2 Years M. Sc. Programme in Mathematics

Offered
by
Department of Mathematics, IIT Patna

Master of Science (Mathematics)

The Department of Mathematics would start a two year Master of Science (Mathematics) Programme in 2016. This programme is designed to cover a wide range of subjects within both pure and some applied Mathematics. The students will have the access of modern laboratory and computational facilities and during the study they will have assignments involving the same. In project work and on the Master's Thesis the students will have the opportunity to apply their knowledge to fore front areas of the subject. It is expected and desired that a large fraction of M. Sc. passed out students would find their places for higher studies in various prestigious institutes/universities all over the world.

Admission Procedure:

The admission to the two year (Four Semester) M.Sc. (Mathematics) programme will be through the Joint Admission Test (JAM) conducted by all IITs.

Semester-wise Course Structure:

SEMESTER I

Code	Course Name	L	T	P	C
MA 421	Linear Algebra	3	1	0	8
MA 423	Data Structure and Programming Language	3	0	2	8
MA 425	Real Analysis	3	1	0	8
MA 427	Algebra	3	1	0	8
MA 429	Ordinary Differential Equations	3	1	0	8
HS 513	Technical Communication	2	0	0	4
		15	4	2	44

SEMESTER II

Code	Course Name	L	T	P	C
MA 422	Topology	3	1	0	8
MA 424	Complex Analysis	3	1	0	8
MA 426	Probability and Statistics	3	1	0	8
MA 428	Measure Theory and Integrations	3	1	0	8
MA 430	Numerical Analysis	3	0	2	8
		15	4	2	40

SEMESTER III

Code	Course Name	L	T	P	C
MA 521	Functional Analysis	3	0	0	6
MA 523	Partial Differential Equations	3	0	0	6
MA525	Operations Research	3	0	0	6
	Elective -I	3	0	0	6
	Elective -II	3	0	0	6
MA 591	Project Stage I	0	0	8	8
		18	0	0	38

SEMESTER IV

Code	Course Name	L	T	P	C
MA 522	Combinatorics	3	0	0	6
MA 524	Differential Geometry	3	0	0	6
	Elective -III	3	0	0	6
	Elective-IV	3	0	0	6
	Elective-V	3	0	0	6
MA 592	Project Stage II	0	0	8	8
		18	0	0	38

Total Credit =160

Electives: I & II

Code	Course Name	L	T	P	C
MA 527	Algebraic Topology	3	0	0	6
MA 529	Basic Number Theory	3	0	0	6
MA 531	Control Theory	3	0	0	6
MA 533	Graph Theory	3	0	0	6
MA 535	Introduction to Coding Theory	3	0	0	6
MA 537	Mathematical Methods	3	0	0	6
MA 539	Mathematical Modeling	3	0	0	6
MA 541	Statistical Inference	3	0	0	6

Electives: III, IV & V

Code	Course Name	L	T	P	C
MA 526	Differential Manifolds	3	0	0	6
MA 528	Differential Topology	3	0	0	6
MA 530	Fuzzy Sets and Systems	3	0	0	6
MA 532	Introduction to Biomathematics	3	0	0	6
MA 534	Operators on Hilbert Spaces	3	0	0	6
MA 536	Rings and Modules	3	0	0	6
MA 538	Statistical Decision Theory	3	0	0	6
MA 540	Wavelets Transform	3	0	0	6

DETAIL COURSE CONTENT

Course Name	**Linear Algebra**
Course Number	MA421 (Core)
Course Credit	3 – 1 – 0 – 8
Prerequisite	None

Vector spaces over fields, subspaces, bases and dimension, Systems of linear equations, matrices, rank, Gaussian elimination.

Linear transformations, representation of linear transformations by matrices, rank-nullity theorem, duality and transpose.

Determinants, Laplace expansions, cofactors, adjoint, Cramer's Rule, eigenvalues and eigenvectors, singular value decomposition, characteristic polynomials, minimal polynomials, Cayley-Hamilton Theorem, triangulation, diagonallization, rational canonical form, Jordan canonical form.

Inner product spaces, Gram-Schmidt orthonormalization, orthogonal projections, linear functionals and adjoints, Hermitian, self-adjoint, unitary and normal operators, Spectral Theorem for normal operators, Rayleigh quotient, Min-Max Principle.

Bilinear forms, symmetric and skew-symmetric bilinear forms, real quadratic forms, Sylvester's law of inertia, positive definiteness.

Texts / References

1. M. Artin, Algebra, Prentice Hall of India, 1994.
2. K. Hoffman and R. Kunze, Linear Algebra, Pearson Education (India), 2003.PrenticeHall of India, 1991.
3. Bernard Kolman, David Hill, Elementary Linear Algebra with Applications, 9th Edition, Pearson Education, 2007.
4. S. Lang, Linear Algebra, Undergraduate Texts in Mathematics, Springer-Verlag, New York, 1989.
5. P. Lax, Linear Algebra, John Wiley & Sons, New York, Indian Ed. 1997.
6. H. E. Rose, Linear Algebra, Birkhauser, 2002.
7. S. Lang, Algebra, 3rd Ed., Springer (India), 2004.
8. O. Zariski and P. Samuel, Commutative Algebra, Vol. I, Springer, 1975.

Course Name	**Data Structure and Programming Language**
Course Number	MA423 (Core)
Course Credit	3 – 0 –2 – 8
Prerequisite	None

Fundamental Data structures: linked lists, arrays, matrices, stacks, queues, binary trees, tree traversals.

