Sadhu Ram Chand Murmu University of Jhargram

Jhargram, West Bengal

Syllabus

of

Master of Science (M.Sc.)

in **Mathematics**

Under Semester System

Course Duration : 2 years, 4 Semesters

[w.e.f. : 2021-2022]

SADHU RAM CHAND MURMU UNIVERSITY OF JHARGRAM
Jhargram, West Bengal

Syllabus for M.Sc. in Mathematics

The Department of Mathematics is offering M.Sc. Course in Mathematics under the Semester system with the following syllabus.

The syllabus assumes in the students an interest in higher learning and aims at equipping them for an academic career. The Post-graduate programme in this system will be divided into 22 (twenty two) core courses (of 50 marks each) and 2 (two) Extra-departmental / Elective courses and will consist of four Semesters to be covered in two years : the First and the Second Semesters in the first year and the Third and the Fourth in the second year. For each course : Total marks : 50 (End Semester Examination : 40; Internal Assessment : 10). We offer two extra-departmental / Elective courses as a part of Choice Based Credit System (CBCS), one each in the Second Semester (Course No. MTM-201A or MTM- 201B) and in the Third Semester (Course No. MTM-301).

The Department offers two Special Papers :

(a) Advanced Functional Analysis and Advanced Differential Geometry (MTM-305A, MTM-306A, MTM-404A,MTM-405A

(b) Advanced Optimization and Operations Research (MTM-305B, MTM-306B, MTM-404B, 405B and MTM-495B

Each student has to take either of these two.

Semester-I

Course No.	*Topics*	*Marks*	No. of Lectures (L-T-P)	Credit
MTM-101	Real Analysis-I	50	40(3-1-0)	4
MTM-102	Complex Analysis	50	40(3-1-0)	4
MTM-103	Ordinary Differential Equations and Special Functions	50	40(3-1-0)	4
MTM-104	Abstract Algebra	50	40(3-1-0)	4
MTM-105	Partial Differential Equations and Generalized Functions	50	40(3-1-0)	4
MTM-106	Advanced Programming in C++ and MATLAB	50	40(3-1-0)	4

Semester-II

Course No.	*Topics*	*Marks*	No. of Lectures (L-T-P)	Credit
C-MTM-201A	Statistical and Numerical Methods	50	40 (3-1-0)	4
C-MTM-201B	History of Mathematics	50	40 (3-1-0)	4
MTM-202	Functional Analysis	50	40 (3-1-0)	4
MTM-203	Numerical Analysis	50	40 (3-1-0)	4
MTM-204	Unit-I: Elements of Operations Research	25	20 (2-0-0 or 1-1-0)	2
	Unit-II: Calculus on R^n	25	20 (2-0-0 or 1-1-0)	2
MTM-205	General Topology	50	40 (3-1-0)	4
MTM-296	Lab: Computational Methods Using C++ and MATLAB	50	100 (0-0-8)	4

Semester-III

Course No.	*Topics*	*Marks*	No. of Lectures (L-T-P)	Credit
C-MTM-301	Discrete Mathematics	50	40 (3-1-0)	4
MTM-302	Classical Mechanics and Non – linear Dynamics	50	40 (3-1-0)	4
MTM-303	Integral Transforms and Integral Equations	50	40 (3-1-0)	4
MTM-304	Unit-I: Linear Algebra	25	20 (2-0-0 or 1-1-0)	2
	Unit-II: Manifold Theory	25	20 (2-0-0 or 1-1-0)	2
MTM-305A	Special Paper: Advanced Functional Analysis-I	50	40 (3-1-0)	4
MTM-306A	Special Paper: Advanced Differential Geometry-I	50	40 (3-1-0)	4

MTM-305B	Special Paper-OR: Advanced Optimization-I	50	40 (3-1-0)	4
MTM-306B	Special Paper-OR: Advanced Operational Research-I	50	40 (3-1-0)	4

Semester-IV

Course No.	*Topics*	*Marks*	No. of Lectures (L-T-P)	Credit
MTM-401	Continuum Mechanics	50	40 (3-1-0)	4
MTM-402	Unit I: Fuzzy Mathematics with Applications	25	20 (2-0-0 or 1-1-0)	2
	Unit-II: Real Analysis-II	25	20 (2-0-0 or 1-1-0)	2
MTM-403	Unit-I: Stochastic Process and Regression	25	20 (2-0-0 or 1-1-0)	2
	Unit II: Graph Theory	25	20 (2-0-0 or 1-1-0)	2
MTM-404A	Special Paper: Advanced Functional Analysis-II	50	40 (3-1-0)	4
MTM-405A	Special Paper: Advanced Differential Geometry-II	50	40 (3-1-0)	4
MTM-404B	Special Paper-OR: Advanced Optimization-II	50	40 (3-1-0)	4
MTM-405B	Special Paper-OR: Advanced Operational Research-II	25	20 (2-0-0 or 1-1-0)	2
MTM-495B	Special Paper-OR: Lab. OR methods using MATLAB and LINGO	25	40 (0-0-4)	2
MTM-496	Dissertation Project Work	50	80 (0-0-8)	4

Note:

1. There will be two examinations for each paper:
   (i) End semester examination having 40 marks, and
   (ii) Internal assessment (IA) examination having 10 marks. Marks from IA will be evaluated by averaging two marks obtained in two IAs.

2. Department offers two special papers:
   (a) Advanced Functional Analysis & Advanced Differential Geometry (MTM-305A,-306A, -404A, -405A)
   (b) Advanced Optimization and Operations Research (MTM-305B,-306B, -404B, -405B and -495B). Each student has to take either of these two.
   (c) Elective Courses: C-MTM-201A, C-MTM-201B and C-MTM-301. These papers are to be opted by the students of all departments, except Mathematics department.

Semester-I

MTM-101 Real Analysis-I 50 (3-1-0)

Real number system and its completeness, infimum, supremum, Dedekind cuts. (Proofs omitted).

Uniform convergence and differentiability, Dini's theorem, equicontinuity, pointwise and uniform boundedness, Arzela-Ascoli's theorem, Weierstrass approximation theorem, space filling curves, everywhere continuous but nowhere differentiable functions.

Functions of Bounded Variation and their properties, Differentiation of a function of bounded variation, Absolutely Continuous Functions, Representation of an absolutely continuous function by an integral.

Riemann-Stieltjes integral, Riemann's condition, linear properties of integration, necessary conditions for existence of Riemann-Stieltjes integrals, sufficient conditions for existence of Riemann-Stieltjes integrals, reduction to Riemann integral, change of variable in a Riemann-Stieltjes integral, comparison theorems, mean value theorems for Riemann-Stieltjes integrals, integral as a function of the interval, fundamental theorem of integral calculus, improper integrals and tests for their convergence, absolute convergence.

Measurable sets: Algebra, sigma algebra. Definition of outer measure. Caratheodory definition of Lebesgue Measure. Simple properties. Set of measure zero. Cantor set, Borel set and their measurability, Existence of non-measurable sets.

Measurable function: Definition and simple properties, Borel measurable functions, sequence of measurable functions, Characteristic functions, Simple functions and properties.

Concept of Lebesgue function. Inner and outer measure. Simple properties. Set of measure zero. Cantor set, Borel set and their measurability, Non-measurable sets.

