Semester II

Discipline: MECHANICAL ENGINEERING

Stream: ME1 (MACHINE DESIGN)

222TME100	DESIGN OF EXPERIMENTS	CATEGORY	L	T	P	CREDIT
		Discipline Core	3	0	0	3

Preamble:

Investigators perform experiments in virtually all fields of inquiry, usually to discover something about a particular process or system. In this course, you will learn the basic concepts of experimental design, and the statistical analysis of data. On completion of the course, you would be able to plan and conduct experiments, and analyse the resulting data so that valid conclusions can be drawn.

Course Outcomes:

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

CO 1	Perform statistical analysis of data.
CO 2	Conduct statistical hypothesis tests on mean and variance of populations.
CO 3	Design and analyse single factor experiments.
CO 4	Design and analyse full and fractional factorial experiments.
CO 5	Apply Response Surface Methodology to optimise the response in an experiment.
CO 6	Carry out an experimental project and analyse the results using statistical software.

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	3	1	2
CO 2	3	3	3	3	3	1	2
CO 3	3	1	3	3	3		1
CO 4	3	1	3	3	3		1
CO 5	3	1	3	3	3		3
CO 6	3	2	3	3	3	1	3

Assessment Pattern

Bloom's Category	End Semester Examination

Apply	20%
Analyse	20%
Evaluate	10%
Create	10%

Mark distribution

Total Marks	**CIE**	**ESE**	**ESE Duration**
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: 40 Marks

Course based project/Mini project: 20 Marks.

(Identify a relevant problem and design experiments to be carried out. Analyse the results using a software package like R, Minitab, Design Expert, Python etc. and establish the results between the dependent and independent variables.)

Course based task/ Quiz: 10 Marks

Test paper: 10 Marks

(Test paper shall include minimum 80% of the syllabus.)

End Semester Examination Pattern: 60 Marks

The end semester examination will be conducted by the University for Core Courses. 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:

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY SECOND SEMESTER M.TECH DEGREE EXAMINATION			
MECHANICAL ENGINEERING			
222TME100: DESIGN OF EXPERIMENTS			
Max. Marks: 60			Duration: 2.5 Hours
PART A			
		Answer all the questions. Each question carries 5 *marks*	Marks
1		Following data refer to 6 observations on natural frequency (in Hertz) of beams subjected to a load in an experiment: 230.66, 233.05, 232.58, 229.48, and 232.58. Construct a 90% confidence interval for the data.	(5)
2		A cement manufacturer claims that the mean settling time of his cement is not more than 45 minutes. A random sample of 20 bags of cement selected and tested showed an average settling time of 49.5 minutes with a standard deviation of 3 minutes. Test whether the company's claim is true. Use 5 % level of significance.	(5)
3		Describe the roles of randomization, replication and blocking in experimental design.	(5)
4		What are the model adequacy checks generally carried out in a factorial experimental design?	(5)
5		What are the advantages and limitations of fractional factorial designs?	(5)
PART B			
Answer any five full questions. Each question carries 7 *marks.*			
6	(a)	The following data refer to the weights of 10 students (kg) in a class: 63, 64, 59, 58, 65, 70, 56, 68, 60 and 62. Construct a normal probability plot of the data. Does it seem reasonable to assume that the students' weight is normally distributed?	(4)
	(b)	The following data refer to the number of sales of cakes on different days in a season. Represent the data as a box plot. 54, 60, 65, 66, 67, 69, 70, 72, 73, 75, 76	(3)

7	Fifteen adults between the ages of 35 and 50 participated in a study to evaluate the effect of diet and exercise on blood cholesterol levels. The total cholesterol was measured for each person initially, and then three months after participating in an aerobic exercise program and switching to a low-fat diet. The blood cholesterol level data are shown in the following table.	(7)
8	An agricultural officer wants to study the effect of four different fertilizers on the yield (in tons) of a specific crop. Since there might be variability from one plot to another plot, he decides to use the randomized complete block design. The data are presented in the table. Test whether the type of fertilizer used has significant effect on the yield of the crop.	(7)

Subject	1	2	3	4	5	6	7	8	9	10	11	12
Before	265	240	258	295	251	245	287	314	260	279	283	240
After	229	231	227	240	238	241	234	256	247	239	246	218

Plot	**Fertilizer**			
	A	B	C	D
1	100	150	120	70
2	80	70	110	100
3	68	90	85	78
4	125	138	60	124

9		An oil company wants to test the effect of four different blends of gasoline (A, B, C, D) on fuel efficiency. The company has used four cars for testing the four types of fuel. To control the variability due to cars and drivers, Latin square design has been used. The collected data from the experiment is shown in the table below. Analyse the data and test whether the four blends of gasoline, cars and the drivers significantly affect the fuel efficiency.	(7)

Driver	Cars			
	I	II	III	IV
1	D = 15.5	B = 33.9	C = 13.2	A = 29.1
2	B = 16.3	C = 26.6	A=19.4	D = 22.8
3	C = 10.8	A = 31.1	D = 17.1	B = 30.3
4	A = 14.7	D = 34.0	B = 19.7	C = 21.6

10		The yield of a chemical process is being studied. The two most important variables are thought to be the pressure and temperature. Three levels of each factor are selected, and a factorial experiment with two replicates is performed. The yield data are given in the table below. Analyse the data and	(7)

Temperature (^oC)	Pressure (psi)		
	200	215	230
150	90.4	90.7	90.2
	90.2	90.6	90.4
160	90.1	90.5	89.9
	90.3	90.6	90.1
170	90.5	90.8	90.4
	90.7	90.9	90.1

draw conclusions. Use $\alpha = 0.05$

11		A 2^3 factorial design was used to develop a nitride etch process on a plasma etching tool. The design factors are the gap between the electrodes (A), the gas flow (B), and the power applied to the cathode (C). Each factor is run at two levels, and the design is replicated twice. The response variable is the	(7)

etch rate for silicon nitride. The data are given in the table below. Analyse the data to identify the significant factors and interactions.

Coded factors			**Etch rate**	
A	**B**	**C**	**Replication 1**	**Replication 2**
-1	-1	-1	550	604
1	-1	-1	669	650
-1	1	-1	633	601
1	1	-1	642	635
-1	-1	1	1037	1052
1	-1	1	749	868
-1	1	1	1075	1063
1	1	1	729	860

12 The yield of a melting furnace in a foundry is suspected to be affected by the temperature 'T' and melting time 'M'. The data of this experiment with one replication in different treatment combinations are summarized in the table below. Further, five replications are taken at the centre point. Fit a first order response surface for this problem to determine the optimum settings for the temperature and melting time at a significance level of 0.05. (7)

		Melting time	
		60 min.	66 min.
Temperature	400°C	75	77
	410°C	80	84
Centre point replications	1	79	
	2	78	
Temperature (405°C)	3	76	
	4	79	
Melting time (63	5	80	

Syllabus:

Module 1

Introduction to Design of Experiments: One factor at a time experiments and designed experiments; Role of DoE in experimentation. Application of software packages for designing experiments.
Basic statistical concepts: Probability distributions; pdf and cdf; mean and variance. Normal and Student's *t* distributions; Normal probability plot. Tables and charts to represent data; Stem and leaf; Box plot; Pareto chart.
Sampling distribution of the mean: Central Limit Theorem. Constructing Confidence Intervals for a single mean, variance, and difference of two means.

Module 2

Hypothesis Testing: Hypothesis testing of single means. Testing of two means - with known and unknown population variance. Paired t-test. Testing of variances. Analysis of Variance (ANOVA).

Module 3

Single Factor Experiments: Completely randomized design. Replication, Randomization, Blocking. Randomized complete block design. Latin square design.

Model adequacy checking: Residual plots.

Module 4

Factorial experiments: Two and three factors full factorial experiments. 2-level full factorial experiments. Effects and contrasts; Yate's algorithm. Single replicate case. Addition of central points to the 2^k design. Blocking and confounding in the 2^k factorial design.

Module 5

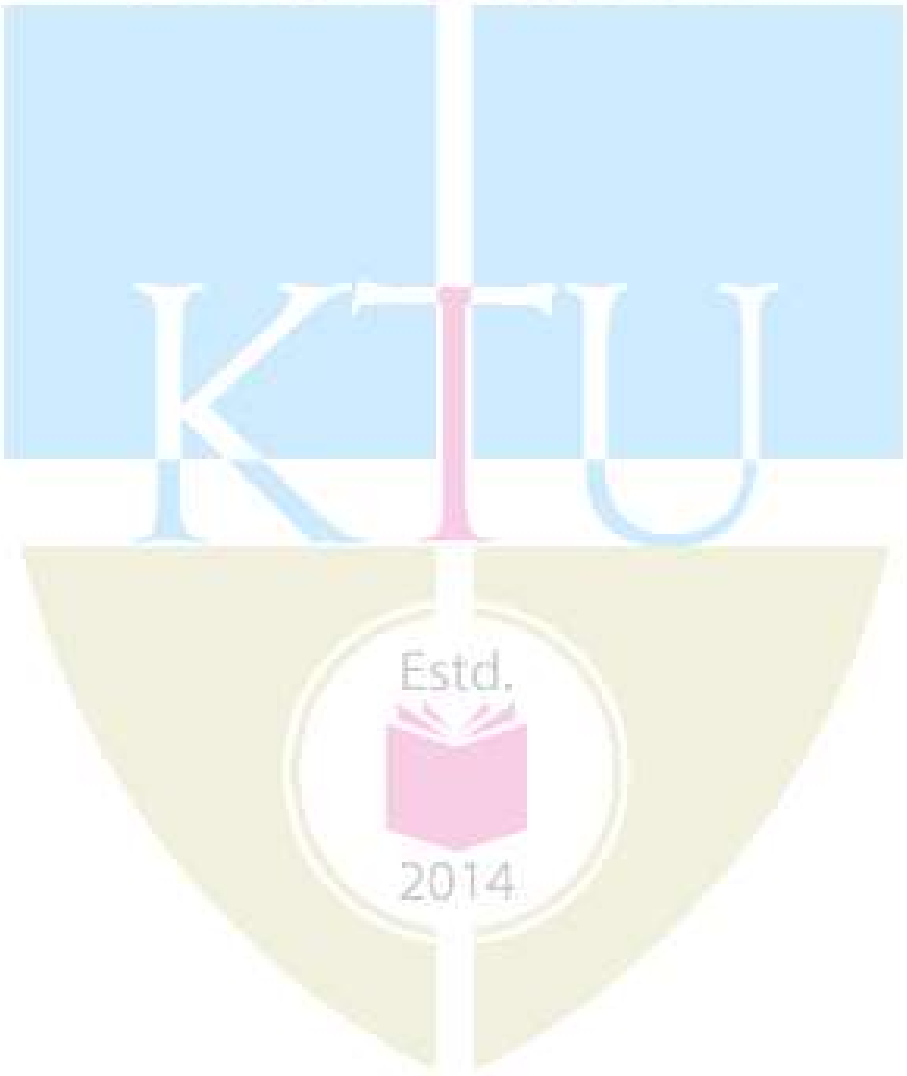
Fractional Factorial Experiments: 2-level fractional factorial design. One-half fraction of the 2^k design. Alias structures in fractional factorial designs; Confounding; Design resolutions.
Response Surface Methodology: Central Composite Design.

