GUJARAT TECHNOLOGICAL UNIVERSITY

COMPUTATIONAL METHOD FOR MECHANICAL ENGINEERING
SUBJECT CODE: 2710002
M.E. 1^{st} SEMESTER

Type of course: Engineering Science

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.

(The subject “Computational Method for Mechanical Engineering” must be taught by the Mechanical Engineering faculties only as per the Circular uploaded on the website: Important Note for the Subject "Computational Methods for Mechanical Engineers.)

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks						Total Marks
L	T	P	C	Theory Marks		Practical Marks				
				ESE (E)	PA (M)	PA (V)		PA (I)		
						ESE	OEP	PA	RP	
3	2	0	4	70	30	30	0	10	10	150

Content:

Sr. No.	Topics	Teaching Hrs.	Module Weightage
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. 1^{st} 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. 2^{nd} 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); Nonhomogeneous ODE, Modelling of Forced Oscillations, Solution by Variation of Parameters.	06	15
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,	04	10

	Integral Equations; Differentiation and Integration of Transforms, ODEs with Variable Coefficients; Systems of ODEs.		
3	**Linear Algebra:** Matrices and Vectors: Addition and Scalar Multiplication, Matrix Multiplication; Linear Systems of Equations and Gauss Elimination, Linear Independence, Rank of a Matrix, Vector Space; Solutions of Linear Systems: Existence and Uniqueness; Determinants and Cramer's Rule; Inverse of a Matrix, Gauss–Jordan Elimination; Vector Spaces, Inner Product Spaces, Linear Transformations; Matrix Eigenvalues, Determining Eigenvalues-Eigenvectors and their applications; Symmetric, Skew-Symmetric, and Orthogonal Matrices; Eigenbases, Diagonalization, Quadratic Forms; Complex Matrices and Forms.	04	10
4	**Vector Calculus:** Vectors in 2-Space and 3-Space; Inner Product, 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's Theorem.	04	10
5	**Numerical Linear Algebra:** Linear Systems: Gauss Elimination; Linear Systems: LU-Factorization, Matrix Inversion; Linear Systems: Solution by Iteration; Linear Systems: Ill-Conditioning, Norms; Least Squares Method; Matrix Eigenvalue Problems: Introduction; Power Method for Eigenvalues; Tridiagonalization and QR-Factorization.	04	10
6	**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, Dirichlet Problem; Modelling Very Long Bars: Solution by Fourier Integrals and Transforms, Modelling: Membrane, Two-Dimensional Wave Equation; Rectangular Membrane, Double Fourier Series; Laplacian in Polar Coordinates, Circular Membrane, Fourier–Bessel Series; Laplace's Equation in Cylindrical and Spherical Coordinates, Potential; Solution of PDEs by Laplace Transforms.	06	15
7	**Numeric Analysis:** Introduction, Solution of Equations by Iteration, Interpolation, Spline Interpolation, Numeric Integration and Differentiation. Numeric Methods for: First-Order ODEs, Multistep Methods, Systems and Higher (upto second) Order ODEs, Elliptic PDEs, Neumann and Mixed Problems, Irregular Boundary, Parabolic PDEs, Hyperbolic PDEs.	04	10
8	**Probability:** Data Representation, Average, Spread; Experiments, Outcomes,	03	07

	Events; Probability, Permutations and Combinations; Random Variables. Probability Distributions; Mean and Variance of a Distribution; Binomial, Poisson, and Hypergeometric Distributions; Normal Distribution, Distributions of Several Random Variables.		
9	**Statistics:** Introduction, Random Sampling; Point Estimation of Parameter, Confidence Intervals; Testing Hypotheses, Decisions; Quality Control, Acceptance Sampling; Goodness of Fit, X^2 - Test, Nonparametric Tests, Regression, Fitting Straight Lines, Correlation	03	08
10	**Curve Fitting:** Least Square Regression: Linear Regression, Polynomial Regression, General Linear Regression, Nonlinear Regression; Interpolation: Newton's Divided-Difference Interpolating Polynomials, Langrange Interpolating Polynomials, Coefficients of an Interpolating Polynomial, Inverse Interpolation;	04	05

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 Outcome:

After learning the course the students should be able to

1. Students will be able to develop mathematical models of physical phenomena.
2. Students will be able to solve ordinary and partial differential equations analytically as well as numerically.
3. Students will learn fundamentals and applications of algebra for engineering problems.
4. Students will learn fundamentals of statistics and probability.

Tutorials:

At least 10 tutorials should be developed from the topics of syllabus. Emphasis should be on developing own generic programmes using Matlab / Scilab using understanding developed and use of available functions should be avoided.