References:

1. W. Rudin, Principles of Mathematical Analysis, 3rd Edition, McGraw-Hill, 2013.
2. W. Rudin, Real and Complex Analysis, International Student Edition, McGraw-Hill, 1987.
3. S. Kumaresan, Topology of Metric Spaces, 2nd Edition, Narosa Publishers, 2011.
4. Inder K. Rana, An Introduction to Measure and Integration, 2nd Edition, Narosa Publishing House, New Delhi, 2002.

MTM-102 Complex Analysis 50 (3-1-0)

Analytic functions. Cauchy- Riemann differential equations. Construction of analytic functions. Jordan arc. Contour. Rectifiable arcs. Cauchy’s theorem. Cauchy’s integral formula. Morera’s theorem. Liouville’s theorem. Taylor’s and Laurent’s series. Maximum modulus principle.

Residues and Poles: Isolated singular points, Residues, Cauchy’s residue theorem, Residue at infinity, Three types of isolated singular points, Residues at poles, Zeros of analytic functions, Zeros and poles, Behaviour of functions near isolated singularity.

Application of residues: Evaluation of improper integrals, Improper integrals from Fourier analysis, Jordan’s lemma, Indented paths. Integration along a branch cut, Definite integrals involving sine and cosine, Argument principle, Rouch´e’s theorem, Inverse Laplace transforms.

Mapping by Elementary Functions: Linear transformations, Mappings by 1/z, Linear fractional transformations, Implicit form, Mappings of the upper half plane, The transformation $w = \sin z$, Square roots of polynomials.

Conformal Mapping: Preservation of oriented angles, Scale factors, Local inverses, Harmonic conjugates, Transformations of Harmonic functions, Transformations of boundary conditions.
Schwarz–Christoffel transformation: Mapping the real axis onto a polygon, Schwarz–Christoffel transformation, Triangles and rectangles, Degenerate polygons.

References:

1. J.W. Brown and R.V. Churchill, Complex Variable and Applications, 8th Edition, Mc Graw Hill.
2. S. Ponnusamy, Foundations of Complex Analysis, Narosa, 1995.
3. H. S. Kasana, Complex Variables: Theory and Applications, Prentice Hall India, 2005.
4. S. Kumaresan, A Pathway to Complex Analysis, Techno World Kolkata, 2021.
5. T. W. Gamelin, Complex Analysis, Springer, 2004.
6. J.E. Marsden and M.J. Hoffman, Basic Complex Analysis, 3e, W.H. Freeman and Company, New York, 1999.
7. D. Sarason, Complex Function Theory, Hindustan Book Agency, 1994.

MTM-103 Ordinary Differential Equations and Special Functions 50 (3-1-0)

Differential equation: Homogeneous linear differential equations, Fundamental system of integrals, Singularity of a linear differential equation, Solution in the neighbourhood of a singularity, Regular integral, Equation of Fuchsian type, Series solution by Frobenius method.
Legendre equation: Legendre functions, Generating function, Legendre functions of first kind and second kind, Laplace integral, Orthogonal properties of Legendre polynomials, Rodrigue’s formula, Schlaefli’s integral.
Bessel equation: Bessel function, Series solution of Bessel equation, Generating function, Integrals representations of Bessel’s functions, Hankel functions, Recurrence relations, Asymptotic expansion of Bessel functions.
Green’s Function: Green’s Function and its properties, Green’s function for ordinary differential equations, Application to Boundary Value Problems.
Eigenvalue problem: Ordinary differential equations of the Strum-Liouville type, Properties of Strum Liouville type, Application to boundary value problems, Eigen values and eigen functions, Orthogonality theorem, Expansion theorem.
System of Linear Differential Equations: Systems of first order equations and the matrix form, Representation of *n*th order equations as a system, Existence and uniqueness of solutions of system of equations, Wronskian of vector functions.

References:

1. G.F. Simmons, Differential Equations, TMH Edition, New Delhi, 1974.
2. S.L. Ross, Differential Equations (3rd edition), John Wiley & Sons, New York, 1984.
3. M. Braun, Differential Equations and Their Applications; an Introduction to Applied Mathematics, 3rd Edition, Springer-Verlag.
4. E.A. Coddington and N. Levinson, Theory of ordinary differential equations, McGraw Hill, 1955.

MTM-104 Abstract Algebra 50 (3-1-0)

Group Theory: Morphism of groups. Quotient groups. Fundamental theorem on homomorphism of groups. Isomorphism theorems. Automorphism. Cayley’s theorem, Class equation.

Matrix groups, Dihedral groups, Quartenion groups. Group actions, Orbits. Burnside theorem, Conjugacy classes, Classification of all groups of order ≤ 12. Sylow theorems, Direct product of groups, Simple groups. Non simplicity of groups of order p^n, pq, p^2q, p^2q^2 (p and q are primes, n is a natural number greater than 1). Determination of all simple groups of order ≤ 60. Nilpotent and Solvable Groups.

Ring Theory: Quotient field of an integral domain.

Polynomial Rings, Matrix rings, Ideals and quotient rings, Ring homomorphism and isomorphism, Isomorphism theorems, Ring embeddings. Chinese embedding theorem.

Prime and irreducible elements, Prime and maximal ideals and their examples in some familiar rings, UFD, PID, ED, Factorisation of polynomials over a commutative ring with identity. Irreducibility of polynomials. Eisenstein's criterion. Rings of fractions.

Field Theory: Fields, Field extensions, Algebraic and transcendental field extensions, Degree of extension, Simple and finite extension, Minimal polynomial of an algebraic element.

Fundamental theorem of algebra, Algebraically closed field, Splitting fields, Algebraic closure, Field of algebraic numbers, Separable and inseparable extensions, Cyclotomic polynomials, Finite fields.

References:

1. D. S. Malik, J. M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, The McGraw-Hill Companies, 1997.
2. D.S. Dummit and R.M. Foote, Abstract Algebra, 2e, John Wiley and Sons, 2003.
3. Kristopher Tapp, Matrix Groups for Undergraduates, American Mathematical Society, 2005.
4. John B. Fraleigh, A First Course in Abstract Algebra, Narosa Publishing House, 1982.
5. Contemporary Abstract Algebra, by Joseph Gallian, 1999, Narosa Publishing House.
6. Thomas W. Hungerford, Algebra, Springer, 1974.

MTM-105 Partial Differential Equations and Generalized Functions 50 (3-1-0)

Partial Differential Equations: First order PDE in two independent variables and the Cauchy problem. Semi-linear and quasilinear equations in two-independent variables. Second order linear PDE. Adjoint and self-adjoint equations. Reduction to canonical forms. Classifications. Fundamental equations: Laplace, Wave and diffusion equations.

Hyperbolic equations: Equation of vibration of a string. Existence. Uniqueness and continuous dependence of the solution on the initial conditions. Method of separation of variables. D'Alembert's solution for the vibration of an infinite string. Domain of dependence. Higher-dimensional wave equations.

Elliptic equations: Fundamental solution of Laplace's equations in two variables. Harmonic function. Characterization of harmonic function by their mean value property. Uniqueness. Continuous dependence and existence of solutions. Method of separation of variables for the solutions of Laplace's equations. Dirichlet's and Neumann's problems. Green's functions for the Laplace's equations in two dimensions. Dirichlet's and Neumann's problem for some typical problems like a disc and a sphere. Poisson's general solution.