Course Plan

No.	Topic	No. of Lectures
1	**Introduction to Design of Experiments**	
1.1	One factor at a time experiments and designed experiments; Role of DoE in experimentation.	1
1.2	Application of software packages for designing experiments.	1
1.3	Basic statistical concepts; Probability distributions; pdf and cdf; mean and variance.	1
1.4	Normal and Student's *t* distributions; Normal probability plot.	1
1.5	Tables and charts to represent data; Stem and leaf; Box plot; Pareto chart.	1
1.6	Sampling distribution of the mean; Central Limit Theorem.	1
1.7	Constructing Confidence Intervals for a single mean, variance, and difference of two means.	2
2	**Hypothesis Testing**	
2.1	Hypothesis testing of single means.	2
	Testing of two means - with known and unknown population variance.	2
2.2	Paired t-test.	1
2.3	Testing of variances.	1
2.4	Analysis of Variance.	2
3	**Single Factor Experiments**	
3.1	Completely randomized design.	2
3.2	Replication, Randomization, Blocking.	1
3.3	Randomized complete block design.	2
3.4	Latin square design.	1
3.5	Model adequacy checking; residual plots.	2
4	**Factorial experiments**	
4.1	Two and three factors full factorial experiments.	2
4.2	2^k full factorial experiments.	2
4.3	Effects and contrasts; Yate's algorithm.	1
4.4	Single replicate case.	1
4.5	Addition of central points to the 2^k design.	1
4.6	Blocking and confounding in the 2^k factorial design.	1
5	**Fractional Factorial Experiments**	
5.1	2-level fractional factorial design.	2
5.2	Alias structures in fractional factorial designs; Confounding; Design resolutions.	2
5.3	Response Surface Methodology.	2
5.4	Central Composite Design.	2

Reference Books

1. Montgomery, D. C. (2001). Design and analysis of experiments, John Wiley, New York.
2. Montgomery, D. C. & Runger, G. C. (2007). Applied Statistics and Probability for Engineers, John Wiley, New York.
3. Krishnaiah, K. & Shahabudeen, P. (2012). Applied Design of Experiments and Taguchi Methods, PHI, New Delhi.
4. George, E. P., et al. (2005). Statistics for experimenters: design, innovation, and discovery, John Wiley, New York.
5. Panneerselvam, R. (2012), Design and Analysis of Experiments, PHI, New Delhi



222TME001	FINITE ELEMENT ANALYSIS	CATEGORY	L	T	P	CREDIT
		Programme Core	3	0	0	3

Course Objectives

Basic understanding of mathematical foundations of FEA. Preprocessing, solution and post processing. Discretization of problem domain into a finite element mesh. Assembly of element equations and boundary condition. Solution for nodal unknowns and derived quantities over each element. Finite element mesh refinement and convergence. Implementation and application of FEM in 1-D, 2-D, 3-D static and dynamic structural analysis, transient, non-linear and coupled field analysis

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

CO 1	To understand various principles used in FE formulation and develop algebraic form of equations using these principles in 1-D domain
CO 2	To understand and develop FE formulation of various elements for beam and plate bending, plane stress/plane strain and 3-D structural problems
CO 3	To understand and apply transformations to develop assembled global matrix form of equations, apply boundary conditions and get elemental level data after solving
CO 4	To understand and apply FE formulation/procedure for modal analysis, transient analysis, Non-linear problems and coupled field problems
CO 5	To develop a full-fledged finite element code for pre-processing, solving and post processing a given structural problem
CO 6	To assimilate latest research/developments in this domain and document it and present as a seminar

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			
CO 2			3	3	2		
CO 3			3	3	2		

CO 4			3	3	2		
CO 5	3	3	3	3	3	2	
CO 6	3	3			2	2	

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	√
Analyse	√
Evaluate	√
Create	

Mark distribution

Total Marks	**CIE**	**ESE**	**ESE Duration**
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: CORE COURSE

Continuous Internal Evaluation: 40 marks

Micro project/Course based project : 20 marks

Course based task/Seminar/Quiz : 10 marks

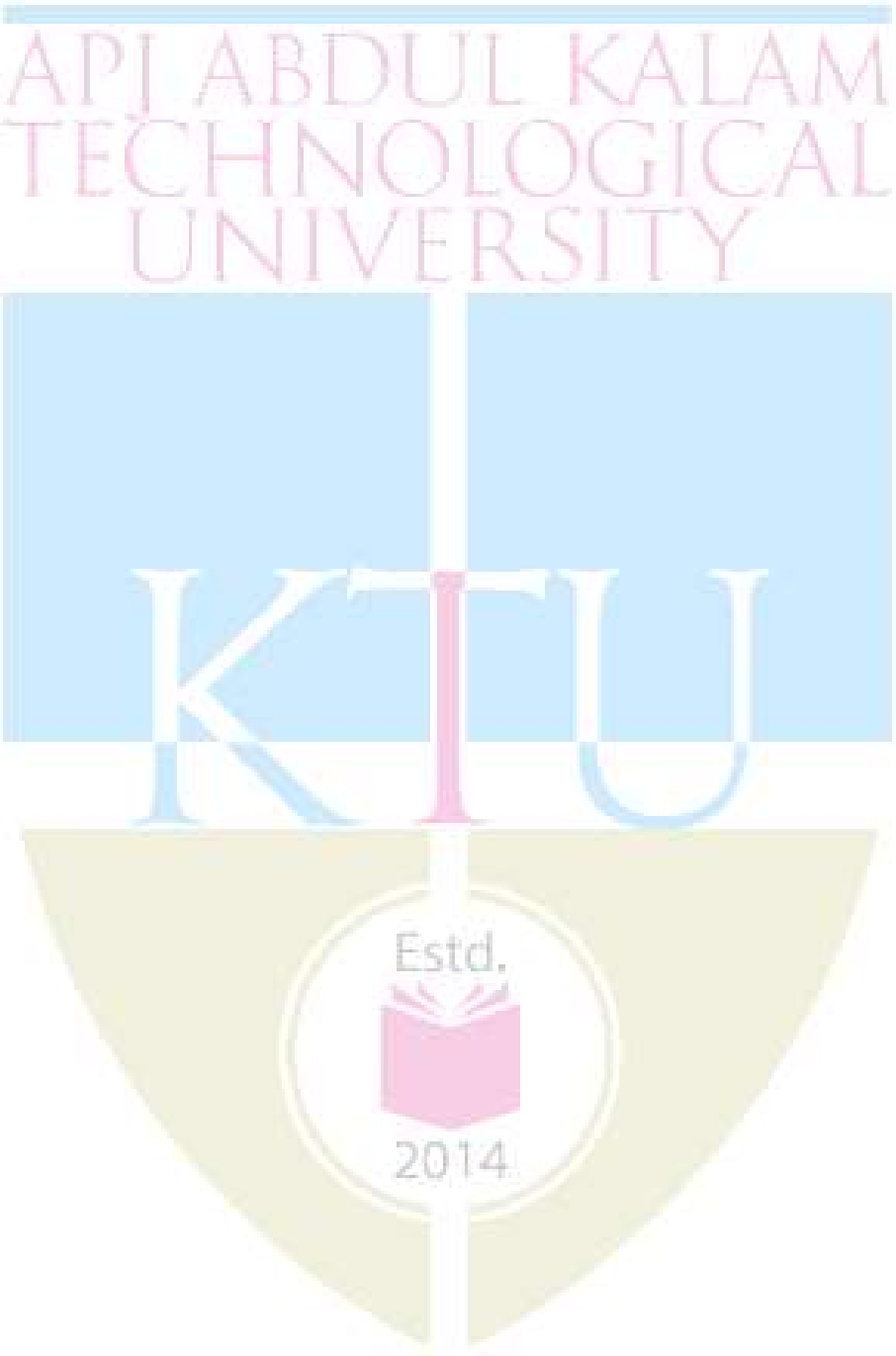
Test paper, 1 No. : 10 marks

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

End Semester Examination Pattern: (60 Marks)

The end semester examination will be conducted by KTU for Core Courses. 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: Total Pages:

Reg No.:_____ Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Stream: MACHINE DESIGN

Course Code: 222TME001

Course Name: **FINITE ELEMENT ANALYSIS**

Max. Marks: 60 Duration: 2.5 Hours

PART A

Answer all questions, each carries 5 marks. Marks

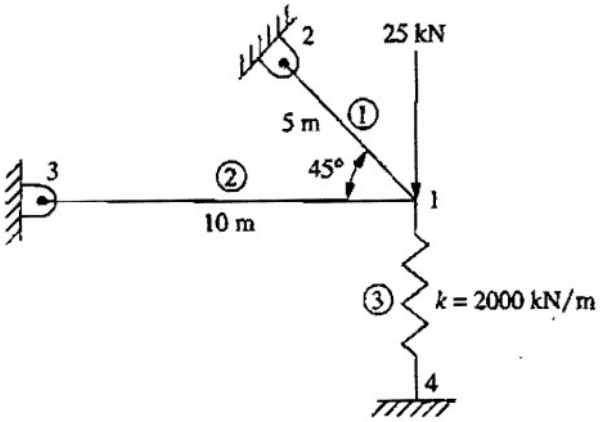
1	Explain virtual work method for developing finite element equations of 1-D bar element	(5)
2	Explain C^0 and C^1 elements with examples	(5)
3	Develop shape functions of CST element in terms of its nodal co-ordinates	(5)
4	What is full and reduced integration? Explain with example	(5)
5	Explain implicit and explicit scheme in dynamic analysis	(5)

PART B

Answer any 5 full question, each question carries 7 marks.

6	(a)Explain with an example, advantages of Weak formulation	(3)
	(b)Derive the stiffness matrix and force vector of a uniform 2-node bar element subjected to uniformly distributed axial force using minimum potential energy principle	(4)
7	Derive the stiffness matrix and force vector of 2-node Euler Bernoulli beam element subjected to UDL	(7)

8 (7)



For the two bar truss with spring support, find the nodal displacements and elemental stresses. E=200 GPa and Area of bars=$5x10^{-4}$ m^2

9 (a) Nodal co-ordinates of a CST element are (10,10), (20,50), (-10,30) all in mm. If the in-plane displacement components at these nodes are found to be (1,-1), (-2,1) and (0.5, -0.5) all in mm respectively, find the variation of displacements, u(x,y) and v(x,y) within the element. (4)

(b) Explain with examples, what are h,p,r refinements (3)

10 (a) Derive the shape functions of 8-noded quadrilateral element in natural co-ordinates (4)

(b) What are the convergence requirements in FEA (3)

11 Find the natural frequencies of transverse vibrations of a two-step beam fixed at both ends using two element configuration. Density-7850 kg/m^3, E=200 GPa, Area of step 1 is 10cm x 10cm and Area of step 2 is 5cm x 5cm. Length of step 1 is 1m and Length of step 2 is 2m. Use consistent mass matrix formulation (7)

12

Explain briefly (4)

(a) Newton-Raphson and modified Newton-Raphson method for non linear analysis

(b) Coupled field analysis with an example (3)

Syllabus

Module-I

Matrix algebra in FEM, Methods of solution of simultaneous equations. Basic concepts of FEM, Virtual work and variational methods. Method of weighted residuals-strong and weak form (Galerkin), Boundary conditions (Essential and natural). FE formulation using Principle of stationary potential energy. Stiffness (Displacement) Method, Spring, Bar elements, torsion elements, conduction and flow elements. Development of truss equations (Stiffness matrix, load vectors)

Module II

Interpolation functions for general element formulation (Lagrangian and Hermite). C^0 and C^1 elements. Development of Euler, Timoshenko beam equations, stress computation. 2-D Frame and grid equations, Transformation of coordinates from local to global. Assembly procedure and Imposing Multipoint constraints (Penalty and Lagrangian Multiplier method). Evaluation of elemental level stress/strain/nodal displacements)

Module III

Development of the Plane Stress and Plane Strain Stiffness Equations. Practical Considerations in Modeling, Interpreting Results and Examples of Plane Stress/Strain Analysis. Development of the CST, Linear-Strain Triangle Equations for plane and axisymmetric problems with point, surface and body forces. Plate Bending Element. Patch test, different type of refinements (h, p and r). Convergence, accuracy and error norms

Module IV

Natural coordinates systems. Iso-parametric formulation. 4-node and 8-node quadrilateral elements. Jacobian matrix. Numerical integration, Full and reduced integration. Shear locking. Higher order elements- convergence requirements-Pascal triangle and Pascal tetrahedron. Three-Dimensional Stress Analysis, Lagrange and Serendipity Elements in 3-D. Inclusion of initial effects (pre-stress/thermal strains) in the element formulation

Module V

Structural Dynamics, Mass matrix computation (lumped and consistent), Evaluation of eigen values and eigen vectors, Modal Analysis. Transient analysis: Euler's method, Central difference technique, Critical time step, Rigid body modes. Newton-Raphson method for solving nonlinear differential equations. Introduction to coupled field analysis.

