Semester I

Discipline: MECHANICAL ENGINEERING

Stream: ME1

CODE	COMPUTATIONAL METHODS FOR ENGINEERS	CATEGORY	L	T	P	CREDIT
221TME100		Discipline Core	3	0	0	3

Preamble:

Numerical simulations are the most reliable tool of mechanical engineers to solve the problems in the domain and advanced computational methods are a critical component of that. This course targets to introduce the advanced numerical techniques required to solve the mechanical engineering problems.

Course Outcomes:

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

CO 1	Solve system of equations using numerical techniques
CO 2	Apply numerical schemes to integrate, differentiate and curve fit
CO 3	Determine solutions of ODE and PDE using computational methods
CO 4	Formulate a Mechanical Engineering problem and solve that using computer based numerical procedure and submit micro-project
CO 5	Apply two different numerical methods to solve (manual/computer) a problem and compare the merits and demerits of those schemes

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

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	20%
Analyse	60%
Evaluate	20%
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 40 Marks

Micro project/Course based project : 20 marks

(Formulate a mechanical engineering problem and solve that using computer based numerical procedure and submit as project. The project shall be done individually. Group projects not permitted.)

Course based task (programming)/Seminar/Quiz: 10 marks

Test paper, 1 No. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination: 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

QP Code: **Total Pages:**

Reg No.:__________ **Name:____________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Discipline: Mechanical Engineering

Course Code:

Course Name: Computational Methods for Engineers

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

PART A

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

1	Use Gauss elimination to solve $3x_1 - 0.1x_2 - 0.2x_3 = 7.85$ $0.1x_1 + 7x_2 - 0.3x_3 = -19.3$ $0.3x_1 - 0.2x_2 + 10x_3 = 71.4$	**(5)**
2	Explain the procedure of Newton-Raphson method and draw a flowchart.	**(5)**
3	Explain the Trapezoidal rule and derive the equation for the same.	**(5)**
4	Use the classical fourth-order RK method to integrate $f(x, y) = -2x^3 + 12x^2 - 20x + 8.5$ using a step size of $h = 0.5$ and an initial condition of $y = 1$ at $x = 0$.	**(5)**
5	Write a short note on any simple implicit method.	**(5)**

PART B

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

6	Use Newton- Raphson method to determine a root of the equation $f(x) = x^3-13x-12$	**(7)**

7 Given these data, (7)

x	1.6	2	2.5	3.2	4	4.5
f(x)	2	8	14	15	8	2

Calculate f(2.8) using Newton's interpolating polynomials of order 1 through 3. Choose the sequence of the points for your estimates to attain the best possible accuracy.

8 Evaluate the following integral: (7)

$$\int_0^{\pi/2} (6 + 3\cos x)\, dx$$

(a) single application of Simpson's 1/3 rule
(b) multiple-application Simpson's 1/3 rule, with n = 4.

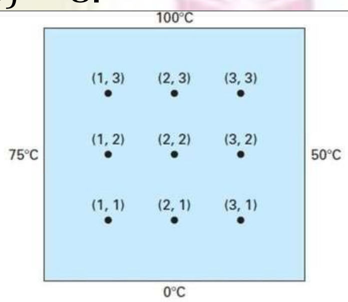
9 Solve the following initial value problem over the interval from t = 0 to 2 where y(0) = 1. Display all your results on the same graph. (7)

$$\frac{dy}{dt} = yt^2 - 1.1y$$

(a) Euler's method with h = 0.5 and 0.25.
(b) Fourth-order RK method with h = 0.5.

10 Use the shooting method to solve $7\, d^2y/dx^2 - 2\, dy/dx - y + x = 0$ with the boundary conditions y(0) = 5 and y(20) = 8. (7)

11 (7)



Use Liebmann's method (Gauss-Seidel) to solve for the temperature of the heated plate in figure. Employ overrelaxation with a value of 1.5 for the weighting factor and iterate to es $\varepsilon_s = 1\%$.

12	Use the simple implicit method to solve for the temperature distribution of a long, thin rod with a length of 10 cm and the following values: k' = 0.49 cal/(s . cm . ºC), Δx = 2 cm, and Δt = 0.1 s. At t =- O, the temperature of the rod is zero and the boundary conditions are fixed for all times at T(0) = 100ºC and T(10) = 50ºC. Note that the rod is aluminium with C = 0.2174 cal/(g . ºC) and ρ = 2.7 g/cm^3 . Therefore, k = 0.49/ (2.7 . 0.2174) 5 0.835 cm^2 /s and λ = 0.835(0.1)/(2)^2 = 0.020875.	**(7)**

Syllabus

Module 1

Introduction to Computational methods, system of equations- Revision - Formulation of engineering problems andsolution using computational methods; significant figures, accuracy, precision, round off error, truncation error,Taylor series expansion of a polynomial. Roots of equation - Bisection, Newton-Raphson, and Bairstow methods. Linear algebraic equations - Gauss Elimination method, LU decomposition. Non- linear equation- Gauss-Jordan method, Newton- Raphson for simultaneous equations. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 2

Curve fitting- Linear regression- linearization of non linear relation, linear least squares, multiple linear regression. Non linear regression- polynomial regression, Gauss- Newton method. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 3

Numerical differentiation and integration- Derivatives- Newton's forward, backward, divided difference and Sterling formula. Integration -Trapezoidal rule, Simpsons one third, Simpsons three eighth, Gauss quadrature-two & three point. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 4

Numerical solutions to ordinary differential equations- Taylors method, Eulers method, Runge-Kutta method fourth order, simultaneous first order, Milne's predictor corrector. Initial value problem - shooting method, Eigen values - polynomial method, power method. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 5

Solution of partial differential equation & Interpolation-

Interpolation - Newtons forward and backward, divided difference linear & quadratic, Lagrange interpolation, cubic splines, Hermites interpolation. Solution of partial differential equation - Difference equations, Elliptic equation- Laplace equation, Poisson equation, Liebmann's iterative methods, Parabolic equation- Bender-Schmidt method, simple implicit, Crank-Nicolson scheme, Solution of hyperbolic equation. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Course Plan

No	Topic	No. of Lectures - 40 Hrs
1	**Introduction to Computational methods, system of equations**	
1.1	Revision - Formulation of engineering problems and solution using computational methods; significant figures, accuracy, precision, round off error, truncation error, Taylor series expansion of a polynomial	2
1.2	Roots of equation - Bisection, Newton Raphson, and Bairstow methods	2
1.3	Linear algebraic equations - Gauss Elimination method, LU decomposition. Non-linear equation- Gauss-Jordan method, Newton- Raphson for simultaneous equations	3
1.4	Case studies with computer programs (Python/Scilab/ C++/Fortran/other) (Not for End Semester Examination)	2
2	**Curve fitting**	
2.1	Linear regression- linearization of non linear relation, linear least squares, multiple linear regression	2
2.2	Non linear regression- polynomial regression, Gauss- Newton method	3
2.3	Case studies with computer programs (Python/Scilab/C++/Fortran/other) (Not for End Semester Examination)	2

3	**Numerical differentiation and integration**	
3.1	Derivatives - Newton's forward, backward, divided difference and Sterling formula	3
3.2	Integration -Trapezoidal rule, Simpsons one third, Simpsons three eighth, Gauss quadrature-two & three point.	3
3.3	Case studies with computer programs (Python/Scilab/ C++/Fortran/other) (Not for End Semester Examination)	2
4	**Numerical solutions to ordinary differential equations**	
4.1	Taylors method, Eulers method, Runge-Kutta method fourth order, simultaneous first order, Milne's predictor corrector	3
4.2	Initial value problem - shooting method, Eigen values -polynomial method, power method	3
4.3	Case studies with computer programs (Python/Scilab/C++/Fortran/other)(Not for End Semester Examination)	2
5	**Solution of partial differential equation & Interpolation**	
5.1	Interpolation - Newtons forward and backward, divided difference linear & quadratic, Lagrange interpolation, cubic splines, Hermites interpolation	3
5.2	Solution of partial differential equation - Difference equations, Elliptic equation- Laplace equation, Poisson equation, Liebmann's iterative methods, Parabolic equation- Bender-Schmidt method, simple implicit, Crank-Nicolson scheme, Solution of hyperbolic equation	3

5.3	Case studies with computer programs (Python/Scilab/ C++/Fortran/other)(Not for End Semester Examination)	2

Reference Books

1. Steven C. Chapra, Raymond P Canale, Numerical Methods for Engineering, 8e, Mc-Graw Hill Education (2020)
2. B.S. Grewal, numerical methods in engineering science with programs in C, C++ and MATLAB(10th edition) Khanna Publisher (2020)
3. E Balaguruswamy, Numerical Methods, McGraw Hill (2017)
4. P. Kandasamy , K. Thilagavathy and K. Gunavathy., Numerical Methods, S Chand & Co Ltd (2016)
5. S. P. Venkateshan, Prasanna Swaminathan, Computational Methods in Engineering, Ane Books (2014)
6. VN Vedamurthy & SN Iyengar, Numerical Methods, S Chand & Co Ltd (2014)
7. AK Jaiswal and Anju Khandelwal, Computer Based Numerical and Statistical Techniques, New Age International (2009)
8. Gilbert Strang, Computational Science and Engineering, Wellesley-Cambridge Press (2007)
9. Joe D Hoffman, Numerical Methods for Engineers and Scientists, Second Edition, Marcel Dekker (2001)

221TME001	ADVANCED THEORY OF VIBRATION	CATEGORY	L	T	P	CREDIT
		PROGRAM CORE 1	3	0	0	3

Preamble:

This course aims at imparting the principles of vibration and methods of analysing single degree and multi degree freedom free, forced, un damped and damped vibrations in machineries and formulation of differential equation of motion and finding the natural frequencies, mode shapes and response of systems and its relevance in the design of systems which are subjected to vibrations.

Course Outcomes

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

CO 1	Understand and apply the fundamentals of vibration, free, forced, and damped and un damped systems in the formulation of differential equation of motion, determination of natural frequencies and its importance in the design of mechanical systems.
CO 2	Understand transient responses, coordinate coupling and analyse two degree of freedom systems and formulate differential equation of motion,
CO 3	Understand and analyse multi degree of freedom systems and formulate differential equation of motion using Langranges method and determination of natural frequencies and mode shapes using various methods.
CO 4	Understand and analyse the various computational methods for the determination of vibration characteristics of multi-degree of freedom systems and carry out modal analysis.
CO 5	Understand and analyse the continuous systems and apply various solution 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	3	3	3	3	
CO 2	2	1	3	3	3	3	
CO 3	2	1	3	3	3	3	
CO 4	2	1	3	3	3	3	
CO 5	2	1	3	3	3	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: CORE COURSES

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 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

QP Code:		**Total pages:**
Reg. No.		**Name:**____________________
APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY **FIRST SEMESTER M.TECH DEGREE EXAMINATION, Month & Year**		
Stream: MACHINE DESIGN **Course Name:** ADVANCED THEORY OF VIBRATION		
Course Code: 221TME001		
Max. Marks: 60		**Duration: 2.5 Hours**
PART A		

1. Explain the various methods of damping. (5 marks)
2. Use convolution integral to determine response of single degree of freedom system to a step excitation shown in figure.2. Also find the response using Laplace transform method. (5 marks)

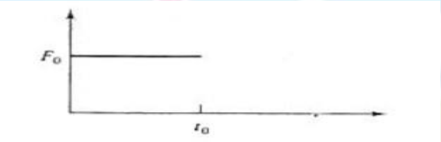
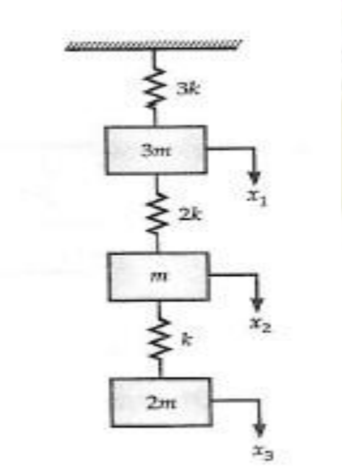