Parabolic equations: Heat equation - Heat conduction problem for an infinite rod - Heat conduction in a finite rod - existence and uniqueness of the solution.

Generalized Functions: Dirac delta function and delta sequences. Test functions. Linear functional. Regular and singular generalized functions. Sokhoski-Plemelj formulas. Operations on generalized functions. Derivatives. Transformation properties of delta function. Fourier transform of generalized functions.

References:

1. Y. Pinchover and J. Rubinstein, An Introduction to Partial Differential Equations, Cambridge University Press, 2005.
2. F. John, Partial Differential Equations, Springer-Verlag, New York, 1978.
3. K.S. Rao, Introduction to Partial Differential Equations, 3rd Edition, PHI Learning Private Limited, New Delhi, 2011.
4. Phoolan Prasad and Renuka Ravindran, Partial Differential Equation, New Age International (P) Limited Publisher, 2005.
5. J.J. Duistermaat and J.A.C. Kolk, Distributions Theory and Applications, Birkhäuser Basel, 2010.
6. I. M. Gel'fand & G. E. Shilov, Generalized Functions, Volume 1: Properties and Operations, American Mathematical Society, 2016.

MTM-106 Advanced Programming in C++ and MATLAB 50 (3-1-0)

Programming in C++: Review of basic concepts of C++ programming**,** Arrays, structure and union, Enum, pointers, pointers and functions, pointers and arrays, array of pointers, pointers and structures, strings and string handling functions, Dynamic memory allocation: using of malloc(), reallc(), calloc() and free(), file handling functions: use of fopen, fclose, fputc, fgets, fputs, fscanf, fprintf, fseek, putc, getc, putw, getw, append, low level programming and C pre-processor: Directive, #define, Macro Substitution, conditional compilation, #if, #ifdef, #ifndef, #else, #endif.

Object. Classes and scope, nested classes, pointer class members. Class initialization, constructor and destructor. Overloaded function and operators. Templates including class templates. Inheritance: multiple and virtual inheritance.

Programming in MATLAB: MATLAB workspace, data types, variables, assignment statements, arrays, sets, matrices, string, time, date, cell arrays and structures, introduction to M–file scripts, input and output functions, conditional control statements, loop control statements, break, continue and return statements.

References:

1. E. Balagurusamy, Object-Oriented Programming with C++, Tata McGraw Hill.
2. D. Ravichandran, Programming with C++, Tata McGraw Hill.
3. Robert Lafore, Object-Oriented Programming in Turbo C++, Galgotia.
4. Bjarne Stroustrup, C++ Programming Language, 3ed.
5. A. Gilat, MATLAB: An Introduction with Applications. New York: Wiley; 2008.
6. W.J. Palm III, Introduction to MATLAB for Engineers. New York: McGraw-Hill; 2011.
7. S.J. Chapman, MATLAB programming with applications for engineers. Cengage Learning; 2012.
8. C. Lopez, MATLAB programming for numerical analysis. Apress; 2014.

Semester-II

C-MTM-201A **Statistical and Numerical Methods** **50 (3-1-0)**

Statistical Methods: Mean, median, mode.

Correlation and regression: Properties and significance. Time series analysis.

Hypothesis testing: chi-square test, t-test and F-test. ANOVA.

Numerical methods: Sources and causes of errors. Types of errors.

Interpolation: Lagrange's and Newton's interpolation (deduction is not required).

Roots of algebraic and transcendental equations: Bisection, Newton-Raphson methods. Rate of convergence.

System of linear equations: Gauss-elimination method, Gauss-Seidel method.

Integration: Trapezoidal and Simpson 1/3 methods.

Ordinary differential equation: Euler's method, Runge-Kutta methods.

References:

1. A.M. Goon, M.K. Gupta & B. Dasgupta, Fundamentals of Statistics, Vol. 1 & 2, Calcutta : The World Press Private Ltd., 1968.
2. S. Biswas, G. L. Sriwastav, Mathematical Statistics: A Textbook, Narosa, 2011.
3. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International (P) Limited, New Delhi, 1984.
4. E.V. Krishnamurthy and S.K. Sen, Numerical Algorithms, Affiliated East-West Press Pvt. Ltd., New Delhi, 1986.
5. J.H. Mathews, Numerical Methods for Mathematics, Science, and Engineering, 2nd ed., Prentice-Hall, Inc., N.J., U.S.A., 1992.
6. M. Pal, Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa, 2007.

C-MTM-201B **History of Mathematics** **50 (3-1-0)**

Ancient Mathematical Sources, Mathematics in Ancient Mesopotamia, The Numeral System and Arithmetic Operations, Geometric and Algebraic Problems, Mathematical Astronomy, Mathematics in Ancient Egypt, Geometry, Assessment of Egyptian Mathematics, Greek Mathematics, Development of Pure Mathematics, Pre-Euclidean Period, Elements, Three Classical Problems, Geometry in the 3rd Century BCE, Archimedes, Apollonius, Applied Geometry, Later Trends in Geometry and Arithmetic, Greek Trigonometry and Mensuration, Number Theory, Survival and Influence of Greek Mathematics. Mathematics in the Islamic World (8th–15th Century), Origins, Mathematics in the 9th Century, Mathematics in the 10th Century, Omar Khayyam, Islamic Mathematics to the 15th Century.

Foundations of Mathematics: Ancient Greece to the Enlightenment, Arithmetic or Geometry, Being Versus Becoming, Universals, Axiomatic Method, Number Systems, Reexamination of Infinity, Calculus Reopens Foundational.

History of Ancient Indian Mathematics: Zero and the place-value notation for numbers, Vedic Mathematics and arithmetical operations, Geometry of the Sulba Sutras, Jain contribution to fundamentals of numbers, The anonymous Bakshali manuscript, Astronomy, Classical contribution to indeterminate equations and algebra, Indian trigonometry, Kerala contribution to infinite series and calculus.

References:

1. Dutt and Singh, History of Hindu Mathematics, 2 Volumes, Asia Publishing House, 1962.
2. H.T. Colebrooke, Algebra with Arithmetic and Menstruation from the Sanskrit of Brahmagupta & Bhaskara, Nabu Press, 2010.
3. John Taylor: Leelavati.
4. T.S. Bhanu Murthy, A Modern Introduction to Ancient Indian Mathematics, Wiley Eastern,1992.
5. Erik Gregersen, The Britannica Guide to The History of Mathematics, Britannica.
6. Eleanor Robson, Jacqueline Stedall, The Oxford Handbook of The History of Mathematics, Oxford.

MTM-202	**Functional Analysis**	**50 (3-1-0)**

Normed spaces. Continuity of linear maps. Bounded linear transformation. Set of all bounded linear transformation $B(X, Y)$ from a NLS X into NLS Y is a NLS. $B(X, Y)$ is a Banach space if Y is a Banach space. Quotioent of normed linear spaces and its consequences. Hahn-Banach Extension theorem and its applications. Banach spaces. A NLS is Banach space if and only if every absolutely convergent series is convergent. Conjugate spaces, Reflexive spaces.
Uniform Boundedness Principle and its applications. Closed graph theorem, Open Mapping Theorem and their applications.
Inner product spaces, Hilbert spaces. Orthonormal basis. Complete Orthonormal basis. Cauchy-Schwarz inequality. Parallelogram law. Projection theorem. Inner product is a continuous operator. Relation between IPS and NLS. Bessel's inequality. Parseval's identity. Strong and Weak convergence of sequence of operators. Reflexivity of Hilbert space. Riesz Representation theorem for bounded linear functional on a Hilbert space.
Definition of self-adjoint operator, Normal, Unitary and Positive operators, Related simple theorems.

