeric bearings–Abutments – General features, Loads on abutments, Stability analysis of abutments–Piers – Types, Loads on Piers, Stability analysis of Piers–Bridge Foundations – Types, selection criteria and suitability.

Course Plan

No	Topic	No. of Lectures
1	**Introduction to bridges (6)**	
1.1	Importance of site investigation	1
1.2	Classification and components of bridges	2
1.3	Review of road (IRC) and railway (IRS) bridge specifications	3
2	**Slab and T Beam Bridges (10)**	
2.1	Loads on slabs, Effective width method	1
2.2	Design of straight and skew slab bridges as per relevant IRC loads	3
2.3	Design of interior panel of deck slab, Pigeauds curves	1
2.4	Distribution of loads on Girders – Courbon's method	1

2.5	Design of T beam bridges (up to three girders only)as per relevant IRC loads	4
3	**Box culvert and Prestressed Concrete Bridges (9)**	
3.1	Box culvert bridges **-** General aspects	1
3.2	Design of box culvert bridges (single cell) as per relevant IRC loads	3
3.3	Pre- stressed Concrete Bridges: Design of single span bridges-	3
3.4	Introduction to various forms-Slab bridges-girder bridges-box girder bridges	2
4	**Steel and Composite bridges (6)**	
4.1	Design of plate girder [bolted and welded connection]	3
4.2	Design of Composite bridge (RCC slab over steel girder)	3
5	**Bearings, substructures, and foundations in bridges (9)**	
5.1	Design of elastomeric bearings	3
5.2	Abutments – General features, Loads on abutments, Stability analysis of abutments	3
5.3	Piers – Types, Loads on Piers, Stability analysis of Piers	2
5.4	Bridge Foundations – Types, selection criteria and suitability	1

Reference Books

1.Johnson Victor. D, “Essentials of Bridge Engineering”, Oxford.
2.N Krishna Raju, “Design of Bridges, Oxford and IBH publishing.
3.Jagadeesh T. R. and Jayaram M. A., “Design of bridge structures”, Prentice Hall of India.
4.Praveen Nagarajan, “Design of Concrete Bridges”, Wiley India Pvt. Ltd.
5. S. Ponnuswamy, “Bridge Engineering”, McGraw Hill Education.
6. Wai-Fah Chen, “Bridge Engineering Handbook: Substructure Design”, CRC Press.
7. V. K. Raina, Raina's Guiding Principles for Design, Construction, Load Capacity Evaluation, Load Testing, & Approximate Costing of 99% of All Bridges, Shroff Publisher.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222ECE038	STABILITY OF STRUCTURES	PROGRAMME ELECTIVE 3	3	0	0	3

Preamble: The course aims to provide anin-depth understanding on how and under what loading condition, a structure becomes unstable. The student is expected to learn stabilty analysis of various structures and how this theoretical knowledge can be transferred to design methods and guidelines. The students will be able to appreciate all structural design standards and confidentally design various structures.

Course Outcomes: After the completion of the course on Stability of Structures, the student will be able to

CO 1	To Identify the relevance of Stability analysis in structures
CO 2	Perform Stabilty Analysis of Columns
CO 3	Perform Stabilty Analysis of Beam - Columns
CO 4	Carryout Stability analysis of Frames with various Boundary and loading conditions
CO 5	To analyse the lateral stability of beams & Buckling of Thin-Walled Open Sections
CO 6	Perform Stability analysis of Plated and shell structures

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1	1	1	2	2	2	1	1
CO 2	1	1	2	2	2	1	1
CO 3	1	1	2	2	2	1	1
CO 4	1	1	2	2	2	1	1
CO 5	1	1	2	3	3	1	1
CO 6	1	1	2	3	3	1	1

Assessment Pattern

Bloom's Category	End Semester Examination
Remember	10
Understand	15
Apply	25
Analyse	10
Evaluate	–
Create	–

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewedoriginal publications (minimum 10 publications shall be referred): 15 marks

Course based task/Seminar/Data collection and interpretation: 15 marks

Test paper 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20% over the average ESE mark % for the core courses. ESE marks awarded to a student for each elective course shall be normalized accordingly. For example, if the average end semester mark % for a core course is 40, then the maximum eligible mark % for an elective course is 40+20 = 60 %.