Fig.2

3. Formulate the differential equation of motion using Lagranges equation for the system shown in fig.3.



4. Describe the procedure to find the response of a single degree of freedom undamped free vibration system using modal analysis. (5 marks)
5. Explain Rayleigh and Rayleigh –Ritz methods. (5 marks)

PART B

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

6. a) Define transmissibility. (2 marks)
   b) An aircraft radio weighing 107 N is to be isolated from engine vibrations ranging in frequencies from 1600 to 2200 cpm. What static deflection must the isolators have for 85 % isolation? (5 marks)
7. Determine the normal modes of vibration and locate the node for each mode of an automobile shown in fig.6 The weight of the automobile is 1800 kg, l_1 = 1.3 m, l_2= 1.7 m,K_1 =30000N/m ,K_2 = 35000 N/m and the radius of gyration about c.g is 1.2 m. (7 marks)

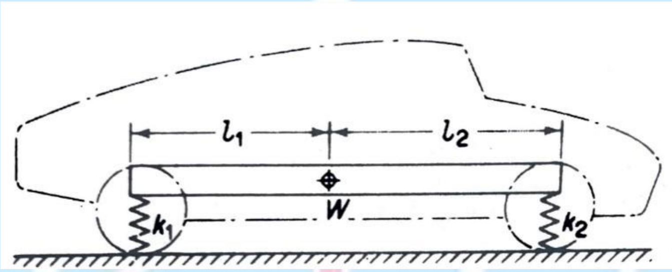


Fig. 7

8. Derive the equation for the magnification ratio for a harmonically excited single degree of freedom vibration system. Also explain the effect of damping ratio on the plots of magnification ratio versus frequency ratio. (7 marks)
9. Determine the flexibility matrix for a cantilever beam having length, L carrying four equally spaced point loads of "W" each. (7 marks)
10. Determine the flexibility matrix of the spring mass system shown in fig.3. Take K = 1 k N /m and m = 1kg . Decompose the stiffness matrix using Cholesky method and reduce to standard form. (7 marks)
11. Using Rayleigh's method find the fundamental frequency of transverse vibration of a simply supported beam of length 1.2 m and uniform cross section with moment of inertia 60 cm^4 .Three loads of 2 kN, 4 kN and 6 kN are acting respectively at 30 cm,60 cm and 90 cm from left end. Take E = 210 GPa. (7 marks)
12. Derive the equation for the natural frequency of torsional vibration ofa fixed -free rod. (7marks)

Syllabus

Module 1

Fundamentals of Vibration, classification, Main causes of Vibration, Elements of Vibration, classification of vibrations, Free vibration and forced Vibration, Damping –Viscous, Coulomb, structural and Interfacial.

Logarithmic decrement and Un damped vibrations, Single degree of freedom systems, Methods of formulation of differential equation of Motion.

Forced vibrations, Harmonically excited vibration, Force transmissibility, Magnification factor, Vibration isolation.

Module 2

Transient Vibration-Impulse excitation, arbitrary excitation, Convolution Integral.

Laplace Transform formulation, Shock Response spectrum, Shock isolation.

Systems with two Degree of freedom, Normal modes and natural frequencies, Dynamics vibration absorber, Coordinate coupling, Torsional Vibrations, Whirling motion and critical speed of shafts.

Module 3

Multi-Degree of freedom systems- Matrix formulation- Influence coefficients-Flexibility and stiffness- Generalized co-ordinates- Virtual work.

Derivation of Lagranges equation-Formulation of differential equation of motion, Formulation of Eigen Value problem of Vibration–Determination of Eigen value and Eigen vectors as Natural Frequencies and mode shapes.

Module 4

Orthogonally of Eigen vectors, Orthonormal modes, Modal matrix, Modal analysis and Mode summation. Computational -Methods –Dynamic Matrix and Matrix iteration.

Cholesky decomposition, Jacobi diagonalisation.

Methods of Vibration measurement.

Module 5

Vibration of Continuous systems- Transverse vibration of a string, Longitudinal vibration of a rod, Torsional vibration of a rod.

Lateral vibration of beam-Euler equation, Rayleigh method.

Rayleigh –Ritz method, Dunkerley's Lower bound approximation.

COURSE PLAN		
Module	**Contents**	**Hours Allotted**
I.1	Fundamentals of Vibration, classification, Main causes of Vibration, Elements of Vibration, classification of vibrations, Free vibration and forced Vibration, Damping –Viscous, Coulomb, structural and Interfacial.	3
1.2	Logarithmic decrement and Un damped vibrations, Single degree of freedom systems, Methods of formulation of differential equation of Motion.	3
1.3	Forced vibrations, Harmonically excited vibration, Force transmissibility, Magnification factor, Vibration isolation.	2
2.1	Transient Vibration-Impulse excitation, arbitrary excitation, Convolution Integral.	2
2.2	Laplace Transform formulation, Shock Response spectrum, Shock isolation.	2
2.3	Systems with two Degree of freedom, Normal modes and natural frequencies, Dynamics vibration absorber, Coordinate coupling, Torsional Vibrations, Whirling motion and critical speed of shafts.	4
3.1	Multi-Degree of freedom systems- Matrix formulation- Influence coefficients- Flexibility and stiffness- Generalized co-ordinates- Virtual work	3
3.2	Derivation of Lagranges equation -Formulation of differential equation of motion,	2
3.3	Formulation of Eigen Value problem of Vibration–Determination of Eigen value and Eigen vectors as Natural Frequencies and mode shapes.	3
4.1	Orthogonally of Eigen vectors, Orthonormal modes,	4

	Modal matrix, Modal analysis and Mode summation. Computational -Methods –Dynamic Matrix and Matrix iteration.	
4.2	Cholesky decomposition, Jacobi diagonalisation.	2
4.3	Methods of Vibration measurement.	2
5.1	Vibration of Continuous systems- Transverse vibration of a string, Longitudinal vibration of a rod, Torsional vibration of a rod.	4
5.2	Lateral vibration of beam-Euler equation, Rayleigh method.	2
5.3	Rayleigh –Ritz method, Dunkerley’s Lower bound approximation.	2

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221TME002	**CONTINUUM MECHANICS**	**PROGRAM CORE 2**	**3**	**0**	**0**	**3**

Preamble: This course targets to develop a systematic and in-depth understanding of the principles of continuum mechanics.

Course Outcomes:

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

CO 1	**Use** the concepts of tensor formalism for practical applications
CO 2	**understand** general stresses and deformations in continuous materials
CO 3	**Use** fundamental laws for problem formulations and study different constitutive models
CO 4	**Apply** the knowledge of continuum mechanics to do microproject and prepare a report following ethical practices
CO 5	**Summarize** current active research in continuum mechanics and present it confidently

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7
CO 1			3				
CO 2	2	2	3	3			
CO 3	2	2	3	2	2		
CO 4	3	3	3	3	2	2	
CO 5	3	3	2	2	2		

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: 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 3**

Register No:
Name:

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Stream: Machine Design

Course Code:221TME002

Course Name: CONTINUUM MECHANICS

Max Marks: 60 **Duration: 2.5 hr**

PART A

Answer all questions

		Marks
1	Prove the vector identity using indicial notation a × (b × c) = (a . c) b − (a . b) c	**5**
2	Given a continuum, where the stress state is known at one point and is represented by the Cauchy stress tensor $[\sigma_{ij}] = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 2 \end{bmatrix}$ Pa. Find the principal stresses and maximum shear stress	**5**
3	Find the infinitesimal stress tensor and the infinitesimal rotation tensor whose displacement field is given by; $u_1 = x_1^2$, $u_2 = x_1x_2$, $u_3 = 0$	**5**

4	Derive the strain compatibility equations.	**5**
5	Obtain the constitutive relation for Newtonian fluid	**5**

PART B

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

			Marks
6	**a**	Write down the equation for Mohr's circle of two-dimensional problems. Write down the equation for the radius of the 2D Mohr's circle.	**3**
	b	σ_{xy}= 2, σ_{xz}= 1, σ_{yy} =0 and σ_{zz} =0 be the known components of stress at a point. Find the value σ_{xx}such that atleast one plane passing through the point is stress free. Also determine the direction cosines of normal of the stress free plane.	**4**
7		The stress matrix representation at P in MPa is $$\sigma_{ij} = \begin{pmatrix} 1 & 4 & 0 \\ 4 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$	
		i. Find the stress vector on the plane whose normal is in the direction of $e_1 + e_2$.	**2**
		ii. Find the normal stress on the same plane.	**2**
		iii. Find the maximum shearing stress.	**3**
8		The motion of a certain continuous medium is defined by the equations $x_1 = \frac{1}{2}[(X_1 + X_2)e^t) + (X_1 - X_2)e^{-t})]$, $x_2 = \frac{1}{2}[(X_1 + X_2)e^t) - (X_1 - X_2)e^{-t})]$,	

		$x_3 = X_3$	
		i. Express the velocity components in terms of material and spatial coordinates.	**4**
		ii. Determine the displacement components in terms of material and spatial coordinates.	**3**
9		Consider the deformation given by $x_1 = 2(X_1 - X_2)$, $x_2 = X_1 + X_2$, $x_3 = X_3$ Determine i. The left stretch tensor V ii. The rotation tensor R iii. The principal stretches of V	**7**
10	**a**	Discuss the principle of material indifference	**4**
	b	Discuss about Generalized Hooke's law	**3**
11	**a**	Using the law of conservation of momentum prove that stress tensor is symmetric	**5**
	b	Derive the Eulerian form of continuity equation	**2**
12		Derive the Beltrami-Michell equations corresponding to isotropic elasticity.	**7**

Syllabus

Module 1

Mathematical preliminaries- Index notation, Einstein's summation convention, Kronecker delta. Levi-Civita symbols, Matrix algebra, Cayley Hamilton theorem. Concept of tensor - Vector space, Inner product space, Cartesian basis, Tensor as a linear transformation, Vector as a first order tensor, second order tensor expressed as a dyad, Dyadic product. Components of a tensor, Coordinate transformation of vectors and tensors. Principal values, trace and invariants, Orthogonal and isotropic tensors, Symmetric and anti-symmetric tensors, Spherical and deviatoric tensors. Algebra of tensors - Dot and cross products, scalar triple product, tensor product, inverse, contraction. Calculus of tensors. Gradient, divergence and curl of vector and tensor fields. Gauss' divergence and Stokes' theorems

Module 2

Kinematics of deformation and motion- Introduction to continuum concept, Continuum body, reference and current configurations, Lagrangian and Eulerian descriptions of motion, Material and spatial derivatives. Displacement, velocity and acceleration fields, Deformation gradient tensor. Transformation of line element, area element and volumeelement, Displacement gradient tensor, Nanson's formula. Right and left Cauchy Green deformation tensors. Lagrangian and Eulerian strain tensors, Infinitesimal deformation theory,Linearized strain, Infinitesimal rotation. Physical interpretation of linearised strain tensor, stretch ratio, Change of angle before and after deformation. Polar decomposition theorem. Rate of deformation gradient, velocity gradient and spin tensors. Strain transformation, Principal strains. Saint Venant strain compatibility equations.

Module 3

Stress analysis- Stress at a point, stress tensor, Normal and shear stresses. Cauchy stress components along orthonormal basis vectors, Components of Cauchy stress vector on any plane. Principal stress components. Principal planes. Principal coordinate system. Spherical and deviatoric stresses, Octahedral stress. Stress transformation. Mohr's circle for 3D and 2D stresses.

Module 4

Balance Laws- Reynold's transportation theorem, Localization theorem, Lagrangian and Eulerian forms of equation for mass balance- Continuity equation. Balance of linear momentum equation- Equilibrium equations. Balance of angular momentum- Symmetry of stress tensor. Law of conservation of energy. Principle of virtual work.

