गणित विभाग
Department of Mathematics
राष्ट्रीय प्रौद्योगिकी संस्थान श्रीनगर
National Institute of Technology Srinagar

PhD Courses offered by the Department of Mathematics

(w.e.f. Autumn-2024)

S.No.	Name of the Course	Course Code	Credits
1	External properties of polynomials	RSMTH-100	3
2	Bounds for the zeros of polynomials	RSMTH-101	3
3	Research Methodology	RSMTH-104	3
4	Differentiable Manifolds	RSMTH-107	3
5	Structures on Manifolds	RSMTH-108	3
6	Numerical Solution of Differential Equations	RSMTH-109	3
7	Fitted Numerical Methods for singular Perturbation Problems	RSMTH-110	3
8	Abstract Algebra	RSMTH-111	3
9	Advanced Algebra & Combinatorics	RSMTH-112	3
10	Applied Statistics	RSMTH-113	3
11	Optimization Techniques	RSMTH-114	3
12	Graph Theory	RSMTH-115	3
13	Spectral Graph Theory	RSMTH-116	3
14	Functions of Complex variables	RSMTH-117	3
15	Functions of Hypercomplex Variable	RSMTH-118	3
16	Seminar	RSMTH-120	1
17	Frames & Wavelets	RSMTH-121	3
18	Time Frequency Analysis	RSMTH-122	3
19	Advanced Geometry of Curves and Surfaces	RSMTH-123	3
20	Finite Element Methods	RSMTH-124	3
21	Computational Fluid Dynamics	RSMTH-125	3
22	Numerics of Partial Differential Equations	RSMTH-126	3
23	Commutative Algebra	RSMTH-127	3
24	Advanced Commutative Algebra	RSMTH-128	3
25	Functional Analysis	RSMTH-129	3
26	Advanced Functional Analysis	RSMTH-130	3
27	Fourier Analysis	RSMTH-131	3
28	Measure Theory and Integration	RSMTH-132	3

Dr. Bilal Ahmad Wani
Ph.D. Coordinator

Head
Department of Mathematics

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Extremal Properties of polynomials	RSMTH-100	3-0-0-3
Evaluation Policy	**Mid-Term**	**InternalAssessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

	Contents	Hours
Module 1	**<u>Derivative Estimates and Growth:</u>** Bernstein Theorem and its generalizations, Erdos-Lax Theorem, its refinements and generalizations, Saff Conjecture and related results, Turan's Theorem and some of its recent refinements, Self-inverse and Self reciprocal Polynomials. Bounds for the maximum modulus of a polynomial on a larger circle $\|z\|=R$, $R \geq 1$ and on the smaller circle $\|z\|=r$, $r \leq 1$ in terms of maximum modulus of a polynomial on the unit circle. Maximum modulus of a polynomial with restricted zeros. Ankeny-Rivlin Theorem, its refinements, generalizations and other related results.	14
Module 2	**<u>Inequalities Preserved by some special Operators:</u>** Inequalities concerning the polar derivative of a Polynomial, B-Operator and inequalities preserved by this operator between Polynomials and some other similar operators, inequalities for a polynomial with prescribed zeros.	14
Module 3	**<u>Integral Mean Estimates for Polynomials:</u>** Zygmund's Inequality, de-Bruijn's Theorem and some of its generalizations, a theorem of Boas and Rahman, Subordination Principle and its use in proving some Zygmund type inequalities.	14

Text Books/ References:

1. T. Sheil-Small, Complex Polynomials, Cambridge University Press, (2009).

2. Q. I. Rahman and G. Schmeisser, Analytic Theory of Polynomials. Oxford Univ. Press, (2002).

3. G. V. Milovanovic, D. S. Mitrinovic, Th. M. Rassias, Topics in Polynomials, Extremal Problems, Inequalities, Zeros. World Scientific, Singapore, (1994).

4. A. Mir; inequalities concerning rational functions with prescribed poles, Indian J. Pure Appl. Math., 50(2): 315-331, June 2019.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Bounds for the Zeros of Polynomials	RSMTH-101	3-0-0-3
Evaluation Policy	Mid-Term	Internal Assessment	End-Term
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Geometry of zeros of a polynomial:** Cauchy's Classical Theorem for the zeros of a polynomial and its generalisations and related results, A Theorem of Montel and Marty and related results, p-zeros of smallest modulus, Pellet's Theorem.	14
Module 2	**Critical points of a polynomial:** Critical points in terms of zeros, Fundamental results and critical points, Gauss Lucas Theorem and its applications, Grace Heawood Theorem, Polar derivative of polynomials, Laguerre's Theorem, Landu's Theorem, Apolar polynomials, Grace's Theorem and Walsh's coincidence Theorem and their generalisations by A. Aziz.	14
Module 3	**Enestrom-Kekeya Theorem and stability for polynomials:** Enestrom-Kekeya Theorem and its generalisations due to Joyal, Labelle and Rahman, Govil and Rahman, Dewan and Bidkham, Aziz and Zargar, Egervary, Aziz and Mohammad and Jain, Aziz and Shah, Shah and Liman. Stable polynomials, Rowth Hurwitz criteria, Shur stability and related results due to Rubio-Massegu and Diaz Barrero, instability of family of complex coefficient polynomials.	14

Text Books/ References:

1. M. Marden, Geometry of Polynomials, 2nd ed., Mathematical survey's Number 3, Amer. Math. Soc., Providence, RI, (1966).

2. G. Polya and G. Szego, Problems and Theorems in Analysis, vol. 1 (New York : Springer verlag) (1972).

3. G. V. Milovanovic, D. S. Mitrinovic, Th. M. Rassias, Topics in Polynomials, Extremal Problems, Inequalities, Zeros. World Scientific, Singapore, (1994).

4. William "Ty" Frazier and Robert Gardner, An Enestrom–Kakeya theorem for new classes of polynomials, Acta Et Commentationes Universitatis Tartuensis De Mathematica Volume 23, Number 1, June 2019.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Research Methodology	RSMTH-104	3-0-0-3
Evaluation Policy	Mid-Term	Internal Assessment	End-Term
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Scientific research and literature survey:** History of mathematics, finding and solving research problems, role of a supervisor, survey of a research topic, publishing a paper, reviewing a paper, research grant proposal writing, Copy right-royalty, intellectual property rights and patent law. Plagiarism, citations and acknowledgement. Research tools. Searching google (query modifiers), MathSciNet, ZMATH, Scopus, ISI Web of Science, Impact factor, h-index, Google Scholar, ORCID, JStor, Online and open access journals, Virtual library of various countries.	**14**
Module 2	**Linear Algebra:** Eigenvalues and eigenvectors, similarity, diagonalization, Unitary similarity and unitary equivalence, Schur's theorem and its consequences, Normal matrices and spectral theorem, Singular value decomposition, Location and perturbation of eigenvalues, Gersgorin disc theorem, Ostrowski theorem.	**14**
Module 3	**Mathematical Software:** Introduction to LaTeX. Structure of LaTeX document. Defining class of the document through document class. Packages and different environments. Writing the first LaTeX content. Creating a Title, chapters and sections and their labeling. Additionally, basics of LaTeX syntax will be introduced. Page style, fonts, font sizes, font styles. Introduction to mathematics environment, writing Greek symbols and some basic mathematics type structure like fractions, superscript, subscript, overline, underline etc. Matrix, determinant and other similar structure. Equations and Arrays. Introduction to amsmath package. Citation in LaTeX using BibTeX. Bibliography styles. Presentations in LaTeX. Introduction to beamer class. Introduction to MATLAB and Maple for solving various mathematical problems.	**14**

Books Recommended:

1. J. Stillwell, Mathematics and its History, Springer International Edition, 4th Indian Reprint, 2005.
2. Kitsakorn Locharoenrat Research Methodolgies for Beginners, Pan Stanford Publishing Pte. Ltd Singapore, 2017.
3. L. Lamport, LaTeX, Document Preparation System, 2nd ed, Addison-Wesley, 1994.
4. Leslie Lamport, LaTeX, a Document Preparation System, Pearson, 2008.
5. R. Horn, C. Johnson, Matrix Analysis, Cambridge University Press, 2013.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Differentiable Manifolds	RSMTH-107	3-0-0-3
Evaluation Policy	Mid-Term	InternalAssessment	End-Term
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Differentiable manifolds:** Definition, Coordinate charts, stereographic projection, transition functions, Examples of Differentiable manifolds: circle, sphere, projective space, GL(n, R), SL(2), product manifolds, Tangent spaces, Structure equation of Cartan, Bianchi's identities.	14
Module 2	**Riemannain Geometry:** Riemannian metric, Riemannian connection, Fundamental theorem of Riemannian Geometry, Levi-Civita connection, Induced metric, Geodesics and parallel transport, Curvature: Riemannian curvature, Sectional Curvature, Ricci Curvature, Scalar curvature, theorem of Cartan on the determination of the metric by means of the curvature.	14
Module 3	**Complex Manifolds:** Almost complex structure, Conditions for existence of an almost complex structure, almost complex structure on a complex manifold, The Nijenhuis tensor, Vanishing of the Nijenhuis tensor as necessary and sufficient condition for integrability. Hermitian structure on vector spaces, Hermitian manifolds.	14

Text Books/ References:

1. M. P. Do Carmo, Riemannian Geometry, Birkhauser, 1992.
2. S. S. Chern, W.H. Chen, and K.S. Lam, Lectures on Differential Geometry, World, Scientific, 2000.
3. J. M. Lee, Introduction to smooth manifolds, Springer, 2006.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Structures on Manifolds	RSMTH-108	3-0-0-3
Evaluation Policy	**Mid-Term**	**InternalAssessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Geometry of Submanifolds:** Induced connection and second fundamental form, Curvature of submanifolds, Gauss map, Gauss and Weingarten formula, Gauss, Codazzi and Ricci equations, basic inequalities for Riemannian submanifolds. .	14
Module 2	**Complex Structures on Manifolds:** Kaehler structure on a manifold, Holomorphic sectional curvature and the space of constant holomorphic sectional curvature (complex space form), Kaehler analogue of Schur's Theorem, An example of a Kaehler manifold, Kaehlerian submanifolds (Invariant, Anti-invariant, slant submanifolds, bi-slant).	14
Module 3	**Contact Structures on Manifolds:** Almost contact structure on a smooth manifold, Contact manifolds, Torsion tensor of an almost contact manifold, Killing vector field, K-contact manifold, Sasakian manifolds, φ-sectional curvature, Generalized Sasakian space forms.	14

Text/Reference Books:

1. B. Y. Chen, Geometry of submanifolds, Dover Publications Inc., 2019.
2. D. E. Blair: Contact Manifolds in Riemannian geometry, Lecture Notes in Maths. 509, Springer-Verlag, Berlin, 1976.
3. K. Yano and M. Kon: Structures on Manifolds, World Scientific Press, 1985.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Numerical Solution of Differential Equations	RSMTH-109	3-0-0-3
Evaluation Policy	Mid-Term	InternalAssessment	End-Term
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Ordinary Differential Equations:** Multistep (Explicit and Implicit) Methods for Initial Value Problems, Stability and convergence analysis, Linear and nonlinear boundary value problems, Quasilinearization. Shooting methods.	14
Module 2	**Finite Difference Methods:** Finite difference approximations for derivatives, boundary value problems with explicit boundary conditions, Implicit boundary conditions, Error analysis, Stability analysis, and Convergence analysis. Cubic splines and their application for solving two-point boundary value problems.	14
Module 3	**Partial Differential Equations:** Finite difference approximations for partial derivatives and finite difference schemes for Parabolic equations: Schmidt's two-level, Multilevel explicit methods, Crank-Nicolson's two-level, Multilevel implicit methods, Dirichlet's problem, Neumann problem, Mixed boundary value problem. Hyperbolic Equations: Explicit methods, implicit methods, One space dimension, two space dimensions, ADI methods. Elliptic equations: Laplace equation, Poisson equation, iterative schemes, Dirichlet's problem, Neumann problem, mixed boundary value problem, ADI methods.	14

Text Books/ References:

1. M.K.Jain: Numerical Solution of Differential Equations, Wiley Eastern, Delhi, 1983.
2. G.D.Smith: Numerical Solution of Partial Differential Equations, Oxford University Press, 1985.
3. P.Henrici : Discrete variable methods in Ordinary Differential Equations, John Wiley, 1964.
4. A.R. Mitchell: Computational Methods in Partial Differential equations, John Wiley & Sons, New York, 1996.
5. Steven C Chapra, Raymond P Canale: Numerical Methods for Engineers, Tata McGraw Hill, New Delhi, 2007.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Fitted Numerical Methods for Singular Perturbation Problems	RSMTH-110	3-0-0-3
Evaluation Policy	**Mid-Term**	**InternalAssessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Uniform numerical methods for problems with initial and boundary layers:** Initial value problems- some uniformly convergent difference schemes, constant fitting factors, optimal error estimates. Boundary value problems- constant fitting factors for a self-adjoint problem	14
Module 2	**Uniform numerical methods for problems with initial and boundary layers:** non-self-adjoint problem, self-adjoint problem in conservation form, non-self-adjoint problem in conservation form, problems with mixed boundary conditions, fitted versus standard method, experimental determination of order or uniform convergence.	14
Module 3	**Fitted numerical methods for boundary layer problems:** Simple fitted mesh methods in one dimension, convergence of fitted mesh finite difference methods for linear convection-diffusion problems in one-dimension, linear convection-diffusion problems in two dimensions and their numerical solutions, fitted numerical methods for problems with initial and parabolic boundary layers.	14

Text Books/ References:

1. "Numerical Methods for Singularly Perturbed Differential Equations: Convection-Diffusion and Flow Problems" by Hans-Görg Roos, Martin Stynes, and Lars Tobiska (Springer, 1996).
2. "Singular Perturbation Methods in Control: Analysis and Design" by Petar V. Kokotovic, Hassan K. Khalil, and John O'Reilly (SIAM, 1999).
3. "Singular Perturbations and Boundary Layer Theory" by John Kevorkian and Joseph D. Cole (Springer, 2012).
4. "Numerical Solution of Singular Perturbation Problems" by Zhensheng Huang and Jian Li (World Scientific, 2015).
5. "Numerical Methods for Singularly Perturbed Boundary Value Problems: Finite Difference Methods" by Zhimin Zhang (Springer, 2017).

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Abstract Algebra	RSMTH-111	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Group Theory:** Group actions, matrix groups and its geometry, semidirect product of groups, p-groups, automorphisms of p-groups, nilpotent and solvable groups, free groups, Cayley and power graphs of groups	14
Module 2	**Ring and Module Theory:** Polynomials in several variables over a field and Grobner, matrix rings, group rings. Properties of ideals, monomial ideals, graphs associated with rings, Generation of Modules, Tensor Products of Modules, Exact Sequences, Projective, Injective, and Flat Modules. Tensor Algebras, Symmetric and Exterior Algebras	14
Module 3	**Field and Galios Theory:** Review of Field Extensions, Algebraic Extensions. Cyclotomic Polynomials and Extensions.The Fundamental Theorem of Galois Theory, Finite Fields, Composite Extensions and Simple Extensions, Galois Groups of Polynomials, Solvable and Radical Extensions: Insolvability of the Quintic, Computation of Galois Groups over rationals	14

Text Books/ References:

1. M. Artin, *Algebra*, 2nd Edition, Pearson Education India, 2015.
2. D. S. Dummit and R. M. Foote, *Abstract Algebra*, Third Edition, John Wiley, 2011.
3. N. Jacobson, *Basic Algebra-I*, Dover Publications, 2009.
4. S. Lang, *Algebra*, 3rd Edition, Springer, 2005.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Advanced algebra and Combinatorics	RSMTH-112	3-0-0-3
Evaluation Policy	**Mid-Term**	**InternalAssessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Representation Theory:** Linear Actions and Modules over Group Rings, Group representations, Shur's Lemma, Wedderburn's Theorem and Some Consequences, Subrepresentations, Tensor products, Lie algebras and its representations.	**14**
Module 2	**Character Theory:** Conjugacy classes, Characters, inner product of characters, irreducible characters, Character tables and Orthogonality relations, Normal subgroups and lifted characters, Induced modules and Characters, Characters of order pq, Characters of some p-groups, Burnside's Theorem, Meckey's irreducibility criterion, Permutations and characters.	**14**
Module 3	**Combinatorics:** Group action on Boolean algebras, Young diagrams and q-Boolean coefficients, Simplicial Complexes, Face rings. The Combinatorial Nullstellensatz and some of its applications. Graphs, Random walks on graphs, Majorisation, Threshold graphs, Spectral Integral variation.	**14**

Text Books/ References:

1. G. James and M. Liebeck, *Representations and Characters of groups*, 2nd Edition, Cambridge University Press, 2001.

2. J. P. Serre, *Linear Representation of Groups*, First Edition, Springer, 2012.

3. Bruce E. Sagan, The Symmetric Group: Representations, Combinatorial Algorithims, and Symmetric Functions, 2nd Edition, Springer, 2001.

