University of Kalyani

COURSE WORK CURRICULUM FOR Ph.D DEGREE

IN

Mathematics

WITH EFFECT FROM THE ACADEMIC SESSION

2023-24

CURRICULUM FOR ONE SEMESTER COURSE WORK IN Mathematics

Total Credits: 16

Full Marks: 200

Transaction Categories: **RM:** Research Methodology;
ALC: Advanced level course;

Evaluation Categories: TEE: Term End Examination; **IA**: Internal Assessment; **VV:** Viva-voce

OUTLINE OF THE COURSE CURRICULUM

Course Code	Course Title	Marks Allotted (TEE+IA+VV)	Credit
Paper-CW-1	*Research Methodology (A)	30+10+10	4
Paper-CW-2	Research Methodology (B)	30+10+10	4
Paper-CW-3	Advanced level course on subject (A)	30+10+10	4
Paper-CW-4	Advanced level course on subject (B)	30+10+10	4
Total	4 courses	200	16

- All courses are to be conducted by the Department
- Paper-CW-3 shall be chosen from a pool of trans disciplinary recognized subjects

❖ Examination Related Course Criteria

Pattern of questions: preferably multiple-choice questions (single/multi-select)/ rank order scaling questions/ text slider questions/likert scale questions/ stapel scale questions/ constant sum questions/demographic questions/ analytical questions/ any other types of questions as selected fit by respective RAC– carrying 1/2/3/4/ marks each.

Detail Course & Contents of Ph.D. Course Work in Mathematics

Course: Paper-CW-1
Course title: Research Methodology (A)
Credit-4;

Full Marks-50 (TEE 30+IA 10+Viva-voce 10)

COURSE CONTENT: 4 Credits (2+1+1) (TEE+IA+VV)

GROUP - A (Research Ethics and Research Communication for all students)

Unit 1: Ethical Aspects of Undertaking Research

Concept of Philosophy, Basic Philosophical Assumption to Social Science Research, Major Philosophies in Social Science Research, Research Philosophy, Approaches to Theory Development in Research, Ethical Judgements in Research

Unit 2: Managing Scientific Conduct

Concept of Academic Integrity: Integrity Concepts, Academic integrity; Scientific Misconduct and Research Fraud (Falsification, Fabrication and Plagiarism: FFP): Scientific misconduct, Research Fraud, Intellectual Honesty in Research; Redundant publications: Duplicate and Overlapping publications, Salami Slicing; Selective Reporting and Misrepresentation of Data: Selective Reporting, Misrepresentation of Data

Unit 3: Publication Ethics

Concept of Publication Ethics, Research Ethics: Concept and Objectives, Ethics Committee, Managing Publication Ethics through Best Practices Standards: COPE, WAME; Publication & Research Misconduct: Concept of Research Misconduct, Concept of Plagiarism, Nature of Plagiarism, UGC Guidelines on Levels of Plagiarism, Plagiarism : AI vs AI; Plagiarism Detection Software-Selection of Appropriate Software, Violation of Publication Ethics, Authorship and Contributorship - Conflict of Interest: Note on Violation of Publication Ethics, Authorship and Contributorship, Conflict of Interest; Identification of Publication Misconduct and Appeal; Concept of Publication Misconduct, Responding to allegations of possible misconduct; Predatory Journals and Publishers: Backdrop, Meaning of Predatory Journal, Characteristics of a Predatory Journal; Way to Find Predatory Journals and Publishers, Role of Academic Community to Fight Against Predatory Publication

Unit 4: Scientific Writing

Structure and components of Scientific Reports, Preparation of Project Proposal, Preparation of manuscript for Seminar Presentation and Publication of Research paper, Components of Doctoral Thesis, Footnotes and Referencing Styles.

Group – C (Syllabus for Computer Applications)

Preliminary knowledge of Computer Technology, Peripheral devices and their uses; Preliminary knowledge of Operating Systems; Basics of Word processing, spreadsheet and slides preparation (offline and cloud-based software).

Office Tools & Technology : Office document Management, Typesetting, Use of office Tools, Use of layout software, Preparation of Power Point Presentation, Table Management and basic calculations using Excel/other spreadsheet programs; Use of Internet; Digital Access Brokers.