Module 5

Constitutive relations- Invariance of constitutive equations; Material frame indifference. Linear elasticity; Material symmetry; Independent constants in the 4th order elasticity tensor for anisotropic, monoclinic, orthotropic and transversely isotropic materials; Generalized Hooke's law for isotropic materials in indicial and matrix forms; Lame's constants, Young's modulus, Poisson's ratio and Bulk modulus, Beltrami-Michael stress equations of compatibility, Navier's equations, Plane stress and plane strain formulation, Viscous stress tensor, Stokesian and Newtonian fluids. Basic equations of viscous flow, Navier-Stoke's equation. Non- Newtonian fluids, Viscoelastic constitutive models-Kelvin Voigt model and Maxwell model

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

Module No	Topic	No. of Lectures
1	**Mathematical preliminaries**	
1.1	Index notation, Einstein's summation convention, Kronecker delta	1
1.2	Levi-Civita symbols, Matrix algebra, Cayley Hamilton theorem.	1
1.3	Concept of tensor - Vector space, Inner product space, Cartesian basis, Tensor as a linear transformation, Vector as a first order tensor, second order tensor expressed as a dyad, Dyadic product	1
1.4	Components of a tensor, Coordinate transformation of vectors and tensors	1
1.5	Principal values, trace and invariants, Orthogonal and isotropic tensors, Symmetric and anti-symmetric tensors, Spherical and deviatoric tensors.	1
1.6	Algebra of tensors - Dot and cross products, scalar triple product, tensor product, inverse, contraction.	1
1.7	Calculus of tensors	1
1.8	Gradient, divergence and curl of vector and tensor fields. Gauss' divergence and Stokes' theorems	1
2	**Kinematics of deformation and motion**	
2.1	Introduction to continuum concept, Continuum body, reference and current configurations, Lagrangian and Eulerian descriptions of motion, Material and spatial derivatives.	1

2.2	Displacement, velocity and acceleration fields, Deformation gradient tensor.	1
2.3	Transformation of line element, area element and volumeelement, Displacement gradient tensor, Nanson's formula.	1
2.4	Right and left Cauchy Green deformation tensors.	1
2.5	Lagrangian and Eulerian strain tensors, Infinitesimal deformation theory, Linearized strain, Infinitesimal rotation	1
2.6	Physical interpretation of linearised strain tensor, stretch ratio, Change of angle before and after deformation.	1
2.7	Polar decomposition theorem	1
2.8	Rate of deformation gradient, velocity gradient and spin tensors.	1
2.9	Strain transformation, Principal strains	1
2.10	Saint Venant strain compatibility equations	1
3	**Stress analysis**	
3.1	Stress at a point, stress tensor,Normal and shear stresses.	1
3.2	Cauchy stress components along orthonormal basis vectors, Components of Cauchy stress vector on any plane.	2
3.3	Principal stress components. Principal planes. Principal coordinate system.	2
3.4	Spherical and deviatoric stresses, Octahedral stress.	1

3.5	Stress transformation.	1
3.6	Mohr's circle for 3D and 2D stresses.	1
4	**Balance Laws**	
4.1	Reynold's transportation theorem, Localization theorem	1
4.2	Lagrangian and Eulerian forms of equation for mass balance- Continuity equation.	1
4.3	Balance of linear momentum equation- Equilibrium Equations.	1
4.4	Balance of angular momentum- Symmetry of stress tensor.	1
4.5	Law of conservation of energy.	1
4.6	Principle of virtual work.	1
5	**Constitutive relations**	
5.1	Invariance of constitutive equations; Material frame indifference	1
5.2	Linear elasticity; Material symmetry; Independent constants in the 4th order elasticity tensor for anisotropic, monoclinic, orthotropic and transversely isotropic materials;	1
5.3	Generalized Hooke's law for isotropic materials in indicial and matrix forms; Lame's constants, Young's modulus, Poisson's ratio and Bulk modulus	1
5.4	Beltrami-Michael stress equations of compatibility	1

5.5	Navier's equations	1
5.6	Plane stress and plane strain formulation	1
5.7	Viscous stress tensor, Stokesian and Newtonian fluids.	1
5.8	Basic equations of viscous flow, Navier-Stoke's equation. Non- Newtonian fluids	1
5.9	Viscoelastic constitutive models-Kelvin Voigt model and Maxwell model	1

Reference Books

1. G. Thomas Mase, George E. Mase. Ronald E. Smelser. Continuum mechanics for engineers 3rd ed CRC Press
2. J. N. Reddy, An Introduction to Continuum Mechanics with applications - Cambridge University Press
3. Sudhakar Nair, Introduction to Continuum Mechanics – Cambridge University press
4. Lawrence E. Malvern. Introduction to the Mechanics of a Continuous Medium – Prentice Hall
5. W. Michael Lai, David Ribin, Erhard Kaempl, Introduction to Continuum Mechanics 4th Ed., Butterworth- Heinemann
6. Y. C. Fung, A First Course in Continuum Mechanics for Physical and Biological Engineers and scientists - Prentice Hal
7. Morton E. Gurtin, An introduction to continuum mechanics, Academic Press

PROGRAM ELECTIVE I

221EME100	FRACTURE MECHANICS	CATEGORY	L	T	P	CREDIT
		PROGRAMME ELECTIVE 1	3	0	0	3

Course Outcomes: COs

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

CO 1	Awareness for the design aspects of fracture mechanics
CO 2	More inclined to R&D based on a stress function approach
CO 3	Can generate data and arrive similar variation like in Paris law
CO 4	Perdition of fatigue life for give stress ratio and device test methodology
CO 5	Students will be able check the design or suggest for modification

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:

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

QP Code: **Total Pages: 3**

RegNo.:_______________ **Name:___________________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, Dec2022

Stream: Machine Design

Course Code: 221EME100

Course Name: Fracture Mechanics

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

PART A

		Answer all questions, each carries 5 marks.	**Marks**
1		What is the equivalent form of E and ν for plane strain condition? Also Determine K_{IC} of a center cracked large size plate with 2a =10mm, loaded inMode-I, if applied stress is 100MPa.	**(5)**
2		Draw plastic zone sizes at the crack tip under Mode -I, Mode -II and Mode -III	**(5)**
3		Why narrow elliptical surface crack is less severe in a pressure vessel? What is the shape it tends to become on growth?	**(5)**
4		Write down the principle of Dugdale model for the plastic zone size and give expression for plastic zone size	**(5)**
5		Describe the phenomenon of crack closure and how it can improve fatigue life?	**(5)**

PART B

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

6	**(a)**	Compare a value of surface energy of a ductile material with and without plasticity	**(3)**

	(b)	Give expressions for the crack tip stresses in an infinite plate for the case of mode III.	**(4)**
7		Draw details of the three types of variation on load with CMOD during testing. Derive the expression for crack tip CTOD due to plastic hinge	**(7)**
8		Draw Chevron notch and explain why it is used. A material has yield strength of 360MPa and a fracture toughness of 120MPa $m^{1/2}$. What are the minimum specimen dimensions (B, a and W) required to conduct a valid K_{IC} test as per ASTM standard.	**(7)**
9		Derive the expression for the critical velocity. How does a dynamic fracture toughness value vary with crack speed?	**(7)**
10		Draw constant amplitude fatigue cycle for stress ratio, R = 0, R> 0 and R= ±1. How does a fatigue crack initiate on a reentrant corner?	**(7)**
11		A wide panel of an aluminum alloy was found to contain a 6 mm long centre crack oriented normal to the applied stress after three years of service. The panel was designed to withstand two cycles of loading having σ_{max} = 210 MPa and σ_{min} = 72 MPa per day for 15 years for all the 360 days in the year. The cyclic crack growth rate is represented by equation $da/dN = 3.3 \times 10^{-9} (\Delta K)^3$ where "a" is in meters and ΔK in MPa $m^{1/2}$. Check the design adequacy of the panel for the expected period.	**(7)**
12		Explain in details on environments assisted fatigue failure and explain remedial steps to slow down/ arrest such failures.	**(7)**

Syllabus

Module 1

ROLE OF FRACTURE MECHANICS- Stress-strain behaviour of elastic, plastic and elastoplastic deformations-Fracture based failure scenario, role of fracture mechanics. General 2D, 3-D relations, Plane stress, plane strain behaviour on material properties. Mohr's circle, Tresca, von Mises criteria-Stress raisers, notches -Fractography, General modes of failure.

Module 2

STRESS FUNCTION APPRACH- Linear Elastic Fracture Mechanics (LEFM), Griffith's Energy balance, Irwin's modification- R curve concept with thickness effect -Superposition of SIF. Bi-harmonic equations, analytical approach for SIF, crack tip stresses-Finite width correction. Single edge, centre, double edge elliptical cracks- Embedded cracks-plane stress plane characteristics of elliptical crack growth.

Module 3

CRACK TIP PLASTICITY- Small scale yielding, Irwin's plastic zone size-Dugdaleapproach-Plastic zone size and shapes, thickness effect. Prediction on fracture load -plain stress, plane strain, iterative methods. CTOD, CMOD, COD - SSY, low and large yielding material classifications.

Module 4

TESTING and FATIGUE CRACK GROWTH- Evaluation of K_{IC}- Standard J_{IC} - Crack opening displacement (COD) test. Fatigue crack test associated with time to failure (TTF), variable amplitude - simulating environmental crack growth rate testing. Formation of fracture surface, Paris Law- Over loading, variable amplitude, Crack closure- Environmental factors affecting SIF. Prediction fatigue life, stress ratio, modified Paris law, crack growth arrest (singlepath).

Module 5

NON-LINEAR FRACTURE MECHANICS- J– Integral, COD approach and design curve, relation between **J** and COD-Tearing modulus concept. Dynamic energy balance, multiple crack growth, principle of crack arrest, dynamic fracture toughness. Fracture design based on selection of material-fail safe design in engineering problems, pressure vessels-scaling of growth under environmental effect.

Course Plan

Module	Topic	No. of Lectures
1	**ROLE OF FRACTURE MECHANICS**	
1.1	Stress-strain behaviour of elastic, plastic and elastoplastic deformations-Fracture based failure scenario, role of fracture mechanics	2
1.2	General 2D, 3-D relations, Plane stress, plane strain behaviour on material properties.	2
1.3	Mohr's circle, Tresca, von Mises criteria- Stress raisers, notches -Fractography, General modes of failure	2
2	**STRESS FUNCTION APPRACH**	
2.1	Linear Elastic Fracture Mechanics (LEFM), Griffith's Energy balance, Irwin's modification- R curve concept with thickness effect -Superposition of SIF	3
2.2	Bi-harmonic equations, analytical approach for SIF, crack tip stresses-Finite width correction.	3
2.3	Single edge, centre, double edge elliptical cracks-Embedded cracks-plane stress plane characteristics of elliptical crack growth.	2
3	**CRACK TIP PLASTICITY**	
3.1	Small scale yielding, Irwin's plastic zone size-Dugdaleapproach-Plastic zone size and shapes, thickness effect.	3
3.2	Prediction on fracture load -plain stress, plane strain, iterative methods.	3
3.3	CTOD, CMOD, COD - SSY, low and large yielding material classifications.	2
4	**TESTING and FATIGUE CRACK GROWTH**	
4.1	Evaluation of K_{IC}- Standard J_{IC} - Crack opening displacement (COD) test Fatigue crack test associated with time to failure (TTF), variable amplitude - simulating environmental crack growth rate testing.	4
4.2	Formation of fracture surface, Paris Law- Over loading, variable amplitude, Crack closure-Environmental factors affecting SIF.	3
4.3	Prediction fatigue life, stress ratio, modified Paris law, crack growth arrest (singlepath).	2
5	**NON-LINEAR FRACTURE MECHANICS**	

5.1	J- Integral, COD approach and design curve, relation between J and COD-Tearing modulus concept.	4
5.2	Dynamic energy balance, multiple crack growth, principle of crack arrest, dynamic fracture toughness.	4
5.3	Fracture design based on selection of material-fail safe design in engineering problems, pressure vessels-scaling of growth under environmental effect.	3

Reference Books

1. Prasant Kumar, Elements of Fracture Mechanics, Tata McGraw Hill, New Delhi, India
2. David Broek, Elementary Engineering Fracture Mechanics,Springer Dordrecht
3. NPTEL, Fracture Mechanics by Prof. K. Ramesh, Dept. Applied Mechanics, IIT Madras
4. ASM Metal Hand book, Vol. 12, Fractography, ASMInt., 2004.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EME001	ACOUSTICS AND NOISE CONTROL	PROGRAM ELECTIVE I	3	0	0	3

Preamble: To gain fundamental concepts of acoustics and noise control and apply noise control measures in various engineering applications.

