Revised Syllabus for Two Years Programme

in

M.Sc. in Engineering Mathematics

DEPARTMENT OF MATHEMATICS

INSTITUTE OF CHEMICAL TECHNOLOGY
(University Under Section-3 of UGC Act, 1956)
Elite Status Government of Maharashtra

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INSTITUTE OF CHEMICAL TECHNOLOGY

(University Under Section-3 of UGC Act, 1956)

DEPARTMNET OF MATHEMATICS

A. Semester wise pattern of the M.Sc. in Engineering Mathematics Course

SEMESTER I

SUBJECT CODE	SUBJECT	L	T	C
MAT 2201	Applied Linear Algebra	3	1	4
MAT 2202	Advanced Calculus	3	1	4
MAT 2203	Differential Equations I	2	1	3
MAT 2301	Applied Statistics I	3	1	4
MAT 2204	Algebra	3	1	4
MAT 2401	Numerical Methods I	2	1	3
MAT 2501	Computer Programming (Python/C/JAVA)	4 (L)	0	2
	Total	**20**	**6**	**24**

SEMESTER II

SUBJECT CODE	SUBJECT	L	T	C
MAT 2205	Optimization Techniques	3	1	4
MAT 2206	Complex Analysis and Mathematical Methods	3	1	4
MAT 2207	Advanced Real Analysis	3	1	4
MAT 2302	Applied Statistics II	3	1	4
MAT 2208	Differential Equations II	2	1	3
MAT 2402	Numerical Methods II	2	1	3
MAT 2502	Software Lab I	4 (L)	0	2
	Total	**20**	**6**	**24**

SEMESTER III

SUBJECT CODE	SUBJECT	L	T	C
MAT 2209	Number Theory	3	1	4
MAT 2304	Machine Learning	3	1	4
MAT 2102	Momentum, Heat & Mass Transfer	3	1	4
MAT 2503	Software Lab II	4		2
MAT 2303	Applied Statistics III	3	1	4
	Elective I	3	1	4
	Total	**19**	**5**	**22**

SEMESTER IV

SUBJECT CODE	SUBJECT	L	T	C
MAT 2305	Stochastic Processes	3	1	4
MAT 2105	Computational Fluid Dynamics	3	1	4
MAT 2210	Applied Functional Analysis	3	1	4
MAT 2211	Coding theory and Cryptography	3	1	4
	Elective II	3	1	4
	Elective III	3	1	4
	Total	**18**	**6**	**24**

Abbreviations
C - No. of credits per course
L – No. of lectures per week per course
T – No. of tutorial hours week per course

B. Detailed Syllabus of the M.Sc. in Engineering Mathematics

SEMESTER - I

MAT 2201: APPLIED LINEAR ALGEBRA

Review of Vector Spaces, Subspaces, Linear dependence and independence, Basis and dimensions, Basic concepts in Linear Transformations, Use of elementary row operations to find coordinate of a vector, change of basis matrix, matrix of a linear transformations and subspaces associated with matrices.
Inner Product Spaces, Orthogonal Bases, Gram-Schmidt Orthogonalization, QR Factorization, Normed Linear Spaces, Matrix Norm, condition numbers and applications.
Eigenvalue and Eigenvectors, Diagonalization and its applications to ODE, Dynamical Systems and Markov Chains, Positive Definite Matrices and their applications, Computation of Numerical Eigenvalues
Singular Value Decomposition, Matrix Properties via SVD, Projections, Least Squares Problems, Application of SVD to Image Processing.
Adjoint operators, Normal, Unitary, and Self-Adjoint operators, Spectral theorem for normal operators

References:

- S. Kumaresan, Linear Algebra – A Geometric Approach, Prentice Hall India
- Carl D. Mayer , Matrix Analysis and Applied Linear Algebra, SIAM
- David C Lay, Linear Algebra and its Applications, Adition-Wesley
- G. C. Cullen, Linear Algebra with Applications, Addison Wesley
- Richard Bronson and Gabriel B. Costa, Matrix Methods, Academic Press
- G. Strang,Linear Algebra and its Applications, Harcourt Brace Jovanish
- Robert Beezer, Linear Algebra, a free online book.

MAT 2202: ADVANCED CALCULUS

Differential Calculus: Functions of several variables, Level Sets, Convergence of sequences in several variables, Limits and continuity, Derivatives of scalar fields, Directional derivatives, Partial derivatives, Total derivative, Gradient of scalar fields, Tangent planes, Derivatives of vector fields, curl, divergence, Chain rules for derivatives, Derivatives of functions defined implicitly, Higher order derivatives, Taylor's theorem and applications.

Applications of Differential Calculus: Local Maxima, Local Minima, Saddle points, Stationary points, Lagrange's multipliers, Inverse function theorem, Implicit function theorem.