Algorithms for sorting and searching: linear search, binary search, insertion-sort, bubble-sort, quicksort.

Priority Queues: lists, heaps.

Graphs: representations, depth first search, breadth first search.

Hashing: separate chaining, linear probing, quadratic probing.

Search Trees: binary search trees, red-black trees, AVL trees, splay trees, B-trees. The disjoint set union problem; String matching.

Experiments would be designed to provide hands-on experience in programming data structures and Algorithms, to learn a few systems programming tools, and scripting.

References :

1. T. H. Cormen, C E Leiserson, R L Rivest and C Stein, Introduction to Algorithms, MIT Press, 2001.
2. Jon Kleinberg and Eva Tardos, Algorithm Design, Addison Wesley, 2005.
3. M. A. Weiss, Data Structures and Algorithm Analysis in C++, Addison-Wesley, 2007.

Course Name	**Real Analysis**
Course Number	MA425 (Core)
Course Credit	3 – 1 – 0 – 8
Prerequisite	None

Review of real number system: Completeness property, Archimedean property, Denseness of rationals and irrationals, Countable and uncountable sets, Cardinality, Zorn's lemma.

Metric spaces: Open sets, Closed sets, Continuous functions, Completeness, Cantor intersection theorem, Baire's category theorem, Compactness, Totally boundedness, Finite intersection property.

Functions of several variables: Differentiation, Inverse and implicit function theorems.

Riemann-Stieitjes integral: Definition, Existence and properties of the integrals.

Sequence and Series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. Equicontinuity, Ascoli's Theorem.

Texts / References:

1. T. M. Apostol, "Mathematical Analysis", Narosa Publishing House, 2002.
2. K. Ross, Elementary Analysis: The Theory of Calculus, Springer, 2004.
3. W. Rudin, Principles of Mathematical Analysis, McGraw-Hill, 1976.

Course Name	**Algebra**
Course Number	MA427 (Core)
Course Credit	3 – 1 – 0 – 8
Prerequisite	None

Review of Groups, subgroups, normal subgroups, Examples: permutation groups, cyclic groups, dihedral groups, matrix groups.

Homomorphisms, quotient groups, Isomorphisms.Cayley's theorem, groups acting on sets, Sylow theorems and applications, direct products, finitely generated abelian groups, Structure Theorem for finite abelian groups.

Basic properties of rings, units, ideals, homomorphisms, quotient rings, prime and maximal ideals, fields of fractions, Euclidean domains, principal ideal domains and unique factorization domains, polynomial rings.

Elementary properties of finite field extensions and roots of polynomials, finite fields.

Text Books:

1. D. Dummit and R. Foote, Abstract Algebra, 3rd edition, Wiley, 2004.
2. J. A. Gallian, Contemporary Abstract Algebra, 4th ed., Narosa, 1999.

Reference Books:

1. M. Artin, Algebra, Prentice Hall of India, 1994.
2. T. T. Moh, Algebra, World Scientific, 1992. S. Lang, Undergraduate Algebra, 2nd Ed., Springer, 2001.
3. S. R. Nagpaul and S. K. Jain, Topics in Applied Abstract Algebra, Amer. Math. Soc., First Indian Edition, 2010.
4. J. B. Fraleigh, A First Course in Abstract Algebra Paperback, Addison-wesley 1967.

Course Name	**Ordinary Differential Equations**
Course Number	MA429 (Core)
Course Credit	3 – 1 – 0 – 8
Prerequisite	None

First Order ODE y' = f(x,y) geometrical interpretation of solution, review of solution methods for first order equations, orthogonal trajectories,

Existence and uniqueness of IVPs: Picard's and Peano's Theorems, Gronwall's inequality, continuation of solutions and maximal interval of existence, continuous dependence,Higher order equations, existence and uniqueness of solution of IVP, Wronskian and general solution of homogeneous and non-homogeneous equations.

Variable coefficients,power series method, Frobenious method, Legendre polynomials, Bessel functions, solving system of linear order using eigenvalue- eigenvector, non-homogeneous equations, variation of parameters, stability of linear systems, BVPs, Green's function, Sturm comparison theorems, eigenvalue problems.

Text Books:

1. G. Birkhoff and G. C. Rota, Ordinary Differential Equations, 4th Edition, Wiley, 2003.
2. G. F. Simmons, Differential Equations with Applications and Historical Notes, Second edition, Tata McGraw Hill, 1991.

Reference Books:

1. E. A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, Tata McGraw Hill, 1984.
2. L. Perko, Differential Equations and Dynamical Systems, Springer-Verlag, 2006.
3. S.G. Deo, V. Lakshmikantham and V. Raghavendra, Textbook of Ordinary Differential Equations, 2nd Edition, Tata McGraw Hill, 2002.

Course Name	**Topology**
Course Number	MA422 (Core)
Course Credit	3 – 1 – 0 – 8
Prerequisite	None

Definition and examples of topological spaces (including metric spaces), Open and closed sets, Subspaces and relative topology, Closure and interior, Accumulation points, Dense sets, Neighbourhoods, Boundary, Bases and sub-bases. Construction of Topological spaces from known spaces. Product spaces, Cone and Suspension construction. Identification spaces.Neighbourhoodsystems. Nets and Filters. Continuous functions and homeomorphism, Quotient topology, First and secondcountability and separability, Lindelof spaces. The separation axioms T0, T1, T2, T3,T3_1/2 , and T4; their characterizations and basic properties. Urysohn's lemma, Tietze's extension theorem.Compactness.Basic properties of compactness.Compactnessand the finite intersection property, Local compactness, One-point compactification.Connected spaces and their basic properties.Connectedness of the real line.Components, Locally connected spaces.Tychonoff 's theorem,

Text and References:

1. M. A. Armstrong, Basic Topology, Springer, 2014.
2. J. L. Kelley, General Topology, Van Nostrand, 1995.
3. James R. Munkres, Topology, 2nd Edition, Pearson International, 2000.
4. J. Dugundji, Topology, Prentice-Hall of India, 1966.
5. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 1963.