4. R. P. Stanley, *Algebraic Combinatorics*, 2nd Edition, Springer, 2010.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Applied Statistics	RSMTH-113	3-0-0-3
Evaluation Policy	**Mid-Term**	**InternalAssessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Advanced Principles of Probability Theory:** Distribution Function, Properties of distribution function, Generating functions(Fourier and Laplace transformation), Law of Large Numbers, Standard Distributions, Two dimensional random variables for discrete and continuous case, Transformation of two-dimensional random variables, Chebychev's inequality. **Analytic Tests of Plausibility and Significance:** Large sample theory, Types of Sampling, Parameter and Statistic, Tests of Significance, Procedure for Testing of Hypothesis, Tests of Significance for Large Samples, Sampling of Attributes, Sampling of Variables, higher Sampling Distributions & applications.	14
Module 2	**Advanced theory of Estimation and Tests:** Theory of Estimation-Characteristics of Estimators, Unbiasedness, Consistency, Efficient Estimators, Sufficiency, Convergence in probability, Statistical Hypothesis, Simple and Composite, Optimum Test under Different situations, Compound distributions, order statistics, truncated distributions, Neyman J and Pearson E. S Lemma, Likelihood Ratio Test	14
Module 3	**Analysis of Variance:** One- way Classification, Total variation, Variation within Treatments, Variation between Treatments, Linear Mathematical Model for Analysis of Variance, Expected Values of the Variations, Distributions of the variations, The F Test for the Null Hypothesis of Equal Means , Analysis of Variance Tables, Modifications for Unequal Numbers of Observations, Two-way Classification of Two-Factor Experiments, Variations for Two-Factor Experiments, Analysis of Variance for Two-Factor Experiments, Two-Factor Experiments with Replication, Experimental Design	14

Text Books/ References:

1. S. G. Heeringa, B. T. West and P. A. Berglund, Applied Survey Data Analysis, Taylor and Francis Group, 2010

2. J. E. Fruend and M. Irwin, Probability and statistics for Engineers, Pearson 5th Edition .

3. G. Schay, Introduction to Probability with Statistical Applications, Birkhauser 2007.

4. D. J. Crawshaw&Joan Sybil Chambers, A Concise Course in Advanced Level Statistics with worked examples, Revised Edition.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Optimization Techniques	RSMTH-114	3-0-0-3
Evaluation Policy	**Mid-Term**	**InternalAssessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Formulation of Mathematical Programming Model:** Optimal problem formulation, Design variable constraints, Objective function, Variable bounds, Optimization algorithms. **Linear Programming Techniques:** Maximization &Minimization Models, Simplex Method, Artificial variable technique, management applications, Revised simplex method, Duality in Linear Programming, Sensitivity Analysis, other algorithms for solving LP problems, Transportation, Assignment and other applications.	14
Module 2	**Multivariable Optimization Algorithms:** Optimality criteria, Unidirectional search, Direct search method: Simplex search method, Hooke-Jeeves pattern search method.	14
Module 3	**Non-Linear Programming:** Non-linear programming Quadratic form, Hessian Matrix, Positive definite and negative definite, Methods of Lagrange multipliers, Wolfe's method of solving Quadratic programming problem. Characteristics of a constrained problems, Cutting plane method, indirect method, Transformation techniques.	14

Text Books/ References:

1. N. S. Kambo, Mathematical Programming Techniques, Affilated East-West Press Pvt Ltd, 2008.
2. H. A. Taha, Operations Research: An Introduction, Pearson Education, 10 Edition, 2010.
3. G. V. Shenoy, Linear Programming, Methods and Application, New Age international PVT. Lmt., 1998.
4. S. S. Rao, Optimization theory and Applications, John Wiley & Sons, 1978.
5. D. P. Bertsekas, Non linear programming, Athena Scientific, 3 Edition, 2016.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Graph Theory	RSMTH-115	3-0-0-3
Evaluation Policy	Mid-Term	Internal Assessment	End-Term
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Degree Sequences and Matchings:** Necessary and sufficient condition for a sequence of nonnegative integers to be a degree sequence, Havel Hakimi criterion, Wang Kleitman criterion, Erdos Gallai criterion, Isomorphism and degree sequences, Degree sequences in trees. Matchings, Berge's and Hall's theorem.	**14**
Module 2	**Edge graphs and coloring:** Basic properties of edge graphs, Krausz characterization, Van Rooij and wilf characterization, Beineke characterization, Edge graphs and traversability, Edge graphs of Eulerian graphs and Hamiltonian graphs, Total graph, Vertex coloring, Brooks theorem, Edge coloring, Vizings theorem.	**14**
Module 3	**Distance and Eccentricity in graphs:** Concept of distance and eccentricity in graphs, Basic properties of an eccentricity sequences, Lesniak theorem on eccentricity sequence of a graph, Necessary and sufficient condition for a sequence of positive integers to be an eccentricity sequence of a tree, Distance degree graphs and distance regular graphs	**14**

Text Books/ References:

1. F Harary, Graph Theory, Narosa Publishing House (2001).
2. S. Pirzada, An introduction to Graph Theory, Universities Press, Orient Balckswan, Hyderabad, (2012).
3. D. B. West, Introduction to Graph Theory, 2nd Edition, Pearson Publication (2002).

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Spectral Graph Theory	RSMTH-116	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Matrix Analysis**: Unitary Similarity and Unitary Equivalence, Introduction, QR factorization, Unitary and real orthogonal triangularizations, Consequences of Schur's triangularization theorem, Normal matrices, Unitary equivalence and singular value decomposition, Polar decomposition.	**14**
Module 2	**Nonnegative Matrices and their properties**: Nonnegative matrices, Positive matrices, Perron-Frobenius theorem and its consequences, irreducible nonnegative matrices and primitive matrices, Variational characterizations of eigenvalues of Hermitian Matrices, Rayleigh-Ritz theorem, Courant –Fischer theorem, Wely's theorem, Cauchy interlacing theorem.	**14**
Module 3	**Spectra of Graphs**: Matrices associated to graphs, Adjacency matrix, Laplacian Matrix, Characteristic polynomial of a graph, Sach's coefficient theorem and its applications, Adjacency and Laplacian spectra of some basic graphs like cycle, path, complete graph, and complete bipartite graph. Regular graphs and spectra, Strongly regular graphs their basic properties and spectra, Matrix tree theorem, Finding spanning trees of special graphs using matrix tree theorem.	**14**