Model Question Paper

Max Marks 60 **Duration 2.5 Hours**

PART A

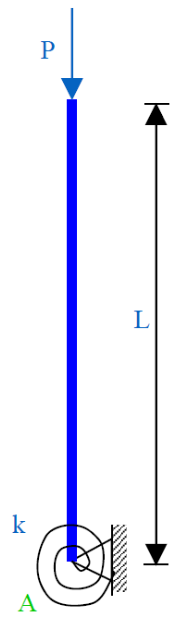
(Answer *ALL* questions , each question carries 5 marks)

1. Explain bifurcation buckling and limit load buckling.
2. Explain Rayleigh-Ritz method for estimation of buckling load of columns.
3. Derive the differential equation for a beam-column.
4. Describe in detail torsional and torsional-flexural buckling.
5. Differentiate between thin and thick plates.

PART B

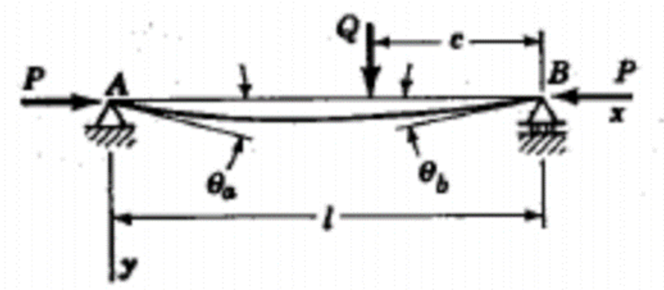
(Answer Any *FIVE* questions only, each question carries 7 marks)

6. Obtain the elastic buckling load of the system composed of a rigid bar partially fixed at the base by a rotational spring as shown in the figure. Use energy approach.



7. Using higher order differential equation representing the buckling behaviour of columns , estimate the buckling load for a column with fixed-fixed conditions

8. Find the buckling load of given beam- column



9. Explain post buckling strength.
10. Describe various buckling modes of Thin-walled open sections
11. Find the buckling load of cylindrical shell subjected to uniform external pressure.
12. Find the critical load for a simply supported plate uniformly compressed in one direction.

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Concepts of Stability (6)**	
1.1	Introduction - Stability Criteria – Stable, unstable and neutral Equilibrium	2
1.2	Fourth order Elastic- largedeflection of bars - differential equation for generalizedbending problems	2
1.3	Elastic instability of columns-Euler's theory-assumptions and limitations-Energy principles	2
2	**Compression Members (9)**	
2.1	Higher order Differential equations - analysis for various boundary conditions	2
2.2	Behaviour of imperfect column -initially bent column - eccentrically loaded column	2
2.3	Energy method- Rayleigh Ritz, Galerkin methods	1
2.4	Effect of shear on buckling – Large deflection ofcolumns.	2
2.5	Matrix Stiffness Method – Flexural members and compression members	2
3	**Beam Columns & Buckling of Frames (7)**	
3.1	Beam Columns:Introduction – Differential Equation forBeam-columns	1
3.2	Solution of differential equation forconcentrated lateral loads - distributed loads – differentend conditions - bottom fixed-bottom hinged	3
3.3	Buckling of frames: Solutions for various end conditions	2
3.4	Horizontal compressionmembers	1
4	**Lateral Stability of Beams & Buckling of Thin-Walled Open Sections (7)**	
4.1	Lateral Stability of Beams: Differential equations forlateral buckling	2
4.2	Lateral buckling of beams in purebending	1
4.3	Lateral buckling of cantilever and simplysupported I beams	1
4.4	Buckling of Thin-Walled Open Sections: Introduction	1
4.5	Torsional buckling - Torsional flexural buckling	1
4.6	Equilibrium and energy approaches	1
5	**Stability of Plates and Shells(11)**	
5.1	Stability of Plates -Governing Differential equation - Equilibrium, energy concepts	2
5.2	Buckling of rectangularplates of various end conditions	3
5.3	Finite differencemethod - post-buckling strength	2
6.1	Donnel's Equation – SymmetricalBuckling of Cylinder under uniform axial Compression	2
6.2	Cylinder under uniform external lateral pressure	1
6.3	Cylinder subjected to torsion.	1