Multiple Integrals: Double and triple integrals, Iterated integrals, Change of variables formula, Applications of multiple integrals to area and volume etc.

Line Integrals: Paths and line integrals, Fundamental theorems of calculus for line integrals, Line integrals of Vector fields, Green's theorem and its applications, Conservative Vector Fields

Surface Integrals: Parametric representation of a surface, Stokes' theorem, Gauss' divergence theorem

References:

- T.M.Apostol, Calculus Vol. II, 2nd Ed., John Wiely& Sons, 2003.
- T.M.Apostol, Mathematical Analysis, 2nd Ed., Narosa Pub. House
- H.M.Edwards, Advanced Calculus-A Differential Forms Approach
- Susane Jane Colly, Vector Calculus, 4th Edition, Pearson
- J. E. Marsden, A. Tromba, and A.Weinstein, Basic Multivariable Calculus, Springer-Verlag

MAT 2203: DIFFERENTIAL EQUATION I

Review of first and second order ODEs, Existence and Uniqueness theorems for first order ODEs, Higher order Linear ODE with constant and variable coefficient, Solutions of Initial and Boundary value problems, Power series method of solving ODE's and special functions, System of linear ODEs.

Integral Equations: Classification of Integral Equation, Converting IPV to Volterra Integral Equation and vice-versa, Converting BVP to Fredholm Integral Equation and vice-versa, Solution of Volterra and Fredholm Integral Equations using Adomian Decomposition method and successive approximation and series method.

References:

- William E. Boyce, Richard C. DiPrima, Elementary Differential Equation,
- E. A. Coddington, An Introduction to Ordinary Differential Equations, PHI
- G. F. Simons, S. G. Krantz, Differential Equation, Theory Techniques and Practice Tata McGraw-Hill
- Zill, Dennis G, A First Course in Differential Equations
- Abul-Majid Wazwaj, Liner and Nonlinear Integral Equation, Pringer

MAT 2301: APPLIED STATISTICS-I

Probability: Introduction to probability, axiomatic definition, Partitions, total probability and Bayes theorem, Random variables and distribution functions, discrete and continuous distribution function, Multiple random variables, covariance and correlation, expectation, moments, conditional expectation, probability inequalities, Some important discrete and continuous distributions, binomial, Poisson, normal, gamma, exponential etc. convergence concepts, Central limit theorem, normal and Poisson approximation to binomial.
Statistics: Introduction to Statistics and data description,Concept of population and sample, parameters. Concept of sampling distributions, chisquare, t and F distribution, **Point estimation:** properties of estimators, unbiasedness, sufficiency, completeness, maximum likelihood estimation, method of moments, comparing two estimators, factorization theorem, **Interval estimation:** confidence interval estimation, single sample and two sample confidence interval, prediction interval.

References:

- P.G. Hoel, S.C. Port and C.J. Stone, Introduction to Probability, Universal Book Stall, New Delhi, 1998.
- K. Md. Ehsanes Saleh and V. K. Rohatgi. An Introduction to Probability and Statistics. Wiley
- G. Casella and R. L. Berger. Statistical Inference. Duxbury Press. 2011
- W. W. Hines, D. C. Montgomery, Probability and Statistics in Engineering. John Wiley.
- V. Robert Hogg, T. Allen Craig. Introduction to Mathematical Statistics, McMillan Publication.

MAT 2204: ALGEBRA

Groups, subgroups and factor groups,Lagrange's Theorem, homomorphisms, normal subgroups, Quotients of groups, Basic examples of groups: symmetric groups, matrix groups, group of rigid motions of the plane and finite groups of motions.
Cyclic groups, generators and relations,Cayley's Theorem, group actions, Sylow Theorems, Direct products, Structure Theorem for finite abelian groups.
Rings, Examples (including polynomialrings, formal power series rings, matrix rings), ideals, prime and maximal ideals, rings of fractions, Chinese Remainder Theorem for pairwise comaximal ideals, Euclidean Domains, Principal Ideal Domainsand Unique Factorizations Domains. Polynomial rings over UFD's

References:

- M. Artin, Algebra, Prentice Hall of India, 1994.
- D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Edition, John Wiley, 2002.
- J. A. Gallian Contemporary Abstract Algebra, 4th Edition, Narosa, 1999

