GUJARAT TECHNOLOGICAL UNIVERSITY

Master of Engineering
Subject Code: 3710812
Semester – I
Computational Methods for Mechanical Engineers

Type of course: Core course

Prerequisite: Zeal to learn the subject

Rationale: The course intends to provide mathematical foundations to graduate students. The course should enhance their ability to develop mathematical models and solve problems using analytical and numerical methods.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

L- Lectures; T- Tutorial; P- Practical; C- Credit; ESE- End Semester Examination; PA- Progressive Assessment

Content:

Sr. No.	Content	Total Hrs
1	**Differential Equations:** Basic Concepts: Modelling, Differential Equations, Ordinary and Partial differentiation, Order of the equation, Solution, Existence and Uniqueness of Solution, Initial Value problem, Boundary Value Problem, Linear and Non-Linear Equation. 1st Order ODE: Geometric Meaning of y'= f(x, y), Direction Fields, Euler's Method; Separable ODEs; Exact ODEs (Integrating Factors Method, Existence and Uniqueness of Solution); Linear ODEs(Homogeneous and Non-Homogeneous, Reduction to Linear problems); Orthogonal Trajectories. 2nd Order ODE: Linear Dependence and Linear Independence; Homogeneous Linear ODEs of Second Order (Principal of Superposition, Initial Value Problem, Boundary Value Problem); Homogeneous Linear ODEs with Constant Coefficients (Euler's formula and review of the circular and hyperbolic function, Exponential Solutions, Repeated Roots and Stability); Differential Operator; Modelling of Free Oscillations of Spring-Mass System; Homogeneous Linear ODEs with Non-constant Coefficient (Cauchy-Euler Equation, Existence and Uniqueness of Solutions)	08
2	**Laplace Transforms:** Laplace Transform, Linearity, First Shifting Theorem (s-Shifting); Transforms of Derivatives and Integrals, ODE; Unit Step Function (Heaviside Function), Second Shifting Theorem (t-Shifting); Short Impulses, Dirac's Delta Function, Partial Fractions; Convolution, Integral Equations; Differentiation and Integration of Transforms, ODEs with Variable Coefficients; Systems of ODEs.	05
3	**Linear Algebra:** Matrices and Vectors: Vectors in 2-Space and 3-Space; Addition and Scalar Multiplication, Matrix Multiplication; Linear Systems of Equations and Gauss Elimination, Ill-Conditioning, Linear Independence, Rank of a Matrix, Solutions of Linear Systems: Existence	07

	and Uniqueness; Determinants and Cramer's Rule; Inverse of a Matrix, Gauss–Jordan Elimination; Solution by Iteration. Vector Spaces, Inner Product Spaces, Norms, Linear Transformations; Matrix Eigenvalues, Determining Eigenvalues-Eigenvectors and their applications; Power Method for Eigenvalues; Symmetric, Skew-Symmetric, and Orthogonal Matrices	
4	**Vector Calculus:** Vector Product; Vector and Scalar Functions and Their Fields, Vector Calculus: Derivatives; Curves, Arc Length, Curvature, Torsion; Gradient of a Scalar Field, Directional Derivative; Divergence of a Vector Field, Curl of a Vector Field. Line Integrals, Path Independence of Line Integrals; Green's Theorem in the Plane, Surfaces for Surface Integrals, Surface Integrals; Triple Integrals, Divergence Theorem of Gauss, Further Applications of the Divergence Theorem, Stokes' Theorem.	05
5	**Fourier Analysis and PDE:** Fourier Series; Arbitrary Period, Even and Odd Functions, Half-Range Expansions; Forced Oscillations; Approximation by Trigonometric Polynomials; Sturm–Liouville Problems, Orthogonal Functions; Orthogonal Series, Generalized Fourier Series; Fourier Integral; Fourier Cosine and Sine Transforms; Fourier Transform, Discrete and Fast Fourier Transforms. Basic Concepts of PDEs; Modeling: Vibrating String, Wave Equation; Solution by Separating Variables; Use of Fourier Series; D'Alembert's Solution of the Wave Equation, Characteristics; Modelling: Heat Flow from a Body in Space, Heat Equation: Solution by Fourier Series. Steady Two-Dimensional Heat Problems	08
6*	**Numeric Analysis:** Introduction, Solution of Equations by Iteration, Interpolation, Newton's Divided-Difference Interpolating Polynomials, Lagrange Interpolating Polynomials, Coefficients of an Interpolating Polynomial, Inverse Interpolation; Spline Interpolation, Numeric Integration and Differentiation. Numeric Methods for: First-Order ODEs, Multistep Methods, Systems and Higher (up to second) Order ODEs, Elliptic PDEs	-
7	**Probability:** Data Representation, Average, Spread; Experiments, Outcomes, Events; Probability, Permutations and Combinations; Random Variables. Probability Distributions; Mean and Variance of a Distribution; Binomial, Poisson, and Hypergeometric Distributions; Normal Distribution	03
8	**Statistics:** Introduction, Random Sampling; Point Estimation of Parameter, Confidence Intervals; Testing Hypotheses, Decisions; Goodness of Fit, X^2 - Test, Nonparametric Tests, Regression, Linear Regression, Polynomial Regression, General Linear Regression, Nonlinear Regression, Correlation	06

Exam paper should be based on applications of above topics in Mechanical engineering rather than merely derivation of standard theory or its mathematical solution.

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
10	20	50	20	-	-

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Advanced Engineering Mathematics, 9/e, By Erwin Kreyszig, John Wiley & Sons Inc.
2. Advanced Engineering Mathematics, 2/e, By M D Greenberg, Pearson Education
3. Numerical Methods for Engineers, S C Chapra, and R C Canale, McGraw-Hill

Course Outcomes:

Sr. No.	CO statement	Marks % weightage
CO-1	To solve ordinary and partial differential equations analytically as well as numerically for Mechanical applications	35
CO-2	To apply Laplace transforms for solution of ODE	10
CO-3	To explain fundamentals and applications of linear algebra and vector calculus for Mechanical engineering problems	25
CO-4	To apply Fourier transformation to Mechanical systems	10
CO-5	To explain fundamentals of statistics and probability for nondeterministic Mechanical systems	20

List of Experiments:

Students are required to prepare computer program (using any computer software) for following topics:

1. Solution of first order differential equation using numerical techniques.
2. Solution of nonlinear equation using bisection method, false position and Newton Raphson method.
3. Interpolation by Lagrange, Newton's divided-difference and spline method.
4. Numerical integration by trapezoidal and Simpson's rules.
5. Matrix operations and power method for Eigen values and Eigen vectors.
6. Finding DFT of one dimensional signal.
7. Solving linear systems of equation using elimination and iteration methods.
8. Solution of PDE by finite difference method.
9. Fitting a straight line and quadratic curve to the given data.
10. Finding mean and variance of binomial, Poison & hyper geometric distribution.

Major Equipment: Computational facility

List of Open Source Software/learning website: