THE UNIVERSITY OF BURDWAN

Syllabus of M.A/M.Sc. Mathematics

[with effect from 2014-15]

Semester	Course Type	Course Code	Name of the Course	Credit Pattern (L:T:P)	Total class hrs./week	Credit
First Semester	Core	MMATG101	Real Analysis	3:1:0	5	4
		MMATG102	Functional Analysis –I & Calculus of R^n – I	3:1:0	5	4
		MMATG103	Complex Analysis	3:1:0	5	4
		MMATG104	Classical Mechanics & Calculus of Variations	3:1:0	5	4
		MMATG105	Ordinary Differential Equations	1:1:0	3	2
		MMATG106	Abstract Algebra –I	2:0:0	2	2
		MMATG107	Computer Programming & Numerical Analysis	3:1:0	5	4
Second Semester	Core	MMATG201	Topology – I	3:1:0	5	4
		MMATG202	Linear Algebra	1:1:0	3	2
		MMATG203	Integral Equations	2:0:0	2	2
		MMATG204	Differential Geometry	3:1:0	5	4
		MMATG205	Partial Differential Equations	1:1:0	3	2
		MMATG206	Integral Transform	2:0:0	2	2
		MMATG207	Operations Research	3:1:0	5	4
		MMATG208	Computer Aided Numerical Practical	0:0:2	4	2

Semester	Course Type	Course Code	Name of the Course	Credit Pattern (L:T:P)	Total class hrs./week	Credit
Third Semester (Pure Stream)	Core	MMATP301	Abstract Algebra –II	3:1:0	5	4
		MMATP302	Functional Analysis –II	1:1:0	3	2
		MMATP303	Topological Vector Space	2:0:0	2	2
		MMATG304	Introduction to Manifolds	3:1:0	5	4
		MMATP305	Operator Theory	1:1:0	3	2
	Choose any one from the following courses for Major Elective - 1.					
	Major Elective-1	MMATPME306	Advanced Functional Analysis-I	3:1:0	5	4
		MMATPME307	Advanced Abstract Algebra-I	3:1:0	5	4
		MMATPME308	Algebraic Topology-I	3:1:0	5	4
		MMATPME309	Advanced Complex Analysis-I	3:1:0	5	4
		MMATPME310	Measure and Integration-I	3:1:0	5	4
	Choose any one from the following courses for Major Elective - 2.					
	Major Elective-2	MMATAME311	Advanced Optimization and Operations Research-I	3:1:0	5	4
		MMATPME312	Euclidean and non – Euclidean Geometries-I	3:1:0	5	4
		MMATPME313	Geometric Mechanics on Riemannian Manifolds-I	3:1:0	5	4
		MMATPME314	Advanced Differential Geometry-I	3:1:0	5	4
		MMATPME315	Operator Theory and Applications-I	3:1:0	5	4
	Students have to choose one minor elective course of 2 credit offered by other departments.					

Semester	Course Type	Course Code	Name of the Course	Credit Pattern (L:T:P)	Total class hrs./week	Credit
Third Semester (Applied Stream)	Core	MMATA301	Methods of Applied Mathematics (Theory of distributions, Operator equations on Hilbert spaces)	1:1:0	3	2
		MMATA302	Wavelet Analysis	2:0:0	2	2
		MMATA303	Continuum Mechanics	3:1:0	5	4
		MMATG304	Introduction to Manifolds	3:1:0	5	4
		MMATA305	Boundary Value Problems	1:1:0	3	2
	Choose any one from the following courses for Major Elective - 1.					
	Major Elective-1	MMATAME306	Boundary Layer Flows and Magneto - hydrodynamics-I	3:1:0	5	4
		MMATAME307	Turbulent Flows-I	3:1:0	5	4
		MMATAME308	Quantum Mechanics-I	3:1:0	5	4
		MMATAME309	Elasticity-I	3:1:0	5	4
	Choose any one from the following courses for Major Elective - 2.					
	Major Elective-2	MMATAME310	Non – Linear Programming-I	3:1:0	5	4
		MMATAME311	Advanced Optimization and Operations Research-I	3:1:0	5	4
		MMATPME312	Euclidean and non – Euclidean Geometries-I	3:1:0	5	4
		MMATPME313	Geometric Mechanics on Riemannian Manifolds-I	3:1:0	5	4
		MMATPME314	Advanced Differential Geometry-I	3:1:0	5	4
Students have to choose one minor elective course of 2 credit offered by other departments.						

List of Minor Electives for the students of other departments.						
Third Semester	Minor Elective	MMATMIE316	Operations Research	2:0:0	2	2
		MMATMIE317	Introduction to Graph Theory	2:0:0	2	2

Semester	Course Type	Course Code	Name of the Course	Credit Pattern (L:T:P)	Total class hrs./week	Credit
Fourth Semester (Pure Stream)	Core Core	MMATP401	Abstract Algebra – III	1:1:0	3	2
		MMATP402	Calculus of R^n –II	2:0:0	2	2
		MMATP403	Topology –II	3:1:0	5	4
		MMATP404	Set Theory and Mathematical Logic	1:1:0	3	2
		MMATG405	Graph Theory	1:1:0	3	2
	Choose any one from the following courses for Major Elective - 3.					
	Major Elective-3	MMATPME406	Advanced Functional Analysis-II	3:1:0	5	4
		MMATPME407	Advanced Abstract Algebra-II	3:1:0	5	4
		MMATPME408	Algebraic Topology-II	3:1:0	5	4
		MMATPME409	Advanced Complex Analysis-II	3:1:0	5	4
		MMATPME410	Measure and Integration-II	3:1:0	5	4
	Choose any one from the following courses for Major Elective - 4.					
	Major Elective-4	MMATAME411	Advanced Optimization and Operations Research-II	3:1:0	5	4
		MMATPME412	Euclidean and non – Euclidean Geometries-II	3:1:0	5	4
		MMATPME413	Geometric Mechanics on Riemannian Manifolds-II	3:1:0	5	4
		MMATPME414	Advanced Differential Geometry-II	3:1:0	5	4
		MMATPME415	Operator Theory and Applications-II	3:1:0	5	4
	Project	MMATPSO416	Project and Social Outreach Programme	0:0:2	4	2

Semester	Course Type	Course Code	Name of the Course	Credit Pattern (L:T:P)	Total class hrs./week	Credit
Fourth Semester (Applied Stream)	Core	MMATA401	Fluid Mechanics	3:1:0	5	4
		MMATA402	Dynamical Systems	1:1:0	3	2
		MMATA403	Chaos and Fractals	2:0:0	2	2
		MMATA404	Quantum Mechanics	1:1:0	3	2
		MMATG405	Graph theory	1:1:0	3	2
	Choose any one from the following courses for Major Elective - 3.					
	Major Elective-3	MMATAME406	Boundary Layer Flows and Magneto - hydrodynamics-II	3:1:0	5	4
		MMATAME407	Turbulent Flows-II	3:1:0	5	4
		MMATAME408	Quantum Mechanics-II	3:1:0	5	4
		MMATAME409	Elasticity-II	3:1:0	5	4
	Choose any one from the following courses for Major Elective - 4.					
	Major Elective-4	MMATAME410	Non – Linear Programming-II	3:1:0	5	4
		MMATAME411	Advanced Optimization and Operations Research-II	3:1:0	5	4
		MMATPME412	Euclidean and Non – Euclidean Geometries-II	3:1:0	5	4
		MMATPME413	Geometric Mechanics on Riemannian Manifolds-II	3:1:0	5	4
		MMATPME414	Advanced Differential Geometry-II	3:1:0	5	4
	Project	MMATPSO416	Project and Social Outreach Programme	0:0:2	4	2

Duration of P.G. course of studies in Mathematics shall be two years with four semesters each of six months duration leading to Semester-I, Semester-II, Semester-III and Semester-IV examination in Mathematics at the end of each semester. Syllabus for P.G. courses in Mathematics is hereby framed according to the following schemes and structures.

Scheme of course will be Choice Based Credit System (CBCS) as per university guidelines**.** All the students will have to take compulsorily core papers and project papers. The major elective courses that will run in a particular year for Sem-III & IV will be decided by the Department .The student will give option for taking major electives and they have to take two major elective courses for Sem-III & IV. Students have to take same title of major elective courses both in Sem-III and Sem-IV. The option norm for selection of major elective courses is to be framed by the Department in each year according to SGPA of Sem-I of the students. However, the distribution of students to the major elective courses will be equally divided as far as practicable. All faculty members will supervise the students for project work. Students will be almost equally distributed among the supervisors for project work. Project work will be done from any topic on Mathematics and its Applications. The marks distribution of the Project work is 25 Marks for written submission, 10 Marks for Seminar presentation and 5 Marks for Viva-Voce. Social outreach programme is for 10 marks and will be done according to the decision of the department in every year**.**

Semester - I

Course – MMATG101

Real Analysis (Marks – 50)

Total lectures Hours: 50

Monotone functions and their discontinuities. Functions of bounded variation and their properties. [5]
Riemann Stieltjes integral, existence and other properties. [6]

Lebesgue Outer measure, countability, subadditivity, measurable sets and their properties,non-measurable sets. Lebesgue measure, notions of σ-algebra, Borel sets, F_σ –sets, G_δ –sets. [6]

Measurable Functions, continuity and measurability, monotonicity and measurability, measurability of Supremum and Infimum, simple functions, sequence of measurable functions, Egorov's Theorem. [8]

The Lebesgue Integral: Lebesgue integral of a non negative measurable function (bounded or unbounded), Integrable functions and their simple properties, Lebusgue Integral of functions of arbitrary sign, Integral of pointwise limit of sequence of measurable functions,Lebesgue Monotone convergence Theorem and its consequences, Fatou's Lemma, dominated convergence theorem, Comparison of Lebesgue and Riemann integral, Lebesgue criterion of Riemann integrality. [14]
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Vitali Lemma, differentiation of monotone functions, differentiation of an integral, absolute continuity. [4]

Fourier series, Dirichlet's kernel, Riemann Lebesgue Theorem, point wise convergence of Fourier series of functions of bounded variation. [7]

Text Books :

1. G.de Barra, *Measure Theory and Integration* , New Age International (P) Ltd, Publisher, 2000.
2. B.K.Lahiri and K.C.Roy, *Real Analysis*, World Press, 1988.
3. H.L.Royden, *Real Analysis*- 3rd Edn, Pearson, 1988.