Data Science & Statistical Tools: Statistical packages (R, SPSS etc.), Statistical Computing, Internet Technology and its Internal Architecture; Advanced Spreadsheet operations; Document and slides preparation in LaTeX. Prgramming Language: Matlab, Maple, Lingo20.0.

Course: Paper-CW-2
Course title: Research Methodology (B)
Credit-4;
Full Marks-50 (Report 30 + Presentation 10 + viva-voce 10)

The importance of literature review, obtaining literature sources, searching the literature,

Review of Published research, Documentation/ submission of Reports on Review work and Presentation

Paper-CW-3: Advanced level course on subject (A)*
Trans-disciplinary Components
Full Marks: 50 (TEE: 30; IA: 10; VV: 10)
Credit: 4

Trans disciplinary Components
Shall be chosen from the following Trans disciplinary subjects

Trans-disciplinary subjects

Subjects
OPTIMIZATION TECHNIQUES AND DECISION MAKING USING FUZZY AND ITS VARIANTS
COMPLEX ANALYSIS AND VALUE DISTRIBUTION THEORY

OPERATIONS RESEARCH AND OPTIMIZATION TECHNIQUES
RIEMANNIAN GEOMETRY AND GEOMETRIC EVOLUTION EQUATIONS
MATHEMATICAL BIOLOGY
THEORY OF NONLINEAR WAVES
MODERN THEORY OF PARTIAL DIFFERENTIAL EQUATIONS
ADDITIVE COMBINATORIES
ALGEBRA

Paper-CW-3: Advanced level course on subject (A)*
Trans-disciplinary Components
Full Marks: 50 (TEE: 30; IA: 10; VV: 10)
Credit: 4

Subject: Optimization Techniques and Decision Making using Fuzzy Sets and Its Variants

Research Methodology including Computer Applications

A brief knowledge on the Software: , Matlab, Python, Hyper Lingo, Lindo, Latex, Microsoft Office.

Subject Up-gradation

Operations on Fuzzy Sets, Fuzzy Numbers, Fuzzy Logic, Fuzzy Inference, Fuzzy Control and Fuzzy Expert Systems. Analytic Hierarchy Process, Fuzzy multi objective decision making, multicriteria decision making, Fuzzy mathematical programming, Pythagorean fuzzy programming, Applications of decision making in different areas of real life.

References

1 Fuzzy Sets and Fuzzy Logic: J. G. Klir and B. Yuan
2 Miettinen, K.M. (1999) - Non-linear multi-objective optimization, Kluwer's Academic Publishing.
3 Ehrogott, M. (2005) - Multi-critetion Optimization, Springer Berlin - Heidelberg.
4 Beightler, G. S. and D. T. Phillips (1976) - Applied Geometric Programming. Wiley. New York.
5 Changkong, V. and Haimes Y.Y. (1983) - Multi-objective decision making, North-Holland Publishing, New York, Amsterdam.
6 Cao, B. Y. (2002) : Fuzzy geometric programming, Kluwer Academic Publishers, London.
7 Hadley, G. and Whitin, T.M. (1958): Analysis of inventory systems, Prentice Hall, Englewood clifs, NJ.
8 Kapur, J.N. and Kesavan, H. K. (1992): Entropy Optimization Principles with Applications, Academic Press, San Diego.
9 Wilson, A. G. (1970): Entropy in Urban and Regional Modeling, Pion, London.
10 Zener, C. (1971): Engineering design by geometric programming, Wiley.
11 Kapur, J. N. (1993): Maximum-Entropy Models in Science and Engineering, Wiley Eastern Limited, New Delhi.
12 Fuzzy Control and Modeling: H. Ying
13 Goal Programming and Extensions: J. P. Ignizio
14 Fuzzy Sets and their Applications: H. — J. Zimmermann

Subject: COMPLEX ANALYSIS AND VALUE DISTRIBUTION THEORY

Review of general theory of entire and meromorphic functions, Uniqueness of entire and meromorphic functions sharing values, Growth properties of entire and meromorphic functions,

Deficiencies of meromorphic functions and their generalizations, Infinite products and related problems.

Nevanlinna's first fundamental theorem, Cartan's identity and convexity theorems, Orders of growth, Order of a meromorphic function, Comparative growth of logM(r) and T(r). Nevanlinna's second fundamental theorem, Estimation of S(r), Nevanlinna's theorem on deficient functions, Nevanlinna's five-point uniqueness theorem, Milloux theorem.

Classical Cauchy's bounds for zeros. Enström-Kakeya theorem, Perturbation of critical points, Gauss-Lucas theorem, Hurwitz theorem. Function with real zeros.

Meromorphic solutions to differential equations: Malmquist's theorem, Linear differential-difference equation, meromorphic solution. Bounding radii of discs, Slowly moving targets, Fixed points and iteration.

Iteration of Rational Function: Rational function, polynomial function, iteration of quadratic polynomial $z \to z^2$, fixed point, critical and periodic point, classification of periodic point, exceptional point.

Iteration of Transcendental Function: Entire function, omitted value, Picard's theorem, open mapping theorem, Riemann mapping theorem, types of singularity, singular and asymptotic value, direct and Logarithmic singularity.

References:

1. E. T. Copson**:** An Introduction to the Theory of Functions of a Complex Variable.
2. E. C. Titthmarsh**:** The Theory of Functions.
3. A. I. Markushevich**:** Theory of Functions of a Complex Variable (Vol. I, II &III).
4. L. V. Ahlfors **:** Complex Analysis.
5. C. C. Yang and H. X. Yi: Uniqueness Theory of Meromorphic Functions, Science Press, Beijing (2003).
6. A.S.B. Holland: Introduction to the theory of Entire Functions, Academic Press, New York (1973).
7. J. B. Conway**:** Functions of One Complex Variable.
8. A. I. Markushevich**:** The Theory of Analytic Functions, A Brief Course.
9. G. Valiron**:** Integral Functions.
10. C. Caratheodory**:** Theory of Functions of a Complex Variable.
11. R. P. Boas**:** Entire Functions.
12. W. Kaplan: An Introduction to Analytic Functions.
13. H. Cartan: Theory of Analytic Functions.
14. W. K. Hayman: Meromorphic Functions.
15. L. Yang: Value Distribution Theory.
16. A.F. Beardon: Iteration of rational functions, Springer Verlag, 1991.
17. John Milnor: Dynamics in One Complex Variable, Third edition, Princeten University Press.
18. L. Carleson and T.W. Gamelin: Complex Dynamics, Springer Verlag, 1993.
19. X. Hua, X. Wang and C.C. Yang: Dynamics of Transcendental functions, Springer Verlag.

20. S. Morosawa, Y. Nishimura, M. Taniguchi and T. Ueda: Holomorphic Dynamics, Cambridge studies in advanced Mathematics.

Subject: Operations Research and Optimization Techniques

Inventory Problems, Transportation Problems, Reliability optimization models, Information Theory, Multi-objective Programming Problem, Geometric Programming, Goal Programming, Nonlinear Programming, Dynamic Programming, Linear Fractional Programming, Fuzzy Sets and its variants, Operations on Fuzzy Sets, Fuzzy Numbers, Decision making in crisp and fuzzy environment, Fuzzy multi objective decision making.

References:

1. Fuzzy Sets and Fuzzy Logic: J. G. Klir and B. Yuan
2. Miettinen, K.M. (1999) - Non-linear multi-objective optimization, Kluwer's Academic Publishing.
3. Beightler, G. S. and D. T. Phillips (1976) - Applied Geometric Programming. Wiley. New York.
4. Changkong, V. and Haimes Y.Y. (1983) - Multi-objective decision making, North-Holland Publishing, New York, Amsterdam.
5. Cao, B. Y. (2002) : Fuzzy geometric programming, Kluwer Academic Publishers, London.
6. Hadley, G. and Whitin, T.M. (1958): Analysis of inventory systems, Prentice Hall, Englewood clifs, NJ.
7. Kapur, J.N. and Kesavan, H. K. (1992): Entropy Optimization Principles with Applications, Academic Press, San Diego.
8. Wilson, A. G. (1970): Entropy in Urban and Regional Modeling, Pion, London.
9. Zener, C. (1971): Engineering design by geometric programming, Wiley.
10. Kapur, J. N. (1993): Maximum-Entropy Models in Science and Engineering, Wiley Eastern Limited, New Delhi.
11. Goal Programming and Extensions: J. P. Ignizio
12. Fuzzy Sets and their Applications: $H.-$ J. Zimmermann