Course Name	**Complex Analysis**
Course Number	MA424 (Core)
Course Credit	3 – 1 – 0 – 8
Prerequisite	None

Complex numbers and the point at infinity.Analytic functions, Cauchy-Riemann conditions, Harmonic Conjugates, Mappings by elementary functions, Riemann surfaces, Bilinear and Conformal mappings, Mobius Transformations, Schwarz-Christoffel Transformation.

Contour integrals, Cauchy-Goursat Theorem.

Uniform convegence of sequences and series, Taylor and Laurent series, Classification of singularities, Isolated singularities and residues, Zeroes and poles, , Residue theorem and applications, Maximum Modulus Principle, Argument Principle, Rouche's theorem and Gauss-Lucas Theorem.

Text Books / Reference Books

1. J. B. Conway, Functions of One Complex Variable, 2nd ed., Narosa Pub. House, New Delhi, 1978.
2. T. W. Gamelin, Complex Analysis, Springer International Edition, 2001.
3. R. Remmert, Theory of Complex Functions, Springer Verlag, 1991.
4. A. R. Shastri, An Introduction to Complex Analysis, Macmilan India, New Delhi, 1999.

Course Name	**Probability and Statistics**
Course Number	MA426 (Core)
Course Credit	3 – 1 – 0 – 8
Prerequisite	None

Review of Probability Theory: Elementary properties of Probability Models, Mathematical Expectations, Moment and Probability Generating Functions, Classical Discrete and Continuous Probability Distributions, Transformations of Random Variables and Vectors. Ordered Statistics and their joint distributions, Minimum and Maximum order Statistics, Chi-square, T, F distributions and their properties, Distributions of Sample Mean and Sample Variance.

Estimation: Unbiased Estimation, Minimum Variance Unbiased Estimator, Rao-Cramer Inequality and its attainment, Rao-Blackwell and Lehmann-Scheffe Theorems, Fisher Information, Maximum Likelihood Estimator and its invariance property, Efficiency, Mean Square Error.

Confidence Interval: Coverage Probability, Confidence level, Sample size determination, Shortest Length interval, Pivotal quantities, interval estimates for various distributions.

Testing of Hypotheses: Null and Alternative Hypotheses, Test Statistic, Error Probabilities, Power Function, Level of Significance, Neyman-Pearson Lemma, One and Two Sided Tests for Mean, Variance and Proportions, One and Two Sample T-Test, Pooled T-Test, Paired T-Test, Chi-Square Test, Contingency Table Test, Maximum Likelihood Test, Duality between Confidence Intervals and Testing, P-Values, Sign Test, Wilcoxon Signed Rank Test and Rank Sum Test.

Books:

1. Mathematical Statistics with applications, Kandethody M. Ramachandran, Chris P. Tsokos, Academic Press, 2009.
2. Probability and Statistics in Engineering, William W. Hines, Douglas C. Montgomery, David M. Goldsman, John Wiley & Sons, Inc, 4th Ed., 2003.
3. An Introduction to Probability and Statistics, V.K. Rohatgi and A.K.Md. EhsanesSaleh, John Wiley, 2nd Ed, 2009.
4. Statistical Inference, G. Casella and R.L. Berger, Duxbury Advanced Series,2nd Ed., 2007.

Course Name	**Measure Theory and Integrations**
Course Number	MA428 (Core)
Course Credit	3 – 1 – 0 – 8
Prerequisite	None

Review of Riemann Integral, Its drawbacks and Lebesgue's recipe to extend it. Extension of length function, Semi-algebra and algebra of sets, Lebesgue outer measure, Measurable sets, Measure space, Complete measure space. The Lebesgue measure on R, Properties of Lebesgue measure, Uniqueness of Lebesgue Measure, Construction of non-measurable subsets of R.

Lebesgue Integration: The integration of non-negative functions, Measurable functions, Fatou's Lemma, Integrable functions and their properties, Lebesgue's dominated convergence theorem. Absolutely continuous function, Lebesgue-Young theorem (without proof), Fundamental theorem of Integral calculus and its applications. Product of two measure spaces, Fubini's theorem. Lp-spaces, Holder's inequality, Minkowski's inequality, Completion of Lp-spaces.

Text and References:

1. Inder K. Rana, An introduction to Measure and Integration, Narosa, 1997.
2. G. de Barra, Measure Theory and Integration, John Wiley & Sons, 1981.
3. J.L. Kelly, T. P. Srinivasan, Measure and Integration, Springer, 1988.
4. H. L Royden, Real Analysis, Pearson, 2007
5. M. E. Taylor, Measure Theory and Integration, AMS, 2012.

Course Name	**Numerical Analysis**
Course Number	MA430 (Core)
Course Credit	3 – 0 – 2 – 8
Prerequisite	None

Numerical errors and their analysis, interpolations, Finite Difference and Divided Difference Operators, Solution of system of linear equations, Gauss Elimination Method, Jacobi and Gauss-Seidel Methods, Eigen values and Eigen vectors, Solutions of nonlinear equations, Numerical differentiation, Numerical Integration, Trapezoidal, Simpson's 1/3 and 3/8 rules, Romberg integration, Gaussian quadrature formulae, Numerical solution of ordinary and partial differential equations.