Reference Book :

1. T. M. Apostol – *Mathematical Analysis,* Narosa Publi. House, 1985.
2. J. C. Burkil & H. Burkil – *A second Course of Mathematical Analysis,* CUP, 1980.
3. R. R. Goldberg – *Real Analysis,* Springer-Verlag, 1964
4. I. P. Natanson – *Theory of Functions of a Real Variable,* Vol. I, Fedrick Unger Publi. Co., 1961.
5. W. Rudin- *Principle of Mathematical Analysis,* Mc Graw Hill, N.Y., 1964.
6. Charles Swartz: *Measure, Integration and Function Spaces*, World Scientific, 1994.
7. E. C. Titchmarsh – *Theory of Functions,* CUP, 1980

Course – MMATG102

(Functional Analysis - I & Calculus of R^n- I)

Group- A

Functional Analysis-I (Marks - 30)

Total lectures Hours: 30

Baire's category Theorem, Banach Contraction Principle and its applications to solutions of system of linear algebraic equations, Picard's existence theorem on differential equation, Implicit function theorem, Fredholm Integral equations. [8]

Normed linear spaces and Banach spaces, Cauchy sequences, bounded sequences, convergent sequences with some basic properties, examples like $\mathbb{C}^n, C[a,b]$ (with sup metric), $C_0, l_p (1 \le p \le \infty), L_2[a,b]$, finite dimensional normed linear spaces, Quotient space, equivalent norms and its properties. [8]

Inner product spaces and Hilbert spaces, examples of Hilbert spaces such as R^n, C^n, l_2, $L_2[a,b]$, continuity of inner product, Minkowski inequality for integrals, C-S inequality, basic results on Inner product spaces and Hilbert spaces, parallelogram law, Pythagorean law, Polarization identity, orthogonal and orthonormal vectors, Bessel's inequality, Persevals'equality, Fourier expansion. [8]

Linear operators and linear functionals, continuity and boundedness of a linear operator on a normed linear space, norm of an operator, linear operator on finite dimensional normed linear spaces. [6]

Text Books :

1. B.Chowdhary, Sudarsan Nanda, *Functional Analysis with Applications*, Wiley Eastern ltd, 1991.
2. B.K. Lahiri-*Elements of Functional Analysis*, The world Press Pvt. Ltd., Kolkata, 1994.

Reference Books:

1. G. Bachman & L. Narici- *Functional Analysis*, Academic Press,1966.
2. N. Dunford & J. T. Scwarz – Linear operators, Vol – I & II, Interscience, New York, 1958.
3. K.K. Jha- *Functional Analysis, Student's Friends*,1986.
4. L.V. Kantorvich and G.P. Akilov-*Functional Analysis*, Pergamon Press,1982.
5. E. Kreyszig-*Introductory Functional Analysis with Applications*,Wiley Eastern,1989.
6. I.J.Madox- *Elements of Functional Analysis*,Universal Book Stall,1992.
7. A.H. Siddiqui, K. Ahmed and P. Manchanda, *Introduction to Functional Analysis with applications*, Anshan Publishers, 2007.
8. G.F. Simmons- *Introduction to Topology and Modern Analysis* ,Mc Graw Hill, New York, 1963.
9. A.E. Taylor- *Functional Analysis*, John wiley and Sons, New York,1958.

Group - B
Calculus of R^n - I (Marks - 20)

Total lectures Hours: 20

Functions from R^n to R^m, projection functions, component functions , scalar and vector fields, open balls and open sets, limit and continuity. [4]

Derivative of a scalar field with respect to a vector, directional derivatives and partial derivatives, partial derivatives of higher order., Chain rule, Frechet derivative, matrix representation of derivative of functions., continuously differentiable functions, C^∞-functions, real analytic functions. [12]

Implicit function theorem, inverse function theorem (local and global). [4]

Text Books:

1. T. M. Apostol, *Calculus, Vol – II,* John Wiley Sons, 1969.
2. J. R. Munkres*, Analysis on manifolds,* Addison-Wesley Pub. Comp., 1991.

Reference Books:

1. R. Courant and F. John, *Introduction to Calculus and Analysis, Vol – II,* Springer Verlag, New York, 2004.
2. T. Marsden, *Basic Multivariate Calculus*, Springer, 2013.
3. M.Spivak-*Calculus on Manifolds,* The Benjamin/Cummings Pub.comp.,1965.

Course – MMATG103

Complex Analysis (Marks – 50)

Total lectures Hours : 50

Complex Integration, line integral and its fundamental properties, Cauchy's fundamental theorem, index of a closed curve, Cauchy's integral formula and higher derivatives, power series expansion of analytic functions. [15]

Zeros of analytic functions and their limit points, entire functions, Liouville's theorem. Fundamental theorem of algebra. Primitives of analytic functions, Morera's theorem, Open mapping theorem. [10]

Singularities. Laurent's series expansion and classification of isolated singularities, essential singularities and Casorati-Weierstrass's theorem. Cauchy's residue theorem and evaluation of improper integrals. [10]

Argument principle, Rouche's theorem and its application, Maximum modulus theorem, Minimum Modulus Theorem, Meromorphic functions, Conformal mappings, Schwarz's Lemma and its consequence, Riemann mapping theorem. [10]

Schwarz reflection principle, analytic continuation along a path, analytic continuation by power series, Monodromy theorem.
[5]

Text Book:

1. J. B. Conway, *Functions of one complex variable, 2nd Ed.*, Narosa Publishing House, New Delhi, 1997.

Reference Books:

1. L. V. Ahlfors – *Complex Analysis- 3rd Edn*, McGraw-Hill, 1979
2. R. P. Boas – *Entire Functions,* Academic Press, 1954
3. H. Cartan – *Elementary Theory of Analytic Functions of One or Several Complex Variables,* Dover Publication, 1995.
4. E. T. Copson, *Introduction to the Theory of Function of a Complex Variable,* Oxford University press, 1970
5. K. Kodaria, *Complex Analysis,* Cambridge University Press, 2007.
6. R. Remmmert, *Theory of complex functions,* Springer-Verlag, New York, 1991.
7. W. Rudin – *Real and Complex Analysis,* Tata McGraw-Hill Education, 1987
8. E. C. Titchmarsh – *Theory of Functions,* Oxford University Press, 2nd Edn., 1970.

Course– MMATG104

(Classical Mechanics and Calculus of Variations)

Group - A

Classical Mechanics (Marks - 40)

Total lectures Hours: 40

Constrained motion: Generalised coordinates, Constraints, Types of Constraints, Forces of constraints, Classification of a Dynamical system, Virtual Work, Generalised Principle of D'Alembert, Generalised forces and generalized momentum, Expression for kinetic energy, Lagrange's equation of motion of first kind. [5]

Lagrangian mechanics: Lagrange's equations of motion for holonomic and non-holonomic systems, Velocity dependent potential, Dissipative forces, Rayleigh's dissipation function. [6]

Hamiltonian mechanics: Cyclic coordinates, Routh's process for the ignoration of co-ordinates and applications, Legendre dual transformation, Hamilton's canonical equations of motion. [5]

Variational principles: Action Integral, Hamilton's principle for conservative, non-holonomic system, Hamilton's principle for non-conservative, non-holonomic system, derivation of Hamilton's principle from Lagrange's equations, derivation of Lagrange's equations from Hamilton's principle, Principle of least action, Principle of energy. [10]

Rotating frames of reference: Rotating coordinate system, Motion of a particle relative to rotating earth, Coriolis force, Deviation of freely falling body from vertical, Foucault's pendulum. [4]

Motion of a rigid body: Two-dimensional motion of a rigid body rotating about a fixed point- velocity, angular momentum and kinetic energy, Euler's dynamical equations and its solution, Invariable line and invariable plane, Torque free motion, Euler angles, Components of angular velocity in terms of Euler angles, Motion of a top in a perfectly rough floor, Stability of top motion. [10]

Text Books:

1. H. Goldstein, *Classical Mechanics,* Narosa Publ. House, 1997.
2. N. C. Rana & P.S. Jog, *Classical Mechanics*, Tata McGraw Hill, 2001.

Reference Books:

1. F. R. Gantmakher – *Lectures in Analytical Mechanics,* Mir Publishers, 1970.
2. *D.* T. Green Wood – *Classical Dynamics,* Dover Publication, 2006.
3. K.C. Gupta, *Classical Mechanics of Particles and Rigid Bodies*, John Wiley & Sons Inc., 1988.
4. J. L. Synge & B. a. Graffith, *Principles of Mechanics*, Mc. Graw-Hill Book Co. 1960.
5. *E.* T. Whittaker – *A Treatise on the Analytical Dynamics of Particles and Rigid Bodies, C*ambridge University Press, 1993.

Group - B

Calculus of Variations (Marks -10)

Total lectures Hours: 10

Calculus of Variations: Concept of variation, Linear functional, Derivation of Euler-Lagrange differential equation- Some special cases, Euler-Lagrange differential equation for n-dependent variables, Functionals dependent on higher order derivatives, Functionals dependent on functions of several variables. [5]

Applications of calculus of variations to various problems: Shortest distance, minimum surface of revolution, Brachistochrone problem, geodesic, Isoperimetric problem, Calculus of variations for problems in parametric form, Variational problems with moving boundaries. [5]

Text Books:

1. A. S. Gupta, *Calculus of Variations with Applications*, Prentice –Hall of India, 1996.
2. Zafar Ahsan, Differential Equation and their applications, PHILearning , New Delhi, 2004

Reference Books:

1. V. B. Bhatia, *Classical Mechanics with introduction to nonlinear oscillation and chaos*, Narosa Publishing House, 1997.
2. I. M. Gelfand and S.V. Fomin, *Calculus of Variations,* Prentice Hall Inc, 2012.