Course Outcomes:

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

CO 1	Describe basic acoustic principles and terminologies
CO 2	Execute noise measurement
CO 3	Choose suitable acoustic materials and proper noise control measures for real-life problem
CO 4	Understand the latest developments in noise control and prepare a review article
CO 5	Prepare a seminar on the latest developments in acoustics and noise control and present it confidently

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO7
CO 1	2	2	3	3			
CO 2	3	2	2		2		
CO 3	3	2	3	3	3	3	
CO 4	2	3	2	2	2	2	

CO 5	2	3	2	2	2	2	

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: 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.

MODEL QUESTION PAPER

QP Code **Total Pages**

Register No:

Name:

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIRST SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Stream: Machine Design

Course Code:221EME001

Course Name: ACOUSTICS AND NOISE CONTROL

Max Marks: 60 **Duration: 2.5 hr**

Part A

(Answer *all* questions – each question carries 5 marks)

1	A plane sound wave is propagated in air at 15^{o}C and 101.3 Pa. The intensity of the wave is 10 x10^{-3} W/m^{2}. Determine the density and acoustic velocity.	**5**
2	Obtain the expression for pressure reflection and pressure transmission coefficient when sound transmits from one medium to another normally.	**5**
3	Explain about the different levels used in acoustics.	**5**
4	With neat sketch explain about the hearing mechanism in human beings.	**5**
5	Describe about i. Mufflers. ii. Acoustic filters.	**5**

Part B

(Answer *any* 5 questions – each question carries 7 marks)

			Marks
6		Derive the acoustic wave equation. Deduce the plane wave equation from the acoustic wave equation.	**7**
7	**a**	Discuss about acoustic materials.	**4**
	b	Briefly explain about standing waves.	**3**
8	**a**	A fan alone produces a sound intensity level of 82 dB. A pump and a fan together produce an intensity level of 88.2 dB. Determine the intensity level of the sound produced by the pump.	**2**
	b	Determine the average sound pressure level L_p at a location for a series of measurements taken at different times: 96, 88, 94, 102 &90 dB.	**2**
	c	Explain about sound power level.	**3**
9	**a**	Discuss about directivity	**3**
	b	How sound measurement is performed in anechoic chamber?	**4**
10	**a**	Describe about auditory area.	**3**
	b	With neat sketch describe about equal loudness contours.	**4**
11	**a**	Describe about noise and number index.	**4**
	b	Discuss about noise criteria.	**3**
12		What are Helmholtz resonators. Obtain the expression for resonance frequency. Mention two applications of Helmholtz resonators	**7**

Syllabus

Module 1

Fundamentals and basic acoustic terminology: - Introduction. Sound generation and propagation. Acoustic wave parameters. Relation between the acoustic wave parameters. Acoustic field variables. Acoustic wave equation. Helmholtz equation, Plane waves, harmonic solution. Pure tone and complex waves. Beat, Octaves, Standing waves, Acoustic intensity, Sound power, Inverse square law, Particle velocity, Energy density, Acoustic impedance, Properties of acoustic waves, Spherical waves.

Module 2

Human Hearing and response to noise: - Introduction to Human Hearing. Ear: its structure and function related to hearing. Noise. Noise measures. Thresholds of hearing. Sensitivity. Auditory area. Loudness of sound. Annoyance and perceived noise level. Masking. Speech interference level. Equal loudness contour. Loudness level. Phon and sone. Frequency weightings. Effects of noise on people. Hearing loss. Prosthetics for hearing

Module 3

Sound source and directivity-simple source, dipole source, quadrupole source, line source, piston in an infinite baffle, Piston without baffle, Near field and far field, Directivity pattern, Directivity factor and directivity index

Transmission and reflection coefficient. Sound transmission from one medium to another – normal and oblique incidence. Transmission through pipes-junctions and branches. Resonators- Helmholtz resonator. Transmission loss. Mass Law, Absorption coefficient, Reflection at plane surface

Module 4

Levels. Decibel scale. Sound pressure level, Sound intensity level and Sound power level. Addition, subtraction and averaging of Decibels

Instrumentation for Noise measurement: - Microphone. Sound level meter. Noise dosimeter. Noise analyzers and signal generators. Equipment for data acquisition. Intensity meter. Sound measurement in anechoic and reverberation chambers.

An overview of noise criteria and noise standards practicing nationally and internationally

Module 5

Principles of noise control-control at source, during transmission and at receiver. Acoustic materials – partitions, enclosures, barriers, absorbers. Performance metrics.

Acoustic filters. Plenum chamber. Perforated and microperforated plates. Baffles.

Mufflers and silencers-Electroacoustic modelling. Transfer matrix modelling. Classification.

Machinery noise control: - fans and blowers, pumps and plumbing systems, compressors, gears, bearings.

Course Plan (For 3 credit courses, the content can be for 40 hrs and for 2 credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30 hours).

No	Topic	No. of Lectures: 40
1	Fundamentals and basic acoustic terminology: - Introduction. Sound generation and propagation. Acoustic wave parameters. Relation between the acoustic wave parameters. Acoustic field variables. Acoustic wave equation. Helmholtz equation, Plane waves, harmonic solution. Pure tone and complex waves. Beat, Octaves, Standing waves, Acoustic intensity, Sound power, Inverse square law, Particle velocity, Energy density, Acoustic impedance, Properties of acoustic waves, Spherical waves.	8
2	Human Hearing and response to noise: - Introduction to Human Hearing. Ear: its structure and function related to hearing. Noise. Noise measures. Thresholds of hearing. Sensitivity. Auditory area. Loudness of sound. Annoyance and perceived noise level. Masking. Speech interference level. Equal loudness contour. Loudness level. Phon and sone. Frequency weightings. Effects of noise on people. Hearing loss. Prosthetics for hearing	8
3	Sound source and directivity-simple source, dipole source, quadrupole source, line source, piston in an infinite baffle, Piston without baffle, Near field and far field, Directivity pattern, Directivity factor and directivity index Transmission and reflection coefficient. Sound transmission from one medium to another – normal	8

	and oblique incidence. Transmission through pipes- junctions and branches. Resonators- Helmholtz resonator. Transmission loss. Mass Law, Absorption coefficient, Reflection at plane surface	
4	Levels. Decibel scale. Sound pressure level, Sound intensity level and Sound power level. Addition, subtraction and averaging of Decibels Instrumentation for Noise measurement: - Microphone. Sound level meter. Noise dosimeter. Noise analyzers and signal generators. Equipment for data acquisition. Intensity meter. Sound measurement in anechoic and reverberation chambers. An overview of noise criteria and noise standards practicing nationally and internationally	8
5	Principles of noise control-control at source, during transmission and at receiver. Acoustic materials – partitions, enclosures, barriers, absorbers. Performance metrics. Acoustic filters. Plenum chamber. Perforated and microperforated plates. Baffles. Mufflers and silencers-Electroacoustic modelling. Transfer matrix modelling. Classification. Machinery noise control: - fans and blowers, pumps and plumbing systems, compressors, gears, bearings.	8

Reference Book

1. Kinsler and Frey – Fundamentals of Acoustics
2. Istvan L. Ver and Leo L. Beranek– Noise and Vibration Control Engineering Principles and Applications
3. David A. Bies and Colin H. Hansen- Engineering Noise Control Theory and practice
4. Douglas D. Reynolds- Engineering Principles of Acoustics – Noise and vibration Control
5. M L Munjal-Noise and Vibration Control

6. Daniel R. Raichel-The Science and Applications of Acoustics
7. F. Alton Everest -The Master Handbook of Acoustics
8. Grad – Industrial noise and vibration
9. F. Alton Everest -The Master Handbook of Acoustics
10. Malcolm J. Crocker (Editor)- Handbook of Noise and Vibration Control
11. Lasithan L G- Mechanical Vibrations and Industrial Noise Control

221EME002	ROBOTICS	CATEGORY	L	T	P	CREDIT
		PROGRAMME ELECTIVE I	3	0	0	3

Preamble:

To provide the students an understanding of the robotic fundamentals and also to enable them in analysing a multilink robot in terms of position, orientation, velocity and force acting on individual links and end effectors.

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

CO 1	1. Gain knowledge of the various robotic classifications based on industrial application and work envelop. 2. Distinguish between FMS and robotics. 3. Understand the various robotic elements and their classifications.
CO 2	1. Represent a multi link robot in a coordinate system. 2. Apply the transformation matrices on individual links and end effectors.
CO 3	1. Obtain the position and orientation of the end effector based on the orientation of individual links. 2. Obtain the position and orientation of individual links for achieving various end effector positions
CO 4	1. Conduct velocity analysis of individual inks and end effector. 2. Conduct static force analysis of individual links and end effector 3. Conduct Dynamic force analysis of individual links.
CO 5	1. Understand the design and activation mechanism of various robotic end effectors. 2. Understand robotic languages and software used in the industry.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Understand	30 %

Apply	60 %
Analyze	10 %
Evaluate	0 %

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

FIRST SEMESTER M.TECH DEGREE EXAMINATION, Dec 2022

Stream: Machine Design

Course Code: 221EME002

Course Name: ROBOTICS

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

PART A

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

1		List out any 5 considerations while designing a robotic work cell.	**(5)**
2		Explain briefly the X-Y-Z method for representing orientation of frame {B} with respect to frame {A}.	**(5)**
3		Explain the necessary conditions for obtaining unique solution and multiple solutions of link orientations for a given wrist position while solving a given robotic subspace.	**(5)**
4		Elaborate on the concept of Jacobian matrix with reference to a 6 link robotic arm.	**(5)**
5		Using neatly labelled diagram, explain the working of an adhesive gripper.	**(5)**

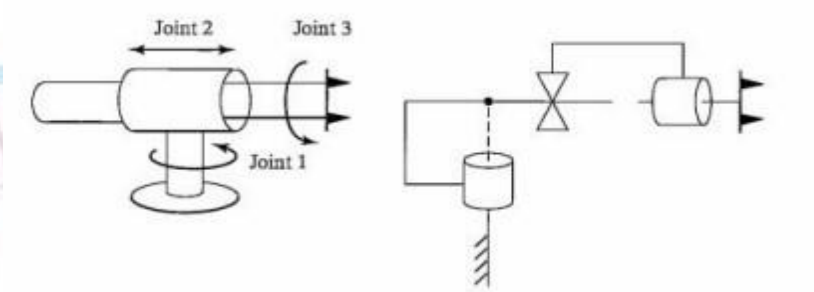
PART B

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

6	**(a)**	Explain flexible automation process in detail and list out its merits.	**(3)**

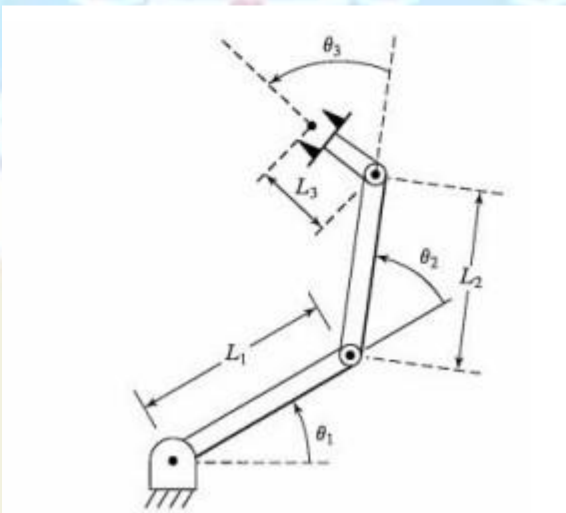
(b) Classify sensors used in robotics based on application. **(4)**

7 **(a)** Obtain the D-H parameters for the below mentioned mechanism. **(4)**



(b) With the help of neat diagram, explain the significance of D-H parameters in robotic link connection. **(3)**

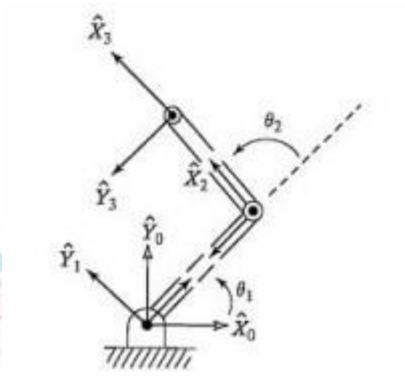
8 Obtain the expression for the transformation matrix of the wrist frame with respect to the base frame in terms of D-H parameters. **(7)**



9 Using suitable figures and abbreviations derive the force and torque acting on a link in a robotic arm. **(7)**

10 With the help of a neat diagram, conduct a force analysis of a gripper design. **(7)**

11 Obtain the velocity of the tip of the arm of a two-link manipulator with rotational joints in terms of frame {O}. **(7)**



12	Broadly classify the grippers used in robotics and with the help of a neat diagram, explain the working a mechanical gripper.	**(7)**

Syllabus

Module 1

Classification of robots and robotic elements- Classification based on work envelope. Classification of robot cell layout, considerations in work cell design. Flexible automation versus Robotic technology – Applications of Robots. Robotic Elements- joints, links, actuators, and sensors. Actuator types – stepper, DC servo and brushless motors. Types of transmissions. Sensors-purpose of sensors, internal and external sensors, common sensors – encoders, tachometers, strain gauge based force-torque sensors, proximity and distance measuring sensors, and vision.