Course Plan

Module	Contents	Hours Allotted
1.1	Review of Matrix Algebra and solution of Simultaneous equations	1
1.2	Basic concepts of FEM, Virtual work and variational methods	1
1.3	Method of weighted residuals-strong and weak form (Galerkin), Boundary conditions (Essential and natural)	2
1.4	FE formulation using Principle of stationary potential energy	1
1.5	Stiffness (Displacement) Method, Spring, Bar elements, torsion elements, conduction and flow elements	1
1.6	Development of truss equations (Stiffness matrix, load vectors)	2
2.1	Interpolation functions for general element formulation (Lagrangian and Hermite). C0 and C1 elements	1
2.1	Development of Euler, Timoshenko beam equations, stress computation	3
2.3	2-D Frame and grid equations, Transformation of coordinates from local to global.	1
2.4	Assembly procedure and Imposing Multipoint constraints (Penalty and Lagrangian Multiplier method). Evaluation of elemental level stress/strain/nodal displacements)	3
3.1	Development of the Plane Stress and Plane Strain Stiffness Equations	2
3.2	Practical Considerations in Modeling, Interpreting Results and Examples of Plane Stress/Strain Analysis	2
3.3	Development of the CST, Linear-Strain Triangle Equations for plane and axisymmetric problems with point, surface and body forces	2

3.4	Plate Bending Element formulation and load vector formulation	1
3.5	Patch test, different type of refinements (h, p and r).	1
3.6	Convergence, accuracy and error norms	1
4.1	Iso-parametric formulation. 4node and 8node quadrilateral elements.	1
4.2	Natural co-ordinates, Numerical integration, Full and reduced integration, Shear locking	2
4.3	Higher order elements- convergence requirements- Pascal triangle and Pascal tetrahedron	2
4.4	Three-Dimensional Stress Analysis, Lagrange and Serendipity Elements in 3-D	2
4.5	Inclusion of initial effects (pre-stress/thermal strains) in the element formulation	1
5.1	Mass matrix computation (lumped and consistent), Evaluation of eigen values and eigen vectors, Modal analysis	2
5.2	Transient analysis: Euler's method, Central difference technique, Critical time step, Rigid body modes	2
5.3	Newton-Raphson method for solving nonlinear differential equations	2
5.4	Introduction to coupled field analysis	1

Text Books:

1. Fundamentals of FEM by David V Hutton, Mc Graw Hill

2. A First Course in the Finite Element Method Fifth Edition - Daryl L. Logan - Thomson

3. An introduction to the Finite Element Method, 3rdEdn. Reddy J. N.

4. Introduction to finite elements in engineering, T. R.Chandrupatla and Ashok D. Belegundu , PHI

5. Textbook of Finite Element Analysis, P. Seshu, PHI

References

1. Finite element procedures K. J. Bathe, PHI
2. The Finite element methods in engineering, S S Rao
3. Elementary Finite Elements Method, Desai C. S.
4. The Finite Element Method, Zienkiewicz O. C.
5. Applied finite element analysis, Larry J.Segerlind
6. Finite Element Method, R. D. Cook
7. Finite Element Method, C.S. Krishnamurthy
8. Basics of F E M- Solid Mechanics, Heat transfer and Fluid mechanics, Dubuque I A and W C Brown.
9. Introduction to Nonlinear Finite Element Analysis, Nam-Ho Kim, Springer
10. An Introduction to Nonlinear Finite Element Analysis: with applications to heat transfer, fluid mechanics, and solid mechanics, J N Reddy, Springer
11.Fundamental Finite Element Analysis and Applications: with Mathematica and Matlab Computations, wiley
12.The finite element method using MATLAB, Young W. Kwon, Hyochoong Bang, CRC Press

PROGRAM ELECTIVE III

222EME000	DESIGN AND ANALYSIS OF COMPOSITE STRUCTURES	CATEGORY	L	T	P	CREDIT
		Programme Elective	3	0	0	3

Preamble:

To enable the students to understand and analysis aspects of structural materials such as FRPs; which are having high specific strength and modulus, and are not isotropic but orthotropic or anisotropic in nature; to design structures for light weight applications

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

CO 1	1. Gain knowledge of Composite materials used for light weight structural applications such as FRPs, its applications and advantages 2. Understand Latest developments in FRPs 3. Understand micromechanical behaviour and evaluate the properties of composite from its constituents
CO 2	1. Establish the constitutive equations for anisotropic, orthotropic and transversely isotropic materials 2. Determine the elastic constants/elasticity tensor
CO 3	Understand the classical laminate theory and apply it for analysis of structures under various loading conditions. To gain knowledge of stress analysis and failure analysis of composites.
CO 4	1. Understand failure modes of composite structures 2. To do the failure predictions/evaluations of fracture in composites.
CO 5	1. Design of sandwich/laminate structures at application level 2. To analyse with Finite Element Methods/tools

Mapping of course outcomes with program outcomes

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

CO 3			3	2	2		
CO 4	3		3		2		
CO 5			3	3	3		

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	35 %
Analyse	35 %
Evaluate	20 %
Create	10 %

Mark distribution

Total Marks	**CIE**	**ESE**	**ESE Duration**
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern: Programme Elective

Continuous Internal Evaluation: 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.

End Semester Examination Pattern: (60 Marks)

The end semester examination will be conducted by the respective College for Programme Electives. 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:		**Total Pages: 3**
Reg No.:_____		**Name:**_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

2nd SEMESTER M.TECH DEGREE EXAMINATION, July 2023

Stream: Machine Design

Course Code: 222EME100

Course Name: DESIGN AND ANALYSIS OF COMPOSITE STRUCTURES

Max. Marks: 60	*Missing data if any may be suitably assumed*	**Duration: 2.5 Hours**

PART A

		Answer all questions, each carries 5 marks.	**Marks**
1		What is WRM? Where will you use it? Write a note on different types of textile weaving	**(5)**
2		How do the independent elastic constants in the elastic tensor reduce to 13 (from 91) in the case of monoclinic material? Explain.	**(5)**
3	**(a)**	Write the Kirchhoff hypothesis	**(2)**
	(b)	Write the equilibrium equations for a composite laminate under general loading condition	**(3)**
4		Compare the fracture behavior of composites and metals	**(5)**
5		What are the advantages and applications of using sandwich composites? Obtain the expression for flexural rigidity of a sandwich panel	**(5)**

PART B

Answer any 5 full question, each question carries 7 marks.

6	**(a)**	Derive the expression for longitudinal modulus of a unidirectional composite material	**(3)**
	(b)	Determine the engineering constants (properties) of the unidirectional GFRP lamina containing 50 % volume of fibers. Take E_f = 230 GPa, E_m = 3.5 GPa, ν_f = 0.2 , ν_m = 0.3	**(4)**
7		A tensile specimen of a unidirectional composite with a rectangular cross section of dimensions 12.5 mm x 4 mm has the fibers oriented at 30^0 to a longitudinal edge of the specimen. It is subjected to an axial force of 500 N. Properties of the composites in L-T directions are E_L = 14 GPa, E_T = 3.5 GPa, ν_{LT} = 0.4 , G_{TL} = 4.2 GPa a) Calculate normal strains in the axial and perpendicular directions, and shear strain on the specimen (b) Calculate off-axis modulus, the Poisson's ratio and cross-coupling coefficient for this specimen.	**(7)**
8		From the fundamentals, obtain the relation between engineering constants and elements of stiffness matrix for a specially orthotropic material	**(7)**
9		The following material properties are given for a unidirectional symmetric ply laminate of thickness, h = 2 mm. $[A]=\begin{bmatrix}60 & 19 & 0\\ 19 & 12 & 0\\ 0 & 0 & 20\end{bmatrix}$ GPa-mm $[D]=\begin{bmatrix}10 & 2 & 0\\ 2 & 3 & 0\\ 0 & 0 & 1.5\end{bmatrix}$ GPa-mm^3 The mass density is 2 N-s^2/mm^4. If the plate is simply supported on all four edges, what is the fundamental frequency?	**(7)**
10		Suppose you are provided with carbon fiber (WRM) and epoxy as raw materials and asked by your supervisor to experimentally evaluate as per standards the Mode-I and Mode-II fracture toughness of the eight layer CFRP laminates they manufacture; how do you evaluate it in your lab? Explain the procedure.	**(7)**
11		A unidirectional composite lamina with fibers oriented at 30^o to the x- axis, has allowable tensile stress of 650 MPa in the fiber direction and 50 MPa in the fiber transverse direction;	**(7)**

		and the allowable compressive stress of 400 MPa in the fiber direction and 100 MPa in the fiber transverse direction. The allowable shear stress is 50 MPa. If the lamina is subjected to loading conditions given as, σ_x = 50 MPa (Compression), σ_y = 150 MPa (Compression) and τ_{xy} = 50 MPa (+ve), Determine whether, the lamina will fail under the applied stresses using (i) Maximum stress theory and (ii) Tsai- Hill Theory	
12		Briefly discuss the steps in FE analysis of a simply supported composite beam under point load.	**(7)**

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Introduction and Micromechanics**	
1.1	Definition and classification of Composites, Fiber reinforced polymer (FRPs) materials, Constituents- reinforcement and matrix materials, Terminologies,	3
1.2	Types of textile weaving, 3D composites, Nano-composites.	2
1.3	Micromechanics of lamina- volume and mass fractions, density and void content, Evaluation of strength, elastic moduli, Poisson's ratio - of composites from constituent properties- rule of mixture.	3
2	**Constitutive Equations**	
2.1	Constitutive equations- Generalised Hooke's law, Hooke's law for anisotropic, monoclinic, specially orthotropic and transversely isotropic material, stiffness and compliance matrices.	3
2.2	Macro-mechanics of orthotropic lamina- plane stress analysis, reduced stiffness matrix, transformed reduced stiffness matrix.	3
2.3	Determination of strength and stiffness characteristics of orthotropic materials.	2
3	**Stress Analysis of Laminates**	
3.1	Classical laminate theory: Assumptions, Kirchhoff-Love assumption, In-plane resultant forces and moments, synthesis of stiffness matrix, laminate constitutive equation, determination of stress- strain variation in a laminate.	4
3.2	Laminate orientation code, types of laminates, coupling effects. Interlaminar stresses.	2
3.3	Equilibrium equations for laminated plates, boundary conditions; Bending, Buckling and Vibration equations, and solution techniques.	3
4	**Failure Modes and Predictions**	
4.1	Modes of failure of composites under static loading, Strength failure criteria- Maximum stress, Maximum	3

	strain, Tsai-Hill and Tsai-Wu theories	
4.2	Impact, fatigue failure mechanisms. Fracture behaviour of composites -interlaminar and intralaminar, evaluation of fracture toughness.	4
5	**Structural design & FEA**	
5.1	Basic principles of sandwich structures, manufacturing process, sandwich local instabilities. Design of sandwich plate	3
5.2	Design of stiffened structures, bolted and bonded joints.	2
5.3	Finite element analysis of composite beam, plate/shell composite structures.	3

Reference Books

1. Robet M. Jones,- Mechanics of Composite Materials, CRC Press, Taylor and Francis Group.
2. B. D. Agrawal and L.J. Brountman, K. Chandrasekhara, Analysis and Performance of Fiber Composites, John Wiley & Sons.
3. J. N. Reddy and A.V. Krishna Moorty, —Composite Structures, Testing, Analysis and Design Narosa Publishing House, New Delhi.
4. Stephen W.Tsai and H. Thomas Hahn, Introduction to Composite Materials, Technomic Publishing Company Inc., Lancaster.
5. Mallick, P.K., Fiber-Reinforced Composites: Materials, manufacturing and Design, CRC Press, Taylor and Francis Group, New York.
6. Autar K Kaw, Mechanics of Composite Materials, CRC Press, Taylor and Francis Group.

222EME001	COURSE NAME: DESIGN OF POWER TRANSMISSION ELEMENTS	CATEGORY	L	T	P	CREDIT
		Programme Elective	3	0	0	3

Preamble: Transmission and its requirements in industries are inevitable. Therefore in order to understanding more the transmission elements this course introduces firstly the design criteria of V belts, Flat belts, wire ropes, pulley, chain and sprockets and teaches design procedure and method for clutches and brakes, shafts subjected to steady or unsteady axial loads and combined bending and twisting moments, Kinematic requirements of tooth geometry, cycloids and involutes. Involute trigonometry, detailed design and analysis of spur, helical gearing for parallel and bevel, worm gearing for non-parallel shafts and finally provides knowledge of design and synthesis of multi speed gear boxes.

Course Outcomes:

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

CO 1	To understand the design criteria of V belts, Flat belts, wire ropes, pulley, chain and sprockets.
CO 2	Design and analysis of different types of clutches and brake discs.
CO 3	Design and analysis of shafts subjected to steady or unsteady axial loads and combined bending and twisting moments.
CO 4	To understand the gear terminology and detailed design and analysis of spur, helical gearing for parallel and bevel, worm gearing for non- parallel shafts.
CO 5	Design and synthesis knowledge of multi speed gear box.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	35 %
Analyse	35 %
Evaluate	30 %
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 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.

End Semester Examination Pattern: (60 Marks)

The end semester examination will be conducted by the respective College for Programme Electives. 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.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Introduce the importance of power transmission elements in mechanical engineering design.
2. Introduce the selection criteria involved for power transmission elements.
3. Learn the design aspects of pulleys and sprockets.

Course Outcome 2 (CO2):

1. Define uniform wear and uniform pressure theories applied to clutches.
2. Learn the design steps involved in the design of mechanical clutches.
3. Analyse the theories involved in the design of multiplate, cone and centrifugal clutches.