Subject: Riemannian geometry and Geometric Evolution Equations

Differentiable manifolds, Tangent spaces, Differential forms, Linear connections, Fundamental theorem of Riemannian geometry, Contact manifolds, Complex manifolds, Ricci flow, Yamabe flow, Ricci solitons, Yamabe solitons and their applications.

References:

1. J. M. Lee, *Introduction to smooth manifolds*.
2. J. M. Lee, *Riemannian manifolds, An introduction to curvature*.
3. D. E. Blair, *Riemannian geometry of contact and symplectic manifolds*.
4. R. S. Hamilton, *Theory of Ricci flow*.

Subject: Mathematical Biology

Density dependent and ratio-dependent models, delay models, stochastic models, non-existence of periodic solutions for higher dimensional models, maximum sustainable yield in harvesting. Turing model, conditions for diffusive stability and instability, pattern generation with single species model. Stochastic epidemic model. Models with more than one disease strain. Stability conditions of single strain and multi-strain. Models of emerging diseases: Ebola, HIV and SARS. Quarantine and isolation modelling techniques.

Survey of relevant papers.

Basic knowledge on the Software: Matlab, Python, Latex, Microsoft Office

Reference books

1. S.L.Ross: Diffrential Equations.
2. G.Birkhoff and G.C.Rota: Ordinary Differential Equations.
3. I. N. Sneddon : The Use of Integral Transforms.
4. C. E. Froberg : Introduction to Numerical Analysis.
5. F. B. Hilderbrand: Introduction to Numerical Analysis.
6. K. Atkinson and W. Cheney : Numerical Analysis.
7. F. Seheid : Numerical Analysis.
8. Mark Kot : Population Biology.
9. J.D. Murray : Mathematical Biology.
10. H.L. Smith, P. Waltman: The Theory of the Chemostat: Dynamics of Microbial Competition.
11. M.A.Nowak and R.M.May: Virus Dynamics.
12. K.Gopalsamy: Stability and Oscillations in Delay Differential Equations of Population Dynamics.
13. Hall Smith: An Introduction to Delay Differential Equations with Applications to the Life Sciences.
14. Y.Kuang: Delay Differential Equations with Applications in population dynamics.
15. J.Guckenheimer and P.Holmes: Nonlinear Oscillations of Dynamical Systems.

Subject: Theory of Nonlinear Waves

Prerequisite: Special functions, Elliptic functions, Ordinary and partial differential equations.

Nonlinear Model Equations and Variational Principles: Basic Concepts and Definitions, Some Nonlinear Model Equations, Variational Principles and Euler-Lagrange Equation, Variational Principle for Nonlinear Water Waves and for Nonlinear Models.

Conservation Laws and Shock Waves: Conservation Laws, Discontinuous Solutions and Shock Waves, Weak or Generalized Solutions.

Nonlinear Dispersive Waves and Whitham's Equations: Linear Dispersive Waves, Wave Packet and Dispersion, Initial Value Problems and Asymptotic Solutions, Nonlinear Dispersive Waves and Whitham's Equations, Whitham's Theory of Nonlinear Dispersive Waves, Whitham's Averaged Variational Principle, Whitham's Instability Analysis and its Application to Water Waves.

Nonlinear Diffusion-Reaction Phenomena, Burger's and Fisher's Equation: Burger's Equation and Plane Wave Solution, Traveling Wave Solutions and Shock-Wave Structure, Cole-Hopf Transformation and Exact Solution of Burger's Equation and its Asymptotic Behaviour, N-Wave Solution, Fisher's Equation and Diffusion-Reaction Process, Traveling Wave Solution and Stability Analysis, Nonlinear Reaction-Diffusion Equations.