Text Books/ References:

1. R. B. Bapat, Graphs and Matrices, Hindustan Book Agency (2014).
2. A. E. Brouwer and W. H. Haemers, Spectra of Graphs, Springer (2012).
3. R. A. Horn and C. R. Johnson, Matrix Analysis, Cambridge University.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Functions of Complex variables	RSMTH-117	3-0-0-3
Evaluation Policy	**Mid-Term**	**InternalAssessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Operators on Polynomials:** The polar derivative, Grace Theorem, locating critical points, critical points of rational functions, Borwein-Erdélyi Inequality, linear operators, Iliff-sendov conjecture Inequalities relating the nearest critical point to the nearest second zero, some inequalities for analytic and trigonometric polynomials, Generalized convolution operators.	**14**
Module 2	**Location of Zeros:** Location of zeros of polynomial, Cauchy's Theorem and its various generalizations and refinements, Enströ̈m-Kakéya Theorem and its various generalizations and refinements, self-inversive polynomials, polynomials with interspersed zeros on the unit circle.	**14**
Module 3	**Bernstein-Type Inequalities:** Bernstein-Type inequalities for polynomials and rational functions, Growth of polynomials and rational functions. Matrix Polynomials, Zeros of Matrix polynomial.	**14**

Text Books/ References:

1. T. Sheil-Small, Complex Polynomials, Cambridge University Press, (2009).
2. Q. I. Rahman and G. Schmeisser, Analytic Theory of Polynomials. Oxford Univ. Press, (2002).
3. G. V. Milovanovic, D. S. Mitrinovic, Th. M. Rassias, Topics in Polynomials, Extremal Problems, Inequalities, Zeros. World Scientific, Singapore (1994).
4. I. Gohberg, P. Lancaster, L. Rodman, Matrix Polynomials, SIAM Edition (2009).

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Functions of Hypercomplex Variable	RSMTH-118	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Quaternionic and Bicomplex Numbers:** Introduction, The quaternion units, Adding and subtracting quaternions, Pure Quaternion, Unit Quaternion, Additive form of a quaternion, Binary form of a quaternion, Norm of a Quaternion, Quaternionic Products, Inverse Quaternion, Quaternion algebra. Conjugation and Moduli of bicomplex numbers, Idempotent representations, Euclidean norms and the product, Algebraic structures, Geometry and Trigonometric Representations, Lines and curves.	14
Module 2	**Properties of Functions of Quaternionic variable:** Regular functions, Affine representation, Algebraic structure, Regular power series, Basic, algebraic and topological properties of zeros. Roots of Quaternions, Factorization of polynomials, Division algorithm, Regular reciprocal and quotients, Integral formulas, Argument Principle, Maximum and Minimum modulus theorems, Extremal properties of polynomials.	14
Module 3	**Functions of Bicomplex Variable:** Limits and continuity, Elementary Bicomplex functions, Properties of bicomplex holomorphic functions, Sequence and series, Integral formulas and theorems, Maximum modulus and Minimum modulus principle, Extremal properties of polynomials.	14

Text Books/ References:

1. G. Gentili, C. Stoppato, D. C. Struppa, Regular Functions of a Quaternionic Variable, Springer (2012).
2. M. Elena Luna- Elizarrarás, M. Shapiro, D.C. Struppa, A. Vajiac, Bicomplex Holomorphic Functions: The Algebra, Geometry and Analysis of Bicomplex Numbers, Frontiers of Mathematics (Birkhäuser) (2015).
3. John Vince, Quaternions for computer graphics, Springer-Verlag London Limited (2011).
4. B.S. Nathan Bushman, Hypercomplex Numbers and Early Vector Systems: A History, Ph. D Thesis, The Ohio State University (2020).

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Frames and Wavelets	RSMTH-121	3-0-0-3
Evaluation Policy	Mid-Term	InternalAssessment	End-Term
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Frames and Bases:** Finite frames, Canonical reconstruction formula, frames and matrices, Similarity and unitary equivalence of frames, frame bounds and frame algoriths, Frames and Bessel sequences in infinite dimensional Hilbert spaces, Frame sequence, Gram matrix, Frames and operators, Characterization of frames, Dual frames, Tight frames, Continuous frames, Frames and signal processing, Tight frames and dual frame pairs. Riesz bases, Frames versus Riesz bases, Conditions for a frame being a Riesz basis, Frames containing a Riesz basis, Bases in Banach spaces, Limitations of bases.	14
Module 2	**Wavelets**: Wavelets, Haar wavelets, Basic properties of the Haar scaling function, Haar decomposition and reconstruction algorithms, Daubechies wavelets, Wavelet bases, Scaling function, Biorthogonal wavelets, Semi-orthogonal wavelets.	14
Module 3	**Multiresolution Analysis:** Definition and examples of multiresolution analysis (MRA), properties of scaling functions and orthonormal wavelet bases, construction of orthonormal wavelets with special reference to Haar wavelet, Franklin wavelet and Battle- Lemarie wavelet, Spline wavelets. Extensions of Multiresolution Analysis.	14

Text Books/ References:

1. A. Boggess and F.J. Narcowich, A First Course in Wavelets with Fourier Analysis, Second Edition, John Wiley& Sons, 2009.

2. O. Christensen, An Introduction to Frames and Riesz Bases, Second Edition, Birkhäuser, 2016.

3. D. Han, K. Kornelson, D. Larson and E. Weber, Frames for Undergraduates, American Mathematical Society, Student Mathematical Library, Volume 40, 2007.