MAT 2401: NUMERICAL METHODS I

Solution of Algebraic and transcendental equation: Bisection method, Secant method, Regula-Falsi method, Newton-Raphson method and convergence criteria for these methods.
Numerical solution of linear equations: Gauss-Jacobi, Gauss-Seidel iteration, Successive over relaxation(SOR) and under relaxation method and convergence criteria for these methods. Numerical solution of Eigenvalue problems
Interpolations: Lagrange Interpolation, Divided difference, Newton's backward and forward interpolation, Central difference interpolation(Hermite), Cubic Spline interpolation, Numerical Differentiation and Integration(Trapezoidal rule, Simpsons 1/3 ,3/8 rules). Gauss quadrature formula
Numerical solution of initial value problems (first and higher order ODE): Taylor series, Runge-Kutta explicit methods(second and forth order), Predictor–Corrector methods (Adam-Basforth, Adam-Moulton method). Stiff differential equations and its solutions with implicit methods, Numerical Stability, Convergence and truncation Errors for the different methods
Numerical Solution of boundary value problems using initial value method and Shooting techniques (Newton Raphson and Principle of superposition method).

Reference:

- M. K. Jain, S. R. K.Iyengar and R.K.Jain: Numerical methods for scientific and engineering computation, Wiley Eastern Ltd. 1993, Third Edition.
- S.S. Sastry, Introductory methods of Numerical analysis, Prentice- Hall of India, New Delhi (1998) D.V. Griffiths and I.M. Smith, Numerical Methods for Engineers, Blackwell Scientific Publications (1991).
- S.D. Conte and C. deBoor, Elementary Numerical Analysis-An Algorithmic Approach, McGraw Hill.

MAT 2501: COMPUTER PRGRAMMING (PYTHON/C/JAVA)

Introduction to one the programming languages such as Python/C/C++/JAVA, Developpping computer programmes to solve different types of mathematical and engineering problems.

SEMESTER II

MAT 2205: OPTIMIZATION TECHNIQUES

Introduction to Optimization problems and formulations, One dimensional Optimization: Golden Section method, Fibonacci search Method, Polynomial interpolation method, Iterative methods

Classical optimization Techniques: Unconstrained optimization, Constrained Optimizations: Penalty methods, Method of Lagrange multiplier, Kuhn-Tucker method.
Linear Programming: Simplex Method, Revised Simplex Method and other advanced Methods, Duality, Dual Simplex Method, Integer Programming Problems
Unconstrained Optimization Techniques: Direct search methods such as Powel's method, Simplex method, etc.
Gradient Search Methods: Steepeset descent method, Conjugate gradient method, Newton's method, Quasi-Newton's method, DFP, BFGS method etc.
Dynamic Programming, Genetic Algorithms, Simulated Annealing, Ant Colony Optimization

References

- Edvin K. P. Chong &Stanislab H. Zak , An Introduction to Optimization, Wiley Publication
- Leunberger, Linear and Nonlinear Programming, Springer
- Jorge *Nocedal*, Stephen J. *Wright, Numerical Optimization*
- S.S. Rao, Engineering Optimization: theory and practices, New Age International Pvt. Ltd,
- K. Deb, Optimization for Engineering Design, Prentice Hall, India
- L. Davis, Handbook of genetic Algorithm, New York Van Nostrand Reinhold
- Z. Michaleuwicz, Genetic Algorithm+Data Structure=Evolution Programme, Springer-Verlag
- R. K. Belew and M. D. Foundations of Genetic Algorithms, Vose, San Francisco, CA: Morgan Kaufmann

MAT 2206: COMPLEX ANALYSIS AND MATHEMATICAL METHODS

Stereographic projection, Analytic functions, Cauchy-Riemann Equations, Elementary functions, Conformal mappings, Fractional linear Transformations. Complex integration, Cauchys theorem, cauchy's integral formula, Liouville's theorem, Morera's Theorem, Cauchy-Goursat Theorem

Uniform convergence of sequences and series, Taylor and Laurent series, isolated singularities and residues, Classification of singularities, Residue theorem, Evaluation of real integrals
Maximum Modulus Principle, Argument Principle, Rouche's theorem
Fourier series, Laplace Transforms and Fourier integrals and their applications to ODE and PDE.

References:

- J. B. Conway, Functions of One Complex Variable, 2nd Edition, Narosa, New Delhi, 1978.
- T.W. Gamelin, Complex Analysis, Springer International Edition, 2001.
- M. J. Ablowitz and A.S. Fokas Complex variables, Introduction and applications, Cambridge texts in applied mathematics.

MAT 2207: ADVANCED REAL ANALYSIS

Sequences and series of functions, Uniform convergence, Power series and Fourier series, Weierstrass approximation theorem, Equicontinuity, Arzela-Ascoli theorem. Sigma-algebra of measurable sets.Completion of a measure. Lebesgue Measure and its properties. Non-measurable sets.Measurable functions and their properties.Review of Riemann Intergral, Integration and Convergence theorems. Lebesgue integral, Functions of bounded variation and absolutely continuous functions. Fundamental Theorem of Calculus for Lebesgue Integrals. Product measure spaces, Fubini's theorem.
L^p spaces, duals of L^p spaces. Riesz Representation Theorem for C([a,b]).