Solitons, Integrability and The Inverse Scattering Transform: Solitons and Soliton Interaction, Boussinesq and KdV Equation, Traveling Wave Solutions of the KdV Equation-Solitons and Cnoidal Waves, Lie Group Method and Similarity and Rational Solutions of Kdv Equation, Miura Transformations, Conservation Laws and Nonlinear Transformations, Time Independent Schrödinger Equation and Compatible Linear System, Inverse Scattering Transform Method, Lax Formulation-its Kdv Hierarchy and Zakharov-Shabat Scheme, AKNS Method.

The Nonlinear Schrödinger Equation and Solitary Waves: One Dimensional Linear Schrödinger Equation, Derivation of Nonlinear Schrödinger Equation and Solitary Waves, Conservation Laws and IST Method for the Nonlinear Schrödinger Equation, Application to Nonlinear Optics.

Bilinearization of Soliton Equations and Integrability: Linearization of Nonlinear Differential Equations, The Hirota D-Operator, Bilinearization of Nonlinear Differential Equations, Solutions of Bilinear Equations, Transformation from Bilinear to Nonlinear Form. Bäcklund Transformation for Kdv Type Equations, KP and BKP Equation, Notion of Integrability, Painleve Analysis and Integrability, Symmetries and Integrability.

Fundamentals of MATLAB, MATHEMATICA, MAPLE, Microsoft OFFICE and LATEX.

References:

1. Nonlinear Partial Differential Equations for Scientists and Engineers: Lokenath Debnath.
2. Linear and Nonlinear Waves: G.B. Whitham.
3. Nonlinear Dispersive Waves-Asymptotic Analysis and Solitons: M.J. Ablowitz.
4. Solitons, Nonlinear Evolution Equations and Inverse Scattering: M.J. Ablowitz, P.A. Clarkson.
5. Nonlinear Dynamics-Integrability, Chaos and Patterns: M. Lakshmanan, S. Rajasekar.
6. The Direct Method in Soliton Theory: R. Hirota.

Subject: Modern Theory of Partial Differential Equations

Theory of distributions: Test functions and distributions, supports and singular supports of distributions, regular and singular distributions, generalised derivatives, convolution of functions, convolutions of distributions, fundamental solutions, Fourier transform, Schwartz space, Fourier inversion formula, Tempered distributions.

Sobolev Spaces: Definition and basic properties, approximation by smooth functions, dual spaces, continuous imbedding, compact imbedding and trace results.

Elliptic Boundary Value Problems: abstract variational problems, Lax-Milgram Lemma, weak solutions and well posedness with examples, regularity result, maximum principles, eigenvalue problems.

Semigroup Theory and Applications: Unbounded linear operators, The exponential map, C_0-Semigroup, The Hille-Yosida theorem. Contraction Semigroup on Hilbert Spaces, the heat equation, the wave equation, the schrodinger equation, the inhomogenious equations.

Literature review including Computer application :
Some fixed point theorems, montone iterations, variational method. Working knowledge of latex.

Survey on relevant research article.

Referernces:

(1). S. Kesavan, Topics in Functional Analysis Wiley Eastern Ltd., New Delhi, 1989.
(2) M. Renardy and R.C. Rogers, An Introduction to Partial Differential Equations,2 nd Edition, Springer Verlag International Edition, New York, 2004.
(3) L.C. Evans, Partial Differential Equations, American Mathematical Society, Providence, 1998.(4). Walter Rudin, Real and Complex Analysis.

Subject: Additive Combinatorics

Basic Group theory, Basic point set topology, Measure and Integration(Algebra of Sets, Measure, Integration, Fubini Theorem, Radon-Nikodym Theorem, Signed measure, Convolution, Haar measure) Functional Analysis (Banach spaces, Hilbert spaces, Operator theory). * As far as possible in the due course of time.

References:

1. M. A. Armstrong, Basic Topology,
2. J. B. Conway, A Course in Functional Analysis,
3. G. F. Simmons, Mordern Analysis,
4. K. B. Athreya and S. Lahiri, Measure and Integration.