Reference Books

1. Chajes, A., " Principles of Structural Stability Theory", Prentice Hall, 1974.
2. Iyengar, N.G.R., "Elastic Stability of Structural Elements", Macmillan India Ltd.,Newdelhi,2007.
3. Ziegler H, "Principles of structural stability", Blarsdell, Wallham, Mass, 1963.
4. Thompson J M, G W Hunt, "General stability of elastic stability", Wiley,New York.
5. Timoshenko, Gere, "Theory of elastic stability", Mc Graw Hill, New York.
6. Don O Brush, B O Almorth, "Buckling of Bars, plates and shells", Mc Graw Hill,1975
7. Cox H L, "The buckling of plates and shells", Macmillam, New York, 1963.
8. AshwiniKukar, "Stability of Structures ", Allied Publishers LTD, New Delhi, 1998.
9. Murali L. Gambir," Stability Analysis and Design of Strucures", Springer-Verlog, Berlin, 2004

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
222ECE039	THEORY OF PLATES AND SHELLS	PROGRAMME ELECTIVE 3	3	0	0	3

Preamble: The course aims to provide a basic understating of the behaviour of the plates and shells with different geometry under various types of loads. The student is expected to identify the various thin-walled structures in the form of plates and shellssuitable foruse in different structural systems.

Course Outcomes: After the completion of the course on Theory of Plates and Shellsthe student will be able to

CO 1	Explain the classification of plates, assumptions in the theory of thin plates and bending of long rectangular plates to a cylindrical surface
CO 2	Describe symmetrical bending of circular plates and use the concept to analyse annular plates
CO 3	Derive the differential equations for small deflections of laterally loaded plates for different boundary conditions and solve using Navier and Levy's method
CO 4	Understand the theory of folded plates
CO 5	Explain the theory, load carrying mechanism, state of stress and classification of shells
CO 6	Compute the stresses in cylindrical shell under dead and snow loads

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CO 1			1				
CO 2	2		1				
CO 3	2		1				
CO 4			1				
CO 5	1		1				
CO 6	1		1				

(1-Weak, 2-Medium, 3- strong)

Assessment Pattern

Bloom's Category	End Semester Examination
Remember	10
Understand	38
Apply	12
Analyse	
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed

original publications (minimum 10 publications shall be referred): 15 marks

Course based task/Seminar/Data collection and interpretation: 15 marks

Test paper, 1 no.: 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. Therewill be two parts; Part A and Part B. Part A will contain 5 numerical/short answerquestions with 1 question from each module, having 5 marks for each question(such questions shall be useful in the testing of knowledge, skills, comprehension,application, analysis, synthesis, evaluation and understanding of the students).

Students should answer all questions. Part B will contain 7 questions (suchquestions shall be useful in the testing of overall achievement and maturity of thestudents in a course, through long answer questions relating totheoretical/practical knowledge, derivations, problem solving and quantitativeevaluation), with minimum one question from each module of which studentshould answer any five. Each question can carry 7 marks.

Note: The marks obtained for the ESE for an elective course shall not exceed 20%over the average ESE mark % for the core courses. ESE marks awarded to astudent for each elective course shall be normalized accordingly. For example, if theaverage end semester mark % for a core course is 40, then the maximum eligiblemark % for an elective course is 40+20 = 60 %.

Model Question Paper

QP CODE:

Reg No.:_______________

Name:__________________________ ___

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SECOND SEMESTER M.TECH. DEGREE EXAMINATION,

MONTH & YEAR

Course Code: XXXX

THEORY OF PLATES AND SHELLS

Max. Marks: 60 Duration: 2.5 hours

PART A

(Answer ALL questions; each question carries 5 marks)

1. Show that for the small deflection of a plate subjected to pure bending, the directions of zero slope and max slope are perpendicular to each other.
2. A solid circular plate of radius 0.3 m with its outer edge completely restrained is subjected to a pressure load of 10 MPa. If the allowable stress in the plate is limited to 100 MPa, determine (i) The thickness of the plate, (ii) The maximum deflection, (iii) The stress at the centre of the plate. Take E = 200 GPa, ν = 0.3.
3. How would you compare Navier solution and Levy's solution as used for simply supported rectangular plates?
4. How shells are classified based on Gaussian curvature?
5. Show that there is a compression along the meridians of a spherical shell of radius a subjected to the action of its own weight of magnitude q per unit area.