References:

1. B.V. Limaye, Functional Analysis, 2nd Edition, New Age International Private Limited New Delhi, 2014.
2. J.B. Conway, A Course in Functional Analysis, 2nd Edition, Springer-Verlag New York, 1985.
3. E. Kreyszig, Introduction to Functional Analysis with Applications, John Wiley & Sons, New York, 1989.
4. A. Taylor and D. Lay, Introduction to Functional Analysis, Wiley, New York, 1980.

MTM-203	**Numerical Analysis**	**50 (3-1-0)**

Cubic spline interpolation. Lagrange's bivariate interpolation. Approximation of function. Chebyshev polynomial: Minimax property. Curve fitting by least square method. Use of orthogonal polynomials. Economization of power series.
Numerical integration: Newton-Cotes formulae-open type. Gaussian quadrature: Gauss-Legendre, Gauss-Chebyshev. Integration by Monte Carlo method.
Roots of polynomial equation: Bairstow method.
System of linear equations: Pivoting, Matrix inverse. LU decomposition method. Tri-diagonal system of equations. Ill-conditioned linear systems. Relaxation method.

System of non-linear equations, fixed point method, Newton methods. Convergence, rate of convergence.
Eigenvalue problem. Power method. Jacobi's method.
Ordinary differential equation: Runge-Kutta method for linear ODEs and second order IVP. Predictor-corrector method: Milne's method. Stability. Second order BVP: Shooting method, finite difference method, finite element method.
Partial differential equation: Finite difference scheme. Explicit and implicit methods of Hyperbolic and Parabolic equations, Crank-Nicolson method. Elliptic equation. Stability. Consistency and convergence.

References:

1. A. Gupta and S.C. Bose, Introduction to Numerical Analysis, Academic Publishers, Calcutta, 1989.
2. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International (P) Limited, New Delhi, 1984.
3. E.V. Krishnamurthy and S.K. Sen, Numerical Algorithms, Affiliated East-West Press Pvt. Ltd., New Delhi, 1986.
4. J.H. Mathews, Numerical Methods for Mathematics, Science, and Engineering, 2nd ed., Prentice-Hall, Inc., N.J., U.S.A., 1992.
5. M. Pal, Numerical Analysis for Scientists and Engineers: Theory and C Programs, Narosa, 2007.
6. Pradip Niyogi, Numerical Analysis and Algorithms, McGraw Hill Education India Pvt. Ltd., 2003.
7. Pradip Niyogi, S.K. Chakrabartty and M.K. Laha, Introduction to Computational Fluid Dynamics, Pearson, 2002.

MTM 204	Unit-I: Elements of Operations Research	25 (2-0-0 or 1-1-0)

Inventory control: Deterministic Inventory control including price breaks and Multi-item with constraints.

Queuing Theory: Basic Structures of queuing models, Poisson queues –M/M/1, M/M/C for finite and infinite queue length, Non-Poisson queue -M/G/1.

Classical optimization techniques: Single variable optimization, multivariate optimization (with no constraint, with equality constraints).

References:

1. S.D. Sharma, Operations Research: Theory, Method and Application, Kedar Nath Ram Nath, 2002.
2. F.S. Hillier, Introduction to operations research. Tata McGraw-Hill Education, 2012.
3. S.S. Rao, Engineering optimization: Theory and practice, John Wiley & Sons, 2009.
4. H.A. Taha, Operations research: An introduction. Pearson Education India, 2004.
5. J.K. Sharma, Operations Research: Theory and application, Macmillan Publishers, 2006.

MTM 204	Unit-II: Calculus on R^n	25 (2-0-0 or 1-1-0)

Scalar and vector fields, Directional derivative and continuity, total derivative, total derivative expressed in terms of partial derivatives, Jacobian matrix, chain rule, matrix form of the chain rule. Mean value theorem for differentiable functions, sufficient condition for differentiability, sufficient condition for equality of mixed partial derivatives, Taylor's formula for functions

from R^n to R^1.
Inverse function theorem, Implicit function theorem.

References:

1. T. M. Apostol, Mathematical Analysis, Narosa Publishing House, New Delhi.
2. T. Marsden, Basic Multivariate Calculus, Springer, 2013.
3. C. Goffman, Calculus of Several Variables, A Harper International Student reprint, 1965.
4. Tom M. Apostol, Calculus, Volume II, Wiley India Pvt. Limited, 2002.
5. Michael Spivak, Calculus on Manifolds, Westview Press, 1965.
6. James R. Munkres, Analysis on Manifolds, Westview Press, 1990.

MTM 205	General Topology	50 (3-1-0)

Definition and examples of topological spaces, closed sets, closure, dense subsets, neighborhood, interior, exterior and boundary, accumulation point, derived set, bases and subbases, subspace topology, finite product of topological spaces, Kuratowski closure operator.
Open, closed and continuous functions and homeomorphism, topological invariants, isometry and metric invariants
First and second countability, separability and Lindelöf property, T_i (i = 1, 2, 3, 3½, 4, 5) property, regularity, complete regularity, normality and complete normality, basic properties, Urysohn's lemma, Tietze's extension theorem.
Compactness and separation axiom, compactness and continuous functions.
Connectedness of the real line, locally connected space, path connectedness.
Convergence and cluster points, Hausdörfness, continuity, canonical way of converting nets to filters and vice-versa.
Tychönoff product topology, projection maps, product spaces.

References:

1. J.R. Munkres, Topology, 2nd Ed., Pearson Education (India), 2000.
2. M.A. Armstrong, Basic Topology, Springer (India), 1983.
3. K.D. Joshi, Introduction to General Topology, New Age International Private Limited, New Delhi, 2014.
4. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, New York, 1963.

MTM 296	Lab: Computational Methods Using C++ and MATLAB	50 (0-0-8)

Problem: 40 marks; Lab. Note Book and Viva-Voce: 10.

Working with matrix: Generating matrix, Concatenation, Deleting rows and columns. Symmetric matrix, matrix multiplication, Test the matrix for singularity, magic matrix. Matrix analysis using function: norm, normest, rank, det, trace, null, orth, rref, subspace, inv, expm, logm, sqrtm, funm.
Array: Addition, Subtraction, Element-by-element multiplication, Element-by-element division, Element-by-element left division, Element-by-element power. Multidimensional arrays, Cell arrays, Characters and text in array,
Graph Plotting: Plotting process, Creating a graph, Graph components, Figure tools, Arranging graphs within a figure, Choosing a type of graph to plot, Editing plots, Plotting two variables with plotting tools, Changing the appearance of lines and markers, Adding more data

to the graph, Changing the type of graph, Modifying the graph data source, Annotating graphs for presentation, Exporting the graph.