Subject: Algebra

Algebra: Permutations, combinations, pigeon-hole principle, inclusion-exclusion principle, derangements.

Fundamental theorem of arithmetic, divisibility in Z, congruences, Chinese Remainder Theorem, Euler's Ø-function, primitive roots.

Groups, subgroups, normal subgroups, quotient groups, homomorphisms, cyclic groups, permutation groups, Cayley's theorem, class equations, Sylow theorems.

Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain.

Polynomial rings and irreducibility criteria.

Finitely Generated Abelian Group: Basis theorem, canonical decomposition, free abelian group, fundamental theorem of finite abelian group, isomorphism classes of abelian group, existence of subgroups in abelian group.

Fields, finite fields, field extensions, Galois Theory.

Topology: basis, dense sets, subspace and product topology, separation axioms, connectedness and compactness.

Course: Paper-CW-4
Course title: Advanced level course on subject (A)
Credit-4;

Full Marks-50 (TEE 30+IA 10+Viva-voce 10)

Subject Specific Components

UNIT – 1

Analysis: Elementary set theory, finite, countable and uncountable sets Real number system as a complete ordered field, Archimedean property, supremum, infimum.

Sequences and series, convergence, limsup, liminf. Bolzano Weierstrass theorem, Heine Borel theorem.

Continuity, uniform continuity, differentiability, mean value theorem.

Sequences and series of functions, uniform convergence.

Riemann sums and Riemann integral, Improper Integrals.

Monotonic functions, types of discontinuity, functions of bounded variation, Lebesgue measure, Lebesgue integral.

Functions of several variables, directional derivative, partial derivative, derivative as a linear transformation, inverse and implicit function theorems.

Metric spaces, compactness, connectedness. Normed linear Spaces. Spaces of continuous functions as examples.

Linear Algebra: Vector spaces, subspaces, linear dependence, basis, dimension, algebra of linear transformations.

Algebra of matrices, rank and determinant of matrices, linear equations.

Eigenvalues and eigenvectors, Cayley-Hamilton theorem.

Matrix representation of linear transformations. Change of basis, canonical forms, diagonal forms, triangular forms, Jordan forms.

Inner product spaces, orthonormal basis. Quadratic forms, reduction and classification of quadratic forms.

UNIT – 2

Complex Analysis: Algebra of complex numbers, the complex plane, polynomials, power series, transcendental functions such as exponential, trigonometric and hyperbolic functions. Analytic functions, Cauchy-Riemann equations.

Contour integral, Cauchy's theorem, Cauchy's integral formula, Liouville's theorem, Maximum modulus principle, Schwarz lemma, Open mapping theorem.

Taylor series, Laurent series, calculus of residues.

Conformal mappings, Mobius transformations.

Algebra: Permutations, combinations, pigeon-hole principle, inclusion-exclusion principle, derangements.

Fundamental theorem of arithmetic, divisibility in Z, congruences, Chinese Remainder Theorem, Euler's Ø- function, primitive roots.

Groups, subgroups, normal subgroups, quotient groups, homomorphisms, cyclic groups, permutation groups, Cayley's theorem, class equations, Sylow theorems.

Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain.

Polynomial rings and irreducibility criteria.

Fields, finite fields, field extensions, Galois Theory.

Topology: basis, dense sets, subspace and product topology, separation axioms, connectedness and compactness.

UNIT – 3

Ordinary Differential Equations (ODEs): Existence and uniqueness of solutions of initial value problems for first order ordinary differential equations, singular solutions of first order ODEs, system of first order ODEs.

General theory of homogenous and non-homogeneous linear ODEs, variation of parameters, Sturm-Liouville boundary value problem, Green's function.

Partial Differential Equations (PDEs): Lagrange and Charpit methods for solving first order PDEs, Cauchy problem for first order PDEs.

Classification of second order PDEs, General solution of higher order PDEs with constant coefficients, Method of separation of variables for Laplace, Heat and Wave equations.

Calculus of Variations: Variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema. Variational methods for boundary value problems in ordinary and partial differential equations.