Books:

1. S. S. Sastry, Introductory Methods of Numerical Analysis, 4^{th} Edition, PHI Learning Pvt. Ltd., New Delhi, 2011.
2. M. K. Jain, SRK Iyengar and R.K. Jain, Numerical Methods For Scientific & Engg 5e, New Age International (P) Ltd (2008), ISBN-13:978-8122420012.
3. S. D. Conte and Carl de Boor, Elementary Numerical Analysis, An Algorithmic Approach, Macgraw Hill International Editions, 1981.
4. K. E. Atkinson, An Introduction to Numerical Analysis, John Wiley & Sons, paperback, 1989.

Course Name	**Functional Analysis**
Course Number	MA521 (Core)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Normed spaces, Convergence and absolute convergence of a series in normed linear space. Continuity of linear maps, Hahn-Banach Extension and Separation Theorems, Banach spaces, Dual spaces and transposes.

Uniform Boundedness Principle and its applications, Closed Graph Theorem, Open Mapping Theorem and its applications, Spectrum of a bounded operator, Examples of compact operators on normed spaces.

Inner product spaces, Hilbert spaces, Orthonormal basis, Projection theorem and Riesz Representation Theorem.

Texts / References

1. J. B. Conway, A Course in Functional Analysis, 2nd ed., Springer, Berlin, 1990.
2. C. Goffman and G. Pedrick, A First Course in Functional Analysis, Prentice-Hall, 1974.
3. E. Kreyzig, Introduction to Functional Analysis with Applications, John Wiley & Sons, New York, 1978.
4. B. V. Limaye, Functional Analysis, 2nd ed., New Age International, New Delhi, 1996.
5. M. T. Nair, Functional Analysis: A First Course, PHI Pvt. Ltd, 2004.

Course Name	**Partial Differential Equations**
Course Number	MA523 (Core)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Analysis, ODE

Introduction to PDE, basic concepts, linear and quasi linear & nonlinear PDEs-Lagrange and Charpit's methods, Cauchy-Kowalewski theorem, second order PDEs and classification of second order semi linear PDE (Canonical forms), D'Alemberts solution and Duhamel's principle for one dimensional wave equation, uniqueness of solutions, solution of Heat equation, uniqueness of solutions via energy method, Laplace equation and Poisson equations, maximum-minimum principle with application, existence theorem, Fourier Series and Fourier transform and its application to solution of wave, heat and Laplace equation.

Text Books:

1. N. Sneddon, Elements of Partial Differential Equations, Dover, 2006.
2. R. Haberman, Applied Partial Differential Equations, 4th Edition, Prentice Hall, 2003.

Reference Books:

1. E. T. Copson, Partial Differential Equations, Cambridge University Press, London, 1975.
2. W. E. Williams, Partial Differential Equations, Clarendon Press, Oxford, 1980.
3. T. Myint-U, L Debnath, Linear Partial Differential Equations for Scientists and Engineers, 4th edition, Birkhauser, 2007.

Course Name	**Operations Research**
Course Number	MA525 (Core)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Framework and overview of linear optimization including examples of continuous and discrete optimization

Non Liner Programming: Constraint qualification and Kuhn-Tucker necessary conditions. Sufficiency of Kuhn-Tucker necessary conditions and convex programs. Iterative methods and associated issues. Line search methods: Stationarity of limit points of steepest decent, successive step-size reduction algorithms, etc. Hessian based algorithms: Newton, Conjugate directions and Quasi-Newton methods. Quadratic programming .

Dynamic Programming: Bellman's principle of optimality and recursive relationship of dynamic programming for various optimization problems.

Inventory control problem: Concept of inventory and various costs, EOQ formula. Single and Multi period models

Queuing Theory: Introduction to waiting line models steady state behavior of M/M/1 and M/M/C queues-the problem of machine interference and use of finite queuing tables-introduction to M/G/1, and G/M/1.

Introduction to Multiple criterion decision making problems. Typical application to solve real-life problems.

Texts & References

1. J. K. Sharma, Operation Research Theory and Applications, Macmillan , India, 2013.
2. V. Chvatal, Linear Programming, W.H. Freeman, New York, 1983.
3. S. Tijs, Introduction to Game Theory, Hindustan Book Agency, New Delhi, 2003.
4. D. P. Bertsekas, Dynamic programming and optimal control, Athena Scientific, Belmont, 1995.
5. J. L. Cohon, Multiobjective programming and planning, Academic Press, New York, 1978.
6. C. F. Daganzo, Fundamentals of transportation and traffic operations, Pergamon, Oxford, 1997.
7. H. A. Taha, Operations Research - An Introduction, Macmillan, N.Y, 1982.

Course Name	**Algebraic Topology**
Course Number	MA527 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Algebra (MA427) and Topology (M 422)

Homotopic maps, homotopy type, retraction and deformation retract. Fundamental groups. Computation of fundamental groups of n-spheres, the cylinder, the torus, and the punctured plane, the Mobius strip, projective plane and the Klein bottle. Applications: the Brouwer fixed-point theorem, the fundamental theorem of algebra.

Covering projections, the lifting theorems, relations with the fundamental group, classification of covering spaces, universal covering space. The Borsuk-Ulam theorem, free groups, Seifert Van Kampen theorem and its applications.