Module 2

Robotic link representation and transformation in coordinate plane- Generalized coordinate system. Position and orientation of a multilink body. Homogeneous transformations. Positions, Orientations and frames. Changing descriptions from frame to frame. Operators: Translations, Rotations and Transformation. Representation of joints and links using D-H parameters, Examples of D-H parameters and link transforms.

Module 3

Robotic Kinematics- Forward Kinematics: Introduction, Direct kinematics problems, Examples of kinematics of common serial manipulators, workspace of a serial robot. Inverse kinematics: Inverse kinematics of constrained and redundant robots. Inverse kinematics solution for the general 6R serial manipulator.

Module 4

Robotic kinetics and dynamics- Velocity of robotic manipulators: -Linear and angular velocity of links, Velocity propagation from link to link. Singularity. Manipulator Jacobians for serial and parallel manipulators. Statics- Statics of serial and parallel manipulators. Dynamics of obots- Mass and inertia of links, Lagrangian formulation for equations of motion forserial and parallel manipulators.

Module 5

End effectors and robotic languages- Classification of End effectors – Tools as end effectors. Drive system for grippers. Gripper types-Mechanical-adhesive-vacuum-magnetic-Hooks &scoops. Active and passive grippers. Gripper force analysis and gripper design. Robot languages -.computer control and Robot software

Course Plan

Module No	Topic	No. of Lectures
1	**Classification of robots and robotic elements**	
1.1	Classification based on work envelope. Classification of robot cell layout, considerations in work cell design.	3
1.2	Flexible automation versus Robotic technology – Applications of Robots.	2
1.3	Robotic Elements- joints, links, actuators, and sensors. Actuator types – stepper, DC servo and brushless motors. Types of transmissions. Sensors-purpose of sensors, internal and external sensors, common sensors – encoders, tachometers, strain gauge based force-torque sensors, proximity and distance measuring sensors, and vision.	3
2	**Robotic link representation and transformation in coordinate plane**	
2.1	Generalized coordinate system. Position and orientation of a multilink body. Homogeneous transformations. Positions, Orientations and frames. Changing descriptions from frame to frame. Operators: Translations, Rotations and Transformation.	5
2.2	Representation of joints and links using D-H parameters, Examples of D-H parameters and link transforms.	3
3	**Robotic Kinematics**	
3.1	Forward Kinematics: Introduction, Direct kinematics problems, Examples of kinematics of common serial manipulators, workspace of a serial robot.	4
3.2	Inverse kinematics: Inverse kinematics of constrained and redundant robots. Inverse kinematics solution for the general 6R serial manipulator.	4
4	**Robotic kinetics and dynamics**	
4.1	Velocity of robotic manipulators: -Linear and angular velocity of links, Velocity propagation from link to link. Singularity. Manipulator Jacobians for serial and parallel manipulators.	4
4.2	Statics- Statics of serial and parallel manipulators.	1

4.3	Dynamics of robots- Mass and inertia of links, Lagrangian formulation for equations of motion for serial and parallel manipulators.	3
5	**End effectors and robotic languages**	
5.1	Classification of End effectors – Tools as end effectors. Drive system for grippers. Gripper types-Mechanical-adhesive-vacuum-magnetic-Hooks &scoops. Active and passive grippers. Gripper force analysis and gripper design.	4
5.2	Robot languages -.computer control and Robot software	4

Reference Books

1. Deb S. R. and Deb S., "Robotics Technology and Flexible Automation", Tata McGraw Hill Education Pvt. Ltd, 2010.
2. John J.Craig , "Introduction to Robotics", Pearson, 2009.
3. Mikell P. Groover et. al., "Industrial Robots - Technology, Programming and Applications", McGraw Hill, New York, 2008.
4. Richard D Klafter, Thomas A Chmielewski, Michael Negin, "Robotics Engineering – An Integrated Approach", Eastern Economy Edition, Prentice Hall of India Pvt. Ltd., 2006.
5. Fu K S, Gonzalez R C, Lee C.S.G, "Robotics : Control, Sensing, Vision and Intelligence",
   McGraw Hill, 1987

221EME003	MECHANICAL BEHAVIOUR OF MATERIALS	CATEGORY	L	T	P	CREDIT
		PROGRAMME ELECTIVE 1	3	0	0	3

Preamble:

To enable the students to understand and analyze the behaviour of engineering metals under different conditions of loading, with emphasis on a close analysis of failure of materials.

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

CO 1	1. Understand the stress strain relationships of materials 2. Analysis of different states of stress and strain.
CO 2	1. To understand the concepts of plasticity. 2. Understand apply the concepts of fracture mechanics
CO 3	1. To understand concepts of different composite materials. 2. Understand the concepts of creep behaviour.
CO 4	1. Gain comprehensive grasp of fatigue and impact loading behaviour.
CO 5	1. Understand the viscoelasticity and viscoplasticity behaviour. 2. To understand and evaluate mechanical characterisation of materials

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
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	30
Analyse	30
Evaluate	
Create	

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**

RegNo.:_______________ **Name:___________________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

1st SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Stream: Machine Design

Course Code: 221EME003

Course Name: MECHANICAL BEHAVIOUR OF MATERIALS

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

PART A

	Answer all questions, each carries 5 marks.	**Marks**
1	Strain gauge measurements made on the free surface of a steel plate indicate that the principal strains are 0.004 and 0.001. What are the principal stresses ?	**(5)**
2	Stress analysis of a spacecraft structural member gives the state of stress given below. If the part is made from 7075-T6 aluminium alloy with σ_o = 500 MPa, will it exhibit yielding? If not, what is the safety factor? σ_x = 200 MPa, σ_y = 100 MPa, σ_z = -50 MPa, τ_{xy} = 30 MPa	**(5)**
3	Write a brief note on Metal Foams	**(5)**
4	A mild steel plate is subjected to constant amplitude uniaxial fatigue loads to produce stresses varying from σ_{max} = 180 MPa to σ_{min} = -40 MPa. The static properties of the steel are σ_0 = 500 MPa, S_u = 600 MPa, E = 207 GPa and K_c = 100 MPa $m^{1/2}$. If the plate contains an initial through thickness edge crack of 0.5 mm, how many fatigue cycles will be required to break the plate ? Assume α = 1.12.	**(5)**
5	Explain the snock effect on BCC metals	**(5)**

PART B

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

6	**a.**	Determine the modulus of elasticity for tungsten and iron in the <111> and <100> directions. What conclusions can be drawn about their elastic anisotropy?	**(5)**

	S11	S12	S44
Fe	8.0	-2.8	8.6
W	2.6	-0.7	6.6

	b.	State the differences between hydrostatic and deviatoric states of stresses.	**a. (2)**
7	**a.**	Write a note on Griffith's theory. Derive an expression of Griffith's criterion.	**(4)**
	b.	Illustrate the 3 fracture modes with sketches.	**(3)**
8		An aluminium thin walled tube (radius/thickness = 20mm) is closed at each end and pressurized to 7 MPa to cause plastic deformation. Neglect the elastic strain and find the plastic strain in the circumferential direction of the tube. The plastic stress-strain curve is given by $\sigma = 170\ \varepsilon^{0.25}$, where stress is in MPa.	**(7)**
9		Give a detailed study of Brick wall model for particulate composites, with necessary equations and sketches.	**(7)**
10		Explain in detail all the four mechanisms of creep deformation.	**(7)**
11		Explain the following terms. a) Temper embrittlement b) Hydrogen embrittlement c) Stress corrosion cracking.	**(7)**
12		What is viscoelasticity ? Explain different rheological models of viscoelastic behaviour, with neat sketches.	**(7)**

Syllabus

Module 1

Stress strain relationship- Stress at a point, 3-D stress state, Stress Tensor, 3D Mohr circle, Hydrostatic and Deviator components of stress. Strain at a point, Mohr circle of strain, Elastic stress-strain relations. Calculation of stresses from elastic strains, anisotropy of elastic behaviour, stress concentration, Finite element methods

Module 2

Plasticity & Fracture Mechanics- Introduction to plasticity, Flow curve, True stress and true strain. Theories of failure, Yielding criteria for ductile materials, combined stress tests, Yield locus, Anisotropy in yielding, Yield surface and normality. Octahedral shear stress and shear strain, invariants of stress and strain, plastic stress-strain relations. Plastic stress-strain relations, two dimensional plastic flow- slip line field theory. Fracture - Ductile and Brittle, Impact energy, Introduction to fracture mechanics, theoretical strength, stress concentration. Griffith theory, Orowan theory, fracture modes, Irwin's analysis, Plastic zone size, thin sheets, Temperature and rate of loading. Metallurgical variables, fracture mechanics in design, Crack opening displacements, **J** Integral, R Curve, Probabilistic Aspects of Fracture Mechanics, Toughness of Materials.

Module 3

Composites and Creep- Composites - FRC, Elastic properties and strength, volume fraction of fibers, orientation dependance, fiber length, failure with discontinuous fiber and under compression, typical properties. Particulate composites, brick wall model, lamellar composites, morphology of foams, mechanical properties of foams, metal foams, flexible foams - open cell and closed cell. Time dependent mechanical behaviour, Creep curve, stress rupture test, structural changes during creep, Mechanisms of creep, mechanism maps. Activation energy for steady state creep, superplasticity, fracture at elevated temperatures, High temperature alloys, presentation of engineering creep data, prediction of longtime properties, creep under combined stresses, creep fatigue interaction.

Module 4

Fatigue of Metals and Impact testing- Stress cycles, S-N curve, statistical nature of fatigue, effect of mean stress, Cyclic stress strain curve, Low cycle fatigue, strain life equation, structural features, fatigue crack propagation. Effect of stress concentration, Size effect, surface effects, Fatigue under combined stresses, cumulative damage and sequence effect, effect of metallurgical variables, design for fatigue, Machine design approach- Infinite life design, local strain approach, corrosion fatigue, effect of temperature. Brittle fracture problem, notched bar impact tests, charpy test, significance of transition temperature and metallurgical factors affecting it, impact tests, fracture analysis diagram, temper embrittlement, environment sensitive fracture, flow and fracture under rapid loading rates.