4. Learn the construction details of mechanical brake systems.
5. Analyse the theories involved in the design of mechanical brake systems.
6. Evaluate the dimensions of Mechanical clutches and brakes.

Course Outcome 3 (CO3):

1. Introduce the Maximum principal stress and Maximum shear stress theories involved in the design of shafts subjected to combined loading.
2. Analyse the theories involved in the design of shafts subjected to combination of loading for different cases.
3. Learn the design steps involved in the design of shaft based on rigidity.

Course Outcome 4 (CO4):

1. Introduce the gear tooth terminology, selection and design consideration involved in the design of different types of gears for power transmission.
2. Analyse the theories involved in the design of Spur and Helical gears for parallel shafting.
3. Evaluate the proportions of Spur and Helical gearing for parallel shafting.
4. Analyse the theories involved in the design of Bevel and Worm gears for non-parallel shafting.
5. Evaluate the proportions of Bevel and Worm gearing for non-parallel shafting.

Course Outcome 5 (CO5):

1. Introduce geometric progression, standard step ratio, structural diagram and kinematics layout of gear boxes.
2. Learn the design aspects of sliding mesh and constant mesh gear boxes.
3. Synthesis multi speed gear box.

Model Question paper

QP Code: Total Pages:

Reg No.:_____ Name:_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

2nd SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Course Code: **222EME001**

Course Name: **DESIGN OF POWER TRANSMISSION ELEMENTS**

Max. Marks: 60 *Use of Design Data Book is permitted* Duration: 2.5 Hours

PART A

Answer all questions, each carries 5 marks. Marks

1		Explain the possible ways by which a chain drive fails.	(5)
2		What is a self-energizing brake? When does a brake become Self-locking?	(5)
3		Explain the design steps and considerations adopted in designing the shaft for machine tool spindles?	(5)
4		Discuss the mechanisms of gear tooth failure.	(5)
5		Explain the term virtual or formative bevel gear. Derive an expression for it.	(5)

PART B

Answer any 5 full question, each question carries 7 marks.

6	(a)	In what ways, timing belts are superior to ordinary V-belts?	(3)
	(b)	Explain the possible ways by which a chain drive fails.	(4)

7 A centrifugal clutch is to be designed to transmit 15 kW at 900 rpm. The clutch has four shoes. The speed at which the engagement begins is (3/4) th of the running speed. The inside radius of the drumis 150 mm. The shoes are lined with ferrodo whose coefficient of friction is taken as 0.25. Determine 1. Mass of the shoes and 2.Size of the shoes. (7)

8 A line shaft running at 100 rpm transmits 20kW. It carries a central load of 1 kN. It is supported in bearings, the distance between their centres being 1 m. For a permissible shear stress of 45 N/mm2 and bending stress of 70 N/mm2, determine the diameter of shaft, assuming minor shock loading. (Refer the Fig. 1 given below). (7)

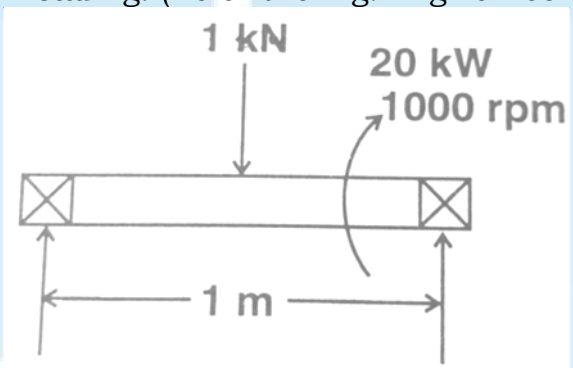


Fig. 1

9 Design a helical gearing to transmit 60 HP. The pinion runs at 6000 rpm. The speed ratio is 3. Take 20° full depth system with helix angle as 20°. Design the gearing if centre distance between shaft axes is 400 mm (adjustable by ± 3 mm). Use C30 (H & T) for pinion and C45 (N) for the gear. Also design the gear shaft if the gear is to be mounted overhung. (7)

10 A straight bevel pinion having 20 teeth is to mesh with a straight bevel gear having 60 teeth. The axes of the pinion and gear are at right angles. The pinion and gear are made of case hardened steel (σut =720 MPa and 580 MPa respectively). The pinion shaft receives 15 kW at 1440 rpm from an electric motor. The surface hardness of the gear is to be 350 BHN. Design the gear pair with a factor of safety of 1.5 assuming velocity factor for accounting dynamic load. (7)

11 A pair of worm gear is designated as 1/30/10/8. Calculate (7)

(i) centre distance, (ii) speed reduction, (iii) dimensions of worm and (iv) dimensions of worm wheel.

12 A gear box is to be designed to provide 12 output speeds ranging from 160 to 2000 rpm. The input speed of motor is 1440 rpm. Choosing a standard speed ratio, construct the structural diagram and sketch the kinematic arrangement. (7)

Syllabus

Module I

Selection of V belts and pulleys, selection of Flat belts and pulleys, Selection of Wire ropes and pulleys, Selection of Transmission chains and Sprockets. Design of pulleys and sprockets.

Module II

Design of plate clutches, axial clutches, multiple plate clutches, cone clutches, internal expanding rim clutches. Brakes, internal and external shoe brakes disk brakes-self actuating brakes fixed, link and sliding anchor drum brakes.

Module III

Shafts: Design of shafts subjected to twisting moment, bending moment, combined twisting and bending moments Design of shafts subjected to fluctuating loads, design of shafts based on rigidity.

Module IV

Gear Terminology, Speed ratios and number of teeth, Force analysis, Tooth stresses, Dynamic effects, Fatigue strength, Factor of safety, Gear materials, Module and Face width-power rating calculations based on strength and wear considerations, Selection of right kind of gears, Estimating the size of spur gears. Parallel axis Helical Gears, Pressure angle in the normal and transverse plane- Equivalent number of teeth-forces and stresses. Estimating the size of the helical gears. Design of gear shaft and bearings. Straight bevel gear: Tooth terminology, tooth forces and stresses, equivalent number of teeth. Estimating the dimensions of pair of straight bevel gears.

Module V

Worm Gear: Merits and demerits- terminology. Thermal capacity, materials-forces and stresses, efficiency, estimating the size of the worm gear pair. Design of gear shaft and bearings. Analysis of gear tooth failures, gear tooth wear and failure, tooth breakage, pitting, scoring, wear, overloading, gear-casing problems, lubrication failures. Geometric progression, Standard step ratio, Ray diagram, Structural diagram, kinematics layout. Design of sliding mesh gear box, Constant mesh gear box. Synthesis of multi speed gear boxes.

Course Plan

No	Topic	No. of Lectures
1	**Module-I**	6 Hours
1.1	Selection of V belts and pulleys, selection of Flat belts and pulleys, Selection of Wire ropes and pulleys	2 hours
1.2	Selection of Transmission chains and Sprockets.	1 hours
1.3	Design of pulleys and sprockets.	3 hours
2	**Module-II**	7 Hours
2.1	Design of plate clutches, axial clutches, multiple plate clutches, cone clutches, internal expanding rim clutches.	3 hours
2.2	Cone clutches, internal expanding rim clutches.	1 hour
2.3	Brakes, internal and external shoe brakes disk brakes-self actuating brakes fixed, link and sliding anchor drum brakes.	3 hours
3	**Module-III**	6 Hours
3.1	Shafts: Design of shafts subjected to twisting moment, bending moment, combined twisting and bending moments	3 hours
3.2	Design of shafts subjected to fluctuating loads	2 hours
3.3	Design of shafts based on rigidity	1 hour
4	**Module-IV**	8 Hours
4.1	Gear Terminology, Speed ratios and number of teeth, Force analysis, Tooth stresses, Dynamic effects, Fatigue strength, Factor of safety, Gear materials, Module and Face width-power rating calculations based on strength and wear considerations, Selection of right kind of gears.	2 hours
4.2	Estimating the size of spur gears.	2 hours
4.3	Parallel axis Helical Gears, Pressure angle in the normal and transverse plane- Equivalent number of teeth-forces and stresses. Estimating the size of the helical gears. Design of gear shaft and bearings.	2 hours
4.4	Straight bevel gear: Tooth terminology, tooth forces and stresses, equivalent number of teeth. Estimating the dimensions of pair of straight bevel gears.	2 hours
5	**Module-V**	10 Hours
5.1	Worm Gear: Merits and demerits- terminology. Thermal capacity, materials-forces and stresses, efficiency, estimating the size of the worm gear pair.	2 hours
5.2	Design of gear shaft and bearings. Analysis of gear tooth failures, gear tooth wear and failure, tooth	2 hours

	breakage, pitting, scoring, wear, overloading, gear-casing problems, lubrication failures.	
5.3	Geometric progression, Standard step ratio, Ray diagram, Structural diagram, kinematics layout.	2 hours
5.4	Design of sliding mesh gear box, Constant mesh gear box.	2 hours
5.5	Synthesis of multi speed gear boxes.	2 hours

Reference and Data Hand Books

1. ShigleyJ.E and Mischke C. R., "Mechanical Engineering Design", Sixth Edition, Tata McGraw-Hill , 2003.

2. Jalaludeen, Machine Design, Anuradha Publications, 2016.

3. Juvinall R.C and Marshek K.M., Fundamentals of Machine Component Design, John Wiley, 2011.

4. V.B.Bhandari, Design of Machine elements, McGraw Hill, 2016.

5. Rajendra Karwa, Machine Design, Laxmi Publications (P) LTD, New Delhi, 2006.

6. Henry E.Merrit, Gear Engineering, Wheeler publishing, Allahabad,1992

7. Earle Buckingham, Analytical mechanics of gears, Dover publications, New York, 1949.

8. M. F. Spotts, T. E. Shoup, Design of Machine Elements, Pearson Education, 2006

9. Maleev and Hartman, Machine Design, C.B.S. Publishers, India.

10. G. Niemann, Machine Elements Design and Calculation in Mechanical Engineering: Vol 2: Gears, Springer Berlin Heidelberg, 1980. ISBN 3540780068.

11. Mahadevan, K., and K. Balaveera Reddy, Design Data Handbook, Mechanical
Engineers in SI and Metric Units. CBS Publishers & Distributors, New Delhi, 2018.

12. PSG Design Data, DPV Printers, Coimbatore, 2012

CODE 222EME002	THEORY OF PLATES AND SHELLS	CATEGORY	L	T	P	CREDIT
		Program Elective	3	0	0	3

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

CO 1	To understand thin plates
CO 2	To analyze different plates with different boundary conditions and loadings
CO 3	To understand design of plates
CO 4	To understand classification of shells
CO 5	To design cylindrical shells
CO 6	To assimilate stability of shells

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			
CO 2			3	3	2		
CO 3			3	3	2		
CO 4			3	3	2		
CO 5	3	3	3	3	3	2	
CO 6	3	3			2	2	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 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.

End Semester Examination Pattern: (60 Marks)

The end semester examination will be conducted by the respective College for Programme Electives. 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: **Total Pages:**

Reg No.:_____ **Name:**_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

…… SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Course Code: 222EME002

Course Name: THEORY OF PLATES AND SHELLS

Max. Marks: 60 **Duration: 2.5 Hours**

PART A

	Answer all questions, each carries 5 marks.	**Marks**
1	Give a brief account of classifications of plates.	**(5)**
2	Derive the general solution for simply supported rectangular plates.	**(5)**
3	Explain orthotropic plates with an example.	**(5)**
4	Differentiate between long shells and short shells	**(5)**
5	Explain prestressing of shells	**(5)**

PART B

Answer any 5 full question, each question carries 7 marks.