Text and References:

1. F. H. Croom, Introduction to Algebraic Topology, Springer, 2014.
2. M. A. Armstrong, Basic Topology, Springer-Verlag, 1983.
3. W. S. Massey, A Basic Course in Algebraic Topology, Springer-Verlag, 2007.
4. J. J. Rotman, An Introduction to Algebraic Topology, Springer-Verlag, 1988.
5. E. H. Spanier, Algebraic Topology, Springer-Verlag, 1989.

Course Name	**Basic Number Theory**
Course Number	MA529 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Prerequisites: Divisibility, Basic Algebra of Infinitude of primes, discussion of the Prime Number Theorem, infinitude of primes in specific arithmetic progressions, Dirichlet's theorem (without proof).

Arithmetic functions, Mobius inversion formula. Structure of units modulo n, Euler's phi function Congruences, theorems of Fermat and Euler, Wilson's theorem, linear congruences, quadratic residues, law of quadratic reciprocity. Binary quadratics forms, equivalence, reduction, Fermat's two square theorem, Lagrange's four square theorem.

Continued fractions, rational approximations, Liouville's theorem, discussion of Roth's theorem, transcendental numbers, transcendence of "e" and "pi".

Diophantine equations: Brahmagupta's equation (also known as Pell's equation), Fermat's method of descent, discussion of the Mordell equation.

Optional Topics: Discussion of Waring's problem; Discussion of the Bhargava-Conway "fifteen theorem" for positive definite quadratic forms; The RSA algorithm and public key encryption, Primality testing, discussion of the Agrawal- Kayal-Saxena theorem; Catalan's equation, discussion of the Gelfond-Schneider theorem, discussion of Baker's theorem.

Texts / References

1. W. W. Adams and L.J. Goldstein, Introduction to the Theory of Numbers, 3rd ed., Wiley Eastern, 1972.
2. A. Baker, A Concise Introduction to the Theory of Numbers, Cambridge University Press, Cambridge, 1984.
3. I. Niven and H.S. Zuckerman, An Introduction to the Theory of Numbers, 4th Ed., Wiley, New York, 1980.
4. Thomas Koshy, Elementary Number Theory with Applications, Second Edition, Academic Press, 2007.

Course Name	**Control Theory**
Course Number	MA531 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Mathematical models of control systems, State space representation, Autonomous and non-autonomous systems, State transition matrix, Solution of linear dynamical system.

Transfer function, Realization, Controllability, Kalman theorem, Controllability Grammian, Control computation using Grammian matrix, Observability, Duality theorems, Discrete control systems, Controllability and Observability results for discrete systems.

Companion form, Feedback control, State observer, Liapunov stability, Stability analysis for linear systems, Liapunov theorems for stability and instability for nonlinear systems, Stability analysis through Linearization, Routh criterion, Nyquist criterion, Stabilizability and detachability.

State feedback of multivariable system, Riccatti equation, Introdction to Calculus of variation, Euler- Hamiltonian equations, Computation of optimal control for linear systems.

Texts / References

1. S. Barnett, Introduction to Mathematical Control Theory, Clarendon press Oxford 1975
2. R. V. Dukkipati, Control Systems, Narosa 2005
3. I. J. Nagrath and M. Gopal, Control System Engineering, New Age international 2001.
4. B. Datta, Numerical Methods for Linear Control Systems, Academic press Elsevier, 2004.

Course Name	**Graph Theory**
Course Number	MA533 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Basic notions of Graph theory, Eulerian graph, Bipartite graph, Adjacency and Incidence matrices, Graph isomorphism, Bipartite graph and matrices, Diameter and eigenvalues, Trees, Leaves, Forests, Counting labelled trees, Spanning subgraphs,

Minimum spanning trees and Kruskal's Algorithm, Colouring Graphs, Colouring Trees and Cycles, Polya Theory, The Marriage theorem, Matching in general graph, Connectivity, Planar graphs, Euler's formula, The five colour theorem, Edges and cycles, Edge colouring, Hamiltonian cycles, Regular graphs, Eigen values of regular graphs, Diameter of regular graphs, Ramanujan graphs.

Text and References:

1. Reinhard Diestel, Graph Theory, Graduate Texts in Mathematics, Springer, 1997.
2. B. Bollobas, Graph theory an introductory course, GTM 63, Springer-Verlag, New york, 1979.
3. J. Bondy and U S R Murty, Graph Theory, Springer, 2014.
4. J. H. van Lint and R.M. Wilson, A course in combinatorics, Cambridge University press, 1992.
5. S. M. Cioaba and M. Ram Murty, A first Course in Graph Theory and Combinatorics, TRIM, Hindustan Book Agency, 2009.

Course Name	**Introduction to Coding Theory**
Course Number	MA535 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Algebra (MA 427)

Polynomial rings over fields, Extension of fields, Computation in GF(q), n-th roots of unity, Vector space over finite fields.

Error correcting codes: Binary group codes, Hamming codes, Linear block codes, The structure of cyclic codes, Quadratic residue codes, Reed Mueller codes, Simplex codes.

Nonlinear codes, Golay, Hadamard, Justeen, Kerdock, Nordstorm-Robinson codes, First and Second order Reed-Mueller codes, t-designs, steiner systems, Weight distribution of codes.

Generalized BCH codes. Self-dual codes and invariant theory, Covering radius problem, Convolutional codes, LDPC codes, Turbo codes.