Using Basic Plotting Functions: Creating a plot, Plotting multiple data sets in one graph, Specifying line styles and colors, Plotting lines and markers, Graphing imaginary and complex data, Adding plots to an existing graph, Figure windows, Displaying multiple plots in one figure, Controlling the axes, Adding axis labels and titles, Saving figures.

Programming: Conditional control – if, else, switch, Loop control – for, while, continue, break, Error control – try, catch, Program termination – return.

Scripts and Functions: Scripts, Functions, Types of functions, Global variables, Passing string arguments to functions, The eval function, Function handles, Function functions, Vectorization, Preallocation.

Linear Algebra: Systems of linear equations, Inverses and determinants, Factorizations, Powers and exponentials, Eigenvalues, Singular values.

Polynomials: Polynomial functions in the MATLAB® environment, Representing Polynomials, Evaluating polynomials, Roots, Derivatives, Convolution, Partial fraction expansions, Polynomial curve fitting, Characteristic polynomials.

Numerical Problems: Evaluation of determinant by Gauss elimination method, using partial pivoting. Matrix inverse by partial pivoting. System of linear equations- Gauss Seidel iteration method, LU decomposition method, Gauss elimination method. Tri-diagonal equations. Cubic spline interpolation. Gauss quadrature rule, Integration by Monte Carlo method, Double integration. Solution of ODE by Predictor and Corrector method: Milne method. Solution of PDE by Finite difference method. Eigenvalue of a matrix: Power method, Jacobi method.

Statistical Problems:

On bivariate distribution: Correlation coefficient, Regression lines, Curve fitting. Multiple regression. Simple hypothesis testing.

References:

1. E. Balagurusamy, Object-Oriented Programming with C++, Tata McGraw Hill.
2. D. Ravichandran, Programming with C++, Tata McGraw Hill.
3. Robert Lafore, Object-Oriented Programming in Turbo C++, Galgotia.
4. A. Gilat, MATLAB: An Introduction with Applications. New York: Wiley; 2008.
5. W.J. Palm III, Introduction to MATLAB for Engineers. New York: McGraw-Hill; 2011.
6. S.J. Chapman, MATLAB programming with applications for engineers. Cengage Learning; 2012.
7. C. Lopez, MATLAB programming for numerical analysis. Apress; 2014.

Semester-III

C-MTM-301 Discrete Mathematics 50 (3-1-0)

Boolean algebra: Basic definitions, Duality, Basic theorems, Boolean algebra and lattice, Representation theorem, Sum-of-product form, Product-of-sum form, Propositional logic, Tautology.
Sets and propositions: Cardinality, Mathematical induction, Principle of inclusion and exclusion.
Computability and formal languages: Ordered sets, Languages, Phrase structure grammars, Types of grammars and languages.
Finite state machines: Equivalent machines, Finite state machines, Partial order relations and lattices, Chains and antichains.
Graph Theory: Walks, paths, connected graphs, regular and bipartite graphs, cycles and circuits. Tree and rooted tree. Spanning trees. Eccentricity, Radius and diameter, Centre, Hamiltonian and Eulerian graphs, Planar graphs. Matrix representation of graphs.

References:

1. N. Deo, Graph Theory with Applications to Engineering and Computer Science, PHI.
2. D. B. West, Introduction to Graph Theory, Pearson Education, 2002.
3. K.H. Rosen, Discrete Mathematics and its Applications, McGraw-Hill, 2007.
4. R.J. Wilson & J.J. Watkins, Graphs: An Introductory Approach: A First Course in Discrete Mathematics, John Wiley & Sons Inc, 1990.

MTM-302 Classical Mechanics and Non-linear Dynamics 50 (3-1-0)

Motion of a system of particles. Constraints. Generalized coordinates. Holonomic and non-holonomic system. Principle of virtual work. D'Alembart's Principle. Lagrange's equations. Plane pendulum and spherical pendulum. Cyclic coordinates. Coriolis force. Motion relative to rotating earth.
Principle of stationary action. Hamilton's principle. Deduction of Lagrange from Hamilton's principle. Brachistochrone problem. Lagrange's equations from Hamilton's principle.. Invariance transformations. Conservation laws. Infinitesimal transformations. Space-time transformations. Hamiltonian. Hamilton's equations. Poisson bracket. Canonical transformations. Liouville's theorem.
Small oscillation about equilibrium. Lagrange's method. Normal coordinates. Oscillations under constraint. Stationary character of a normal mode. Small oscillation about the state of steady motion. Normal coordinates
Orientation and displacement of a rigid body. Eulerian angles. Principal axis transformation. Euler equations of motion. Motion of a free body about a fixed point.
Special theory of relativity in Classical Mechanics:-Postulates of special relativity. Lorentz transformation. Consequences of Lorentz transformation. Force and energy equations in relativistic mechanics.
Nonlinear Dynamics: Linear systems. Phase portraits: qualitative behavior. Linearization at a fixed point. Fixed points. Stability aspects. Lyapunov functions (stability theorem). Typical examples. Limit cycles. Poincare-Bendixson theory. Bifurcations. Different types of bifurcations.

References:

1. H. Goldstein, Classical Mechanics, Addison-Wesley, Cambridge, 1950.
2. A.S. Gupta, Calculus of Variations with Applications, Prentice-Hall of India, New Delhi, 2005.
3. B.D. Gupta and S. Prakash, Classical Mechanics, Kedar Nath Ram Nath, Meerut, 1985.
4. T.W.B. Kibble, Classical Mechanics, Orient Longman, London, 1985.
5. N.C. Rana and P.S. Joag, Classical Mechanics, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2004.
6. M. Pal, A Course on Classical Mechanics, Narosa, New Delhi, & Alpha Science, Oxford, London, 2009.
7. K.R. Symon, Mechanics, Addison-Wesley Publ. Co., Inc., Massachusetts, 1971.
8. R.G. Takwale and S. Puranik, Introduction to Classical Mechanics, Tata McGraw-Hill Publ. Co. Ltd., New Delhi, 1980.

MTM-303 Integral Transforms and Integral Equations 50 (3-1-0)

Fourier transform: Properties of Fourier transform, Inversion formula, Convolution, Parseval's relation, Multiple Fourier transform, Bessel's inequality, Application of transform to Heat, Wave and Laplace equations (Partial differential equations).

Laplace Transform: Properties of Laplace transform, Inversion formula, Bromwich formula, Convolution theorem, Applications to ODEs and PDEs.

Wavelet Transform: Properties, Application in physical systems.

Integral Equation: Formulation of integral equations, Fredholm and Volterra type, Successive approximations, Resolvent kernel, Degenerate kernels, Abel's integral equation, Convolution type, Fredholm's theorems, Symmetric kernel, Eigenvalue and eigen function, Fredholm alternative.

References:

1. L. Debnath, Integral Transforms and Their Applications, CRC Press, 1995.
2. P.P.G. Dyke, An Introduction to Laplace Transform and Fourier Series, Springer 2005.
3. R.P. Kanwal, Linear Integral Equations; Theory & Techniques, Academic Press, New York, 1971.
4. W.V. Lovitt, Linear Integral Equations, Dover Publications, 1950.
5. L. Debnath, Wavelet Transforms and Their Applications, Birkhauser Boston, 2002.
6. C. Sidney Burrus, Ramesh A. Gopinath & Haitao Guo, Introduction to Wavelets and Wavelet Transforms, PHI, 1998.