6	Derive the relations between bending moments and curvature in pure bending of plates.	**(7)**
7	Find the deflection equation for a plate subjected to hydro static pressure use Levy's basic equation for calculating deflection.	**(7)**
8	Explain the bending and membrane theories for analysis of shells.	**(7)**

9	Derive the membrane stress resultants for rectangular hyperbolic paraboloid on straight line generators.	**(7)**
10	Derive the governing differential equation of a plate subjected to lateral loads from fundamentals.	**(7)**
11	Write boundary conditions for simply supported cylindrical shells with the edge conditions. i) Single shell without edge beam ii) single shell with edge beam.	**(7)**
12	Derive the expression for the governing differential equation of orthotropic plate.	**(7)**

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Introduction to thin plates**	
1.1	Small deflection theory, Isotropic and orthotropic plates	3
1.2	Plate equation in Cartesian and polar co-ordinates for isotropic rectangular and circular plates.	4
2	**Analysis of plates**	
2.1	Analysis of rectangular and circular plates with different boundary conditions and loadings	3
2.2	Analysis of circular plates with opening.	2
2.3	Cylindrical bending of long rectangular plates with different boundary conditions and loadings -	2
2.4	Design of plates.	
3	**Orthotropic plates**	
3.1	Analysis of orthotropic plates	1
3.2	Differential equation, Determination of rigidities	2
3.3	Analysis of rectangular plates. Plates on elastic foundation	2
3.4	Differential equation, Rectangular and continuous plates on elastic foundation.	2
4	**Shells**	
4.1	Shell behavior, shell surfaces and characteristics,	1
4.2	Classification of shells - Properties of curves - Membrane and bending theory for singly curved and doubly curved shells -	3
4.3	Various approximations - Beam theory of cylindrical shells - Lundgren's method.	3
5	**Design of cylindrical shells**	
5.1	Shallow shells, Principles of design of Elliptic paraboloids, Hyperbolic paraboloids and Conoids -	3
5.2	membrane solution of elliptic paraboloids and hyperboloids. Solution of some typical problems.	3
5.3	Introduction to stability of shells. Prestressing of shells.	1

Syllabus

Module 1: Introduction to thin plates, small deflection theory, Isotropic and orthotropic plates, Plate equation in Cartesian and polar co-ordinates for isotropic rectangular and circular plates.

Module 2: Analysis of rectangular and circular plates with different boundary conditions and loadings – Analysis of circular plates with opening. Cylindrical bending of long rectangular plates with different boundary conditions and loadings - Design of plates.

Module 3: Analysis of orthotropic plates - Differential equation - Determination of rigidities - Analysis of rectangular plates. Plates on elastic foundation - Differential equation - Rectangular and continuous plates on elastic foundation.

Module 4: Shells: Shell behavior, shell surfaces and characteristics, Classification of shells - Properties of curves - Membrane and bending theory for singly curved and doubly curved shells - Various approximations - Beam theory of cylindrical shells - Lundgren's method.

Module 5: Design of cylindrical shells, Shallow shells, Principles of design of Elliptic paraboloids, Hyperbolic paraboloids and Conoids - membrane solution of elliptic paraboloids and hyperboloids. Solution of some typical problems. Introducing to stability of shells. Prestressing of shells.

Reference Books

1. S. Timoshenko, “Theory of Plates and Shells”, McGraw-Hill Publishing Company
2. Rudolph Szilard. Theories and Application of Plate Analysis, John Wiley & Sons, USA (2004)
3. Glibson J. E., “Theory of Cylindrical Shells”, North-Holland Publishing Co
4. N. K. Bairagi, “Shell Analysis” , Khanna Publishers

222EME003	APPLIED ELASTICITY AND PLASTICITY	CATEGORY	L	T	P	CREDIT
		Program Elective	3	0	0	3

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

CO 1	Understand and apply principles of elasticity to estimate various stress and strain measures and develop elastic constitutive relations for various material models
CO 2	Formulate and solve 2D problems applying Airy's stress function in cartesian and polar coordinates and apply numerical techniques to solve practical problems involving elasticity
CO 3	Understand the classical theories to characterize plastic behaviour and solve problems
CO 4	Apply the principles of elasticity and plasticity to undertake micro projects in the domain
CO 5	Investigate current research areas in the domain and present seminars

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Understand	√
Apply	√
Analyse	√
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

ELECTIVE COURSES

Continuous Internal Evaluation: 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.

End Semester Examination Pattern: (60 Marks)

The end semester examination will be conducted by the respective College for Programme Electives. 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.

Syllabus and Course Plan

No	Topic	No. of Lectures
1	Analysis of stress – Surface and body forces, concept of stress at a point, stress tensor and components, stress transformation, stress on an inclined plane, invariants, principal stresses and planes, spherical and deviatoric components, equilibrium equations and boundary conditions Analysis of strain – State of strain at a point, strain displacement relations, strain invariants, St.Venant's compatibility conditions, principle of superposition, measurement of surface strains using strain gauges	7
2	Elastic behaviour - Generalized Hooke's law for isotropic, orthotropic and transversely isotropic materials, elastic constants, strain energy density Two dimensional formulation in cartesian coordinates – Governing equations and boundary conditions, compatibility in terms of stresses, plane strain and plain stress formulations, Airy's stress function applied to 2-D elasticity in cartesian coordinates, solution by polynomials, end effects, uniaxial tension, pure bending, end-loaded cantilever beam Introduction to propagation of waves in solid media	8
3	Two dimensional formulation in polar coordinates – Strain displacement relations, compatibility and Airy's stress function in polar coordinates, quarter circle beam with end load, axi-symmetric problems, Lame's thick cylinder problem, rotating circular disc Torsion – Torsion of non-circular bars, membrane analogy, Prandtl's stress function, torsion of elliptical shafts, torsion of shafts with equilateral triangular cross section Application of numerical techniques in cartesian coordinates- Strain energy and dummy load methods applied to a simply supported rectangular beam, Finite difference method applied to governing equations of simple elasticity problems.	10
4	Introduction to plastic deformation, idealized stress-	7

	strain behaviour of linear elastic, non-linear elastic, elastic-plastic, rigid perfectly plastic, elastic- work hardening models Classical theories of plasticity-Henky deformation theory and flow or incremental theory Concept of plastic potential Elastoplastic behaviour in one dimension, flow rule, loading criteria, yield function and hardening/softening, Yield criteria-Tresca and von mises, loading/unloading and consistency conditions	
5	Prandtl-Reuss and Levi-Mises relations, isotropic and kinematic hardening, Prager's and Ziegler's rules, mixed hardening. 3D Stiffness formulation-elastoplastic constitutive matrix, plane stress and plane strain formulation. Concept of plastic potential Integration of rate constitutive equations-radial return algorithm	8

Reference Books

1. S P Timoshenko and J N Goodier, Theory of Elasticity, McGraw-Hill Education

2. Martin H Sadd, Elasticity, Elsevier 2020

3. Sadhu Singh, Theory of Elasticity, Khanna Publishers 2014

4. Ronaldo I Borja, Plasticity : Modelling and Computation, Springer 2013

5. David Rees, Basic Engineering Plasticity, Elsevier 2006

6. Jane Helena, Theory of Elasticity and Plasticity, PHI Learning Pvt Ltd 2017

7. Simo and Hughes, Computational Inelasticity, Springer 1998

8. Wai-Fah Chen, Constitutive Equations for Engineering Materials -Volume 1 and Volume 2, Elsevier

PROGRAM ELECTIVE IV

222EME006	DESIGN OF PREEUSRE VESSEL AND PIPING	CATEGORY	L	T	P	CREDIT
		Programme Elective	3	0	0	3

Course objective: To gain knowledge of pressure vessel design, designing of piping and piping systems, and familiarize with codes and practices in design.

Course Outcomes:

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

CO Nos	Course Outcomes	Level of learning domain
CO 1	Explain the design considerations of various shapes used pressure vessels and relevant ASME codes	2
CO 2	Explain the design methodology of thick cylinders under various kind of loadings	2
CO 3	Use the design concepts in the design of shell and supports of vertical and horizontal pressure vessels	3
CO 4	Analyse the problems involving the thickness and stiffener support requirements of cylinders under buckling loads	3
CO 5	Analyse the problems involving pipe stress and flexibility analysis and inculcate the idea of using fracture based design concepts in pressure vessels.	3

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3			1								1
CO 2	3			1								1
CO 3	3	3	3	1								1
CO 4	3	3	3	1								1
CO 5	3	3	3	1	1							1

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	20
Analyse	20
Evaluate	20
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 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.

End Semester Examination Pattern: (60 Marks)

The end semester examination will be conducted by the respective College for Programme Electives. 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: **Total Pages:**

Reg No.:_____ **Name:**_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Course Code: 222EME006

Course Name: DESIGN OF PREEUSRE VESSEL AND PIPING

Max. Marks: 60 **Duration: 2.5 Hours**

PART A

Answer all questions, each carries 5 marks. **Marks**

1	Derive the expression for dilation of a spherical shell under internal pressure	**(5)**
2	Explain with sketches the stress pattern in a built-up cylinder after assembly	**(5)**
3	What is stress intensification factor?	**(5)**
4	What is meant by flexibility analysis?	**(5)**
5	What is meant by modes of fracture? What is stress intensity factor	**(5)**

PART B

Answer any 5 full question, each question carries 7 marks.

6	Derive an expression to find out the stress distribution on an elliptical cover	**(7)**
7	How beam on elastic foundation theory is made applicable to pressure vessel analysis? Derive an expression to find the displacement and bending moment of an infinite beam on elastic foundation?	**(7)**

8	Derive an equation to determine whether a circular ring will fail under the action of two equal and opposite external forces.	**(7)**
9	Explain the design steps in the design of tall cylindrical vessel under wind load.	**(7)**
10	Find out the thickness of a pressure vessel using the following data? Internal pressure 20N/mm^2, Wind pressure = 5N/mm^2, Length of the vessel = 25m, Diameter of the vessel= 1.2m, Insulation thickness= 6cm, Allowable stress of the material= 400Mpa. The vessel has a hemispherical cover at the top.	**(7)**
11	A short Thick cylinder with 1000 mm internal diameter and 1300mm outside diameter subjected to an internal pressure of 40 MPa. Determine the location and magnitude of maximum tangential, radial, shear stresses induced. Find also the dilation of its inner and outer radii.	**(7)**
12	Explain the design procedure of a tall vessel under wind load as per ASME code?	**(7)**

Syllabus

Module 1

Pressure vessel – Terminology – Types of loads – Types of pressure- Stresses in pressure vessels – Dilation of pressure vessels
Membrane stress analysis of vessel shell components- cylindrical shells, spherical shells, torus, conical head, elliptical head (Familarisation of corresponding ASME section 8 codes)
Bending of circular plates under uniform pressure load with simply supported and clamped edges (no derivation)

Module 2

Stresses in thick-walled cylinders – Lame's equation for internal and external pressure Shrink-fit stresses in Built up cylinders, autofrettage of thick cylinders
Thermal stresses and their significance
Discontinuity stress analysis in pressure vessels

Module 3

Design of pressure vessels- shell and support design of tall vessel under wind and seismic load
Shell and support design of horizontal vessels
Theory of reinforcement
Familiarization with relevant ASME codes and standard practices in pressure vessel design

Module 4

Buckling -Elastic buckling of cylinders or pipes under external pressure- Pipe sizing under external pressure- Design of Stiffeners
Buckling under combined compressive pressure and axial load

Module 5

Piping- Various pipe fittings
Pipe stress Analysis -allowable displacement stress range for expected cyclic life-stress intensification factor and flexibility factor-Thickness calculation of pipe- Flexibility Analysis (Analysis as per clause 119.7.1 in Code ASME B31.1/clause 319.4.1 in ASME B31.3 only)
(Introduction to software such as CAESAR, CAEPIE, PVELITE etc. But not to be included in the examination.)
Fracture based pressure vessel design- Different modes of fracture-stress intensity factor -through thickness and surface cracks in pressure vessels (Mode-I only)-fracture toughness-leak before break-failure assessment diagram

Course Plan (For 3 credit courses, the content can be for 40 hrs)

No	Topic	No. of Lectures
1	Design of thin pressure vessels	
1.1	Membrane stresses in general axisymmetric shell under internal pressure	3
1.2	Stresses and dilation in various kinds of components	2
1.3	Bending plates	2
2	Design of thick pressure vessels	
2.1	Stresses in thick walled cylinders – Lame's equation - Shrink fit stresses in built up cylinders in Built up cylinders	3
2.2	Autofrettage in cylinders	2
2.3	Thermal stresses and significance	2
2.4	Discontinuity stress	2
3	Vertical and horizontal vessel design	
3.1	Design of tall vertical shell structure and its supports	3
3.2	Design of shell and supports for horizontal vessels	3
3.3	Familiarization with standards and codes	2
4	Buckling Analysis	
4.1	Derivation of critical buckling pressure under external pressure	2
4.2	Pipe sizing and stiffener support design	3
4.3	Combined circumferential and axial buckling design	2
5	Flexibility analysis and fracture design	
5.1	Pipe stress and flexibility analysis	2
5.2	Fracture fundamentals	2
5.3	SIFs, leak before break and failure assessment diagram	3

Text Books

1. John F. Harvey, "Theory and Design of Pressure Vessels" CBS Publisher and Distributors
2. Brownell, L. E., and Young, E. H., "Process Equipment Design", John Wiley and Sons
3. Somnath Chathopadhyay, "Pressure Vessels Design and practice", C. R. C Press

4. Prashant Kumar, “Elements of fracture mechanics”, McGraw Hill Education India

Reference Books

1. Henry H. Bender, “Pressure Vessels Design hand book“
2. ASME Pressure Vessel Codes Section VIII, 2006
3. Dennis Moss,”Pressure Vessel Design Manual” Gulf publishing, 2003
4. J. Phillip Ellenberger, “Pressure Vessels: ASME Code Simplified”, ASME
5. “American standard code for pressure piping, B 31.1”, ASME.
6. Smith P, “Fundamentals of Piping Design”, Elsevier
7. ASME Pressure Vessel and Boiler code, Section VIII Div. 1, 2, and 3”, ASME
8. T. L Anderson “Fracture Mechanics: Fundamentals and applications” Taylor &Francis
9. D. Broek, “Elementary Engineering Fracture Mechanics”, Kluwer Academic Publications

222EME007	EXPERIMENTAL STRESS ANALYSIS	CATEGORY	L	T	P	CREDIT
		Programme Elective	3	0	0	3

Preamble:

To enable the students to understand the basic aspects of experimental stress analysis that includes the most versatile techniques like photoelasticity and strain gauges as well as non destructive testing (NDT) methods.