Text Books:

1. Ron Roth, Introduction to Coding Theory, Cambridge University Press, 2006.
2. J. H. van Lint, Introduction to Coding Theory, Springer, 1999.
3. Raymond Hill, A First Course in Coding Theory (Oxford Applied Mathematics and Computing Science Series), Clarendon Press, 1986.

Course Name	**Mathematical Methods**
Course Number	MA537 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Integral Equations: Introduction and Relation between Integral and Differential Equations, Classification of integral equations, Fredholm equations, The Green's function. Hilbert Schmidt theory, Iterative methods for solving equations of the second kind, The Neumann Series and Fredholm Theory. Singular integral equations.

Integral Transforms: Laplace Transform, Fourier Transform, Fourier sine/cosine Transforms with their inverse transforms (properties, convolution theorem and application to solve differential equation).

Calculus of Variation: Variational problem with functionals containing first order derivatives and Euler equations. Functionals containing higher order derivatives and several independent variables. Variational problem with moving boundaries. Boundaries with constraints. Higher order necessary conditions, Weiretrass function, Legendre's and Jacobi's condition. Existence of solutions of variational problems. Rayleigh-Ritz method.

Texts:

1. A.H. Nayfeh, Introduction to Perturbation Techniques, John Wiley & Sons, 2004.
2. Francis B. Hildebrand, Methods of Applied Mathematics, Dover Publications; 2nd edition, 1992.
3. R. Haberman, Applied Partial Equations, 4th Edition, Prentice Hall, 2003.

References:

1. Lokenath Debnath and D. Bhatta, Integral Transform and their Applications, Taylor & Francis Group, 2002.
2. S.G. Mikhlin, Variation Methods in Mathematical Physics, Pergaman Press, Oxford 1964. C.M.
3. R. Courant & D. Hilbert, Methods of Mathematical Physics, Vol. I, Wiley Eastern Pvt. Ltd., New Delhi, 1975.

Course Name	**Mathematical Modeling**
Course Number	MA539 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

System of differential equations; Linear and nonlinear stability; Basic idea of bifurcation; some illustrations with help of computer programming

Introduction to modeling; Elementary mathematical models and General modeling ideas; General utility of Mathematical models, Role of mathematics in problem solving; Concepts of mathematical modeling; System approach; formulation, Analyses of models; Pitfalls in modeling;

Illustrations models such as Population dynamics, Traffic Flow, Social interactions, Viral infections, Epidemics, Finance, Economics, Management, etc. (*The choice and nature of models selected may be changed with mutual interest of lecturer and students.*)

Introduction to probabilistic models.

Text & References:

1. D. N. P. Murthy, N. W. Page, Ervin Y. Rodin, Mathematical modelling: a tool for problem solving in engineering, physical, biological, and social sciences, Pergamon Press, 1990.
2. W. E. Boyce and R.C. DiPrima, Elementary Equations and Boundary Value Problems, 7th Edition, Wiley, 2001.
3. J. D. Murray, Mathematical Biology, Vol I, 3rd Ed, Springer, 2003.
4. Wei-Bin Zhang, Differential equations, bifurcations, and chaos in economics, Series on Advances in Mathematics for Applied Sciences, Vol 68, World Scientific, 2005.

Course Name	**Statistical Inference**
Course Number	MA541 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Estimation problems and sufficiency, Factorization method for sufficiency, Lehmann-Scheffe method, minimal sufficiency, exponential families, unbiased estimators and properties, mean square error, Rao-Blackwell Theorem, method of moments estimators, maximum likelihood estimation, goodness criteria, Cramer-Rao inequality, Bhattacharya bounds, equivariance principal and applications, confidence intervals, pivotal quantities, optimal confidence intervals.

Tests of hypotheses, simple and composite hypotheses, error probabilities, significance probabilities, size of a test, monotone likelihood ratio property, Neyman-Pearson Lemma, uniformly most powerful tests, uniformly most powerful unbiased tests, likelihood ratio tests, chi-square tests.

References:

1. R. L. Berger and G. Casella, Statistical Inference, Duxbury Advanced Series, Second Edition, 2007.
2. A. M. Mood, F. A. Graybill and D. C. Boes, Introduction to the Theory of Statistics, Tata McGraw-Hill, 2009.
3. V. K. Rohatgi & A. K. Md. E. Saleh, An Introduction to Probability and Statistics. John-Wiley, Second Edition, 2009.
4. E. J. Dudewicz & S. N. Mishra, Modern Mathematical Statistics. John Wiley, 1988.

Course Name	**Combinatorics**
Course Number	MA522 (Core)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Mathematical Logic and Relations: Statements, Logical connectives, Truth tables, Equivalence, Inference and deduction, Predicates, Quantifiers. Partial ordering, well ordering principle.
Recurrence Relations: Permutations & Combinations, Elementary counting principles, Binomial Coefficients, Derangements, Involutions, Fibonacci, Catalan and Bell numbers.
The principle of inclusion and exclusion, Stirling Numbers of first and second kinds, Posets and Mobius functions, Lattices, Partitions.

Text and References:

1. R. P. Grimaldi, Discrete and Combinatorial Mathematics, Pearson Education, 1999.
2. S. M. Cioaba and M Ram Murty, A first course in graph theory and combinatorics. HBA, 2009.
3. M. Aigner, A course in Enumeration, Springer (SIE), 2007.
4. L. L. Dornhoff and E. F. Hohn, Applied Modern Algebra, McMillan Publishing Co., 1978.

Course Name	**Differential Geometry**
Course Number	MA524 (Core)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Serret-Frenet formulae, Locus of center of Spherical Curvature, Determination of a curve when its curvature and torsion are functions of arc – length, Helics, Bertrand curves.