Linear Integral Equations: Linear integral equation of the first and second kind of Fredholm and Volterra type, Solutions with separable kernels. Characteristic numbers and eigenfunctions, resolvent kernel.

UNIT – 4

Numerical Analysis: Numerical solutions of algebraic equations, Method of iteration and Newton-Raphson method, Rate of convergence, Solution of systems of linear algebraic

equations using Gauss elimination and Gauss-Seidel methods, Finite differences, Lagrange, Hermite and spline interpolation, Numerical differentiation and integration, Numerical solutions of ODEs using Picard, Euler, modified Euler and Runge-Kutta methods.

Classical Mechanics: Generalized coordinates, Lagrange's equations, Hamilton's canonical equations, Hamilton's principle and principle of least action, Two-dimensional motion of rigid bodies, Euler's dynamical equations for the motion of a rigid body about an axis, theory of small oscillations.

Operational Research Modelling: Definition and scope of Operational Research. Different types of models. Replacement models and sequencing theory, inventory problems and their analytical structure. Simple deterministic of queueing system, different performance measures. Steady state solution of Markovian queueing models : M/M/1, M/M/1 with limited waiting space M/M/C, M/M/C with limited waiting space. 16. Linear Programming - Linear Programming. Simplex method, Duality in linear programming. Transformation and assignment problems. Two person-zero sum games. Equivalence of rectangular game and linear programming.

Mathematical Programming: Revised simplex method. Dual simplex method, Sensitivity analysis and perametric linear programming. Kuhn-Tucker conditions of optimality. Quadratic programming; methods due to Beale, Wofle and Vandepanne, Duality in quadratic programming, self duality, Integer programming.

Inventory and Queueing theory : Inventory (S,s) policy, periodic review models with stochesitic demand. Dynamic inventory models. Probabilistics re-order point, lox size inventory system with and without lead time. Distribution free analysis. Solution of inventory problem with unknown density function. Warehousing problem. Queues : Imbeded markov chain method to obtain steady state solution of M/G/1,G/M/1 and M/D/C, Network models. Machine maintenance models. Design and control of queing systems.

Dynamic Programming: Nature of dynamic programming, Determinstic processes, Non-sequential discrete optimisation-allocation problems, assortment problems. Sequential discrete optimisation long-term planning problems, multistage production processes.

SUGGESTED READINGS/REFERENCES:

1. W. Rudin**:** Principles of Mathematical Analysis.
2. H. L. Royden**:** Real Analysis.
3. W. Sierpinsky**:** Cardinal Number and Ordinal Number.
4. I. P. Natanson**:** Theory of Integrals of a Real Variable (Vol. I and II).
5. Malik and Arora: Mathematical Analysis
6. R. V. Churchill and J. W. Brown **:** Complex Variables and Applications.