4. D.F. Walnut, An Introduction to Wavelet Analysis, Springer, 2013.

5. I. Daubechies, *Ten Lectures on Wavelets*, CBS-NSF Regional Conferences in Applied Mathematics, 61, SIAM, Philadelphia, PA, 1992.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Time Frequency Analysis	RSMTH-122	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Fourier Transforms**: Fourier transforms in $L^1(R)$ and $L^2(R)$, Basic Properties, Convolution theorem, Plancherel's and Parseval's formulae, Inversion Formula, Poisson summation formula, Discrete Fourier transforms, Fast Fourier transform Shannon sampling theorem, Heisenberg's uncertainty principle. Fractional Fourier transform, Inversion formula, Discrete fractional Fourier Transform, Polar Fourier transform and their fundamental properties, Windowed Fourier transform, Fundamental properties of windowed Fourier Transform including convolution theorem, Moyal's principle, reconstruction formula, characterization of range, Heisenberg's uncertainty principle, Windowed fractional Fourier transform, and its fundamental properties. Special Affine Fourier transform and its fundamental properties	14
Module 2	**Wavelet Transforms:** Continuous and discrete wavelet transforms with examples, basic properties ofwavelet transforms, Examples of Haar wavelet, Mexican hat wavelet and their Fourier transforms, dyadic orthonormal wavelet bases, Gabor transforms, basic properties of Gabor transforms, Fractional Wavelet transforms and its various extensions. Fundamental properties of fractional wavelet transforms.	14
Module 3	**Linear Canonical Transforms:** Linear canonical transform and its fundamental properties, Windowed linear canonical transform and its fundamental properties, various extensions of linear canonical transforms and their fundamental properties.	14

Text Books/ References:

1. S. T. Ali, J. P. Antoine and J. P. Gazeau, Coherent States, Wavelets, a their Generalizations, Springer, New York, 2014 .

2. D. K. Ruch and P. J. Van Fleet, *Wavelet Theory,* John Wiley, 2009

3. J.J. Healy, M.A. Kutay, Ozaktas and J.T. Sheridan, *Linear Canonical Transforms,* New York, Springer, 2016.

4. C. K. Chui, *An Introduction to Wavelets*, Academic Press, New York, 1992.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Advanced Geometry of Curves and Surfaces	RSMTH-123	3-0-0-3
Evaluation Policy	**Mid-Term**	**InternalAssessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Intrinsic geometry:** Isometries, Vector fields and covariant derivatives, Riemannian curvature tensor, Riemannian metric, geodesics, exponential map, geodesic and polar coordinates, parallel transport, Jacobi fields. Divergence theorem.	**14**
Module 2	**Local spaces:** Lorentz-Minkowki spaces, spacelike, timelike and lightlike vectors, curves in Minkowski space. Concepts of spacelike and timeline immersions. Geometry of Constant curvature surfaces. Geometry of Galilean, pseudo-Galilean spaces, isotopic and semi-isotropic spaces, Bianchi-Cartan-Vranceanu spaces (BCV-spaces) , Heisenberg group and hyperbolic spaces.	**14**
Module 3	**Constant curvature surfaces:** First variation of area, Minimal and developable surfaces, Weingarten surfaces. Classification of constant mean and constant Gaussian curvature surfaces in different ambient surfaces. conformal representation and analycity of minimal surfaces, Bernstein's theorem, Laplace Beltrami operator. **Construction of minimal surfaces:** Adjoint surface, branch points, Enneper-Weierstrass representation formula, Bjorlings problem, complete minimal surfaces, polynomial minimal surfaces, Plateau's problem.	**14**

Text/Reference Books:

1. C. Bar, Elementary Differential Geometry, Cambridge press, 2010.
2. U. Dierkes, S. Hildebrandt, F. Sauvigny, Minimal surfaces, Springer, 2010.
3. R. Lopez, Differential geometry of curves and surfaces in Lorentz-Minkowski spaces, https://doi.org/10.48550/arXiv.0810.3351
4. Ruled Weingarten surfaces in the Galilean spaces, Zeljka Milin Sipus, Periodica Mathematica Hungarica, Vol. 56 (2), 2008, pp. 213–225.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Finite Element Methods	RSMTH-124	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction to Finite Element Method:** Introduction to FEM: Basic concepts, and applications. Mathematical Preliminaries: Variational calculus, functional analysis, and numerical methods. Approximation Theory: Interpolation, least squares approximation, and approximation error analysis. Finite Element Discretization: Discretization of continuous problems, shape functions, and element types. Assembly and Solution Techniques: Finite element equations, global stiffness matrix assembly, and solution methods.	**14**
Module 2	**Finite Element Analysis in One Dimension:** One-Dimensional Problems: Formulation of one-dimensional problems using FEM. Scalar Field Problems: Heat conduction, diffusion problems, and Poisson's equation. Beam and Frame Analysis: Stiffness matrix formulation, boundary conditions, and applications. Time-Dependent Problems: Transient heat conduction and diffusion problems.	**14**
Module 3	**Finite Element Analysis in Two and Three Dimensions:** Two-Dimensional Problems: Formulation of two-dimensional problems using FEM. Plate and Shell Analysis: Thin plate theory, membrane and bending problems, and applications. Solid Mechanics: Stress analysis, elasticity equations, and applications. Fluid Mechanics: Navier-Stokes equations, computational fluid dynamics (CFD), and applications. Electromagnetic Problems: Maxwell's equations, finite element analysis in electromagnetics.	**14**

Text Books/ References:

1. "The Finite Element Method: Linear Static and Dynamic Finite Element Analysis" by Thomas J.R. Hughes - Published in 1987, Volume 1.
2. "Finite Element Procedures" by K.J. Bathe - Published in 2014, Volume 1.
3. Finite Element Analysis: Theory and Application with ANSYS" by Saeed Moaveni - Published in 2015, Volume 2.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Computational Fluid Dynamics	RSMTH-125	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction:** Historical Perspective, Comparisons of experimental, Theoretical and Numerical approaches, Different numerical approaches, Eulerian and Lagrangian descriptions of fluid motion, Kinematics of fluid motion, Some analytical solutions of the Navier-Stoke's equations and their physical interpretation, Well-posed problems.	14
Module 2	**Governing Equations and Numerical Solution:** Classification of PDEs, Physical Classification, Mathematical Classification, Navier-Stokes System of equations, Derivation of Finite Difference Equations, Accuracy of Finite Difference solutions. Elliptic Equations, Parabolic Equations, Hyperbolic Equation, Stability, Convergence and Consistency of the Solution.	14
Module 3	**Application of Finite Difference Methods to the Equations of Fluid Mechanics:** Numerical Methods for Inviscid Flow Equations, Numerical Methods for Boundary-Layer Type Equations.	14