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

CO 1	Perform stress analysis for plane stress and plane strain conditions
CO 2	Determine the strains and stresses using readings from strain gauge arrangements
CO 3	Explain the instrumentation for strain measurement
CO 4	Obtain relations for stresses from photoelastic techniques
CO 5	Explain the brittle coating and NDT techniques.

Mapping of course outcomes with program outcomes

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

1

Assessment Pattern

Bloom's Category	End Semester Examination
Analyse	50%
Apply	50 %

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 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.

End Semester Examination Pattern: (60 Marks)

The end semester examination will be conducted by the respective College for Programme Electives. 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: **Total Pages: 2**

Reg No.:_____ **Name:**_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

2nd SEMESTER M.TECH DEGREE EXAMINATION, July 2023

Stream: Machine Design

Course Code: 222EME007

Course Name: EXPERIMENTAL STRESS ANALYSIS

Max. Marks: 60 **Duration: 2.5 Hours**

PART A

Answer all questions, each carries 5 marks. **Marks**

1		Derive a relation for bulk modulus in terms of Young's modulus.	**(5)**
2		Explain the concept of stress gauge.	**(5)**
3		Discuss any one method of calibrating a strain gauge.	**(5)**
4		What is stress optic law?	**(5)**
5		Derive an expression for coating stresses.	**(5)**

PART B

Answer any 5 full question, each question carries 7 marks.

6	**(a)**	A plane element is subjected to tensile stress of 400 MPa on one side and 150 MPa on it's perpendicular side, along with a shear stress of 100 MPa. Find the principal stresses, their directions and the maximum shear stress.	**(4)**
	(b)	With the help of a neat figure, explain any one type of mechanical strain gauge.	**(3)**
7	**(a)**	Calculate the principal strains, principal stresses and maximum shear strains of a steel plate (E = 200 GPA, ν =	**(4)**

0.3), if Delta rosette gives the following readings, ε_a = -250μm/m, ε_b = 250μm/m and ε_c = -200μm/m.

(b) Mention the steps involved in strain gauge mounting. **(3)**

8 **(a)** Explain the different ways in which a wheatstone bridge can be balanced. **(3)**

(b) What is temperature compensation in strain gauge? **(2)**

(c) Explain the working principle of cathode ray oscilloscope. **(2)**

9 **(a)** Derive an expression for intensity of emergent light from a plane polariscope. **(5)**

(b) Explain about photoelastic coatings and it's uses. **(2)**

10 **(a)** Briefly illustrate any three types of brittle coatings used? **(3)**

(b) Explain the failure theories of brittle coatings. **(4)**

11 **(a)** What are residual stresses? Why are they important in design? **(2)**

(b) Explain the procedure of dye penetrant testing with neat figures. **(3)**

(c) What is the difference between X-rays and Gamma Rays? **(2)**

12 **(a)** Explain magnetic particle testing with neat figures. **(3)**

(b) Explain ultrasonic inspection with neat figures. **(4)**

Syllabus and Course Plan

Module No	Topic	No. of Lectures
1	**Overview of stress analysis**	
1.1	Theory of Elasticity, Plane stress and plane strain conditions, compatibility conditions.	3
1.2	problems using plane stress and plane strain conditions, three-dimensional stress strain relations.	3
1.3	Principal stresses and strains. Mohr's circle-measurement of strains and stresses.	2
2	**Strain measurement**	
2.1	Strain gauges and Stress gauges. Mechanical, Optical and Electrical gauges- construction and applications. Variable resistance strain gauges.	2
2.2	Gauge characteristics, Gauge sensitivity, static and dynamic strains- reduction of strain gauge data-compensation-strain measurement over long period at high and low temperature.	3
2.3	Strain rosettes- Rectangular rosette, Delta rosette.	3
3	**Instrumentation**	
3.1	Strain Circuits, Potentiometer Circuits, Range and sensitivity.	2
3.2	The Wheatstone Bridge, Sensitivity, Galvanometer, Transient response, Oscillograph, Cathode Ray Oscilloscope.	2
3.3	Transducers- Displacement, Force, Pressure, Velocity, Acceleration	2
4	**Photoelasticity**	
4.1	Stress optic law, Photo elastic model materials.	2
4.2	Polariscope arrangements – Plane polariscope and Circular polariscope, Dark Field and Light field, Isochromatics and Isoclinics..	4
4.3	Compensation techniques. Use of photo elastic coatings.	2
5	**Residual stresses, Brittle coatings & NDT**	
5.1	Residual stresses: Beneficial and harmful effects – Principle of residual stress measurement-methods only.	3

5.2	Brittle coatings: Crack detection, Types of coatings, Steps in brittle coating tests, Coating selection, Surface preparation.	3
5.3	Non destructive testing (NDT) methods : Types –dye penetrant methods, Radiography-X-ray and Gamma ray, Magnetic particle method, Introduction to lasers in NDT.	4

Reference Books

1. J. W. Dally and W. F. Riley, Experimental Stress Analysis - McGraw Hill, 1991
2. L.S. Srinath, M.R. Raghavan, K. Lingaiah, G. Gargesa, B. Pant, and K. Ramachandra, Experimental Stress Analysis, Tata Mc Graw Hill, 1984.
3. A. Mubin, Experimental Stress Analysis, Khanna Publishers, 2003.
4. Sadhu Singh, Experimental Stress Analysis, Khanna Publishers, 1996.
5. Jayamangal Prasad, C. G. Krishnadas Nair, Non-Destructive Test And Evaluation Of Materials, Tata McGraw-Hill, 2008
6. M. Hetenyi, Handbook of Experimental Stress Analysis, John Wiley & Sons Inc, New York, 1950
7. C.C. Perry and H.R. Lissener, Strain Gauge Primer, McGraw Hill, 2nd Ed., 1962.
8. W.J. McGonnagle-Non-destructive Testing-Mc Graw Hill, 1961.
9. Davis Joseph R. (ed.), .American Society for Metals Handbook- Volume 17, Non-destructive Evaluation and Quality Control, ASM International Materials Park, Ohio.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
222EME008	INDUSTRIAL TRIBOLOGY	Programme Elective	3	0	0	3

Preamble: This course targets to develop a systematic and applied knowledge of industrial tribology.

Course Outcomes:

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

CO1	Understand the concepts of green tribology and its applications
CO2	Understand and apply the knowledge of friction,wear and lubrication
CO3	Understand and apply various methods to improve the tribological properties of surfaces
CO4	Understand the various applications of tribology
CO5	Understand the methods of surface characterization

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO1	2	2	2			2	
CO2	3	3	3	2		2	
CO3	3	3	3	2	2	2	
CO4	2	2	2	3	2	2	
CO5	2	2	2	2	2		

Assessment Pattern

Bloom'sCategory	End Semester Examination
Understand	
Apply	√
Analyze	√
Evaluate	

Markdistribution

Total Marks	**CIE**	**ESE**	**ESE Duration**
100	40	60	2.5hours

Continuous Internal Evaluation Pattern:

ELECTIVECOURSES
Continuous Internal Evaluation: 40marks

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: 15marks
Testpaper, 1No.10marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern :(60 Marks)

The end semester examination will be conducted by the respective College for Programme Electives. 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: **Total Pages:**

Reg No.:_____ **Name:**_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Stream:
Course Code:
Course Name:

Max. Marks: 60 **Duration: 2.5 Hours**

PART A

Answer all questions, each carries 5 marks. **Marks**

1	List out the principles of green tribology	(5)
2	Explain the stick slip phenomenon with neat sketch	(5)
3	Explain the characteristics of wear resistant coating	(5)
4	Elucidate the working principle of TENG	(5)
5	Explain the optical methods to measure surface characteristics.	(5)

PART B

Answer any 5 full question, each question carries 7 marks.

6	(a)	Explain the history and developments in tribology	(3)
	(b)	Explain the economic significance of tribology with reference to Jost report	(4)
7		Explain bourdon Tabor theory of friction	(7)
8		Elucidate the working principle of physical vapour deposition	(7)
9		Explain tribochemistry of magnetic storing devices	(7)
10		Explain the principles of thermal spraying	(7)
11		Explain the physio-chemical characteristics of solid surfaces	(7)
12		Explain the working principles of AFM	(7)

Syllabus and Course Plan

Module	Topic	No. of Lectures
1	**Introduction to Green Tribology**	
1.1	History and industrial significance of tribology : Jost Report	1
1.2	Principles of green tribology	1
1.3	Biomimetic surfaces , Biomimetic Surface Effects, Self-Organization at the Frictional Interface	1
1.4	Green Nanotribology and Sustainable Nanotribology in the Frame of the Global Challenges for Humankind.	1
1.5	Wear-Resistant and Oleophobic Biomimetic Composite Materials.	1
1.6	Polymer Adhesion and Biomimetic Surfaces for Green Tribology	1
2	**Friction, Wear & Lubrication**	
2.1	Types of friction and theories of friction, Stick slip phenomenon	2
2.2	Types of wear: Abrasive wear, adhesive wear, impact wear, chemical wear, Electrical arc induced wear, fretting corrosion	2
2.3	Mechanism and quantification of Adhesive and Abrasive wear, Hertzian Contact	2
2.4	Friction of materials: Friction of metals & alloys, Friction of ceramics and friction of polymers.	1
2.5	Wear of materials: Wear of metals and alloys, wear of ceramics and wear of polymers	1
2.6	Measurement of friction and wear : Four ball tester , Pin on Disk	1

2.7	Lubricants: functions of lubricant , factors affecting boundary lubrication- Effect of adsorbed gases, effect of monolayer and multi layers, effect of chemical films, effect of chain length	2
2.8	Types of liquid lubricants: Physico-chemical and tribological properties of lubricants, Viscosity-measurement, effect of temperature and pressure on viscosity, oxidative stability, corrosive stability, friction and wear properties.	2
3	**Methods to improve friction and wear**	
3.1	Reduction of friction by soft metallic films	1
3.2	Reduction of friction by metal oxides at high temperatures	1
3.4	Techniques of producing wear resistant coatings	1
3.5	Physical vapour deposition	1
3.6	Chemical vapour deposition	1
3.7	Thermal spraying	1
3.8	Laser surface hardening and alloying	1
3.9	Application of coatings and surface treatments in wear and friction control , Characteristics of wear resistant coatings	2
4	**Applications of Tribology**	
4.1	Tribological issues in wind turbine	1
4.2	Triboelectric effect and Triboelectric nano generators	1
4.3	Biotribology & human tribology	1
4.4	Tribology of Metal cutting, metal forming	1
4.5	Tribo chemistry and tribo corrosion	1

4.6	Macro scale applications in tribology	1
4.7	Microscale applications in tribology	1
5	**Measurement of Tribological and surface characteristics**	
5.1	Surface characterization :Physico-chemical characteristics of solid surfaces – Deformed layer, Beilby layer, chemically reacted layer, physisorbed layer, chemisorbed layer, Surface tension, surface energy and surface wetting	1
5.2	Analysis of surface roughness: Average roughness parameter.	1
5.3	Measurement of surface roughness : Mechanical stylus method, Optical methods, Scanning Probe Microscopy methods, Fluid methods, Electrical methods, Electron Microscopy Methods, Scanning Electron Microscope,	2
5.4	Description of Atomic force microscope (AFM)	1

Text Books:

1. Bharat Bhusan : Principles and applications of tribology - John Wiley & Sons, Inc
2. Bharat Bhusan – Green Tribology , Biomimetic, conservation of energy and sustainability- Springer
3. Mervin H Jones and Douglas Scott - Industrial Tribology, the practical aspects of friction lubrication and wear- Elseveir
4. Pradeep L Menzes et al. - Tribology for scientists and engineers- Springer
5. Gwidon.W.Stachowiak and Andrew.W.Batchelor-Engineering Tribology-Butterworth
   Heinemann Publishers
6. BC Majumdar: Introduction to Tribology of Bearing, S Chand Publishing.
7. Prasanta Sahoo : Engineering Tribology , PHI Learning Pvt. Ltd

222EME009	ADVANCED VEHCLE DYNAMICS	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 4	3	0	0	3

Course Outcomes:

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

CO 1	Understand the principles underlying the development and design of road vehicles under the influence of dynamic loads
CO 2	Evaluate the performance characteristics of vehicle dynamics topics under various driving circumferences
CO 3	Understand various Suspension systems, selection of springs and dampers
CO 4	Demonstrate the vehicle motion and analyse the vehicle response for various driving conditions
CO 5	Know about tyres, ride characteristics and effect of camber, camber thrust

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Understand	30%
Apply	40%
Analyse	30%
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 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.