Course – MMATG105

Ordinary Differential Equations (Marks- 30)

Total lectures Hours: 30

First-order equations: Well-posed problems, existence and uniqueness of solution, simple illustrations, Peano's and Picard theorems (Statements only), Picard's Successive approximations.
[3]

Green's function and its properties, Solution of ordinary differential equation using Green's function, Sturm-Liouville boundary value problem
[5]

Linear Systems: Basic Matrix Theory, Matrix functions, Differentiation of Matrix Functions, Exponential matrix, The Fundamental Theorem of Linear system, Linear systems in R^2, Solving Linear Systems using Eigen values and Eigen Vectors, Solutions using Fundamental theorem, Phase Plane Analysis, The flow defined by a differential equation, Linearization with examples. [9]

Special Functions: Concepts of ordinary and singular points of a second order linear differential equation in a complex plane, Fuch's theorem, Solution at an ordinary point, Regular singular point, Frobenius Method, Solution at a regular singular point, Series solutions of Legendre and Bessel equations.
[8]

Legendre polynomial: Generating function, Rodrigue's formula, recurrence relations, orthogonality property, expansion of a function in a series of Legendre polynomials. Bessel function and its properties. [5]

Text Books:-

1. E. A. Coddington, *An introduction to ordinary Differential Equations*, Prentice- Hall of India, 2012.
2. Lawrence Perko, *Differential Equations and Dynamical Systems,* Springer, 2001.

Reference Books:

1. R. P. Agarwal & R. C. Gupta, *Essentials of Ordinary Differential Equations* , MGH, 1993.
2. G. Birkhoff & G. Rota, *Ordinary Differential Equation* , Wiley, 1989.
3. J. C. Burkill, *The Theory of Ordinary Differential Equations*, Oliver & Boyd, London, 1968.
4. N. N. Lebedev, *Special Functions and Their Applications*, PHI, 1972.
5. E. D. Rainville, *Special Functions* , Macmillan, 1971.
6. G. F. Simmons, Di*fferential Equations* , TMH, 2006.
7. I. N. Sneddon, *Special Functions of mathematical Physics & Chemistry,* Oliver & Boyd, London, 1980.

Course– MMATG106

Abstract Algebra -I (Marks – 20)

Total lectures Hours: 20

Group : Homomorphism, Isomorphism Theorems, Fundamental Theorem, Correspondence Theorem, Automorphism, Inner Automorphism, Automorphism group of any cyclic group, classification of groups of order up to eight. [6]

Ring : Ideal, Quotient ring; Homormorphism and Isomorphism between two rings; ring embeddings; prime, maximal and primary ideal; Principal ideal domain; Euclidean domain; prime elements and irreducible elements; associates; greatest common divisor; least common multiple; quotient field; polynomial rings. [14]

Text Books:

1. D. M. Burton, *A First Course in Rings and Ideals*, Addison-Wesley Publishing Company, 1970.
2. D. S. Malik, J. M. Mordeson and M. K. Sen, *Fundamentals of Abstract Algebra*, McGraw-Hill, 1997.

Reference Books:

1. J. B. Fraleigh, *A First Course in Abstract algebra* , Addison-Wesley, 1967.
2. J. A. Gallian, *Contemporary Abstract algebra*, Cengage Learning, 1986.
3. I. N. Herstein – *Topics in Algebra* , Vikas Publishing House Pvt. Ltd, New Delhi, 1985.
4. M. K. Sen, S. Ghosh & P. S. Mukhopadhyay – *Topics in Abstract Algebra* , University Press, 2006

Course – MMATG107

(Computer Programming & Numerical Analysis)

Group – A

Computer Programming (Marks-30)

Total lectures Hours: 30

Programming in C: Introduction, Basic structures, Character set, Keywords, Identifiers, Constants, Variable-type declaration, Operators: Arithmetic, Relational, Logical, assignment, Increment, Decrement, Conditional.
[3]

Operator precedence and associativity, Arithmetic expression, Evaluation and type conversion, Character reading and writing, Formatted input and output, Statements. [3]

Decision making (branching and looping) – Simple and nested *if, if – else, switch, while, do-while, for* statements. [8]

Concept of array variables, String handling with arrays – reading and writing, String handling functions. [4]

User defined functions, cell-by-value, cell-by-reference function and their uses, Return values and their types, Nesting of functions, Recursion. [4]

Structures: Declaration, initialization, nested structure, array of structures, array within structures. [4]

Pointers: Declaration, initialization, Accessing variables through pointer, pointer arithmetic, pointers and arrays. [4]

Text Books:

1. E. Balaguruswamy, *Programming in ANSI C*, Tata McGraw-Hill, 2011.
2. B. S. Gottfried, *Programming with C*, Tata McGraw-Hill, 2011.

Reference Books:

1. G. C. Layek, A. Samad and S. Pramanik- *Computer Fundamentals, Fortran – 77, C and Numerical Problems*, Levrant, 2008.
2. K. R. Venugopal and S. R. Prasad, *Programming with C*, TMH, 1997.
3. C. Xavier, *C Language and Numerical Methods*, New Age International (P) Ltd. Pub, 2007.

Group - B

Numerical Analysis (Marks-20)

Total lectures Hours: 20

Polynomial approximations: Spline interpolation, Cubic spline, Hermite interpolation.
[3]

Numerical integration: Romberg Integration, Gauss' theory of quadrature, Gauss-Legendre formula.
[3]

Initial Value Problems: Solution of Initial Value Problems for first order ordinary differential equation by multi-step predictor-corrector method- Adam-Bashforth and Milne's method.
[4]

Boundary Value Problems: Boundary Value Problems for second order ordinary differential equation and its solution by finite difference method, Shooting method for the solution of linear and non-linear equations, Largest Eigen value and Eigen vector by Power method.
[5]

Numerical solution of partial differential equations by finite difference method: Explicit and Implicit methods, heat conduction equation: Discretization error , convergence & stability, Solution of wave equation: error, convergence & stability
[5]

Text Books:

1. K. E. Atkinson, *An introduction to Numerical Analysis,* John Wiely & Sons, Singapore, 1989.
2. M. K. Jain, S. R. K. Iyenger & P. K. Jain, *Numerical methods for scientific and engineering computation – 4th Ed*, New Age International (P) Ltd., New Delhi, 2003.

Reference Books:

1. S. S. Sastry, *Introductory methods of Numerical Analysis*, Prentice Hall India Pvt. Ltd., New Delhi, 1999.
2. Scarborough, *Numerical Mathematical Analysis,* Oxford &IBH Publishing Co., Calcutta, 1966.
3. G.D. Smith, *Numerical solution of partial differential equations*, Oxford University Pres, 1985.

Semester - II

Course – MMATG201

Topology - I (Marks – 50)

Total lectures Hours: 50

Topological spaces; open sets, closed sets, closure, denseness, neighbourhoods, interior points, limit points, derived sets, basis, subbasis, subspace. generation of a topology using Kuratowski closure operator and neighbourhood systems.
[11]

Continuous functions, homeomorphism and topological invariants.
[3]

Countability axioms: First and second countable spaces, Lindelöf spaces, separable spaces and their relationship and characterizations.
[6]

Separation axioms: T_0, T_1, T_2, T_3, $T_{3½}$, T_4 , T_5 spaces, their properties, characterizations and their relationship. Regularity, complete regularity, normality and complete normality; their characterizations and basic properties. Urysohn's lemma, Tietze's extension theorem.
[10]

Compactness : Characterizations and basic properties, Alexander subbase theorem. Compactness and separation axioms, compactness and continuous functions, Sequentially, Frechet and countably compact spaces. Compactness in metric spaces.
[10]

Connectedness : Connected sets and their characterizations, connectedness of the real line, components, totally disconnected spaces, locally connected spaces. Path connectedness, path components, locally path connected spaces.
[10]

Text Books :

1. J. R. Munkres, *Topology, A First Course*, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
2. G. F. Simmons, *Introduction to Topology and Modern Analysis*, Tata McGraw-Hill, 2004.

Reference Books:

1. J. Dugundji, *Topology*, Allyn and Bacon, 1966.
2. K. D. Joshi, *Introduction to General Topology*, New Age International(P) Ltd*, 1983*
3. J. L. Kelley, *General Topology*, Springer, 1975.

4. S. Willard, *General Topology*, Dover Publications, 2004

Course – MMATG202

Linear Algebra (Marks - 30)

Total lectures Hours: 30

Quotient spaces with examples. [2]

Inner product spaces: Real and complex inner product spaces, orthonormal basis, Gram-Schmidt orthogonalization process, orthogonal complements and projections. [3]

Linear transformation in finite dimensional spaces, invertible linear transformation, matrix of linear transformation, correspondence between linear transformations and matrices, necessary and sufficient condition for a linear transformation to be invertible, relation between rank of a linear transformation and rank of the corresponding matrix, dual space and dual basis, transpose of a linear transformation and matrix representation of the transpose of a linear transformation, annihilator of a subset of a vector space. [9]

Eigen vectors, spaces spanned by eigen vectors, similar and congruent matrices, characteristic polynomial, minimal polynomial, diagonalization, diagonalization of symmetric and Hermitian matrices, Cayley-Hamilton theorem, reduction of a matrix to normal form, Jordan Canonical form. [11]

Bilinear form, matrix associated with a bilinear form, quadratic form, rank, signature and index of a quadratic form, reduction of a quadratic form to normal form, Sylvester's law of inertia, simultaneous reduction of two quadratic forms, applications to Geometry.[5]

Text Books :

1. S. H. Friedberg, A. J. Insel and L. E. Spence, *Linear Algebra*, PHI, 4th Edn., 2012.
2. K. M. Hoffman and R. Kunze, *Linear Algebra*, PHI, 2nd Edn., 2008.

Reference Books:

1. S. Kumaresan, *Linear Algebra: A Geometrical Approach*, PHI, 2000.
2. A. R. Rao and P. Bhimasankaram, *Linear Algebra*, Hindustan Book Agency, New Delhi, 2000.