Text Books/ References:

1. D. A. Anderson, J. C. Tannehill, and R. H. Pletcher, Computational Fluid Mechanics and Heat Transfer, 2nd ed, Taylor & Francis, 1997.
2. S. V. Patankar, Numerical Heat Transfer and Fluid Flow, Hemisphere, 2000.
3. T. J. Chung, Computational Fluid Dynamics, 2nd ed. Cambridge University Press, 2010.
4. P. Niyogi, S. K. Chakrabartty, M. K. Laha, Introduction to Computational Fluid Dynamics, Pearson Publications, 2011.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Numerics of Partial Differential Equations	RSMTH-126	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Introduction:** Overview of PDEs, Classification of second order equations, Initial value problems, boundary value problems, Heat and wave equations, Laplace's and Poisson's equations, Transport equations and Burger's equation.	14
Module 2	**Finite difference schemes:** Finite difference schemes for partial differential equations, explicit schemes, implicit schemes, single step schemes, multi-step schemes, FTCS, backward Euler and Crank-Nicolson schemes, ADI methods, Lax Wendroff method, upwind scheme.	14
Module 3	**Finite element method:** Finite element method for partial differential equations, variational methods, method of weighted residuals, Finite element discretization for one-dimensional and two-dimensional elliptic equations, a priori and a posteriori error estimates.	14

Text Books/ References:

1. G. D. Smith, Numerical Solutions to Partial Differential Equations, Oxford University Press, 3rd Edn., 1986.
2. C. Johnson, Numerical Solution of Partial Differential Equations by the Finite Element Method, Dover Publications, 2009.
3. J. C. Strikwerda, Finite Difference Schemes and Partial Differential Equations, SIAM, 2004.
4. J. N. Reddy, An Introduction to Finite Element Method, 3rd Edn., McGraw Hill, 2005.

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Year (Semester)	Course Title	Course Code	L – T - P: Credits
Ph.D.	Commutative Algebra	RSMTH-127	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Ring Theory:** Rings, ring homomorphism, commutative rings, Polynomial and group rings. Ideals, quotients, zero divisors, Nilpotent elements and units. Prime and maximal and co-maximal ideals, nilradical, Jacobson's radical and radical of an ideal. Operations on ideals, extension and contraction. Chinese remainder theorem and prime avoidance lemma.	**14**
Module 2	**Modules:** Modules and module homomorphisms, Submodules and quotient modules, Operations on submodules. Finitely generated modules, Nakayama lemma, Exact, short exact and split exact sequences. Four and Five lemma. Free Modules: Properties and related results, rank of a module and related results. Tensor product of Modules with basic properties and applications, projective, injective and flat modules. Exactness properties of the tensor product. Algebras, Tensor product of algebras.	**14**
Module 3	**Modules with Chain Conditions**: Chain conditions, Noetherian and Artinian rings. Hilbert basis theorem, primary decomposition and Artinian rings and structure theorem on Artinian rings, modules over PID. Rings and modules of fractions. Extended and contracted ideals in rings of fractions, Localization and Spectrum of a ring. Modules of finite length and primary decomposition in Noetherian rings.	**14**

Text Books/ References:

1. M. F. Atiyah, I. G. Macdonald, Introduction to Commutative Algebra. Addison Wesley, 1969.
2. S. Lang, Algebra, 3rd Edition, Addison-Wesley, 1999.
3. H. Matsumura, Commutative Ring Theory, Cambridge University Press, 1989.

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Year (Semester)	Course Title	Course Code	L – T - P: Credits
Ph.D.	Advanced Commutative Algebra	RSMTH-128	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Prime Ideals and Extension rings**: Localisation and Spectrum of a ring, Hilbert Nullstellensatz, Dimension theory, Associated primes and primary decomposition, Flatness: flat and faithfully modules, extension of coefficients for polynomial rings, local characterization of flatness, Base changing lemma. Completion and Artin-Rees lemma.	14
Module 2	**Dimension Theory and Regular Sequences:** Graded rings and graded modules, associated graded ring, Hilbert functions, Dimension theory of Noetherian local rings, regular sequences and Koszul complex, Cohen-Macaulay rings Gorenstein rings, Regular local ring is a UFD and Complete intersection of rings.	14
Module 3	**Homology**: Complexes, long exact sequences, Homology and cohomology Categories: definitions, examples and basic properties, isomorphisms. Functors: examples and basic properties. Covariant and contra-variant functors, Abelian categories, Projective and Injective resolutions, Left and Right derived functors, Ext and Tor, Local and Cech homology.	14

Text Books/ References:

1. D. Eisenbud, Commutative Algebra with view toward Algebraic Geometry, GTM 150, Springer-Verlag New York, 1995

2. H. Matsumura, Commutative Ring Theory, Cambridge University Press, 1989.

3. C. Weibel, An Introduction to Homological Algebra, Cambridge University Press, 1994.

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Year (Semester)	Course Title	Course Code	L – T - P: Credits
Ph.D.	Functional Analysis	RSMTH-129	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Normed and Banach Spaces:** Normed spaces, Banach spaces and their examples, Examples of incomplete normed spaces, Subspace of normed spaces, Quotient spaces, Infinite series in normed space, Convergence and absolute convergence, finite dimensional normed spaces, Equivalent norms,Compactness, Denseness and separability properties	14
Module 2	**Bounded linear operators on Banach spaces:** Bounded linear operators and bounded linear functionals with their norms and properties. Unbounded linear operators, Space of bounded linear operators, Dual basis, Algebraic and topological duals and relevant results, Duals of some standard norms spaces, Reflexive normed spaces and their properties. Hahn-Banach theorem and its extended forms, Uniform boundedness principle, Open mapping and closed graph theorems and their consequences and applications.	14
Module 3	**Geometry of Hilbert spaces**: Inner product spaces and examples, Hilbert spaces, Parallelogram law, Polarization identity and related results, Schwartz and triangle inequalities, Separability and reflexivity of Hilbert spaces, orthonormal sets and sequences, Bessel inequality, Parseval relation, Bounded linear functionals on Hilbert spaces, Riesz representation theorem.	14