MTM-304 Unit-I: Linear Algebra 25 (2-0-0 or 1-1-0)

Review of linear transformations. Matrix representation, Linear operators, Isomorphism, Isomorphism theorems, Change of coordinate, Diagonalization, Dual space, Minimal polynomial.

Canonical forms: Triangular canonical form, Nilpotent transformations, Jordan canonical form, Rational canonical form.

Inner product spaces, Hermitian, Unitary and Normal transformations, Spectral theorem.

Bilinear forms, Symmetric and Skew-symmetric bilinear forms, Sylvester's law of inertia.

References:

1. K. Hoffman and R. Kunze, Linear Algebra, Pearson Education (India), 2003. Prentice-

Hall of India, 1991.
2. I.N. Herstein, Topics in Algebra, 2nd Ed., John Wiley & Sons, 2006.
3. S.H. Friedberg, A.J. Insel, L.E. Spence, Linear Algebra, Fourth Edition, Pearson, 2015.
4. G. Strang, Linear Algebra and its Applications, Brooks/Cole Ltd., New Delhi, Third Edition, 2003.

MTM-304	Unit-II: Manifold Theory	25 (2-0-0 or 1-1-0)

Topological manifolds, Differentiable manifolds, smooth maps and diffeomorphisms, curves in a manifold, Tangent Vector, Vector fields, integral curves of a vector field, Push-forward mapping, *f*-related vector fields, immersion and submersion, submanifolds, one-parameter group of transformations (Local & Global), complete vector fields.
Cotangent space, *r*-form, exterior product, exterior differentiation, Pull-back Differential form.

References:

1. L.W. Tu, An Introduction to Manifolds, Springer, 2007.
2. J.M. Lee, Introduction to Smooth Manifolds, Springer, 2003.
3. S. Lang, Introduction to Differential Manifolds, John Wiley & Sons, New York, 1962.

MTM-305A	Special Paper: Advanced Functional Analysis-I	50 (3-1-0)

Definition and examples of topological vector spaces. Convex sets, convex hull.
Representation theorem for convex hull. Symmetric sets, balanced sets and absorbing sets and their properties. Locally convex topological vector space. Closed sets, open sets with their properties, local base, characterization of local base at the zero vector. Bounded and totally bounded sets.
Linear maps and their continuity, homeomorphism and linear functionals on a topological vector space. Metrizability of a locally convex topological vector space. Locally compact topological vector space and its properties. Completeness property of a topological vector space. Connectedness property.
Minkowski's functionals and semi-norms with their basic properties and their characterizations in a locally convex topological vector space. Criteria for normability of a topological vector space (Kolmogorov's Theorem).
Extreme points, Krein Milman Theorem, Hyperplanes, separation properties of convex sets by hyperplanes in a topological vector space.
Barelled spaces and Bornological spaces, examples. Criteria for locally convex topological vector spaces to be Barreled and Bornological.

References:

1. J. Horvoth, Topological Vector spaces and Distributions, Addison-Wesley Publishing Co., 1966.
2. W. Rudin, Functional Analysis, TMG Publishing Co. Ltd., New Delhi, 1973.
3. J. Diestel, Geometry of Banach Spaces, Springer, 1975.
4. L. Narici & E. Beckenstein, Topological Vector spaces, Marcel Dekker Inc, New York and Basel, 1985.
5. A.A. Schaffer, Topological Vector Spaces, Springer, 2nd Edn., 1991.
6. A. Wilansky; Modern Methods in Topological Vector Spaces; McGraw Hill Int. Book Co. 1978.

MTM-306A	Special Paper: Advanced Differential Geometry-I	50 (3-1-0)

Curves in plane and space, arc-length, reparameterization, closed curves, simple closed curve, Four vertex theorem.
Regular surface, tangents and normals, orientability, the first fundamental form, developable surface, the second fundamental form, Gauss's formula, Weingarten formula, Gauss & Codazzi equations, different curvatures.
Affine connection (Koszul), Torsion and curvature tensor field, Covariant differential, Parallel transport.
Riemannian manifold, Riemannian connection, Riemann curvature tensor, Bianchi identity, Ricci tensor, Scalar curvature, Einstein manifold, Semi-symmetric metric connection, Weyl conformal curvature tensor, Conformally symmetric Riemannian manifold, it's consequences, Geodesics.

References:

1. A. Pressley, Elementary Differential Geometry, Springer, 2^{nd} Volume, 2010.
2. W.M. Boothby, An Introduction to Differentiable Manifolds and Riemannian Geometry, Academic Press, Revised 2003.
3. S. Kumaresan, A Course in Differential Geometry and Lie Groups, Hindustan Book Agency.

MTM-305B	Special Paper-OR: Advanced Optimization-I	50 (3-1-0)

Revised simplex method. Modified dual simplex.
Large scale linear programming: Decomposition principle of Dantzig and Wolf.
Parametric and post-optimal analysis: Change in the objective function, Change in the requirement vector, Addition of a variable, Addition of a constraint, Parametric analysis of cost and requirement vector.
Search Methods: Fibonacci method, Golden section method.
Gradient Method: Steepest descent, Method of conjugate directions, Newton's method, Davodon-Fletcher-Powell method. Methods of feasible direction, Cutting hyper-plane method.
Integer programming: Gomory's cutting plane algorithm, Gomory's mixed integer problem, Branch and bound algorithm.
Quadratic Programming: Wolfe's modified simplex method, Beale's method.
Geometric Programming: Geometric programming (both unconstrained and constrained) with positive and negative degree of difficulty.

References:

1. S. S. Rao. Engineering optimization: theory and practice. John Wiley & Sons, 2009.
2. Hamdy A. Taha, Operations research: An introduction. Pearson Education India, 2004.
3. A.D. Belegundu and T.R. Chandrupatla, Optimization concepts and applications in engineering, Cambridge University Press, 2011.
4. S.D. Sharma, Operations Research, Kedar Nath Ram Nath & Co., Meerut.

MTM-306B	Special Paper-OR: Operational Research-I	50 (3-1-0)

Dynamic Programming: Nature of dynamic programming, Deterministic processes, Non-Sequential discrete optimization, Allocation problems, Assortment problems, Sequential discrete optimization, Long-term planning problem, Multi-stage decision process, Application in production scheduling and routing problems.

Inventory control: Probabilistic inventory control problems (with and without lead time), Dynamic inventory models. Basic concept of supply–chain management, Two echelon supply chain model.

Network: PERT and CPM: Steps of PERT/CPM Techniques, PERT/CPM Network components and precedence relationships, Critical path analysis, Probability in PERT analysis, Project Time-Cost, Trade-off, Updating of the project.

Replacement and Maintenance Models: Failure mechanism of items, Replacement of items deteriorates with time, Replacement policy for equipment, value of money changes with constant rate, Replacement of items that fail completely, Individual replacement policy, Group replacement policy, Other replacement problems — staffing problem, equipment renewal problem.

Simulation: Steps of simulation process, Advantages and disadvantages, Stochastic simulation, Monte Carlo simulation, Random number generation, Simulation of Inventory Problems, Simulation of Queuing problems, Role of computers in Simulation, Applications of Simulations.