End Semester Examination Pattern: (60 Marks)

The end semester examination will be conducted the respective College for Programme Electives. 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.

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Introduction:**	
1.1	Hypothetical vehicle control loop, Fundamental Approach, Vehicle co-ordinates, motion variables.	2
1.2	Forces – Dynamic axle loads, Static loads on level ground, aerodynamic forces on body, hitch forces	4
1.3	Tire construction, size and load rating, terminology, mechanics of force generation – problems	3
2	**Road Loads:**	
2.1	Aerodynamic, Mechanics of pressure distribution – Aerodynamic forces: lift & drag, Spoilers, Lift force, side force and roll, pitch and yaw moments, Crosswind sensitivity	3
2.2	Rolling Resistance, Factors affecting pressure, velocity, slip temperature, etc – Total road loads – Fuel Economy Effects	3
3	**Suspension :**	
3.1	Requirements, dynamics of spring mass damper system, spring mass frequency	3
3.2	Wheel hop, wheel wobble, wheel shimmy, Choice of suspension spring rate. Calculation of effective spring rate. Vehicle suspension in fore and aft direction.	4
3.3	Hydraulic dampers and choice of damper characteristics. Independent, compensated rubber and air suspension systems. Roll axis and vehicle under the action of side forces.	3
4	**Vehicle Vibration and Ride characteristics:**	
4.1	Excitation sources – road roughness, wheel assembly, driveline excitation, engine transmission.	2
4.2	Wheel Hop Resonance. Rigid body bounce, pitch motion. Effect of vibration on vehicle riding. Influence of pressure in tyre, alignment toe in and toe out, tire wear and tire life	3
4.3	Rollover - Quasi-Static Rollover of a Rigid Vehicle, Quasi-Static Rollover of a Suspended Vehicle, transient Rollover.	2
5	**Tyres and vehicle handling**	
5.1	Types. Relative merits and demerits. Ride characteristics. Behaviour while cornering, slip angle, cornering force, power consumed by a tyre	2

5.2	Design of Modern wheel and tyre characteristics and their influence on vehicle behaviour - Longitudinal and lateral Vehicle dynamics and control	3
5.3	Over steer, under steer, steady state cornering. Effect of braking, driving torques on steering. Effect of camber, transient effects in cornering	2

Reference Books

1. J. Y. Woung -Theory of Ground Vehicles, John Willey & Sons, NY

2. J. G. Giles -Steering, Suspension & Tyres, Illefe Books Ltd., London

3. Jazar**,** Reza N, Vehicle Dynamics, Theory and Application, Springer, 2015

4. Hans Pacejka, Tire and Vehicle Dynamics, Elsevier, 2012

5. Amitosh D, Vehicle Dynamics, Galgotia Book Ltd., 2010

6. Rao V Dukkipati, Road Vehicle Dynamics, Springer 2008

7. Thomas D.Gillespie, "*Fundamentals of Vehicle Dynamics*", SAE International Publication, 2005

INTER DISCIPLINARY ELECTIVE

222EME104	DIGITAL PRODUCT DESIGN AND MANUFACTURING	CATEGORY	L	T	P	CREDIT
		INTERDISCIPLINARY ELECTIVE	3	0	0	3

Preamble:

The focus of digital product design and manufacturing is the integration of digital technology in design and manufacturing functions in creating new products. It also envisages the use of digital tools such as virtual-augmented reality and additive manufacturing in product design and manufacturing.

Course Outcomes:

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

CO 1	Demonstrate the principles of product development process and the role of computers in it.
CO 2	Implement the principles of industrial design to develop new products
CO 3	Apply the innovative digital tools in product design and development
CO 4	Apply the innovative digital tools in simulation and analysis at the design stage
CO 5	Summarize the innovative prototyping techniques in design and understand the industrial practices.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	√
Analyse	√
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

ELECTIVE COURSES

Continuous Internal Evaluation: 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.

End Semester Examination Pattern: (60 Marks)

The end semester examination will be conducted by the respective Colleges. 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: **Total Pages:**

Reg No.:_____ **Name:**_____

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SECOND SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Stream: MACHINE DESIGN

Course Code: 222EME104

Course Name: DIGITAL PRODUCT DESIGN AND MANUFACTURING

Max. Marks: 60 **Duration: 2.5 Hours**

PART A

Answer all questions, each carries 5 marks. Marks

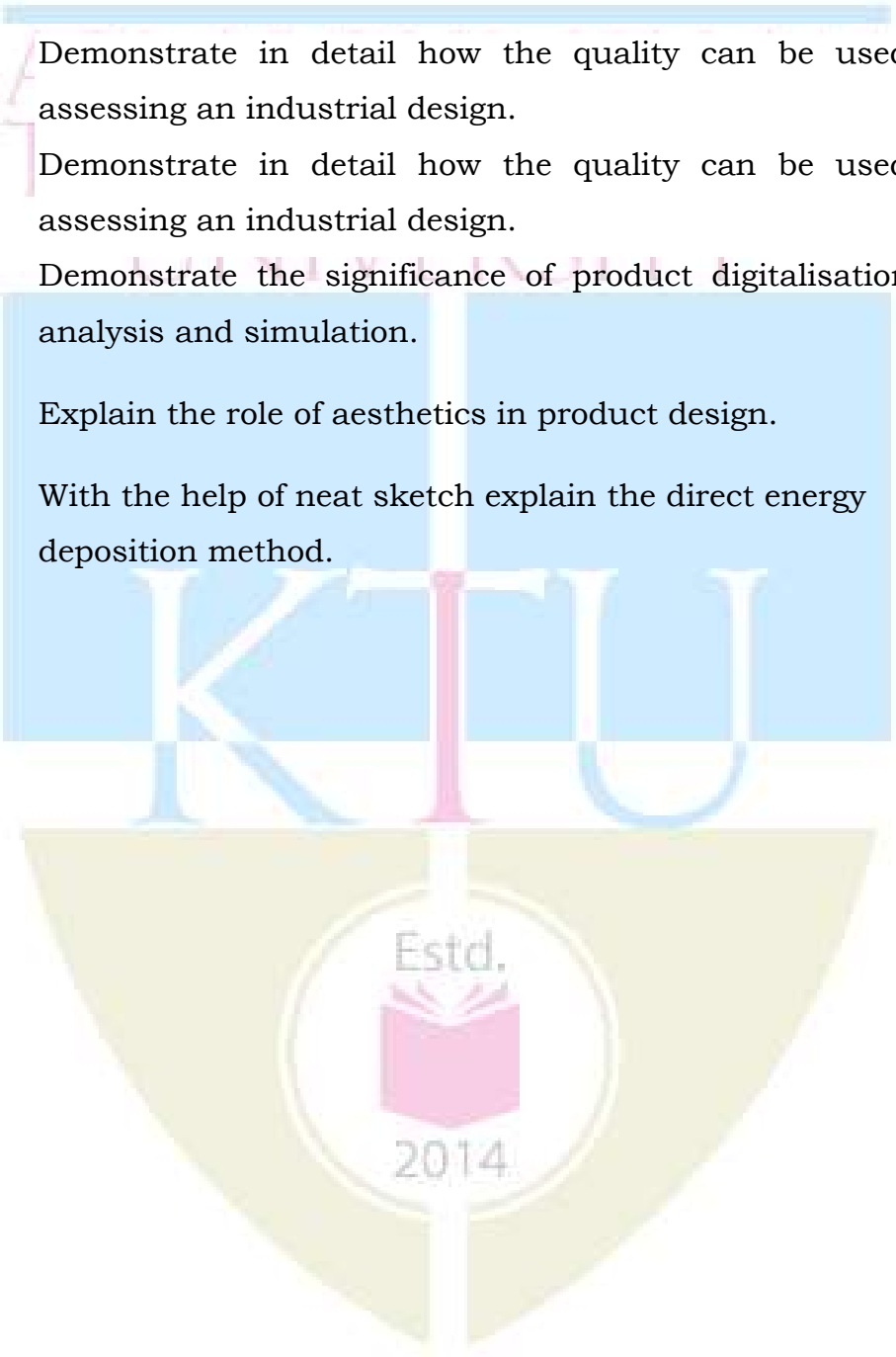
1	Elaborate different phases in design.	(5)
2	Explain the role of planning for product distribution.	(5)
3	Explain how VR can be utilised in product development.	(5)
4	Illustrate the role of virtual human in product development.	(5)
5	Differentiate between material extrusion and material jetting additive manufacturing techniques.	(5)

PART B

Answer any 5 full question, each question carries 7 marks.

6	Explain the concept of standardization in product design with the help of an example.	(7)
7	Explain the various aspects of human factors to be considered in product development.	(7)

8	Explain the importance of break-even analysis during design.	(7)
9	Illustrate with examples how VR and AR can be useful in product development.	(7)
10	Demonstrate in detail how the quality can be used in assessing an industrial design. Demonstrate in detail how the quality can be used in assessing an industrial design. Demonstrate the significance of product digitalisation in analysis and simulation.	(7)
11	Explain the role of aesthetics in product design.	(7)
12	With the help of neat sketch explain the direct energy deposition method.	(7)



SYLLABUS

Module 1

Concept of Product Design: Definition of engineering design, design constraints, different phases in design- conceptual design, embodiment design, detail design, planning for manufacture, planning for distribution, planning for use, Human factors design- ergonomics, anthropometry, comfort criteria, concepts of size, texture and colour, Introduction to product design, product design practices in industry.

Module 2

Tools for product design- drafting-modelling software CAE/CAD, computer aided styling, production process- CAM interface, product development-time and costs. Description of planning for product distribution, Economic factors affecting design.

Module 3

Digital tool enabled design -I: Evolution of digital tools for product design and manufacturing, 2D/3D models to digital mock-up and virtual prototyping (VP). Virtual reality (VR), augmented reality (AR) and Mixed reality, Implementation in product design and manufacturing. Interaction technology, Visualisation technology, Visual display-types- head mounted, organic LEDs, large volume displays, wall type, equipments, characteristics.

Module 4

Digital tool enabled design-II: AR-, tangible, collaborative; examples; AR tracking technology and devices; interaction techniques, haptic technology, olfactory technology. Product digitalization, analysis and simulation. Virtual humans (VH)- for clothing, for ergonomics analysis, biomechanical models.

Module 5

Digital manufacturing: 3D printing- additive manufacturing technology- Classification of additive manufacturing technologies: vat- photo polymerisation, powder bed fusion, material jetting, sheet lamination, material extrusion and direct energy deposition, infill lattice structures.