Course– MMATG203

Integral Equations (Marks – 20)

Total lectures Hours: 20

Linear Integral Equation, Classification, Reduction of differential equation to integral equation and vice-versa, Eigen values and eigen functions. [2]

Fredholm integral equation of second kind with degenerate kernel. [3]

Conditions of uniform convergence and uniqueness of series solution of Fredholm and Volterra integral equations. [2]

Existence, Uniqueness and iterative solution of Fredholm and Volterra Integral equations; Resolvent kernel, Solution of Volterra integral equation of first kind, Integral equations of Convolution type and their solutions by Laplace transform. [7]

Fredholm theorems and Fredholm alternative. [4]

Singular integral equation, Solution of Abel's integral equation. [2]

Text Books :

1. R. P. Kanwal, *Linear Integral Equation: Theory and Techniques*, Academic Press, New York, 2012.
2. WE. V. Lovit, *Linear Integral Equations*, Dover Publishers, 2005.

Reference Books:

1. S. G. Mikhlin, Linear *Integral Equation*, Pergamon Press, 1960.
2. F. G. Tricomi, *Integral Equation*, Interscience Publishers, 1985.

Course – MMATG204

Differential Geometry (50 Marks)

Total lectures Hours: 50

Geometry of Curves: Definition of curves in R^n with examples, arc-length, reparametrization, level curves and parametric curves. Curvature of plane curves and space curves, properties of plane curves, torsion of space curves, properties of space curves, Serret-Frenet formulae. Simple closed curves with periods, isoperimetric inequality, four vertex theorem (statement only). [10]

Geometry of Surfaces: Definition of surfaces with various examples, smooth surfaces with examples. Tangent, normal and orientability of surfaces. Quadric surfaces, Triply orthogonal systems, applications of the Inverse function theory. [10]
First fundamental form, length of curves on surfaces, isometries of surfaces, conformal mapping of surfaces, surface area, equal areal maps and theory of Archimedes. [10]
Curvature of surfaces, second fundamental form, curvature of curves on surfaces, normal and principal curvatures, Euler's theorem, geometric interpretation of principal curvatures. Gaussian curvature and the Gauss map: the Gaussian and mean curvature, pseudosphere, flat surfaces, surfaces of constant mean curvature, Gaussian of compact surfaces, Gauss map. [10]
Geodesics, Geodesic equations, Geodesic on surfaces of revolution, Geodesic as shortest path, geodesic coordinates. Minimal surfaces with examples, holomorphic functions. Gauss Theorema Egregium, developable surfaces. Codazzi Mainardi equation, Third fundamental form, compact surfaces of constant Gaussian curvatures. Gauss-Bonnet theorem for simple closed curves and curvilinear polygons and for compact surfaces (Statement only). [10]

Text Book:

1. A. Pressley, *Elementary Differential Geometry*, Springer-Verlag, 2001, London (Indian Reprint 2004).

Reference Books:

1. M. P. Do Carmo, *Differential Geometry of Curves and Surfaces*, Prentice-hall, Inc., Englewood, Cliffs, New Jersey, 1976.
2. B. O'Neill, *Elementary Differential Geometry*, 2nd Ed., Academic Press Inc., 2006.

Course– MMATG205

Partial differential equations (Marks - 30)

Total lectures Hours: 30

First order partial differential equations (PDE): Basic concepts – quasi-linear equations, semi-linear equations, linear equations, solutions; Cauchy's problem; Integral surfaces; Non-linear equations; Cauchy's method of characteristics; Charpit's method; Hamilton-Jacobi equation. [9]

Second order linear PDE: Classification; Reduction to the normal forms; Solutions – equation with constant coefficients, non-linear equations of the second order by Monge's method. [9]

Second order PDE in applied sciences: Occurrence of PDE – wave equation, heat equation, Laplace equation; Solution by separation of variables – one-dimensional wave equation, one-dimensional heat equation, two-dimensional Laplace equation, two-dimensional wave equation (rectangular and circular membranes), Laplace equation in three-dimension (Cartesian form, cylindrical form, spherical polar form). [12]

Text Books:

1. T.Amarnath , *An Elementary Course in Partial Differential Equations,* Jones and Bartlell Pub., 2011.
2. I. N. Sneddon, *Elements of Partial Differential Equations*, Dover Publications, 2006.

Reference Books:

1. G. W. Bluman, S. Kumei, *Symmetries and Differential Equations*, Springer, 1989.
2. P. Phoolan Prasad & R. Ravindran , *Partial Differential Equations,* Wiley, 1984.

Course – MMATG206

Integral Transform (Marks 20)

Total lectures Hours: 20

Laplace transform and its existence, properties of Laplace transform, Inversion by analytical method and Bromwich path, Lerch's theorem, Convolution theorem, Application to ordinary and partial differential equations. [8]

Fourier transform: Fourier transform & its properties, inversion formula, Convolution theorem, Perseval's relation, Finite Fourier Transform, Application to Heat, Wave and Laplace equations. [12]

Text Books:

1. L. Debnath and D Bhatta, *Integral Transforms and their applications*, C.R.C. Press, 2007.
2. I. N. Sneddon, *Fourior Transforms*, McGraw Hill, 1995.

Reference Books:

1. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, 2010.
2. J. W. Miles, *Integral Transforns in Applied Mathematics*, Cambriddge University Press, 2008.
3. M. R. Spiegel, *Laplace Transforms*, Mc Graw Hill, 1965.

Course – MMATG207

Operations Research (Marks – 50)

Total lectures Hours: 50

Revised simplex method (with and without artificial variables). [4]

Post Optimality Analysis: changes in (i) objective function, (ii) requirement vector, (iii) coefficient matrix; Addition and deletion of variables, Addition of constraints . [8]

Bounded variable technique for L.P.P. [3]

Inventory control: Deterministic inventory models including price breaks. Multi-item inventory model with constraints. [9]

Queueing Theory: Basic features of queueing systems, operating characteristics of a queueing system, arrival and departure (birth & death) distributions, inter-arrival and service times distributions, transient, steady state conditions in queueing process. Poisson queueing models- M/M/1, M/M/C for finite and infinite queue length. [10]

Project Network scheduling by PERT and CPM: PERT/CPM network components and precedence relationships, critical path analysis, probability in PERT analysis, project time cost trade-off procedure. [9]

Integer Programming: Gomory's cutting plane algorithm (All integer and mixed integer algorithms), Branch and Bound method. [7]

Text Books:

1. H. A. Taha, *Operations Research – An Introduction*, Prentice-Hall, 1997.
2. H. M. Wagner, *Principles of Operations Research*, PHI, 1974.

Reference Books:

1. R. Panneerselvam, *Operations Research*, PHI, 2009.
2. J. K. Sharma, *Operations Research : Theory and Applications*, Mcmillan, 2007.
3. L. Takacs, *Introduction to the Theory of Queues*, Oxford University Press, 1972.
4. A. K. Bhunia and L. Sahoo, *Advanced Operations Research,* Asian Books Private Limited, New Delhi, 2011
5. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, TMH, 2008.

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Course – MMATG208

Computer Aided Numerical Practical (Marks – 50)

(Through C Programming)

Total lectures Hours: 50

Group-A

Sessional (Algorithm and Program with output):10 marks

Viva Voce: 10 marks

Numerical Problems(From Sessional): 20 marks(Algorothm:5,Program:10, result:5)

Problems:

1. Solution of Initial Value Problem(IVP) for First & Second orders O.D.E. using i) Milne's Method(First order Equation) ,ii) Forth order Runge-Kutta Method(Second order)
2. Integration by Romberg's method
3. Largest Eigen values of a real matrix by power Method.
4. Solution of Boundary Value Problem (BVP) for second order O.D.E. by Finite Difference Method(FDM) and Shooting Method.

5. Solution of one-dimensional heat conduction equation using two layer explicit formula.
6. Solution of one- dimensional wave equation by Finite Deference Method.

Group- B

Simple problems : 10 Marks (Program :5,Correct output:5)

Text Books:

1. E. Balaguruswamy, *Programming in ANSI C*, TMH, 2011.
2. G. C. Layek, A. Samad and S. Pramanik- *Computer Fundamentals, Fortran – 77, C and Numerical Problems*, Levrant, 2008.

Reference Books:

1. B. S. Gottfried, *Programming with C*, TMH, 2011.
2. K. R. Venugopal and S. R. Prasad, *Programming with C*, TMH, 1997.
3. C. Xavier, *C Language and Numerical Methods*, New Age International (P) Ltd. Pub, 2007.

Semester - III

Course – MMATP301

Abstract Algebra II (Marks - 50)

Total lectures Hours: 50

Group : External and internal direct product of groups; External direct product of cyclic groups; Group action; Cayley's Theorem; Burnside Theorem; conjugacy classes; class equation; Cauchy's Theorem of finite groups; p-group; centre of p-groups; Converse of Lagrange's Theorem; Sylow's Theorem; some applications of Sylow's Theorem; simple groups; non-simplicity of groups of order p^n ($n > 0$), pq, p2q, $p2q^2$ (p, q are primes); determination of all simple group of order up to 60; Normal series; subnormal series; solvable series; composition series; nilpotent group; Jordan-Holder Theorem; Ascending central series; descending central series; commutator subgroup; structure theorem of finite Abelian groups.
[25]

Ring : Ring embedding; Factorization domain; Unique factorization domain; chain condition; Noetherian ring; Artinian ring; Hilbert basis theorem; polynomial ring over a unique factorization domain; D is UFD implies so is D[x]; primitive polynomial; Gauss Lemma; Eisenstein criterion of irreducibility.
[10]

Module: Module; submodule; operation on submodules; morphism between two modules; kernel of morphisms; correspondence theorem in connection with modules; isomorphism theorems; Noetherian module and Artiniam module. [15]

Text Books:

1. T. S. Blyth; *Module Theory: An Approach to Linear Algebra*, Clarendon Press, 1977.
2. D. S. Malik, J. M. Mordeson and M. K. Sen; *Fundamentals of Abstract Algebra*, McGraw-Hill, 1997.