References:

1. Hamdy A. Taha, Operations research: An introduction, Pearson Education India, 2004.
2. S. D. Sharma, Operations Research, Kedar Nath Ram Nath & Co., Meerut.
3. J.K. Sharma, Operations Research: Theory and application, Macmillan Publishers, 2006.
4. F.S. Hillier, Introduction to Operations Research, Tata McGraw-Hill Education, 2012.

Semester-IV

MTM-401 General Theory of Continuum Mechanics 50 (3-1-0)

Continuous media: Deformation. Lagrangian and Eulerian coordinates. Relationship between Lagrangian and Eulerian coordinates. Conservation of mass. Strain tensor. Rate of deformation tensor. Coordinate transformation of strains. Principal strains. Principal strain invariants. Examples. Maximum shear strains. Mohr circle representation. Compatibility equations.

Equilibrium and kinetics: Forces and stresses. Basic balance laws: Balance of linear and angular momentum; Cauchy's first and second laws of motion. Coordinate transformation of stresses. Principal stresses. Principal stress invariants. Examples. Mohr circle representation, the deviatoric stress tensor.

Constitutive equations for linear elastic solids. Generalized Hook's law. Monotropic, orthotropic, Transversely isotropic and isotropic material. Lame constants. Navier equations.

Fluid flow problems: Definition of a fluid, Fluid properties, Classification of flow phenomena, Equations of fluid motion, Navier-Stokes equations (compressible and incompressible), Euler's equations (compressible and incompressible), Bernoulli's equation, Impulsive motion of fluid, Energy equation. Flow and circulation, Kelvin's circulation theorem, Kelvin's minimum energy theorem. Motion in two dimensions, Vorticity, Stream functions, Complex potential, Source, sink, doublet, images, Milne-Thompson circle theorem, Application, Non-dimensionalization of equations, Reynolds number and Prandtl number, RANS equations.

References:

1. T.J. Chung, Continuum Mechanics, Prentice – Hall, 1988.
2. G.R. Mase, Continuum Mechanics: Schaum's Outline of Theory and Problem of Continuum Mechanics, McGraw Hill, 1969.
3. R.N. Chatterjee, Mathematical Theory of Continuum Mechanics, Narosa Publishing House, 1999.
4. A.J.M. Spencer, Continuum Mechanics, Longman, 1980.
5. I.S. Sokolnikoff, The Mathematical Theory of Elasticity, McGraw Hill, 1956.
6. A.J. Chorin and J. E. Marsden, Mathematical Introduction of Fluid Mechanics, Springer, 1993.
7. G.K. Batchelor, Fluid Dynamics, Cambridge University Press, 2000.
8. A.C. Eringen, Mechanics of Continua, Wiley, 1967.
9. D.S. Chandrasekharaiah and L. Debnath, Continuum Mechanics, Academic Press, 1994.

MTM-402 Unit-1: Fuzzy Mathematics with Applications 25 (2-0-0 or 1-1-0)

Basic concept, Definition of fuzzy sets, Sets operations, Basic terminologies- support, α-cut, height, normality, convexity, etc.

Fuzzy relations, properties of α-Cut, Zadeh's extension principle, Interval arithmetic, Fuzzy numbers, properties, arithmetic of fuzzy numbers.

Fuzzy matrices, Basic concepts of fuzzy differential equations.

Linear programming problems with fuzzy resources, Vendegay's approach, Werner's approach.

L.P.P. with fuzzy resources and objective: Zimmermann's approach.

L.P.P. with fuzzy parameters in the objective function, Fuzzy multi objective linear programming problems.

References:

1. G.J. Klir and B. Yuan, Fuzzy sets, fuzzy logic, and fuzzy systems: selected papers by Lotfi A. Zadeh. World Scientific Publishing Co., Inc., 1996.
2. C.R. Bector and S. Chandra, Fuzzy mathematical programming and fuzzy matrix games, Berlin, Springer, 2005.
3. D.J. Dubois, Fuzzy Sets and Systems: Theory and Applications, Academic Press, 1980.
4. L.T. Gomes, L.C. de Barros and B. Bede, Fuzzy differential equations in various approaches. Berlin: Springer, 2015.
5. H.J. Zimmermann, Fuzzy Set Theory and its Applications, Springer, 1996.

MTM-402	**Unit-II: Real Analysis-II**	**25 (2-0-0 or 1-1-0)**

Lebesgue integral on a measurable set: Definition. Basic simple properties. Lebesgue integral of a bounded function over a set of finite measure. Simple properties. Integral of non-negative measurable functions, General Lebesgue integral. Bounded convergence theorem for a sequence of Lebesgue integrable function, Fatou's lemma. Classical Lebesgue dominated convergence theorem. Monotone convergence theorem, Relation between Lebesgue integral and Riemann integral.

Statement of Lusin's theorem, Egoroff's theorem.

Product Measures, Fubini's Theorem.

References:

1. A.M. Bruckner, J. Bruckner & B. Thomson, Real Analysis, Prentice-Hall, New York, 1997.
2. G. De. Barra, Measure Theory & Integration, Wiley Eastern Limited, 1987.
3. G. B. Folland, Real Analysis: Modern Techniques and Their Applications, 2nd Edition, Wiley, 1999.
4. P. R. Halmos, Measure Theory, D. Van Nostrand Co. Inc. London, 1962.
5. E.M. Stein & R. Shakarchi, Real Analysis, Measure Theory, Integration, and Hilbert Spaces, Princeton University Press, 2005.

MTM-403	**Unit-I: Stochastic Process and Regression**	**25 (2-0-0 or 1-1-0)**

Stochastic Process: Markov chains with finite and countable state space, Classification of states, Limiting behaviour of n state transition probabilities, Stationary distribution, Branching process, Random walk, Gambler's ruin problem, Markov processes in continuous time. Poisson's process.

Multiple regression: Partial correlation, Multiple correlations, Advanced theory of linear estimation.

References:

1. A.M. Goon, M.K. Gupta and B. Dasgupta, Fundamentals of Statistics, Vol. 1 & 2, Calcutta: The World Press Private Ltd., 1968.
2. J. Medhi, Stochastic Process, New Age International Publisher, 2ed, 1984.
3. Suddhendu Biswas and G. L. Sriwastav, Mathematical Statistics: A Textbook, Narosa, 2011.
4. D.C. Montgomery, E.A. Peck and G. Geoffrey Vining, Introduction to Linear Regression Analysis, 5ed, Wiley, 2012.

MTM-403	**Unit-II: Graph Theory**	25 (2-0-0 or 1-1-0)

Basic graph theoretical concepts: paths and cycles, connectivity, trees, spanning sub graphs, bipartite graphs, Hamiltonian and Euler cycles, Distance and centre, Cut sets and cut vertices. Colouring and matching, Four colour theorem (statement only). Planar graphs, Dual graph, Directed graphs and weighted graphs, Matrix representation of graphs, Algorithms for shortest path and spanning trees, Intersection graph, Applications of graphs in operations research.

References:

1. D. B. West, Introduction to graph theory, Upper Saddle River: Prentice Hall, 2001.
2. N.S. Deo, Graph Theory with Applications to Engineering And Computer Science, PHI, 2017.
3. G. Chartrand, Introduction to graph theory. Tata McGraw-Hill Education, 2006.
4. J.L. Gross and J. Yellen, Graph theory and its applications, CRC Press, 2005.