Module 5

Viscoelasticity and Mechanical characterization of materials-
Viscoelasticity - Introduction, Rheological models, Series and parallel and combined combination of spring and dashpots, complex models, damping, natural decay. Elastic modulus - relaxed vs unrelaxed, thermoelastic effect, snock effect in bcc metals, other damping mechanisms. Characterization - Mechanical testing for material characterization, measurement techniques in experimental solid mechanics, non destructive testing.

Course Plan

Module No	Topic	No. of Lectures
1	**Stress strain relationship**	
1.1	Stress at a point, 3-D stress state, Stress Tensor, 3D Mohr circle, Hydrostatic and Deviator components of stress.	2
1.2	Strain at a point, Mohr circle of strain, Elastic stress-strain relations.	2
1.3	Calculation of stresses from elastic strains, anisotropy of elastic behaviour, stress concentration, Finite element methods	3
2	**Plasticity & Fracture Mechanics**	
2.1	Introduction to plasticity, Flow curve, True stress and true strain.	1
2.1	Theories of failure, Yielding criteria for ductile materials, combined stress tests, Yield locus, Anisotropy in yielding, Yield surface and normality.	2
2.2	Octahedral shear stress and shear strain, invariants of stress and strain, plastic stress-strain relations.	1
2.3	Plastic stress-strain relations, two dimensional plastic flow- slip line field theory.	1
2.4	Fracture - Ductile and Brittle, Impact energy, Introduction to fracture mechanics, theoretical strength, stress concentration	1
2.5	Griffith theory, Orowan theory, fracture modes, Irwin's analysis, Plastic zone size, thin sheets, Temperature and rate of loading.	2
2.6	Metallurgical variables, fracture mechanics in design, Crack opening displacements, J Integral, R Curve, Probabilistic Aspects of Fracture Mechanics, Toughness of Materials.	3
3	**Composites and Creep**	
3.1	Composites - FRC, Elastic properties and strength, volume fraction of fibers, orientation dependance, fiber length, failure with discontinuous fiber and under compression, typical properties.	2
3.2	Particulate composites, brick wall model, lamellar composites, morphology of foams, mechanical	2

	properties of foams, metal foams, flexible foams - open cell and closed cell.	
3.3	Time dependent mechanical behaviour, Creep curve, stress rupture test, structural changes during creep, Mechanisms of creep, mechanism maps.	2
3.4	Activation energy for steady state creep, superplasticity, fracture at elevated temperatures, High temperature alloys, presentation of engineering creep data, prediction of long time properties, creep under combined stresses, creep fatigue interaction.	2
4	**Fatigue of Metals and Impact testing**	
4.1	Stress cycles, S-N curve, statistical nature of fatigue, effect of mean stress, Cyclic stress strain curve, Low cycle fatigue, strain life equation, structural features, fatigue crack propagation.	2
4.2	Effect of stress concentration, Size effect, surface effects, Fatigue under combined stresses, cumulative damage and sequence effect, effect of metallurgical variables, design for fatigue, Machine design approach-Infinite life design, local strain approach, corrosion fatigue, effect of temperature.	3
4.3	Brittle fracture problem, notched bar impact tests, charpy test, significance of transition temperature and metallurgical factors affecting it, impact tests, fracture analysis diagram, temper embrittlement, environment sensitive fracture, flow and fracture under rapid loading rates.	3
5	**Viscoelasticity and Mechanical characterization of materials**	
5.1	Viscoelasticity - Introduction, Rheological models, Series and parallel and combined combination of spring and dashpots, complex models, damping, natural decay.	2
5.2	Elastic modulus - relaxed vs unrelaxed, thermoelastic effect, snock effect in bcc metals, other damping mechanisms	2
5.3	Characterization - Mechanical testing for material characterization, measurement techniques in experimental solid mechanics, non destructive testing.	2

Reference Books

1. William F. Hosford, Mechanical behavior of materials, Cambridge University Press.
2. G. E. Dieter, Mechanical Metallurgy, McGraw Hill.
3. Norman E. Dowling, Mechanical behavior of materials: Engineering Methods for Deformation, Fracture and Fatigue, Prentice Hall.
4. Marc Meyers and Krishnan K. Chawla, Mechanical behavior of materials, Cambridge University Press.
5. Thomas H. Courtney, Mechanical behavior of materials, Overseas Press.
6. Joachim Roesler, HaraldHarders, and Martin Baeker, Mechanical Behavior of Engineering Materials, Springer.
7. Prashant Kumar, Elements of fracture mechanics, Tata McGraw Hill.
8. S. Suresh, Fatigue of Materials, Cambridge University Press
9. RW Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, John Wiley &Sons.

PROGRAM ELECTIVE II

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EME006	OPTIMIZATION METHODS FOR ENGINEERING	PROGRAM ELECTIVE I	3	0	0	3

Preamble:

This course is proposed as an elective for M. Tech(Machine Design) students, which intends to impart good grasp of the fundamentals and methods of optimization in engineering. Emphasis is also given to create mathematical model for the given engineering problem and apply suitable optimization algorithm/software tool for solution. As most topics treated in this course are general, this course can be of interest to students of other disciplines as well.

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

CO 1	Understand fundamentals of optimization theory
CO 2	Solve the given unconstrained, single variable optimization problem using appropriate method.
CO 3	Solve the given unconstrained, multi-variable optimization problem using suitable method.
CO 4	Solve the given constrained optimization problem using appropriate method.
CO 5	Create a mathematical model for the given problem and/or apply suitable optimization algorithm/software tool for solution.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Remember	

Understand	30%
Apply	70%
Analyse	
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Continuous Internal Evaluation: 40 marks
Preparing a review article based on peer reviewed
Original publications (minimum 10 publications shall be referred): 15 marks
Course based task/Seminar/Data collection and interpretation: 15 marks
Test paper, 1 no. :10 marks
Test paper shall include minimum 80% of the syllabus.

Note:
Course based task recommended: For the given physical device/system,create a mathematical model and apply suitable optimization algorithm/software tool for solution of the problem. Evaluation can be conducted for 30 marks which consist of presentation and submission of report.

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
FIRST SEMESTER M.TECH DEGREE EXAMINATION, Month & Year

Stream: Machine Design

Course Code: 221EME006

Course Name: Optimization Methods for Engineering

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

PART A

		Answer all questions, each carries 5 marks.	**Marks**
1	**a** **b**	What do you mean by a convex set? Compute the Taylor series expansion about (0,0) for $f(x, y) = e^x \log(1+y)$	**(5)**
2		Using Golden section search, minimize the function $2 - 4x + e^x$ in the interval [0.5, 3]	**(5)**
3		What do you mean by parallel subspace property? Explain why the search directions used in a direct-search algorithm must be linearly independent?	**(5)**
4		A rectangle in the plane is placed in the first quadrant so that one corner 'O' is at the origin and two sides adjacent to 'O' are on the axes. The corner 'P' opposite to 'O' is on the curve x+2y=1. Using Lagrange method, find for which point 'P', the rectangle has maximum area?	**(5)**
5		Discuss active, semi-active and inactive constraint with an example.	**(5)**

PART B

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

6	**(a)**	What do you mean by a convex function?	**(3)**
	(b)	Determine the convexity of the following function $f(x, y) = 5 - 5x - 2y + 2x^2 + 5xy + 6y^2$	**(4)**
7		In a process plant, consider the design of a pipeline L feet long that should carry fluid at the rate of Q LPM. The selection of economic pipe diameter D is based on minimizing the annual cost of pipe, pump, and operational expenses. Suppose the annual cost of a pipeline with a standard carbon steel pipe and a motor-driven centrifugal	**(7)**

		pump can be expressed as $C = 0.45L + 0.25LD^{1.5} + 325P^{0.5} + 60P^{0.8} + 100$ where $P = 4.4x10^{-8}\frac{LQ^3}{D^5} + 1.9x10^{-9}\frac{LQ^{2.5}}{D^{4.5}}$ Formulate the appropriate single-variable optimization problem for designing a pipe of length 350m with a flow rate of 80LPM. The diameter of the pipe should be between 6 mm and 150 mm. Solve using the golden section search.	
8		Minimize $f(x, y) = (x^2 + y - 11)^2 + (x + y^2 - 7)^2$ using simplex search method. Initial simplex of three points as given below. $x^{(1)} = (0,0)^T; x^{(2)} = (2,0)^T; x^{(3)} = (1,1)^T$ Expansion factor$(\gamma) = 1.5$; Contractionfactor$(\beta) = 0.5$	**(7)**
9		A company produces two goods, x and y, according to $200 \geq x^2 + y^2$, and consumes all the goods by itself. Its utility function is $u = x \cdot y^3$The company also faces and environmental constraint on its total output of both goods. The environmental constraint is given by $x + y \leq 20$ (a) Write down the Kuhn Tucker first order conditions. (b) Find the company's optimal x and y.	**(7)**
10		Minimize the following using penalty function method. $f(x) = x_1 x_2^2$ subject to $2 \; \square \; x_1^2 \; \square \; x_2^2 \; \square \; 0$ Apply logarithmic penalty function.	**(7)**
11		Give an example of a system in your discipline. Identify all its elements, its hierarchical level, and boundary. Define the analysis model, including a list of assumptions.	**(7)**
12		Formulate the model of a helical compression spring with spring index and wire diameter as the two design variables. Choose weight as objective function. Stress and minimum number of coils are possible constraints.	**(7)**

Syllabus

Module 1

Introduction to optimization theory- Design optimization process and problem formulation. Classification of optimization problems. Mathematics background, Weierstrass Theorem. Taylor Series of two variables. Derivatives and gradients, Hessians. Convex sets and convex functions. Optimality conditions.

Module 2

Unconstrained optimization of single variable function- Bracketing method: Exhaustive search. Region elimination methods: Region elimination rules, Dichotomous search, Fibonacci search, Golden section search. Gradient-based methods: Newton's method, Secant method, Comparison of different methods.

Module 3

Unconstrained optimization of multivariable function- Direct search methods: Simplex search method, Powell's conjugate direction method, Parallel subspace property. Gradient-based methods: Steepest descent method, Newton's method,Conjugate gradient (Fletcher-Reeves) method, Trust regions, Marquardt's method

Module 4

Constrained optimization- Kuhn Tucker conditions, Lagrange method, Interior and exterior penalty function methods, Cutting plane method, Working principles of Genetic Algorithms.

Module 5

Optimization models- Mathematical modelling and Optimization models, Feasibility and boundedness, Topography of the design space, Modeling data, Best fit curves and least squares, Neural networks, Kriging, Modelling considerations, Model boundedness checking, Model preparation procedure

Course Plan

Module No.	Topic	No. of Lectures
1	**Introduction to optimization theory**	
1.1	Design optimization process and problem formulation	1
1.2	Classification of optimization problems	1
1.3	Mathematics background, Weierstrass Theorem	1
1.4	Taylor Series of two variables	1
1.5	Derivatives and gradients, Hessians	2
1.6	Convex sets and convex functions	2
1.7	Optimality conditions	1
2	**Unconstrained optimization of single variable function**	
2.1	Bracketing method: Exhaustive search	1
2.2	Region elimination methods: Region elimination rules, Dichotomous search, Fibonacci search, Golden section search	3
2.3	Gradient-based methods: Newton's method, Secant method, Comparison of different methods.	3
3	**Unconstrained optimization of multivariable function**	
3.1	Direct search methods: Simplex search method, Powell's conjugate direction method, Parallel subspace property	3
3.2	Gradient-based methods: Steepest descent method, Newton's method,Conjugate gradient (Fletcher-Reeves) method, Trust regions, Marquardt's method	4
4	**Constrained optimization**	
4.1	Kuhn Tucker conditions	2
4.2	Lagrange method	2
4.3	Interior and exterior penalty function methods	2
4.4	Cutting plane method	1
4.5	Working principles of Genetic Algorithms.	1
5	**Optimization models**	
5.1	Mathematical modelling and Optimization models	1

5.2	Feasibility and boundedness	1
5.3	Topography of the design space	1
5.4	Modeling data, Best fit curves and least squares	1
5.5	Neural networks	1
5.6	Kriging, Modelling considerations	1
5.7	Model boundedness checking	2
5.8	Model preparation procedure	1

Reference Books

1. Kalyanmoy Deb, Optimization for Engineering Design: Algorithms and Examples, Prentice-Hall of India Pvt. Ltd, 2012.
2. S.S. Rao, Engineering Optimization: Theory and Practice-fourth Edition, John Wiley & Sons, Inc., 2009.
3. A. Ravindran, K. M. Ragsdell, G. V. Reklaitis. Engineering Optimization: Methods and Applications- Second Edition, John Wiley & Sons, Inc., 2006.
4. R. R. Joaquim, A. Martins and Andrew Ning. Engineering Design Optimization. Cambridge University Press, 2021.
5. P.Y. Papalambros and D.J. Wilde. Principles of Optimal Design: Modeling and Computation, 3rd Edition, Cambridge University Press, 2015
6. T. F. Edgar, D. M. Himmelblau, L. S. Lasdon. Optimization of Chemical Processes-Second Edition, McGraw-Hill, 2001.
7. C. P. Lopez. MATLAB Optimization Techniques, Apress Academic, Springer, 2014.