PART B

(Answer any FIVE questions; each question carries 7 marks)

6. Derive the differential equation for the cylindrical bending of long rectangular plates.
7. Derive the differential equation for symmetrical bending of laterally loaded circular plates and obtain the expression for maximum deflection for circular plate with clamped edges.
8. Find the deflection of a circular plate (radius a) with a hole (radius b) at the centre and subjected to moments M1 and M2 at the inner and outer edges respectively.

9. Obtain the differential equation for the small deflections of a laterally loaded plate.
10. A rectangular plate ($\boldsymbol{a} \times \boldsymbol{b} \times \boldsymbol{h}$), simply supported on all four edges is subjected to sinusoidal load ($\boldsymbol{q_0 \sin\frac{\pi x}{a} \sin\frac{\pi y}{b}}$) distributed over the surface of the plate. Find expressions for deflection ($\boldsymbol{w}$), bending moments ($\boldsymbol{M_x}$, $\boldsymbol{M_y}$)
11. Explain the load carrying mechanism of shells.
12. Develop the expressions for the displacements in symmetrically loaded shells having the form of a surface of revolution.

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Syllabus

Module 1

Introduction- Classification of plates -Assumptions in the theory of thin plates-Bending of long rectangular plates to a cylindrical surface. Pure bending of plates-Slope and curvature - Relations between bending moments and curvature-Particular cases of pure bending.

Module 2

Symmetrical bending of circular plates-Differentialequation. Uniformly loaded circular plates with simplysupported and fixed boundary conditions-Annular plate withuniform moments and shear forces along the boundaries.

Module 3

Small deflections of laterally loaded plates-Differentialequation-Boundary conditions-Navier solution and Levy'ssolution for simply supported rectangular plates.

Module 4

Theory-Load carrying action of folded plates.

Classical shell theory- Load carrying mechanism of shells - Types of state of stress for thin shells-Classification of Shells.

Module 5

Shells in the form of a surface of revolution, displacements. Membrane theory of cylindrical shells. General theory of cylindrical shells-A circular cylindrical shell loaded symmetrically with respect to its axis- stresses in cylindrical shell under dead and snow loads.

Course Plan

No	Topic	No. of Lectures
1	**Pure Bending of Plates (10)**	
1.1	Introduction- Classification of plates -Assumptions in the theory of thin plates. Bending of long rectangular plates to a cylindrical surface – Differential equation.	2
1.2	Pure bending of plates-Slope and curvature.	2
1.3	Relations between bending moments and curvature- Particular cases of pure bending.	6
2	**Circular Plates (6)**	
2.1	Symmetrical bending of circular plates- Differentialequation.	1
2.2	Uniformly loaded circular plates with simplysupported and fixed boundary conditions	2
2.3	Annular plate withuniform moments and shear forces along the boundaries.	3
3	**Laterally loaded Plates (10)**	
3.1	Small deflections of laterally loaded plates-Differential equation - Boundary conditions.	4
3.2	Simply supported rectangular plates under sinusoidal load.	2
3.3	Navier solution and Levy's solution for simply supported rectangular plates.	4
4	**Folded Plates and shells (6)**	
4.1	Theory-Load carrying action of folded plates.	2
4.2	Classical shell theory- Load carrying mechanism of shells.	2
4.3	Types of state of stress for thin shells-Classification of shells.	2
5	**Theory of Shells (8)**	
5.1	Displacements in symmetrically loaded shells having the form of a surface of revolution.	2
5.2	Membrane theory of cylindrical shells.	2
5.3	General theory of cylindrical shells-A circular cylindrical shell loaded symmetrically with respect to its axis- stresses in cylindrical shell under dead and snow loads.	4

Reference Books

1. Timoshenko S.P. and Krieger S. W., Theory of Plates and Shells, Tata McGraw Hill, 1959
2. Chandrashekhara K., Theory of Shells, Universities(India)Press Ltd., 2001
3. Ramaswamy G. S., Design and Construction of Concrete Shell Roofs, CBS Publishers, 2005
4. Bairagi N. K., Plate Analysis, Khanna Publishers, 1986

5. Kelkar V. S. and Sewell R.T., Fundamentals of the Analysis and Design of Shell Structures, Prentice Hall Inc., 1987
6. T.K.Varadan& K. Bhaskar, Análysis of plates – Theory and problems, Narosha Publishing Co., 1999.
7. Reddy J N., Theory and Analysis of Plates and Shells, Taylor and Francis, 2006