Envelop, characteristics and edge of regression of a one parameter family of surfaces, Developable surfaces, Osculating developable, Polar developable and Rectifying developable.

Directions on a surface and the fundamental magnitudes, Curvature of normal section and Meunier's theorem.

Curvature on a surface and lines of curvature, principle curvatures. First and second Fundamental forms (curvatures) and their values for a surface given in Monge's form. Euler's theorem, conjugate directions.

Asymptotic lines and their curvature and torsion, Geodesics and their equations, Geodesics on a surface of revolution, Torsion of a Geodesic.

Text/ References:

1. C. E. Weatherburn, Differential Geometry of Three Dimensions, Vol. 1, Camb. Univ. Press, 1961. Indian edition is also available.
2. A. Pressley, Elementary Differential Geometry, Springer, Indian Reprint, 2004.
3. T. J. Willmore, An Introduction to Differential Geometry, Dover Publication, 2012.
4. E. kreyszig, Differential Geometry, Dover Publications, 1991.

Course Name	**Differential Manifolds**
Course Number	MA526 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Real Analysis (MA 425) and Topology (MA 422)

The derivative, continuously differentiable functions, the inverse function theorem, the implicit function theorem.

Topological manifolds, partitions of unity, imbedding and immersions, manifolds with boundary, submanifolds.

Tangent vectors and differentials, Sard's theorem and regular values, Local properties of immersions and submersions.

Vector fields and flows, tangent bundles, Embeddings in Euclidean spaces, smooth maps and their differentials.

Smooth manifolds, smooth manifolds with boundary, smooth submanifolds, construction of smooth functions, Classical Lie groups.

Text and References:

1. J. M. Lee, Manifolds and Differential Geometry, AMS, GSM, 2014.
2. G. E. Bredon, Topology and Geometry, Springer-verlag, 1993.
3. A. Kosinski, Differential Manifolds, Academic Press, 1992.
4. J. R. Munkres, Analysis on Manifolds, Addison-Wesley Publishing Company, 1991.
5. M. Spivak, A Comprehensive Introduction to Differential Geometry I, Publish or Perish, 1979.

Course Name	**Differential Topology**
Course Number	MA528 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Real Analysis (MA425) and Topology (MA 422)

Manifolds and smooth maps: Derivatives and tangents, implicit and inverse function theorems. Immersions, submersions, transversality, homotopy and stability, Sards Theorem and Morse functions, embedding manifolds in Euclidean spaces.

Transversality and Intersection: Manifolds with boundary, transeversality, Intersection theory mod 2, Winding number and the Jordan-Brouwer separation theorem, Borsuk-Ulam theorem.

Text and References:

1. J. M. Lee, Manifolds and differential geometry, AMS, GSM , 2014
2. V. Guillemin and A. Pollack, Differential Topology, Prentice Hall, New Jersey, 1974.
3. M. Spivak, Calculus on manifolds, Benjamin, 1965.

Course Name	**Fuzzy Sets and Systems**
Course Number	MA530 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Introduction, Uncertainty, Imprecision and vagueness, Brief history of fuzzy logic, Fuzzy sets and systems, Fuzzy systems in commercial products, Research fields in fuzzy theory.

Basic Concepts of fuzzy sets, Fuzzy logic, Types of membership functions, Basic concepts (support, singleton, height, a-cut projections), Zadeh's extension principle, Operations on fuzzy sets, S-and T- Norms, Fuzzy measures, Probability and Possibility measures, Linguistic variables and hedges, Membership function design.

Fuzzy inference methodologies, Graphical techniques of inference, Fuzzyifications/ Defuzzification, Classical relations, Fuzzy relations, Fuzzy to crisp conversions.

Fuzzy systems and algorithms, Approximate reasoning, Applications of fuzzy Sets in management, decision making, medicine and computer Science. Case Studies in Various Domain.

Texts:

1. S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, 2nd Ed, Prentice Hall, 2003.
2. H. J. Zimmermann, Fuzzy Set Theory and Its Applications, 2nd Ed., Kluwer Academic Publishers, 1996.
3. D. Dubois and H. Prade, Fuzzy Sets and Systems: Theory and Applications, Academic Press, 1980.

References:

1. E. Charniak and D. McDermott, Introduction to Artificial Intelligence, Addison-Wesley, 1985.
2. E. Rich, Artificial Intelligence, McGraw-Hill, 1983.
3. P. H. Winston, Artificial Intelligence, Addison Wesley, 1993.
4. J. Yen and R.Langari, Fuzzy Logic Intelligence, Control, and Information, Pearson Education, 2005.
5. T. J. Ross, Fuzzy Logic with Engineering Applications, McGraw-Hill, 1997.
6. J. Kacprzyk, Multistage Fuzzy Control, Wiley, 1997.

Course Name	**Introduction to Biomathematics**
Course Number	MA532 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Course Dynamics:

The course will comprise of class room lectures, take home assignments based on class room lectures as well as reading assignments, and a mathematical modeling project with a final report and/or presentation of the work and final written exams. The weightage of different component will be different.

Syllabus:

Mathematical modeling: Role of mathematics in problem solving, Introduction to mathematical modeling and its basic concepts- system description and characterization, model formulation, validation and analysis of models, Pitfalls in modeling.

Population Dynamics: Deterministic models in population dynamics, Stochastic birth-death models.

Models in ecology: Predator-prey models, Spatio-temporal models- diffusion processes, fisheries models.