Course Plan

No	Topic	No. of lectures
1	**Product development process:**	
1.1	Concept of Product Design: Definition of engineering design, design constraints	2
1.2	Different phases in design- conceptual design, embodiment design, detail design, planning for manufacture, planning for distribution, planning for use	3
	Human factors design- ergonomics, anthropometry, comfort criteria, concepts of size, texture and colour	1
1.3	Introduction to product design, product design practices in industry.	2
2	**Embodiment design:**	
2.1	Tools for product design- drafting-modelling software CAE/CAD, computer aided styling, production process- CAM interface, product development- time and costs.	4
2.2	Description of planning for product distribution, economic factors affecting design.	4
3	**Digital tool enabled design-I**	
3.1	Evolution of digital tools for product design and manufacturing, 2D/3D models to digital mock-up, virtual prototyping (VP).	2
3.2	Virtual reality (VR), augmented reality (AR) and Mixed reality implementation in product design and manufacturing.	3
3.3	Interaction technology, VR- immersive, non-immersive, Visualisation technology, Visual display-types- head mounted, organic LEDs, large volume displays, wall type, equipments, characteristics.	3
4	**Digital tool enabled design-II**	
4.1	AR- tangible, collaborative; examples; AR tracking technology and devices; Interaction techniques, Haptic technology, Olfactory technology	3
4.2	Product digitalization, Analysis and simulation.	2
4.3	Virtual humans (VH)- for clothing, for ergonomics analysis, Biomechanical models.	2

5	**Digital manufacturing**	
5.1	3D printing- additive manufacturing technology- Classification of additive manufacturing technologies: Vat- photo polymerisation, powder bed fusion, material jetting, sheet lamination,	4
5.2	Material extrusion and direct energy deposition, Infill lattice structures	3

Reference Books

1. George Dieter and Linda C. Schmidt, Engineering Design, 4th Edition, Published by McGraw-Hill.
2. Monica Bordegoni and Caterina Rizzi, "Innovation In Product Design From CAD To Virtual Prototyping", Springer.
3. Karl T Ulrich and Steven D Eppinger, "Product Design & Development." Tata Mc- Graw Hill, 2003.
4. Ian Gibson, David Rosen and Brent Stucker, "Additive Manufacturing Technologies-3D Printing, Rapid Prototyping, and Direct Digital Manufacturing." Springer.
5. Fei Tao, Meng Zhang and A. Y. C. Nee, "Digital Twin Driven Smart Manufacturing", Academic Press, Elsevier.
6. D. T. Pham, S.S. Dimov, Rapid Manufacturing-The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer – Verlag, London, 2001.
7. Kevin Otto & Kristin Wood Product Design: "Techniques in Reverse Engineering and New Product Development.", Pearson Education New Delhi, 2000.
8. N J M Roozenberg , J Ekels , N F M Roozenberg " Product Design Fundamentals and Methods". John Wiley & Sons.
9. AK Chitale & RC Gupta, "Product Design and Manufacturing", PHI, 2000.

CODE	RELIABILITY ENGINEERING	CATEGORY	L	T	P	CREDIT
222EME105		Inter Disciplinary Elective	3	0	0	3

Preamble:

Reliability engineering fundamentals and applications, Failure data analysis - Basics of Reliability Prediction Hazard models -System reliability models - Fault-tree analysis

Course Outcomes:

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

CO 1	Explain the tools of statistics and probability to determine the reliability of an item or a system.
CO 2	Discuss the methods of reliability prediction and maintenance strategies according to system characteristics and design transition programs to implement these strategies.
CO 3	Develop ability in formulating suitable strategies to enhance system reliability of a manufacturing system.
CO 4	Implement the concepts of RCM, FTA, FMEA and FMECA in managing the manufacturing organisation with highest possible levels of reliability/ availability.
CO 5	Differentiate various strategies adopted for life testing and maintenance.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2		2	2	
CO 2			3	2	
CO 3			2		2
CO 4			2	3	2
CO 5			2		2

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40%
Analyse	30%
Evaluate	30%
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. (Test paper shall include minimum 80% of the syllabus): 10 marks

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.

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Probability and reliability**	
1.1	Probability: Conditional probability, Bayes theorem	1
1.2	Probability distributions – Normal, Lognormal, Poisson, Exponential and Weibull distributions – relationship between them and their significance	2
1.3	Central tendency and dispersion of Normal, Lognormal, Poisson, Exponential and Weibull distributions	1
1.4	Reliability: Definitions, Importance, Quality and reliability,	1
1.5	Bath tub curve -Failure data analysis: Hazard rate, failure rate,	1
1.6	MTTF, MTBF, reliability functions, hazard functions,	1
1.7	Availability and Maintainability	1
2	**Hazard models and system reliability**	
2.1	Reliability hazard models: Parts stress model	1
2.2	Constant and linearly increasing models	1
2.3	Time dependent failure rates, Weibull model	1
2.4	Distribution functions and reliability analysis	1
2.5	System Reliability: Series system configuration	1
2.6	Parallel system configurations	1
2.7	Mixed configurations	1
2.8	k out of m system, standby systems	1
3	**Reliability evaluation and system analysis**	
3.1	Reliability evaluation using Markov model - Development of logic diagram	1
3.2	Set theory, optimal cut set and tie set methods, Markov analysis	2
3.3	Fault-tree analysis: Fault tree construction, calculation of reliability from fault tree	2
3.4	Event tree analysis	1
3.5	FMEA	1
3.6	FMECA	1
4	**Design for reliability**	
4.1	Load – strength interference - Distributed load and strength	1
4.2	Analysis of interference – Effect of safety margin	2
4.3	Software Reliability – software errors – fault tolerance – data reliability – hardware / software interfaces	2
4.4	Reliability prediction of equipments and systems using	1

	MIL-217 standards	
4.5	Reliability prediction of equipments and systems using and NSWC standards	1
4.6	Human Reliability	1
5	**Life testing and maintenance**	
5.1	Maintenance and reliability – Preventive and predictive maintenance	1
5.2	Reliability cantered maintenance	1
5.3	Life Testing – Objectives, Types - Censoring, replacement,	2
5.4	Accelerated life testing – Temperature stress and failure rates – stress combinations, accelerated cycling	2
5.5	HALT	1
5.6	HASS	1

Reference Books

1. Patrick O'Connor, Andre Kleyner, Practical Reliability Engineering, 5th Edition, Wiley India, 2012
2. A Birolini, Reliability Engineering, 8th edition Springer, 2017
3. Naikan V. N. A., Reliability Engineering and Life Testing, PHI, New Delhi, 2009
4. Ebling C. E., "An introduction to Reliability and Maintainability Engineering" Waveland Press, 2019.
5. Balagurusamy E., Reliability Engineering, McGraw Hill Education India P Ltd, 2017
6. Kapoor K. C., Pecht M., Reliability Engineering, Wiley, 2014
7. LS Srinath , Reliability Engineering, East West Press,2017

CODE 222EME106	INDUSTRIAL SAFETY IN ENGINEERING	CATEGORY	L	T	P	CREDIT
		Inter disciplinary Elective	3	0	0	3

Preamble:

The course is intended to give knowledge of various safety management systems, accident prevention techniques, various machine guarding devices, different types of hazards and fire prevention methods. Students will be able to understand the impact of safe industrial operations and become aware of safety responsibilities.

Course Outcomes:

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

CO 1	Discuss the basic concepts of Safety Management.
CO 2	Explain the factors contributing to accidents and how that can be controlled.
CO 3	Summarize general safety precautions and safe practices to be followed in Engineering Industries.
CO 4	Explain the occupational health hazards and the methods of control.
CO 5	Implement the firefighting techniques and understand the methods of pollution control.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1		2	3		
CO 2			3		
CO 3			3		
CO 4	2		3		
CO 5		2	3		

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40%
Analyse	40%
Evaluate	20%
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. (Test paper shall include minimum 80% of the syllabus): 10 marks

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.

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
SECOND SEMESTER M.TECH DEGREE EXAMINATION
222EME106 Industrial Safety in Engineering

Time: 2.5 hrs Max. Marks: 60

Part A

(Answer all questions. Each question carries five marks)

1. Discuss the significance of a safety committee in improving the safety performance of an industry
2. What are the functions of safety professional
3. Which are five 'S' used in housekeeping?
4. Discuss the functions of occupational health services
5. Describe the importance of fire detection systems

Part B

(Answer any five questions. Each question carries seven marks)

6. Discuss the significance of safety policy in reducing the accidents.
7. Differentiate Hazard and Risk with examples
8. Which are the various types of machine guarding devices used industries.
9. Classify the personal protective equipment. List the suitability of at least ten types of PPEs.
10. Discuss the important types of ergonomic hazards associated with industries
11. Describe the selection of different types of fire extinguishers accordance to type of fire
12. Discuss about different types of chemical hazards

Syllabus and Course Plan

No	Topic	No. of Lectures
1	**Module 1**	
1.1	Introduction to safety and safety management - Objectives and principles of safety management - Need for integration of safety, health and environment	2
1.2	Management's safety policy and Formulation – Safety auditing – Safety budget	2
1.3	Safety committees and its functions - Safety education and training - Motivation and communicating safety	2
1.4	Significance of health and safety culture - 4 E's in industrial safety - Role of management in Industrial Safety - Factors impeding safety.	2
2	**Module II**	
2.1	Accidents and Hazard control - Accident causation - Classification of accidents	2
2.2	Accident proneness - Cost of accidents - Accident investigation – Hazard control programme	2
2.3	Risk analysis - Quantitative risk assessment- Roles and functions of safety professional- Job safety analysis	3
3	**Module III**	
3.1	Machine Guarding - Types of guards	1
3.2	Housekeeping: Responsibility of management and employees. Advantages of good housekeeping. 5 s of housekeeping.	2
3.3	Personal protective equipments and personal safety	2
3.4	General safety considerations in material handling - Manual and mechanical - Safety in machine shop	2
3.5	Safety in sewage disposal and cleaning - Disaster management plan for industrial plant.	2

4	**Module IV**	
4.1	Occupational health and industrial hygiene - Functions of occupational health services	1
4.2	Occupational health risks - Functional units of OHS	1
4.3	Occupational diseases - Silicosis - Asbestosis - lead poisoning - Nickel toxicity - Chromium toxicity	2
4.4	Hearing conservation programme - First aid and CPR	1
4.5	Types of industrial hazards and their control - Physical, Mechanical, Electrical, Chemical and Ergonomic hazards	3
5	**Module V**	
5.1	Industrial fire prevention -Methods of extinguishing fire - Classification of fires	1
5.2	Factors contributing towards fire - Fire risk assessment - Fire load	1
5.3	Fire safety plan	1
5.4	Fire detection systems – Fire protection systems	1
5.5	Pollution control in engineering industry - Recent development of safety engineering approaches	2

Reference Books

1. R.K Jain (2000) Industrial Safety, Health and Environment management systems, Khanna Publications.
2. Ronald P. Blake. (1973). *Industrial safety.* Prentice Hall, New Delhi.
3. Krishnan, N.V. (1997). *Safety management in Industry.* Jaico Publishing House, New Delhi.
4. Frank P Lees, 'Loss prevention in process industries',Vol I, II, III, Butterworth, London 1980
5. Heinrich H.W, 'Industrial accident prevention', McGraw Hill Company, New York, 1980.

MECHANICAL ENGINEERING

MINIPROJECT

222PME100	MINI PROJECT	CATEGORY	L	T	P	CREDIT
		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. Exposure to more projects enhances 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	

LABORATORY

222LME100	COMPUTATIONAL ANALYSIS LAB	CATEGORY	L	T	P	CREDIT
		LABORATORY	0	0	2	1

Preamble

To enable the students to familiarise with and develop expertise in using software tools for design and analysis of machine elements. This course will give the students an exposure to different simulation and analysis tools for solving mechanical design problems.

Course Outcomes: After the completion of this lab course the student shall be able to

CO 1	Use commercial software tools/packages (ANSYS/HYPERMESH/Abaqus/COMSOL/MATLAB/SIMULINK etc.) to model and analyse mechanical components or mechanisms.
CO 2	Develop code to solve design problems involving trusses/beam/plate
CO 3	FE Analysis of components under static/dynamic/impact loading using software

Mapping of course outcomes with program outcomes

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

Mark distribution

The laboratory course will be having only Continuous Internal Evaluation and carries 100 marks.

List of Exercises

1. Demonstration of part, assembly and mechanism modeling
2. 3D Modelling of a machine assembly (eg. universal coupling, gear box etc)
3. Meshing of a complicated 3-D model imported from modeling software

4. Static structural analysis- Stress and deflection analysis in beams/trusses with different support conditions
5. Stress analysis of flat plates and simple shells
6. Stress analysis of axi – symmetric components
7. Coupled thermal stress analysis.
8. Modal analysis of beam by modeling in CAD software and exporting the same to finite element analysis software
9. Vibration analysis of spring-mass systems
10. Modal analysis of plate using to finite element analysis software
11. Modal analysis of beam using computer program code
12. FE analysis of cantilever beam using computer program code
13. Modal analysis of plate using computer program code
14. Modal analysis to obtain natural frequencies
15. Buckling analysis
16. Elasto-plastic analysis
17. Transient structural analysis
18. Fluid-structure interaction problem
19. Analysis of a plate subjected with impact loading
20. Simulation and analysis (kinematic/dynamic) of mechanisms

(A minimum of nine exercises to be performed)