Text Books/ References:

1. E. Kreyszig: Introductory Functional Analysis with Applications, John Willey, 1978.
2. P. K. Jain and O. P. Ahuja: Functional Analysis, New Age International Publishers, 2nd Edition, 2010.
3. H. Siddiqi: Applied Functional Analysis: Numerical Methods, Wavelet Methods and Image Processing, CRC Press, 2003.
4. W. Rudin: Functional Analysis, Mc Graw Hill Education, 2nd Edition, 1991.

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Year (Semester)	**Course Title**	**Course Code**	**L – T - P: Credits**
Ph.D.	Advanced Functional Analysis	RSMTH-130	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	**Contents**	**Hours**
Module 1	**Smooth Spaces:** Uniform convex spaces, Strictly convex Banach spaces, Modulus of convexity, Uniform convexity, Strict convexity and reflexivity. Smooth spaces: Modulus of smoothness, duality between spaces, Duality maps of some concrete spaces.	14
Module 2	**Inequalities in Uniformly Convex Spaces:** Basic notions of convex analysis, Inequalities in: p-uniformly convex spaces, Uniformly convex spaces, q-uniformly smooth spaces, Uniformly smooth spaces, Duality maps on uniformly smooth spaces, Duality maps on spaces with uniformly Gateaux differentiable norms.	14
Module 3	**Fixed Points and Fixed Point Iteration Procedures:** Fixed point iteration procedures, Theorem of Nemytzki-Edelstein, quasi non-expansive operators, Non-expansive operators in Hilbert spaces, Strictly pseudo-contractive operators, Lipschitzian and generalized pseudo- contractive operators. The general Mann iteration, Strongly pseudo-contractive operators, Ishikawa iteration for a class of lipschitizian and pseudo-contractive operators in Hilbert spaces, the equivalence between Mann and Ishikawa iterations.	14

Text Books/ References:

1. C. Chidume, Geometric properties of Banach spaces and Nonlinear iterations, Lecture notes in Mathematics, Vol. 1965, Springer-Verley London Limited, 2009.
2. V. Berinde, Iterative Approximation of Fixed points, Lecture notes in Mathematics, Vol. 1912, Springer-Verlag Berlin Heidelberg, 2007.
3. V. I. Istratescu, Fixed Point Theory: An Introduction: Volume 7 (Mathematics and its Applications), D. Reidel Publishing company.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Fourier Analysis	RSMTH-131	3-0-0-3
Evaluation Policy	Mid-Term	Internal Assessment	End-Term
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	Definition, examples and uniqueness of Fourier series, Convolution, Cesaro summability and Abel summability of Fourier series, Mean square convergence of Fourier series, A continuous function with divergent Fourier series, Applications of Fourier series such as isoperimetric problem, wave equation, etc.	14
Module 2	The Schwartz space, Fourier transform on the real line and basic properties, Approximate identity usingGaussian kernel, Solution of heat equation, Fourier inversion formula, Fourier transform for functions in Lp,1=p=2. Theory of distributions, Fourier transform of a tempered distribution.	14
Module 3	Poisson summation formula, Heisenberg's uncertainty principle, Hardy's theorem, Paley-Wiener theorem, Wiener's theorem, Wiener-Tauberian theorem. Spherical harmonics and symmetry properties of Fourier transform, Multiple Fourier series and Fourier transform on R^n.	14

Text Books/ References:

1. E. M. Stein and Rami Shakarchi, Fourier Analysis, An introduction, Princeton University press, 2003
2. W. Rudin, Functional Analysis, Tata Mcgraw-hill, 1985.
3. Stein and Weiss, Fourier analysis on Euclidean space, Princeton university press, First edition, 1971.
4. Kesavan, Functional analysis and applications, 3rd edition, Newage international publishers, 2019.

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Year (Semester)	Course Title	Course Code	L-T-P-Credits
Ph.D.	Measure theory and integration	RSMTH-132	3-0-0-3
Evaluation Policy	**Mid-Term**	**Internal Assessment**	**End-Term**
	26 Marks	24 Marks	50 Marks

Syllabus:

Module No.	Contents	Hours
Module 1	**Abstract Integration:** Set-theoretic notations and terminology, the concept of measurability, simple functions, elementary properties of measures, arithmetic in [0, ∞], integration of positive functions, integration of complex functions, the role played by sets of measure zero. Vector spaces, topological preliminaries, the Riesz representation theorem, regularity properties of Borel measures, Lebesgue measure, continuity properties of measurable functions. Convex functions and inequalities, the L^p –spaces, approximation by continuous functions.	14
Module 2	**Elementary Hilbert Space theory:** Inner products and linear functionals, orthonormal sets, trigonometric series. Descriptive Banach spaces, consequences of Baire's theorem, Fourier series of continuous functions, Fourier coefficients of L^1-functions, the Hahn-Banach theorem.	14
Module 3	**Interpolation theorems and its applications:** Real Method: The Marcinkiewicz Interpolation Theorem Complex Method: The Riesz–Thorin Interpolation Theorem	14

Text Books/ References:

1. W. Rudin, Real and Complex Analysis, McGraw- hills series in Higher mathematics, 1986.
2. Royden and Fitzpatrick, Real analysis, 4th edition, Pearson, 2015.
3. L. Grafakos, Classical Fourier analysis, Springer, 2014