References

- Ajit Kumar and S. Kumaresan, A Basic Course in Real Analysis, CRC Press, 2014
- C.D. Aliprantis, Principle of Real Analysis, Adademic Press
- I. K. Rana, Introduction to Measures and Integration, AMS
- H. L. Royden, Real Analysis, 4th Ed. PHI
- Bartle, Elements of Integration and Lesbegue Measure
- Krishna B.Athreya and S. Lahiri, Measure theory and probability theory, Springer Texts in Statistics, Springer Verlag

MAT 2302: APPLIED STATISTICS – II

Testing of hypothesis: Type-I and type-II error, p-value, tests of hypothesis for single sample and two samples, likelihood ratio tests, tests for goodness of fit, contingency tables, relation between confidence interval and tests of hypothesis.

Regression: Simple and multiple linear regression models – estimation, tests and confidence regions. Check for normality assumption. Likelihood ratio test, confidence intervals and hypotheses tests related to regression; tests for distributional assumptions. Collinearity, outliers; analysis of residuals, Selecting the best regression equation.
Statistical Simulation: Simulation of random variables from discrete, continuous univariate and multivariate distribution, probability integral transform, Introduction to computer intensive methods-Jack-Knife, Bootstrap, Cross-Validation, Monte-Carlo methods, Gibbs sampling.
Application using R/ SPSS.

References:

- D. C. Montgomery and E. A. Peck, An Introduction to Linear Regression Analysis, John Wiley and Sons
- G. Casella and R. L. Berger. Statistical Inference. Duxbury Press. 2011
- R.A. Johnson and D.W. Wichern, Applied Multivariate Analysis, Upper Saddle River, Prentice-Hall, N.J. 1998.
- Held, Leonhard, SabanésBové, Daniel, Applied Statistical Inference- Likelihood and Bayes. Springer 2014.

MAT 2208: DIFFERENTIAL EQUATION II

First order linear and quasi-linear PDEs, The Cauchy problem, Classification of PDEs, Characteristics, Well-posed problems, Solutions of hyperbolic, parabolic and elliptic equations, Dirichlet and Neumann problems, Maximum principles, Green's functions for elliptic, parabolic and hyperbolic equations. Solution of parabolic, elliptic and hyperbolic equations using variable separable methods

References

- Renardy and Rogers: An introduction to PDE's, Springer-Verlag
- W. A Strauss Partial differential equations, An Introduction, Wiley, John & Sons
- DannisZill, W. S. Wright, Advanced Engineering Mathematics, Jones & Bartlett
- L.C. Evans, Partial differential equations, Springer

MAT 2402: NUMERICAL METHODS II

Finite difference Method: Finite difference schemes and their derivation. Solution of boundary value problems (ODE) with finite difference schemes, Solution of partial differential equations (parabolic and hyperbolic) using explicit and implicit finite difference methods, Numerical stability for explicit and implicit method, Solution of elliptic equation using finite difference methods.

Basic principle of calculus of variation.Weighted residual method for solving ODE and PDE: Callocation, Galerkin, Least square and partition methods.

Finite element formulation for the solution of ODE and PDE, Calculation of element matrices, assembly and solution of linear equations.

References:

- M.K. Jain: Numerical solution of differential equations, Wiley Eastern (1979), 2Ed
- M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical methods for scientific and Engineering computation
- S.S. Sastry, Introductory methods of Numerical analysis, Prentice- Hall of India, New Delhi (1998).
- S.C. Chapra, and P.C. Raymond, Numerical Methods for Engineers, Tata Mc Graw Hill, New Delhi.
- J.N.Reddy, An Introduction to Finite Element Methods, McGraw-Hill.
- G.D.Smith, Numerical solution of partial differential Equations: Finite difference methods, New York, NY: Clarendon Press

MAT 2502: SOFTWARE LAB I

Introduction to SageMath (2), Plotting graphs of various tyes of in 2D and 3D (1), Solving problems in Calculus of single and mult-variables in Sage (3), Developing Programmes to solve basics problems in Numerical Methods in Sage (3), Solving problems in Linear algebra using SageMath (4), Solving differential Equations using SageMath (2)

References:

- Sang-Gu Lee, Ajit Kumar, Calculus with Sage, KyongMoon Publication
- Sang-Gu Lee, Ajit Kumar, Linear Algebra with Sage free online book
- Robert Beezer, Linear Algebra, Free online book
- David Jouner, Introduction to Differential Equations Using Sage
- Anastassiou, George A., Mezei, Razvan, Numerical Analysis Using Sage