Reference Books:

1. D. M. Burton; *A First Course in Rings and Ideals*, Addison-Wesley Publishing Company, 1970.
2. N. H. McCoy; *The Theory of Rings*, Chelsea Publishing Company, 1973.

Course – MMATP302

Functional Analysis-II (Marks - 30)

Total lectures Hours: 30

Completion of a metric space, compactness of c[a,b] with sup norm, uniformly bounded and equi-continuous functions of c[a,b], Arzelà Ascoll Theorem, Riesz Lemma and its applications in Banach spaces [6]

Strong and weak convergence of a sequence in a normed linear space , series in Banach spaces, convergence of a series in Banach spaces
[3]

Principle of Uniform boundedness and its consequences. [2]

Hahn Banach Theorem and its applications. [5]

Conjugate spaces and Reflexive spaces with properties. Conjugate spaces of C^n, R^n, l_1, l_p ($1 < p < \infty$). [4]

Invertible mappings, existence of bounded inverse linear operators, open mapping theorem, closed graph theorem. [3]

Orthogonal sets, complete orthonormal sets, minimization of norm problems. Separable Hilbert spaces, Riesz Representation theorem for bounded linear functionals on Hilbert spaces, orthogonal decomposition of Hilbert spaces. Riesz-Fischer theorem. [7]

Text Books:

1. K. K. Jh*a*, *Functial Analysis,* Student's Friends, 1986.
2. E. Kreyszig, *Introductory Functional Analysis with Applications*, Wiley Eastern,1989.

Reference Books:

1. A. L. Brown and A. Page, *Elements of Functional Analysis*, Von Nostrand Reinhold Co., 1970
2. R. E. Edwards, *Functional Analysis*, Holt Rinchart and Wilson, New York,1965.
3. B.V. Limaye, *Functional Analysis*, Wiley Easten Ltd,1996
4. A.E. Taylor, *Functional Analysis*, John Wiley and Sons, New York, 1958.
5. K. Yosida, *Functional analysis*, Springer Verlag, New York,1990.

Course – MMATP303

Topological vector space (Marks – 20)

Total lectures Hours: 20

Convex sets, convex hull, Representation Theorem for convex hull. [3]

Symmetric sets, balanced sets, absorbing sets, bounded sets and their properties, absolutely convex sets, topological vector spaces.

Separation properties of a topological vector space, compact and locally compact topological vector space and its properties

on finite dimensional topological vector spaces, Minkowski functionals. [7]

Linear operators with its continuity on topological vector spaces and homeomorphism. [3]

Closed sets, open sets with its properties, neighbourhoods, local base and its properties. [4]

Hyperplanes, separation of convex sets by hyperplanes. [3]

Text Books:

1. I. J. Madox, *Elements of Functional Analysis*, University Book Stall, 1992.
2. W. Rudin-*Functional Analysis*, TMG Publishing Co. Ltd., New Delhi,1973.

Reference Books:

1. J. Horvoth-*Topological Vector spaces and Distributions*, Addison-Wesley Publishing Co., 1966
2. A. A. Schaffer-*Topological Vector Spaces*, Springer, 2nd Edn., 1991

Course – MMATG304

Introduction to Manifolds (Marks - 50)

Total lectures Hours: 50

Manifolds: What are manifolds?, Why study manifolds?, Topological Manifolds, Topological invariant of Dimension, Coordinates Charts, Examples of Topological Manifolds, Topological Properties of Manifolds, Smooth Structures, Examples of Smooth Manifolds, Examples of non-Hausdorff, non-connected, non-second countable manifolds, Manifolds with Boundary. [10]

Smooth Functions and Smooth Maps: Smooth maps between manifolds, Diffeomorphisms on manifolds and its properties, Partitions of Unity and its applications.

Tangent Vectors: Various Definitions of tangent vectors, The Differential of a Smooth Maps, Computations in Coordinates, Tangent spaces, Tangent Bundle, Velocity Vectors of Curves, Covectors, Cotangent spaces, Cotangent Bundle**,** Pushforward and Pullback maps. [10]

Submanifolds: Maps of Constant Rank, Submersions, Immersion and Embeddings, Embedded Submanifolds, Immersed Submanifolds (Definitions and examples only), Rank Theorem (Statement only)

Vector Fields on Manifolds: Vector Fields on manifolds, Local and global frames, smoothly related vector fields, Lie Brackets and its properties, Integral Curves and Flows, local and global 1-parameter group of transformations, complete vector fields, Distributions, integral manifolds, Centre manifolds, Application of Frobenius theorem.

[10]

Exterior Algebra and Exterior Derivatives: Multilinear Algebra, tensors**,** tensor products, Symmetric and Alternating Tensors, Tensors and Tensor Fields on Manifolds (Definition and examples), Wedge product and exterior algebra, differential forms on manifolds, exterior derivatives. [7]

Hamiltonian Flows: Hamiltonian vector fields, flows and properties, sympletic transformation, Poisson bracket, examples. [5]

Lie Groups and Lie Algebra: Definition and examples of Lie Groups, Lie algebra of Lie groups, Heisenberg Groups, Maurer-Cartan structure equation, Structure constants, Lie group homomorphisms and isomorphisms, Lie Subgroups (Definition and examples, characterization without proof), 1-parameter subgroups and exponential maps, Lie derivatives (Definition and examples). [10]

Text Book:

1. John M. Lee, *Introduction to Smooth Manifolds*, 2nd Ed., Springer-Verlag, 2012.
2. U. C. De and A. A. Shaikh, *Differential Geometry of Manifolds*, Narosa Publ. Pvt. Ltd, New Delhi, 2007.
3. Arnol'd, V.I. *Mathematical Methods of Classical Mechanics*. Berlin etc: Springer,1997.

Reference Books:

1. William H. Boothby, *An Introduction to Differentiable Manifolds and Riemannian Geometry*, Academic Press, New York, 1975.
2. S. Kobayashi and K. Nomizu, *Foundations of Differential Geometry*, Vol. 1, Inter science Press, Newyork, 1969.
3. S. Lang, *Introduction to Differential Manifolds*, John Wiley and Sons, New York, 1962.
4. Abraham, Ralph; Marsden, Jerrold E. *Foundations of Mechanics*. London: Benjamin-Cummings, 1978.
5. McDuff, Dusa; Salamon, D. *Introduction to Symplectic Topology*. Oxford Mathematical Monographs, 1998.

Course – MMATP305

Operator Theory (Marks - 25)

Total lectures Hours: 25

Closed Linear transformation and its properties, bounded inverse Theorem (statement only), closed graph theorem. [3]

Adjoint (conjugate) operators over normed Linear spaces and their algebraic properties. Closure of a linear transformation and its properties. [7]

Adjoint(Hilbert adjoint) operators on inner product spaces and Hilbert spaces, relationship between closure and adjoint operators, relationship between conjugate and adjoint operators. [4]

Normal operators, isometric operators, unitary operators and their properties [3]

Hermitian symmetric self adjoint operators and their properties [3]

Sesquilinear functionals on linear spaces and on Hilbert spaces, generalization of Cauchy-Schwarz inequality. [5]

Text Books:

1. G. Bachman and L. Narici; *Functional Analysis,* Academic Press, 1966.
2. E. Kreyszig; *Introductory Functional Analysis with Applications,* Wiley Eastern, 1989

Reference Books:

1. B. K. Lahiri, *Elements of Functional Analysis*, The World Press Pvt. Ltd., Kolkata, 1994.
2. B. V. Limaye, *Functional Analysis*, Wiley Eastern Ltd, New Delhi, 1981.
3. M. T. Nair, *Functional Analysis*, Prentice-Hall of India Pvt. Ltd, New Delhi, 2002.
4. K. Yosida, *Functional Analysis*, Springer Verlog, New York, 3rd Edn, 1990

Course – MMATPME306

Advanced Functional Analysis -I (Marks - 50)

Total lectures Hours: 50

Locally convex topological vector spaces, bounded sets, totally bounded sets, connectedness and their basic properties, convergence of filter, completeness, Frechet space, quotient spaces ,separation property by hyper plane on locally convex topological vector spaces [12]

Extreme points, Krein Milman Theorem, linear functionals and its boundedness property on a topological vector space, semi- norms and their basic results, generating family of seminorms in a locally convex topological vector spaces. [10]

Criterion for normability of a topological vector space (Kolmogorov Theorem), metrizability of a locally convex topological vector space.
[6]

Barelled spaces, Bornological spaces, criterion for locally convex topological vector spaces to be Barreled and Bornological. [10]

Strict convexity and uniform convexity of a Banach space with examples. [6]

Only statements of Clarkson's Renorming Lemma and Milman and Pettit's theorem, Uniform convexity of a Hilbert space, Reflexivity of a uniformly convex Banch space.
[6]

Text Books:

1. J.Horvoth, *Topological Vector spaces and Distributions*, Addison-Wesley Publishing Co., 1966
2. W. Rudin, *Functional Analysis*, TMG Publishing Co. Ltd., New Delhi,1973.

Reference Books:

1. J. Diestel, *Geometry of Banach Spaces*, Springer, 1975.
2. L. Narici & E. Beckenstein, *Topological Vector spaces*, Marcel Dekker Inc, New York and Basel,1985
3. A.A. Schaffer, *Topological Vector Spaces*, Springer , 2^{nd} Edn., 1991

Course – MMATPME307

Advanced Abstract algebra-I (Marks - 50)

Total lectures Hours: 50

Rings and Modules - I

Modules over a ring with identity, Sub modules, Operations on sub modules. Quotient Modules and module homomorphisms. [4]

Cyclic Modules, Finitely Generated Modules, Free Modules. [6]

Exact Sequences, Five Lemma, Projective Modules and Hom R(M,-), injective modules and
HomR(-,M). [6]

Modules over PID, Fundamental Structure Theorem for finitely generated modules over a PID and its applications to finitely generated abelian groups. The rational canonical form of a linear transformation. [14]

Operations on Ideals, radical of an ideal, Nil radical and Jacobson radical, Nakayama's Lemma, Prime Avoidance, Chinese Remainder Theorem, Extension and Contraction of ideals. [6]

Local rings, Local Properties, Localization, Extended and contracted ideals in rings of fractions. Primary Decomposition in Noetherian Rings. [6]

Integral Dependence, Lying-Over Theorem, Going-Up Theorem, Integrally Closed Domains, Going-Down Theorem, Noether Normalization, Hilbert Nullstellensatz. [8]

Text Books:

1. M. Atiyah, I. G. MacDonald, *Introduction to Commutative Algebra*, Addison-Wesley, 1969.
2. D. S. Dummit, R. M. Foote, *Abstract Algebra*, Second Edition, John Wiley & Sons, Inc., 1999.