Models at molecular level: HIV in vivo model, immune response models, Cancer models.

Modeling disease: Infectious disease models, Models for non-communicable diseases (NCDs),

Models for public health: Diseases control and interventions, Optimal control, Cost optimization.

Computational: Parameter estimation, network models.

Text & References:

1. N. F. Britton, Essential Mathematical Biology, SUMS, Springer
2. F. Brauer and C. Castillo-Chavez, Mathematical models in population biology and epidemiology, Springer, 2012.
3. D. N. P. Murthy, N. W. Page, Ervin Y. Rodin, Mathematical modelling: a tool for problem solving in engineering, physical, biological, and social sciences, Pergamon Press, 1990.
4. J. D. Murray, Mathematical Biology Volume I, 3rd Ed, 2003.
5. F. C. Hoppensteadt, Mathematical methods of population biology. Cambridge: Cambridge Univ. Press, 1982.

Course Name	**Operators on Hilbert Spaces**
Course Number	MA534 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Functional Analysis (MA 521)

Adjoints of bounded operators on a Hilbert space, Normal, self-adjoint and unitary operators, their spectra and numerical ranges.

Compact operators on Hilbert spaces, Spectral theorem for compact self-adjoint operators, Application to Sturm-Liouville Problems.

Texts / References

1. J. B. Conway, A Course in Functional Analysis, 2nd ed., Springer, Berlin, 1990.
2. C. Goffman and G. Pedrick, First Course in Functional Analysis, Prentice Hall, 1974.
3. I. Gohberg and S. Goldberg, Basic Operator Theory, Birkhauser, 1981.
4. E. Kreyzig, Introduction to Functional Analysis with Applications, John Wiley & Sons, New York, 1978.
5. B. V. Limaye, Functional Analysis, 2nd ed., New Age International, New Delhi, 1996.
6. M. T. Nair, Functional Analysis: A First Course, PHI Pvt. Ltd, 2004.

Course Name	**Rings and Modules**
Course Number	MA536 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	Algebra (MA 427)

Modules, sub modules, quotient modules and module homo morphisms, Generation of modules, direct sums and free modules.

Tensor products of modules; Exact sequences, projective modules.

Finitely generated modules over principal ideal domains, invariant factors, elementary divisors, finitely generated abelian groups and linear transformations.

Ascending Chain Condition and Descending Chain Condition, Noetherian rings and modules, Hilbert basis theorem, Primary decomposition of ideals in Noetherian rings.

Radicals: Nil radical, Jacobson radical and prime radical.

Localization of rings and modules.

Texts

1. C. Musili, Introduction to Rings and Modules, Narosa Pub. House, New Delhi, Sec. Edition, 2001.
2. J. A. Beachy, Introduction to Rings and Modules, London Math. Soc., Cam. Univ. Press, 2004.

References

1. M. F. Atiyah and I. G. Macdonald, Introduction to Commutative Algebra, Addison Wesley, 1969.
2. D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
3. N. Jacobson, Basic Algebra I and II, 2nd Ed., W. H. Freeman, 1985 and 1989.
4. S. Lang, Algebra, 3rd Ed., Springer (India), 2004.

Course Name	**Statistical Decision Theory**
Course Number	MA538 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Decision theoretic estimation problems, loss functions, Bayes procedures, proper and non-informative prior distributions, posterior distributions, admissible estimators, equivalent rules, minimax estimators, complete class rules, minimal complete class, illustrations, UMVUE and completeness property, Stein phenomenon, truncated parameter space estimation problems, equivariance of decision rules, location-scale groups of transformations, minimum risk equivariant rules, Bayesian credible intervals, highest posterior density intervals.

References

1. T. S. Ferguson, Statistical Decision Theory, Academic Press, 1967.
2. E. L. Lehmann, Theory of Point Estimation, Springer, Second Edition, 1998.
3. J. O. Berger, Statistical Decision Theory and Bayesian Analysis, Springer, Second Edition, 1993.

Course Name	**Wavelets Transform**
Course Number	MA540 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Various Transforms: Fourier Transforms, Poisson's Summation Formula, The Shannon Sampling Theorem, Heisenberg's Uncertainty Principle, The Gabor Transform, The Zak Transform, The Wigner-Ville Distribution, Ambiguity Functions, The Ambiguity Transformation.

Wavelet Transforms: Continuous Wavelet Transforms, Basic Properties, The Discrete Wavelet Transforms, Orthonormal Wavelets, Multiresolution Analysis and Construction of Wavelets, Properties of Scaling Functions and Orthonormal Wavelet Bases, Construction of Orthonormal Wavelets, Daubechies' Wavelets and Algorithms, Discrete Wavelet Transforms and Mallat's Pyramid Algorithm, Newland's Harmonic Wavelets, Properties of Harmonic Scaling Functions, Wavelet Expansions and Parseval's Formula.

Application: Solutions of ODEs and PDEs by using wavelets.

Text:

1. Lokenath Debnath, Wavelet Transforms and Their Applications, Springer Science+Business, Media, New York, 2002.

Reference:

1. Ülo Lepik, Helle Hein, Haar Wavelets With Applications, Springer, 2014.
2. K. P. Ramachandran, K. I. Resmi, N. G. Soman, Insight into Wavelets: From Theory to Practice, 3rd ed. PHI, 2010.
3. C. K. Chui, An Introduction to Wavelets, Academic Press, 1992.
4. Daubechies, Ten Lectures on Wavelets, SIAM Publication, Philadepphia, 1992.