221EME007	ADVANCED THEORY OF MECHANISMS	CATEGORY	L	T	P	CREDIT
		PROGRAMME ELECTIVE 2	3	0	0	3

Preamble:

To impart adequate knowledge in the field of kinematic analysis, synthesis and design of mechanisms and dynamic analysis.

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

CO 1	Gain comprehensive knowledge for the analysis of velocity and acceleration in mechanisms.
CO 2	Apply the curvature theory to analyse/design mechanisms
CO 3	Apply synthesis techniques to create linkage design solutions to some typical kinematic applications.
CO 4	1. Gain the ability to design cams and analyze its dynamic effects. 2. Attain the ability to synthesize and design mechanisms for specific motions and other applications
CO 5	Gain the ability to analyze the dynamics of moving members in the machinery and design appropriately.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	40 %
Analyse	40 %
Evaluate	10 %
Create	10 %

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.

Note:
Course based task recommended: For the given physical device/system,create a mathematical model and apply suitable optimization algorithm/software tool for solution of the problem. Evaluation can be conducted for 30 marks which consist of presentation and submission of report.

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

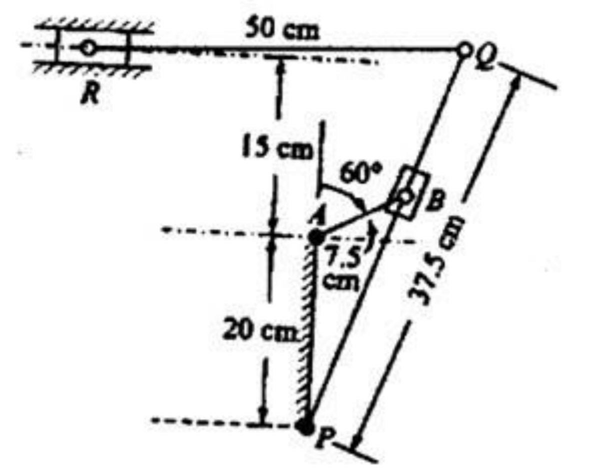
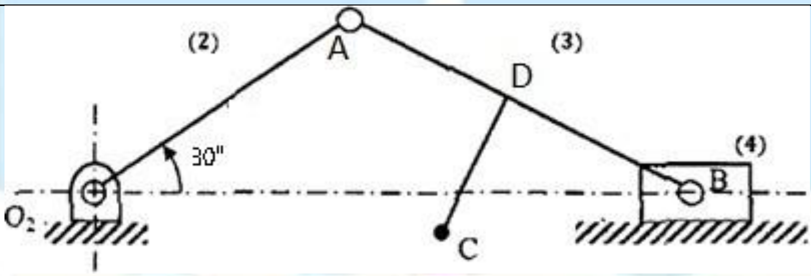
Course Code: 221EME007

Course Name: Advanced Theory of Mechanisms

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

PART A

		Answer all questions, each carries 5 marks.	**Marks**
1		The crank of a slider crank mechanism rotates clockwise at a constant speed of 300 rpm. The crank is 150 mm and the connecting rod is 600 mm long. Determine angular velocity and angular acceleration of the connecting rod, at a crank angle of 45° from inner dead centre position.	**(5)**
2		Give an account on Hartmann construction.	**(5)**
3		Show that any coupler curve of a four bar mechanism can be traced by an equivalent five bar mechanism.	**(5)**
4		Explain jump, crossover shock , spring surge and windup in cams	**(5)**
5		Write down Euler's equations of motion explaining the terms involved.	**(5)**

PART B			
Answer any 5 full question, each question carries 7 marks.			
		 For the mechanism shown, the velocity of point B is 10m/s. Find the Corioli's component of acceleration in the mechanism.	(7)
7		 Find the infection circle for the motion or the coupler of the slider-crank linkage and determine the instantaneous radius of curvature of the path of the coupler point C.O2A = 20mm, AB = 25mm, AD =12.5mm, DC = 10mm.	(7)
8		Derive the four bar chain coupler curve equation.	(7)
9		A dwell rise cam has a rise of 30mmand moves with cycloidal motion for 130o of cam rotation. The follower is assembled with a retaining spring with necessary precompression. The stiffness of the spring is 50 N/mm. The equivalent mass and stiffness of the follower train are 0.3 kg and 75N/mm respectively. Determine the follower response	(7)

		when the cam rotates at 3000 rpm.	
10		Design a double lever mechanism to obtain the following input and output coordination .Input angles θ12 = 450 cw θ13 = 800 cw θ14 = 1100 cw Output angles Φ12 = 300 cw Φ13 = 400 cw Φ14 = 500 cw . Assume fixed frame length is 75mm.	**(7)**
11		Derive the equations for angular momentum of a rigid body in three dimensions.	**(7)**
12	**(a)**	Explain the principle of impulse and momentum for the plane motion of a rigid body.	**(4)**
	(b)	Derive the equations for rotation of a rigid body about a fixed axis.	**(3)**

Syllabus

Module 1

Planar Kinematics of Rigid Bodies- Velocity and acceleration relationships for two points in a rigid link. Graphical approach to velocity and acceleration in mechanisms. Vector approach - two coordinate system approach for velocity and acceleration applied to planar mechanisms. Slider-crank mechanisms, four bar linkages. Brief introduction to complex mechanisms.

Module 2

Curvature Theory- Instantaneous centre or Pole, centrode or polode, polode curvature, collineation axis, radius of curvature. The Euler-Savary equation, the inflection circle, Hartmann's construction, Bobillier constructions - Design based on the above. Cubic of stationary curvature

Module 3

Four-bar coupler-point curves- Equation of coupler curves, circle of foci, multiple points, imaginary points, asymptote. Singular foci, double points and symmetry, cusp, crunode, symmetry. The Roberts-Chebychev Theorem and cognate linkages.

Module 4

Cams-Polydyne cams: Cam Dynamics: Acceleration and Jerk
Analysis of elastic cam systems, follower response: Johnson's numerical analysis .Position error, Jump and cross-over shock, unbalance, spring surge and wind-up. Cam force analysis.

Synthesis of mechanisms

The four-bar linkage - Two and Three position design.
Design of slider crank and double lever mechanisms for specified input crank motion and output crank motion,
Determination of minimum transmission angle.

Module 5

Dynamics- Plane motion of rigid bodies using the principle of impulse and momentum. Kinetics of rigid bodies in three dimensions:- Angular momentum of a rigid body in three dimensions. Application of the principle of impulse and momentum to the three-dimensional motion of a rigid body. Application of the principle of impulse and momentum to the three- dimensional motion of a rigid body. Kinetic energy of a rigid body in three dimensions. Motion of a rigid body in three dimensions. Euler's equation of motion. Motion of a rigid body about a fixed axis.

Course Plan

Module	Topic	No. of Lectures
1	**Planar Kinematics of Rigid Bodies**	
1.1	Velocity and acceleration relationships for two points in a rigid link	1
1.2	Graphical approach to velocity and acceleration in mechanisms.	2
1.3	Vector approach - two coordinate system approach for velocity and acceleration applied to planar mechanisms. Slider-crank mechanisms, four bar linkages.	4
1.4	Brief introduction to complex mechanisms.	1
2	**Curvature Theory**	
2.1	Instantaneous centre or Pole, centrode or polode, polode curvature, collineation axis, radius of curvature.	3
2.2	The Euler-Savary equation, the inflection circle, Hartmann's construction, Bobillier constructions - Design based on the above.	3
2.3	Cubic of stationary curvature.	2
3	**Four-bar coupler-point curves**	
3.1	Equation of coupler curves, circle of foci, multiple points, imaginary points, asymptote.	3
3.2	Singular foci, double points and symmetry, cusp, crunode, symmetry.	2
3.3	The Roberts-Chebychev Theorem and cognate linkages.	2
4	**Cams**	
4.1	Polydyne cams: Cam Dynamics: Acceleration and Jerk	2
4.2	Analysis of elastic cam systems, follower response: Johnson's numerical analysis .Position error, Jump and cross-over shock, unbalance, spring surge and wind-up.	3
4.3	Cam force analysis.	2
4.4	**Synthesis of mechanisms**	
4.5	The four-bar linkage - Two and Three position design.	2
4.6	Design of slider crank and double lever mechanisms for specified input crank motion and output crank motion,	1
4.7	Determination of minimum transmission angle.	1
5	**Dynamics**	

5.1	Plane motion of rigid bodies using the principle of impulse and momentum.	1
5.2	Kinetics of rigid bodies in three dimensions:- Angular momentum of a rigid body in three dimensions.	1
5.3	Application of the principle of impulse and momentum to the three-dimensional motion of a rigid body.	1
5.4	Kinetic energy of a rigid body in three dimensions.	1
5.5	Motion of a rigid body in three dimensions. Euler's quation of motion.	1
5.6	Motion of a rigid body about a fixed axis.	1

Text Books:

1. Dynamics in Engineering Practice- Dara W Childs (CRC Press)
2. Theory of Machines and Mechanisms- Joseph Edward Shigley (Mc Graw Hill)
3. Vector Mechanics for Engineers: Statics and Dynamics- Beer and Johnston (McGraw Hill)
4. Engineering Mechanics- Irving H Shames (Prentice Hall of India)
5. Kinematic Synthesis of linkages-Richard S Hartenberg and Jacques Denavit (Mc Graw Hill)
6. Kinematics and Linkage Design-Allen S Hall Jr,Prentice Hall
7. Cam Design Handbook-Harold A Rothbart. (McGraw Hill)

Reference books:

1. Kinematics and Dynamics of plane motion-Hirchorn **J**(Mc Graw Hill)
2. Kinematic Analysis and Synthesis of Mechanisms-Mallik A.K, Amithabha Ghosh and Gunter Dittrich(CRC Press)
3. Advanced Mechanism Design: Analysis and Synthesis,George N Sandor and Arthur G Erdman. Prentice Hall.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDITS
221EME008	ROTOR DYNAMICS	PROGRAMME ELECTIVE 2	3	0	0	3

Preamble: This course targets to develop a systematic and applied knowledge of Rotor dynamics.

Course Objectives:

- Impart basic understanding of the rotor dynamics phenomena with the help of simple rotor models and subsequently carry out the analysis for real life rotor systems.
- Ability to write down the differential equations of motion for simple, geared and branched rotor bearing system under transverse and torsional vibrations.
- Capability to find out the critical speeds using different numerical methods, balance the unbalanced system and perform the instability analysis.
- Apply of the knowledge of mathematics, science and engineering for the analysis and design of rotor-shaft systems with different kinds of bearings.
- To be capable to boost research in the developing area of the rotor dynamics such as identification of rotor bearing system parameters and its use in futuristic model based condition monitoring and fault diagnostic.

Course Outcomes: The Cos shown are only indicative. For each course, there can be 4to6 COs.