Reference Books:

1. C. W. Curtis, I. Reiner, *Representation Theory of Finite Groups and Associated Algebras*, Wiley-Interscience, NY, 1962.
2. T. W. Hungerford, *Algebra*, Springer, 1974.
3. N. Jacobson, *Basic Algebra, II*, Hindusthan Publishing Corporation, India, 1984.
4. T. Y. Lam, *A First Course in Non-Commutative Rings*, Springer Verlag, 2nd Edn., 2001.
5. S. .Lang, *Algebra*, Addison-Wesley, 1993.
6. D. S. Malik, J. M. Mordesen, M. K. Sen, *Fundamentals of Abstract Algebra*, The McGraw-Hill Companies, Inc., 1997.

Course – MMATPME308

Algebraic Topology-I (Marks - 50)

Total lectures Hours: 50

Homotopy : Definition and some examples of homotopies, homotopy type and homotopy equivalent spaces, retraction and deformation, H-space. [3]

Category: Definitions and some examples of category, factor and natural transformation. [4]

Fundamental group and covering spaces : Definition of the fundamental group of a space, the effect of a continuous mapping on the fundamental group, fundamental group of a product space, notion of covering spaces, liftings of paths to a covering space, fundamental groups of a circle. [16]

Universal cover, its existence, calculation of fundamental groups using covering space.Projection space and torus, homomorphisms and automorphisms of covering spaces, deck transformation group, Borsuk – Ulam theorem for S^2, Brower fixed-point theorem in dimension 2. [27]

Text Books:

1. F. H. Croom, *Basic Concepts of Algebraic Topology*, Springer, NY, 1978.
2. E. H. Spanier, *Algebraic Topology*, McGraw-Hill, 1966.

Reference Books:

1. A. Hatcher, *Algebraic Topology*, Cambridge University Press, 2003.
2. W. S. Massey, *A Basic Course in Algebraic Topology*, Springer-Verlag, New York Inc., 1991.
3. I. M. Singer & J. A. Thorpe, *Lecture Notes on Elementary Topology and Geometry*, Springer, India 2003

Course– MMATPME309

Advanced Complex Analysis-I (50 Marks)

Total lectures Hours: 50

Analytic function, the functions M(r) and A(r). Theorem of Borel and Caratheodary, Convex function and Hadamard three-circle theorem, Phragmen-Lindelof theorem. [15]

Harmonic function, Mean value property, Maximum principle, Harmonic function on a disk, Hamaek's inequality, Dirichlet's problem. [10]

Integral function, Poisson Jenson formula, construction of an integral function with given zeros –Weierstrass theorem, Jensen's inequality, order, exponent of convergence of zeros of an integral function, canonical product, genus, Hadamard's factorization theorem, Borel's theorems, Picard's first and second theorems. *[25]*

Text Books:

1. L. V. Ahlfors, *Complex Analysis,* McGraw-Hill, 3rd Edn., 1979.
2. J. B. Conway , *Functions of One Complex Variable,* Narosa Publishing House, New Delhi, 2nd Edn., 1997.

Reference Books :

1. R. P. Boas – *Entire Functions,* Academic Press, 1954
2. H. Cartan – *Elementary Theory of Analytic Functions of One or Several Complex Variables,* Dover Publication, 1995.
3. E. T. Copson, *Introduction to the Theory of Function of a Complex Variable,* Oxford University press, 1970
4. M. Dutta and L. Debnath , *Elements of The Theory of Elliptic and Associated Functions with Applications, World Press Pvt., 1965*
5. A. I. Markusevich , *Theory of Functions of a Complex Variables,* Vol. I & II, Printice-Hall, 1965.
6. W. Rudin – *Real and Complex Analysis,* Tata McGraw-Hill Education, 1987
7. E. C. Titchmarsh – *Theory of Functions,* Oxford University Press, 2nd Edn., 1970.

Course – MMATPME310

Measure and Integration-I(Marks – 50)

Total lectures Hours: 50

Algebra and σ-algebra of sets. Monotone class of sets. Borel sets. F_σ and G_δ sets. Countably additive set function. [6]

Measure on σ – algebra. Outer measure and measurability. Extension of measures. Complete measures and completion of a measure space. [6]

Construction of outer measures. Regular outer measure. Lebesgue Stieltjes measures and distribution function. Example of non-measurable sets (Lebesgue). [8]

Measurable functions. Approximation of measurable functions by simple functions. Egoroff's Theorem. Lusin's Theorem. Convergence in measure [10]

Integrals of simple functions. Integral of measurable functions. Properties of Integrals and Integrable functions. Monotone convergence theorem. Fatou's Lemma, Dominated convergence Theorem, Vitali convergence theorem. [20]

Text Books:

1. G. D. Barra, *Measure Theory and Integration,* Wiley Eastern Limited, 1987.
2. I. K. Rana, *An Introduction to Measure and Integration,* Narosa Publishing House, 1997.

Reference Books :

1. E. Hewitt and K. Stormberg – *Real and Abstract Analysis,* John – Wiley, N. Y., 1965.

2. I. P. Natanson – *Theory of Functions of a Real Variable*, Vols. I & II, Ungar Publishing Company, 1974.
3. H. L. Royden , *Real Analysis*, PHI, 2005
4. W. Rudin – *Real and Complex Analysis, Tata McGraw-Hill, 1993*
5. Charles Schwartz- Measure , Integration and Function spaces, World Scientific Publisher, Singapore, 1994.

Course – MMATPME312

Euclidean and non-Euclidean Geometries- I (ENEG-I) (Marks - 50)

Total lectures Hours: 50

Euclid's Geometry: Brief Survey of the Beginnings of Geometry, The Pythagoreans, Plato , Euclid of Alexandria, The Axiomatic Method, Undefined Terms, Euclid's First Four Postulates, The Parallel Postulate, Attempts to Prove the Parallel Postulate, The Power of Diagrams, Straightedge-and-Compass Constructions, Briefly, Descartes' Analytic Geometry and Broader Idea of Constructions, Briefly on the Number π. [10]

Logic and Incidence Geometry: Elementary Logic, Theorems and Proof, Negation, Quantifiers, Implication, Law of Excluded Middle and Proof by Cases, Brief Historical Remarks, Incidence Geometry, Models, Consistency, Isomorphism of Model, Projective and Affine Planes, Brief History of Real Projective Geometry. [10]

Hilbert's Axioms: Flaws in Euclid, Axioms of Betweenness, Axioms of Congruence, Axioms of Continuity, Hilbert's Euclidean Axiom of Parallelism. [5]

Neutral Geometry : Geometry without a Parallel Axiom, Alternate Interior Angle Theorem, Exterior Angle Theorem, Measure of Angles and Segments, Equivalence of Euclidean Parallel Postulates, Saccheri and Lambert Quadrilaterals, Angle Sum of a Triangle.

[10]

History of the Parallel Postulate: Review, Proclus, Equidistance, Wallis, Saccheri, Clairaut's, Axiom and Proclus' Theorem, Legendre, Lambert and Taurinus, Farkas Bolyai. [5]

The Discovery of Non-Euclidean Geometry: János Bolyai, Gauss, Lobachevsky, Subsequent, Developments, Non-Euclidean Hilbert Planes, The Defect, Similar Triangles, Parallels Which Admit a Common Perpendicular, Limiting Parallel Rays, Hyperbolic Planes, Classification of Parallels, Strange New Universe? [10]

Text Book:

1. Marvin Jay Grenberg; *Euclidean and non-Euclidean Geometries: Development and History*, W. H. Freeman and Company, New York, *4th Edition* , 2008.

Reference Book:

1. C. B. Boyer and U. Merzbach, *A history of mathematics*, 2nd edn., New York, Wiley, 1991.
2. R. Courant and H. Robbins, *What is mathematics?*, Oxford Univ. Press, New York, 1941.
3. H. S. M. Coxeter, *Introduction to geometry, end ed*., New York, Wiley, 2001.
1. Euclid, *Thirteen Books of the Elements*, 3 Vols. Tr. T. L. Heath, with annotations, New York, Dover, 1956.
2. V. J. Katz, *A history of mathematics: an introduction*, 2nd ed., Reading , Mass: Addison-Wesely Longman, New York, 1998.
3. J. G. Ratcliffe, *Foundations of hyperbolic manifolds*, New Yprk, Springer, 2nd Edn., 2006.
4. H. E. Wolfe, *Introduction to non-euclidean geometry*, New York, Holt, Rinehart and Winston, 1945.