7. E. T. Copson **:** An Introduction to the Theory of Functions of a Complex Variable.
8. J. B. Conway **:** Functions of One Complex Variable.
9. L. V. Ahlfors **:** Complex Analysis.
10. H. S. Kasana **:** Complex Variables – Theory and Applications.
11. 11. S. Ponnusamy, Foundation of Complex Analysis.
12. E. Kreyszig**:** Introductory Functional Analysis with Applications.
13. W. Rudin**:** Functional Analysis.
14. A. E. Taylor**:** Introduction to Functional Analysis.
15. B. V. Limaye**:** Functional Analysis.
16. M.K. Sen, S. Ghosh and P. Mukhopadhyay, Abstract Algebra, University Press.
17. Luthar & Passi – Algebra (Vol. 1).
18. John B. Fraleigh, A First Course in Abstract Algebra, 7th Ed., Pearson, 2002.
19. I. N. Herstein, Topics in Algebra, Wiley Eastern Ltd. New Delhi, 1975.
20. T. W. Hungerford, Algebra, Springer, 1980.
21. Joseph J. Rotman, An introduction to the theory of groups, Springer-Verlag, 1990.
22. M. Artin, Abstract Algebra, 2nd Ed., Pearson, 2011.
23. Malik, Mordeson and Sen, Fundamentals of Abstract Algebra, McGraw-Hill, 1997.
24. S. Lang, Algebra (2nd ed.), Addition-Wesley.
25. N. Jacobson – Lecturers in Abstract Algebra.
26. G. Hadley, Linear Programming
27. G. Hadley, Nonlinear and Dynamic Programming.
28. K. Swarup, P. K. Gupta and Man Mohan, Operations Research
29. H. A. Taha, Operations Research.
30. S. D. Sharma, Operations Research.
31. Optimization: Theory and Applications – S. S. Rao.
32. Nonlinear and Mixed-Integer Optimization – Christodoulos A. Floudas.
33. G. F. Simmons : Differential Equations.
34. E. E. Coddington and N. Levinson : Theory of Ordinary Differential Equations.
35. M. Birkhoff and G. C. Rota **:** Ordinary Differential Equations.
36. E. L. Ince **:** Ordinary Differential Equations
37. N. N. Lebedev **:** Special Functions and Their Applications.
38. I. N. Sneddon **:** Special Functions of Mathematical Physics and Chemistry.
39. E. D. Rainville **:** Special Function
40. A. K. Nandakumaran and P. S. Datti, Partial Differential equations, Cambridge University Press, 2020.
41. L. C. Evans, Partial Differential equations, Vol 19, AMS
42. G. Evans, Analytic methods for partial differential equations, Springer, 2001.
43. T. Amaranath, An elementary course in partial differential equations, Narosa, 2014.
44. K. Sankara, Rao, Introduction to partial differential equations, PHI, 2015.
45. I. N. Sneddon, Elements of partial differential equations, Mc Grew Hill, New York, 1957.
46. A.S. Gupta: Calculus of Variations with Applications, Prentice –Hall of India.
47. I.M. Gelfand and S.V. Fomin, Calculus of Variations, Prentice Hall Inc.
48. L. Elsgolts: Differential equations and the Calculus of Variations.
49. S. Sokolnikoff: Mathematical Theory of Elasticity.
50. Y. C. Fung: Foundations of Solid Mechanics.
51. M. A. Armstrong, Basic Topology, Springer (India), 2004,
52. J.R. Munkres, Topology, 2nd Ed., PHI (India), 2002,
53. J. M. Lee : Introduction to topological Manifolds,
54. G.F. Simmons, Introduction to Topology and Modern Analysis, McGraw- Hill, New York,

1963.
55. E. T. Whittaker **:** A Treatise of Analytical Dynamics of Particles and Rigid Dynamics.
56. Greenwood **:** Dynamics.
57. F. Chorlton **:** Dynamics.
58. Routh **:** Dynamics.
59. H. Lamb **:** Dynamics.
60. R. G. Takwale and P. S. Puranik **:** Introduction to Classical Mechanics.
61. H. Goldstein **:** Classical Mechanics.
62. Classical Mechanics: N. C. Rana and P.S. Joag.
63. F. Chorlton: Textbook of Fluid Dynamics.
64. A.S. Ramsey: A Treatise on Hydromechanics Part II.
65. L. D. Landau and E. M. Lipschitz**:** Fluid Mechanics.
66. M. D. Raisinghania: Integral Equations and Boundary Value Problems.
67. R. P. Kanwal**:** Linear Integral Equations.
68. S. G. Michelins**:** Linear Integral Equations.
69. K. E. Atkinson, An Introduction to Numerical Analysis, 2nd Edition, Wiley-India.
70. Froberg, C. E. – Introduction to Numerical Analysis.
71. Hildebrand, F.B. – Introduction to Numerical Analysis.
72. Atkinson, K. and Cheney, W. – Numerical Analysis.
73. Powell, M. – Approximation Theory and Methods.
74. Jain, M. F., Iyenger, S. R. K. and Jain, R.K. – Numerical Methods for Scientific and Engineering Computation.
75. Sastry, S. S. – Introductory Methods of Numerical Analysis.
76. K. Hoffman and R. Kunze**:** Linear Algebra.
77. J. H. Kwak and S. Hong**:** Linear Algebra.
78. E. D. Nering: Linear Algebra and Matrix Theory.
79. T. S. Blyth: Module Theory.
80. I. S. Luthar and I. B. S. Passi**:** Modules.

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