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

CO1	**Understand**and **apply** the various effects associated with the rotor dynamics.
CO2	**Understand**and**apply**the vibration models of rotor bearing systems with changing complexities for real engineering systems
CO3	**Understand and apply** the response due to unbalance and instability in practical rotor systems
CO4	**Understandand apply** various vibration measuring and balancing instruments
CO5	**Understand** rotor bearing system parameters and capability to carry out research in condition monitoring

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		

Mark distribution

Total Marks	**CIE**	**ESE**	**ESE Duration**
100	40	60	3hours

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.

Note:
Course based task recommended: For the given physical device/system,create a mathematical model and apply suitable optimization algorithm/software tool for solution of the problem. Evaluation can be conducted for 30 marks which consist of presentation and submission of report.

End Semester Examination Pattern: (60Marks)

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 eachmodule, 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 contain7questions (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

Module-I

Rudiments of Rotor Dynamics, Modelling and Bending Critical Speeds of Rotors, Whirling Phenomenon, Rigid rotors in rigid supports, Flexible rotors in rigid supports, Flexible rotors in flexible supports, Factors affecting them such as gyroscopic action, internal damping, fluid film bearings. Methods for analysis such as Transfer Matrix, FEM.

Module-II

Rolling Element Bearings, Contact Forces, Deformations, Stiffness and Damping, Hydrodynamic Bearings, Mechanism of Pressure Development in a Fluid Film, Reynold's Equation, Steady State Solution for Short Bearing, dynamically loaded bearings and stiffness and damping coefficients, Squeeze Film Bearing, Squeeze Film Bearing and Orbital Motion, Matrix Methods.

Module-III

Torsional Vibration of Rotors, Modelling and transfer matrix analysis for free vibrations, Variable Stiffness in Torsional Vibrations, Excitation torques and transient response, Branched and Geared Systems,

Torsional vibrations in reciprocating machinery, Higher order effects and Stability, Hill's Equation, Mathieu's Equation, Strutt Diagram, Routh Hurwitz criterion,

Module-IV

Shafts with dissimilar moments of inertia, Effects of Gravity, Internal Hysteresis of Shafts, Rigid Rotor Instability, Instability of rotors mounted in fluid film bearings, Instability of flexible rotors, Instability due to negative cross-coupling, Instability in torsional vibrations

Module-VI

Rotor Balancing, Classification of Rotors, Rigid rotor balancing, Flexible rotor balancing, Monitoring and Diagnosis, Faults in rotating machinery, Instrumentation and Data Acquisition, Time and Frequency domain characteristics, Knowledge base and expert systems

Text Books:

1. Rotor Dynamics – J. S. Rao. New Age International Publications, 3rd Edition.

Reference Books:

1. Dynamics of Rotor Bearings Systems – M. J. Goodwin. Unwin Hyman
2. A Matrix Method in Elastomechanics – E. C. Petal and F. A. Leckie. Mc Graw Hill.
3. Rotor Dynamics – E. K. Kramer. Springer Verlag.
4. Rotor Dynamics – H. D. Nelson and E. J. Guntur. Mc Graw Hill Book Co.
5. Rotor Dynamics – J. S. Vance. Mc Graw Hill Book Co.

221EME009	MECHATRONIC SYSTEM DESIGN	CATEGORY	L	T	P	CREDIT
		PROGRAM ELECTIVE 2	3	0	0	3

Preamble: Nil

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

CO 1	Understand the working of various sensors and actuators used in mechatronics systems.
CO 2	Develop hydraulic/ pneumatic circuits based on practical applications.
CO 3	Understand the fundamental principles of PLCs, and to construct PLC programs for practical applications.
CO 4	Develop system models in the Mechanical, Electrical, Fluid and Thermal domains.
CO 5	Understand the basic technologies used in mechatronic applications and develop mechatronics based systems.

Mapping of course outcomes with program outcomes

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

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	40 %
Analyse	30 %
Evaluate	20 %
Create	10 %

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: 2**

Reg No.:_______________ **Name:__________________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

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

Stream: Machine Design

Course Code: 221EME009

Course Name: MECHATRONIC SYSTEM DESIGN

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

PART A

	Answer all questions, each carries 5 marks.	**Marks**
1	With neat sketch explain the construction and working of LVDT.	(5)
2	Explain internal relays in PLC ladder program.	(5)
3	Explain cushioning of pneumatic cylinders.	(5)
4	Define the elements used to build Mechanical systems.	(5)
5	Briefly explain the basic elements of data acquisition system.	(5)

PART B

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

6	Explain in detail about the mechanical actuators used in a mechatronics system.	(7)
7	Design a hydraulic circuit for two actuators sequential system.	(7)
8	With neat sketch explain the working of a strain gauge load cell.	(7)

9	Build the mathematical model for a fluid reservoir with q_1 and q_2 as inlet and outlet flow rates and h as the fluid level.	(7)
10	Design a ladder diagram for operating a pump when the water level in an overhead tank is below a lower limit and switch it off as the level reaches upper limit. Also add a manual override option for starting and stopping the pump.	(7)
11	Explain the working of an automobile engine management system using suitable diagrams.	(7)
12	Discuss in detail about the mechatronic application of automatic car parking barrier system. Mention the sensors and actuators used in each control.	(7)

Syllabus

Module 1

Introduction to Mechatronics, Sensors and Actuators- Introduction to Mechatronics - Systems- Need for Mechatronics - Emerging area of Mechatronics - Classification of Mechatronics. Sensors and transducers :Introduction - Performance Terminology – Potentiometers - LVDT - Capacitance sensors - Strain gauges - Eddy current sensor - Hall effect sensor - Temperature sensors - Light sensors Selection of sensors - Signal processing. Actuators: Pneumatic, hydraulic and mechanical actuation systems used for Mechatronics devices.

Module 2

Automation System Design- Design of fluid power circuits –cascade, KV-map and step counter method. Electrical control of pneumatic and hydraulic circuits- use of relays, timers, counters, Interfacing pneumatic and hydraulic circuits with PLCs

Module 3

Programmable Logic Controllers- Introduction Basic structure - Input and output processing, Programming - Mnemonics- Timers, counters and internal relays, Data handling - Selection of PLC

Module 4

Modeling And Simulation- Definition, key elements, mechatronicsapproach for design process, modeling of engineering systems, modelling system with spring, damper and mass. Modeling chamber filled with fluid, modeling pneumatic actuator. Transfer functions, frequency response of systems, bode plot. Software and hardware in loop simulation.

Module 5

Real Time Interfacing and Case studies of Mechatronics systems- Real Time Interfacing: Introduction to data acquisition and control systems, overview of I/O process. Virtual instrumentation, interfacing of various sensors and actuators with PC, Condition monitoring, SCADA systems. Case studies of Mechatronics systems - Pick and place Robot - Conveyor based material handling system - PC based CNC drilling machine - Engine Management system - Automatic car park barrier - Data acquisition Case studies.

Course Plan		
Module No	**Topic**	**No. of Lectures**
1	**Introduction to Mechatronics, Sensors and Actuators**	
1.1	Introduction to Mechatronics - Systems- Need for Mechatronics - Emerging area of Mechatronics - Classification of Mechatronics	2
1.2	Sensors and transducers :Introduction - Performance Terminology – Potentiometers - LVDT - Capacitance sensors - Strain gauges - Eddy current sensor - Hall effect sensor - Temperature sensors - Light sensors Selection of sensors - Signal processing	4
1.3	Actuators: Pneumatic, hydraulic and mechanical actuation systems used for Mechatronics devices.	2
2	**Automation System Design**	
2.1	Design of fluid power circuits –cascade, KV-map and step counter method.	3
2.2	Electrical control of pneumatic and hydraulic circuits- use of relays, timers, counters,	3
2.3	Interfacing pneumatic and hydraulic circuits with PLCs	3
3	**Programmable Logic Controllers**	
3.1	Introduction Basic structure - Input and output processing	2
3.2	Programming - Mnemonics- Timers, counters and internal relays,	3
3.3	Data handling - Selection of PLC	2
4	**Modeling And Simulation**	
4.1	Definition, key elements, mechatronicsapproach for design process, modeling of engineering systems, modelling system with spring, damper and mass.	2
4.2	Modeling chamber filled with fluid, modeling pneumatic actuator.	3
4.3	Transfer functions, frequency response of systems, bode plot. Software and hardware in loop simulation.	3
5	**Real Time Interfacing and Case studies of Mechatronics systems**	
5.1	Real Time Interfacing: Introduction to data acquisition and control systems, overview of I/O process.	2
5.2	Virtual instrumentation, interfacing of various sensors and actuators with PC, Condition monitoring, SCADA systems.	3
5.3	Case studies of Mechatronics systems - Pick and place Robot - Conveyor based material handling system - PC based CNC drilling machine - Engine Management system - Automatic car park barrier -	3

	Data acquisition Case studies.	

Reference Books

1. W. Bolton, Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering, Person Education Limited, New Delhi 2007.
2. HMT, Mechatronics, Tata McGraw-Hill Publishing Company Ltd., New Delhi 2004.
3. K.P. Ramachandran, G.K. Vijayaraghavan, M.S. Balasundaram. Mechatronics: IntegratedMechanical Electronic Systems. Wiley India Pvt. Ltd., New Delhi 2008.
4. David G. Aldatore, Michael B. Histand, Introduction to Mechatronics and Measurement Systems, McGraw-Hill Inc., USA 2003.
5. Vijay K. Varadan, K. J. Vinoy, S. Gopalakrishnan, Smart Material Systems and MEMS: Design and Development Methodologies, John Wiley & Sons Ltd., England 2006.
6. Saeed B. Niku, Introduction to Robotics: Analysis, Systems, Applications, Person Education, Inc., New Delhi 2006.
7. Gordon M. Mair, Industrial Robotics, Prentice Hall International, UK 1998.
8. Devadas Shetty and Richard A Kolk, Mechatronics System Design, Cengage Learning India Pvt Ltd, Delhi, 2012.
9. S. R. Majumdar, “Pneumatic Systems: Principles and Maintenance”, Tata McGrawHill Publishing Company Limited, 1995
10. Anthony Esposito, Fluid power with applications, Pearson Education, 6th Edition, 2003.

221LME100	MECHANICAL DESIGN LAB	CATEGORY	L	T	P	CREDIT
		LABORATORY	0	0	2	1

Preamble:

To enable the students to familiarise with and develop expertise in experimental methods/techniques for understanding vibration characteristics and mechanical behaviour of materials which are quite essential for the design of components. The main areas focused are machine dynamics and material characterization.

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

CO 1	The experimental analysis of various vibration systems
CO 2	Mechanical testing of materials and characterization
CO 3	Micro-structural analysis of materials

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

Mark distribution

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

List of Experiments (ME1)

1. Determination and verification of displacement, velocity, acceleration and phase lag of forced vibration systems
2. Determination of natural frequencies of spring mass system in free vibration
3. Determination of natural frequencies of spring mass system in forced vibration
4. Determine the damping present in a vibrating system using half power bandwidth (or logarithmic decrement) method
5. Experiment on free vibration of a beam
6. Experiment on forced vibration of a beam
7. To find the natural frequencies and mode shapes of a free-free beam (or plate) experimentally and verify the same analytically
8. Estimation of damping of a beam under different damping conditions
9. Conduct an experiment using impedance tube to find the absorption coefficient of a panel

10. Conduct vibration study using laser dopler vibrometer or laser displacement meter
11. Study the field measurements using sound level meter
12. Conduct study of a tuned mass damper system.
13. Experiment on tribological characterization (eg. pin on disc sliding wear test etc.)
14. Determination of mechanical properties (strength, modulus, ductility etc.) of a given material using computerised UTM
15. Fabrication of polymer composites using hand layup technique and/or Determination of strength and modulus of a composite specimen
16. Measurement of strain by using strain gauges
17. Determination of the hardness of the given specimen(s).
18. Experiment on metallographic sample preparation
19. Micro structural examination of the given samples (ferrous and/or non-ferrous) using optical microscope
20. Determination of Young's modulus and shear modulus of the given specimen(s) using ultrasonic longitudinal and shear velocities.

(A minimum of nine experiments are to be performed)