Course– MMATPME313

Geometric Mechanics on Riemannian manifolds-I (Marks 50)

Total lectures Hours: 50

Differentiable manifolds: Embedded manifolds in R^N, The tangent space, The derivative of a differentiable function, Tangent and cotangent bundles of a manifold, Discontinuous action of a group on a manifold, Immersions and embeddings. Submanifolds, Partition of unity. Vector fields, differential forms and tensor fields, Lie derivative of tensor fields, The Henri Cartan formula. Pseudo-

Riemannian manifolds: Affine connections, The Levi-Civita connection, Tubular neighborhood, Curvature, E. Cartan structural equations of a connection. [10]

Newtonian mechanics: Galilean space-time structure and Newton equations, Critical remarks on Newtonian mechanics. Mechanical systems on Riemannian manifolds: The generalized Newton law, The Jacobi Riemannian metric, Mechanical systems as second order vector fields, Mechanical systems with holonomic constraints, Some classical examples, The dynamics of rigid bodies, Dynamics of pseudo-rigid bodies, Dissipative mechanical systems. Mechanical systems with non-holonomic constraints: D'Alembert principle, Orientability of a distribution and conservation of volume, Semi-holonomic constraints, The attractor of a dissipative system. Hyperbolicity and Anosov systems. Vakonomic mechanics: Hyperbolic and partially hyperbolic structures, Vakonomic mechanics, Some Hilbert manifolds, Lagrangian functionals and D-spaces, D'Alembert versus vakonomics. [10]

Special relativity: Lorentz manifolds, The quadratic map of R^{n+1}, Time-cones and time-orientability of a Lorentz manifold, Lorentz geometry notions in special relativity, Minkowski space-time geometry, Lorentz and Poincar´e groups. [10]

General relativity: Einstein equation, Geometric aspects of the Einstein equation, Schwarzschild space-time, Schwarzschild horizon, Light rays, Fermat principle and the deflection of light. Hamiltonian and Lagrangian formalisms: Hamiltonian systems, Euler–Lagrange equations. [10]

Quasi-Maxwell form of Einstein's equation: Stationary regions, space manifold and global time, Connection forms and equations of motion, Stationary Maxwell equations, Curvature forms and Ricci tensor, Quasi-Maxwell equations. [10]

Text Books:

1. Ovidiu Calin, Der-Chen Chang, *Geometric mechanics on Riemannian manifolds*, Springer-Verlag, 2006.
2. W.M. Oliva, *Geometric Mechanics,*Springer, 2002

Course – MMATPME314

Advanced Differential Geometry-I (Marks-50)

Total lectures Hours: 50

Riemannian Geometry

Metrics on Manifolds: Riemannian Metrics**,** Riemannian manifolds, Warped and doubly warped product metrics, Isometry groups of Riemannian manifolds, Spheres as warped product, Semi-Riemannian Metrics, Lorentz metrics, Minkowski metrics, Hyperbolic metrics, The Model Spaces of Riemannian Geometry. [10]

Introduction to curvature: Linear connections, Riemannian connection, Riemann Curvature tensor, Ricci tensor, scalar curvature, Sectional Curvature, Schur's theorem, semisymmetric and quarter symmetric metric connections (Definitions and examples), Einstein manifolds, quasi-Einstein manifolds. [10]

Geodesics: Geodesics on Riemannian manifolds, Riemannian manifolds as metric spaces, Geodesic flows, Parallel vector field, First variation energy and second variation energy, Jacobi equation and Jacobi fields. [10]

Theory of Submanifolds: Submanifolds and Hypersurfaces of Riemannian manifolds, induced connection and second fundamental form, Gauss and Weingarten formulae, Equations of Gauss, Codazzi and Ricci, mean curvature, totally geodesic and totally umbilical submanifolds, minimal submanifolds. [10]

Transformations on Riemann Manifolds: Conformal transformation, Projective transformation, concircular transformation, conharmonic transformation. [10]

Text Books:

1. Manfredo P. Do Carmo, *Riemannian Geometry*, Birkhauser, Boston, 1992**.**
2. P. Petersen, Riemannian Geometry, Springer Verlag, 2006.
3. U. C. De and A. A. Shaikh, *Differential Geometry of Manifolds*, Narosa Publ. Pvt. Ltd, New Delhi, 2007.

Reference Books:

1. S. Kobayashi and K. Nomizu, *Foundations of Differential Geometry*, Vol. 2, Interscience Press, Newyork, 1969.
2. T. J. Willmore, *Riemannian Geometry*, Oxford University Press, 1997.
3. K. Yano and M. Kon, *Structure on Manifold,* World Scientific Publication, Singapore, 1984.
4. J. M. Lee, *Riemannian Manifolds,* An Introduction to Curvature, Springer-Verlag, 2005.

Course– MMATPME315

Operator Theory and Applications –I (Marks-50)

Total lectures Hours: 50

Basic ideas of spectral theory of linear operators on finite and on arbitrary dimensional normed linear spaces, eigen values, resolvent set spectrum. [4]

Brief ideas on Banach algebras , resolvent sets, spectrum and their properties in Banach algebras [4]

Spectral properties of bounded linear operators on normed linear spaces, spectral mapping theorem. Use of complex analysis in spectral theory, Locally holomorphy, holomorphy of resolvent operators . [8]

Compact operators on normed linear spaces and its properties, sequence of compact operators, adjoint and conjugate of compact operators compact extension, weakly compact operators and its properties. [10]

Spectral properties of compact operators, representation of a normed linear spaces as a direct sum of range spaces and null spaces. [6]

Normal operators, unitary operators, isometric operators and their properties, spectral properties of normal operators. [10]

Operator equations involving compact operators, Fredholm alternative theorem. [8]

Text Books:

1. G. Bachman and L. Narici; *Functional Analysis,* Academic Press, 1966.
2. E. Kreyszig; *Introductory Functional Analysis with Applications,* Wiley Eastern, 1989

Reference Books:

1. B. K. Lahiri, *Elements of Functional Analysis,* The World Press Pvt. Ltd., Kolkata, 1994.
2. B. V. Limaye, *Functional Analysis*, Wiley Eastern Ltd, New Delhi, 1981.
3. M. T. Nair, *Functional Analysis*, Prentice-Hall of India Pvt. Ltd, New Delhi, 2002.
4. K. Yosida, *Functional Analysis*, Springer Verlog, New York, 3rd Edn, 1990

Course – MMATA301

Methods of Applied Mathematics (Marks - 30)

Total lectures Hours: 30

Theory of distributions: Basic concepts – Linear functional, test functions; Distributions – regular distributions, singular distributions, translation of a distribution, scale of expansion or contraction, differentiation of a distribution; Sequence and series of distributions – Fourier transforms and integrals; Differential equations in distributions – classical solution, weak solutions, distributional solutions, D'Alembert solution of one-dimensional wave equation. [10]

Operator equations on Hilbert spaces

Prerequisite: Separable Hilbert spaces; Maximal orthonormal set; Complete orthonormal set, Closed sequence, Best approximation theorem; Fourier expansion theorem; Riesz-Fischer theorem. [3]

Linear operators: Basic concepts; Continuity, Boundedness, Invertibility, Spectra of linear operators. [3]

Theory of some operators: Adjoint operators; Unitary operators; Compact operators; Spectral theory for compact self-adjoint operators; Extremal properties of operators; Examples – differential operator, integral operator. [6]

Applications: Integral equations with Hilbert-Schmidt kernel – basic concepts, existence of solution; Regular Sturm-Liouville system – eigen values, equivalent integral equation; Bilinear expansion of Green's function – solution of inhomogeneous equation; Solvability of operator equations – Fredholm's alternatives. [8]

Text Books:

1. I. Stackgold, *Green's Functions and Boundary Value Problems*, John Wiley & Sons, New York, 1979.
2. E. Kreyszig, *Introductory Functional Analysis with Applications*, Wiley, 1989.

Reference Books:

1. S. Hassani, *Mathematical Physics*, Springer, 2001.

Course – MMATA302

Wavelet Analysis (Marks - 20)

Total lectures Hours: 20

Introduction, Review of L^p -spaces and Fourier transforms.

Orthonormal bases, Riesz bases, Continuous and discrete wavelet transforms with basic properties, Orthonormal wavelets, Haar wavelets. [12]

Multiresolution analysis (MRA), Bandlimited functions. [10]

Applications to wavelet transform for physical systems. [8]

Text Books:

1. David F. Walnut, *An Introduction to Wavelet Analysis*, Birkhauser, 2008.
2. L. Debnath, *Wavelet Transforms and Their Applications*, Birkhauser Boston, 2002.

Reference Book:

1. C. Sidney Burrus, Ramesh A. Gopinath and Haitao Guo, *Introduction to Wavelets and Wavelet Transforms*, PHI, 1998.

Course – MMATA303

Continuum Mechanics (Marks - 50)

Total lectures Hours: 50

Continuum: Continuum hypothesis, Continuous media, Body, Configuration, Material and spatial time derivatives. [2]

Theory of deformation and strain: Deformation and flow, Lagrangian and Eulerian descriptions, Deformation gradient tensors, Finite strain tensor, Finite strain components in rectangular Cartesian coordinates, Small deformation, Infinitesimal strain tensor, Infinitesimal strain components, Geometrical interpretation of infinitesimal strain components, Principal strains, Strain invariants, Strain quadric of Cauchy, Compatibility equations for linear strains, Rate of strain tensors-its principal values and invariants, Rate of rotation tensor-vorticity vector, velocity gradient tensor. [10]

Theory of stress: Forces in a continuum, Stress tensor, Equations of equilibrium, Symmetry of stress tensor, Shearing and normal stresses, Maximum shearing stress, Principal stresses and principal axes of stresses, Invariants of stress tensors, Stress quadric of Cauchy and its properties, Beltrami-Michel compatibility equations for stresses. [6]

Motion of a continuum: Principle of conservation of mass, The continuity equation, Principle of conservation of linear and angular momentum, conservation of energy. [5]

Theory of elasticity: Ideal materials, Classical elasticity, Generalized Hooke's Law, Isotropic materials, Constitutive equation (stress-strain relations) for isotropic elastic solid, Elastic modulii, Strain-energy function, Physical interpretation. [5]

Boundary value problems of elasticity: Field equations in linear elasticity, Equations of equilibrium and motion in terms of displacement, Fundamental boundary value problems of elasticity and uniqueness of their solutions (Statement), Saint-Venant's principle. [5]

Motion of fluid: Path lines, stream lines and streak lines, Material (Bounding) surface, Lagrange's criterion for material surface. [5]

Irrotational motion of fluid: Irrotational motion, Velocity potential, Circulation, Kelvin's circulation theorem, Kelvin's theorem of minimum kinetic energy. [3]

Equation of motion of inviscid fluid: Inviscid incompressible fluid, Constitutive equation, Euler's equation of motion & its vector invariant form, Bernoulli's equation and applications to some special cases, Helmholtz's equation for vorticity, Impulsive generation of motion and some properties, Navier-Stokes' Equations, Boundary Conditions [9]

Text Books:

1. A. C. Eringen, *Mechanics of Continua*, Wiley, 1967.
2. I. S. Sokolnikoff , *Mathematical theory of Elasticity*, Tata Mc Grow Hill Co., 1977.