MTM-404A	**Special Paper: Advanced Functional Analysis-II**	50 (3-1-0)

Strict convexity and uniform convexity of a Banach space with examples, properties of strictly convex and uniformly convex normed linear spaces, Clarkson's Renorming Lemma and Milman and Pettit's theorem (Only statements), Uniform convexity of Hilbert spaces, Reflexivity of a uniformly convex Banach space.

Weiresstrass Approximation Theorem in $c[a,b]$, Best approximation theory in normed linear spaces and Hilbert spaces, uniqueness criterion for best approximation.

Algebra, sub-algebra, Stone Weirstrass Theorem in $c(X, R)$.

Banach Algebra, analytic function, invertible and non invertible elements, properties of resolvent sets, resolvent functions, Spectrum, compactness of spectrum, Gelfand Mazur Theorem, spectral radius and its properties, topological divisor of zero, spectral mapping theorem for polynomials.

Quotient algebra, complex homomorphism, isomorphism, ideals, maximal ideals, radical, weak topology, weak* topology in normed linear spaces, Banach Alaoglü Theorem, Gelfand topology, Banach * algebra, B* algebra, involution, Gelfand Neumark Theorem.

References:

1. W. Rudin, Functional Analysis, TMG Publishing Co. Ltd., New Delhi, 1973.
2. Brown and Page, Elements of Functional Analysis, Von Nostrand Reinhold Co., 1970
3. A.E. Taylor, Functional Analysis, John Wiley and Sons, New York, 1958.
4. G. Bachman and L. Narici, Functional Analysis, Academic Press, 1966
5. B.V. Limaye, Functional Analysis, 2nd Edition, New Age International Private Limited New Delhi, 2014.

6. E. Kreyszig, Introductory Functional Analysis with Applications, Wiley Eastern, 1989.

MTM-405A	**Special Paper: Advanced Differential Geometry-II**	50 (3-1-0)

Almost Complex manifolds, Nijenhuis tensor, Eigenvalues of the complex structure, Complex manifold, Almost Hermite manifold, Ka¨ hler manifold, Holomorphic sectional curvature, Bochner Curvature tensor, Affine connection in Ka¨ hler manifold, Conformally flat Ka¨ hler manifold.

Contact manifold, almost contact manifold, Killing vector field, Properties of φ, K-contact manifold, some curvature properties, Sasakian manifold, φ-sectional curvature, C-Bochner curvature tensor, almost para-contact structure and it's properties.

References:

1. R.S. Mishra, Structure on a Differentiable Manifold and their Applications, Chandrama Prakashani, Allahabad, 1984.
2. K. Yano & M. Kon, Structures on Manifolds, World Scientific, 1984.
3. D.E. Blair, Contact Manifolds in Riemannian Geometry, Lecture note in Math, 509, Springer-Verlag 1976.

MTM-404B	**Special Paper-OR: Advanced Optimization-II**	50 (3-1-0)

Optimization: Nature and Scope of optimization, Optimality criterion of linear programming, Application of Farka's theorem, Existence theorem for linear systems, Theorems of the alternatives, Slater's theorem of alternatives, Motzkin theorem of alternatives, Optimality in the absence of differentiability, Constraint qualification, Karlin's constraint qualification, Kuhn-Tucker's saddle point theorem, Fritz-John saddle point theorem, Optimality criterion with differentiability and convexity, Kuhn-Tucker's sufficient optimality theorem, Fritz-John stationary point optimality theorem, Duality in non-linear programming, Weak duality theorem, Wolfe's duality theorem, Duality for quadratic programming.

Stochastic Programming: Chance constraint programming technique.

Game Theory: Preliminary concept of continuous game, Bi-matrix games, Nash equilibrium, and solution of bi-matrix games through quadratic programming (relation with nonlinear programming).

Multi-objective Non-linear Programming: Introductory concept and solution procedure.

Fundamentals of Genetic Algorithm, Particle Swarm Optimization and Quantum Particle Swarm Optimization.

References:

1. Mokhtar S. Bazaraa, Hanif D. Sherali and C.M. Shetty, Nonlinear Programming: Theory and Algorithms, John Wiley & Sons, 2006.
2. Olvi L. Mangasarian, Nonlinear Programming, SIAM, 1994.
3. S.S. Rao, Engineering Optimization: Theory and Practice, John Wiley & Sons, 1996.
4. Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research, McGraw-Hill, 2010.
5. Z. Michalawich, Genetic algorithms + Data structures = evolution Programs, 3rd edition, Springer Verlag, 1996.
6. Andrea E. Olsson, Particle Swarm Optimization: Theory, Techniques and Applications, Nova Science Publishers, 2011.

MTM-405B	**Special Paper-OR: Operational Research-II**	25 (2-0-0 or 1-1-0)

Optimal Control: Performance indices, Methods of calculus of variations, Transversally Conditions, Simple optimal problems of mechanics, Pontryagin's principle (with proof assuming smooth condition), Bang–bang Controls.
Reliability: Concept, Reliability definition, System reliability, System failure rate, Reliability of the systems connected in series or / and parallel. MTBF, MTTF, reliability and quality control comparison, reduction of life cycle with reliability, maintainability, availability, Effect of age, stress, and mission time on reliability, reliability optimization.
Information theory: Introduction, Communication processes— memory less channel, the channel matrix, probability relation in a channel, noiseless channel.
A measure of information: Properties of entropy function, Measure of other information quantities — marginal and joint entropies, conditional entropies, expected mutual information, Axiom for an entropy function, properties of entropy function. Channel capacity, efficiency and redundancy. Encoding-Objectives of encoding, Shannon-Fano encoding procedure, Necessary and sufficient condition for noiseless encoding.

References:

1. K. Swarup, P.K. Gupta and Man Mohan, Operation Research, Sultan Chand & Sons.
2. J.K. Sharma, Operation Research – Theory and Application, Macmillan.
3. P.K. Gupta and D.S. Hira, Operation Research, S. Chand & Co. Ltd.
4. H.A. Taha, Operation Research: An Introduction, PHI.
5. R. Bronson and G. Naadimuthu, Theory and problems of Operations Research, Schuam's Outline Series, MGH.
6. Donald E. Kirk, Optimal Control Theory: An Introduction, Dover Publications, 2012.
7. A.S. Gupta, Calculus of Variations with Applications, PHI.

MTM-495B	**Special Paper-OR: Lab. (OR methods using MATLAB and LINGO)**	25 (0-0-4)

Problems on Advanced Optimization and Operations Research are to be solved by using MATLAB (one question carrying 12 marks) and LINGO (one question carrying 8 marks) (Total: 20 Marks)
Following problems are to be solved:
LPP: Simplex method, Revised simplex method. Stochastic programming. Bi-matrix games. Queuing theory. QPP by Wolfe's modified method. IPP by Gomory's cutting plane method. Inventory. Monte Carlo simulation technique. Dynamic programming. Reliability.

Lab Note Book and Viva-Voce (Total: 5 Marks)

MTM-496	**Dissertation Project Work**	50 (8-0-0)

Dissertation Project will be performed on tutorial/ review work on research papers. Marks are distributed as the following: Project Work-25, Presentation-15, and Viva-voce-10. Project work of each student will be evaluated by the concerned internal teacher/supervisor and one external examiner. The external examiner must be present in the day of evaluation.