Reference Books:

1. S.W. Yuan , *Foundations of Fluid Mechanics*, Prentice – Hall International, 1970.
2. J. L. Bansal, *Viscous Fluid Dynamics*, Oxford and IBH Publishing Co., 1977.
3. R. N. Chatterjee, *Mathematical Theory of Continuum Mechanics*, Narosa Publishing House, New Delhi, 1999.
4. D. S. Chandrasekharaiah and L. Debnath, *Continuum Mechanics*, Academic Press, 1994.

Course – MMATA305

Boundary Value Problems (Marks - 25)

Total lectures Hours: 25

Green's functions in one-dimension: Basic concepts and definition; One-dimensional boundary value problems – BVP for equations of order p, BVP for second-order equations, well-posed problems, ill-posed problems; Green's functions for second order linear differential operators – properties, construction, inhomogeneous boundary conditions; Eigen function expansion of Green's functions.

[4]

Multi-dimensional Green's functions: Multi-dimensional delta function; Green's functions for the Laplacian; Fundamental solution; Integral equation and Green's function. [3]

Cauchy problem for linear partial differential equations: Basic concepts; Properties of linear PDE of order M in m variables; Cauchy problem; Solution criteria for second order PDE in two variables; Riemann method for solving Cauchy problem for linear hyperbolic PDE. [5]

BVP for elliptic equations: Harmonic functions and its properties – mean value theorem, maximum-minimum principle, Boundary value problems – Dirichlet, Neumann, Robin, existence, uniqueness and stability of solutions of Dirichlet, Neumann, Robin problems, Dirichlet principle; Green's function for Dirichlet's problem of Laplace equation – properties, method of images, method of conformal mapping (two-dimensional). [5]

BVP for parabolic equations: Heat equation in two independent variables; Solution of Cauchy problem using Dirac-delta function and Fourier transforms; Maximum-minimu principle; Stability condition. [4]

Special techniques: Fourier transform technique – Green's function for the m-dimensional Laplacian, Helmholtz operator, wave equation; Eigen function expansion technique. [4]

Text Books:

1. I. Stackgold, *Green's Functions and Boundary Value Problems*, John Wiley & Sons, New York, 1979.
2. S. Hassani, *Mathematical Physics*, Springer, 2001.

Reference Books

1. Philip M. *Morse and* H. *Feshbach, Methods of Theoretical Physics, Part I & II*, McGraw-Hill Book Company, 1953.
2. G. F. Roach, *Green's Function,* Cambridge University Press, 2nd Edn., 1982.

Course – MMATAME306

Boundary Layer Flows and Magneto-hydrodynamics I (Marks - 50)

Total lectures Hours: 50

Viscous flows: Navier-Stokes' equations and its dimensionless form, Reynolds number [4]

Some exact solutions of Navier-Stokes' equations: Flow due to suddenly accelerated plane wall, Flow near an oscillating plane wall, Two-dimensional stagnation–point flow, Concept of oblique stagnation-point flow, Flow near a rotating disk (Karman's flow). [10]

Slow motion: Creeping motion, Steady flow past a fixed sphere (Stokes' flow), Steady motion of a viscous fluid due to a slowly rotating sphere, Steady motion between parallel planes, Stokes' solution for slow steady parallel flow past a sphere, Oseen's improvement over Stokes' solution, Oseen's solution for slow steady parallel flow past a sphere [12]

Boundary layer theory and its applications: Fundamental concept of boundary layer, Prandtl's assumptions and derivation of equations of boundary layer, Boundary layer parameters: boundary layer thickness, displacement and momentum thicknesses, Separation of boundary layer flow [5]

Solutions of some boundary layer flows: Blasius boundary layer flows, Blasius equation and approximate solution for steady flow past a flat plate, Self-similar solution of boundary layer equations, Steady boundary layer flow along the wall of a convergent channel, flow past a wedge, Jet flows (two dimensional flow) [10]

Integral method for boundary layer equations: Karman's integral equation, Karman-Pohlhausen method and its applications [4]

Turbulent Boundary Layers: Fundamentals of turbulent flows (Basic ideas only), Closure problem, Self-similarity, Two-layer hypothesis of turbulent boundary layer flows [5]

Text Books:

1. J. L. Bansal, *Viscous Fluid Dynamics*-2^{nd} Edition, Oxford and IBH Publishing Co, 1977.
2. H. Schlichting, *Boundary Layer Theory*, Springer, 2003.

Reference Books:

1. F. Chorlton, *Text Book of Fluid Dynamics*, Van Nostrand Reinhold Co., London, 1990.
2. S.W. Yuan , *Foundations of Fluid Mechanics*, Prentice – Hall International, 1970.
3. P. K. Kundu, *Fluid Mechanics*, Academic Press, 1990.

Course – MMATAME307

Turbulent Flows-I (Marks - 50)

Total lectures Hours: 50

Viscous fluid dynamics: Continuum hypothesis, Stoke's hypothesis, Stoke's law of friction, constitutive equations, fundamental equations of fluid motion, boundary conditions, Reynolds number and its significance, the vorticity transport equation, some exact solutions of Navier-Stokes equations (steady flow between parallel plates, flow in a pipe, flow between concentric cylinders) , high and low Reynolds number flows, Concept of boundary layer, Prandtl hypothesis, Boundary layer approximations, boundary layer equations, boundary layer parameters, Blasius boundary layer flow, Analysis of some boundary layer flows (e.g., flow in convergent channel, jet flows), flow separation phenomenon.
[15]

Turbulent flows: Nature of turbulent motion, statistical description of turbulent motion, Averages, Reynolds decomposition, mean and fluctuating motions, equations for mean motion, Reynolds stress tensor, eddy viscosity, closure problem, homogeneous and isotropic turbulence, Phenomenological theories, mixing length, Prandtl's momentum transfer theory, Taylor's vorticity transfer theory, Karman similarity hypothesis, velocity distribution in channel flow under constant pressure gradient. [20]

Spread of turbulence: Mixing zone between two parallel flows, turbulent wake behind (i) symmetrical cylinder, (ii) a row of parallel rods. Turbulent flow through smooth circular pipe, seventh power velocity distribution law, turbulent boundary layer on a flat plate. [15]

Text books:

(1) G. K. Batchelor: An introduction to fluid dynamics, Cambridge University press, 1967.

(2) S. W. Yuan: Foundations of Fluid Mechanics, Prentice-Hall International, 1970.

(3) D.J. Tritton: Physical Fluid Dynamics, second edition, Oxford Science Publications, 1988.

Reference books:

(1) J.O. Hinze: Turbulence, 2e, McGraw-Hill, New York, 1977.

(2) S.B.Pope: Turbulent Flows, Cambridge University Press, 2000.

Course – MMATAME308

Quantum Mechanics -I (Marks - 50)

Total lectures Hours: 50

Fundamental ideas of quantum mechanics: Nature of the electromagnetic radiation; Wave-particle duality - double-slit experiment, quantum unification of the two aspects of light, matter waves; Wave functions and Schrodinger equation; Quantum description of particle - wave packet, uncertainty relation. [6]

Mathematical formalism of quantum mechanics: Wave function space – bases, representation; State space – bases, representation; Observables – **R** and **P** observables; Postulates of quantum mechanics. [5]

Physical interpretation of the postulates: Statistical interpretation – expectation values, Ehrenfest theorem, uncertainty principle; Physical implications of the Schrodinger equation - evolution of physical systems, superposition principle, conservation of probability, equation of continuity; Solution of the Schrodinger equation – time evolution operator, stationary state, time-independent Schrodinger equation; Equations of motion – Schrodinger picture, Heisenberg picture, interaction picture. [5]

Theory of harmonic oscillator: Matrix formulation – creation and annihilation operators; Energy values; Matrix representation in |n> basis; Representation in the coordinate basis; Planck's law; Oscillator in higher dimensions. [5]

Symmetry and conservation laws: Symmetry transformations – basic concepts, examples; Translation in space; Translation of time; Rotation in space; Space inversion; Time reversal. [5]

Angular momentum: Orbital angular momentum - eigen values and eigen functions of L^2 and L_z; Angular momentum operators $\vec{J}$ – commutation relations, eigen values and eigen functions; Representations of the angular momentum operators. [5]

Spin: Idea of spin – Bosons, Fermions; Spin one-half – eigen functions, Pauli matrices; Total Hilbert space for spin-half particles; Addition of angular momenta; Clebsch-Gordan coefficients – computaion, recursion relations, construction procedure; Identical particles - symmetrisation postulate, Pauli exclusion principle, normalization of states. [5]

One-electron atom: Schrodinger equation; Energy levels, Eigen functions and bound states, Expectation values and virial theorem; Solution in parabolic coordinates; Special hydrogenic atom (brief description) – positronium, muonium, anti-hydrogen, Rydberg atoms. [4]

Time-independent perturbation theory: Basic concepts; Derivation – up to the second order correction to the energy values and wave functions; Applications - anharmonic oscillator; normal helium atom, ground state of hydrogen and Stark effect. [3]

Variational method: Rayleigh-Ritz variational principle; Applications – one dimensional harmonic oscillator, hydrogen atom, helium atom. [2]

Relativistic quantum mechanics: Klein-Gordon equation – plane wave solution, interpretation of K-G equation; Dirac equation – covariant form, charged particle in electromagnetic field, equation of continuity, plane wave solution; Dirac hole theory; Spin of the Dirac particle. [5]

Text Books:

1. B. H. Bransden and C. J. Joachain, *Quantum Mechanics*, Prentics Hall (2005); *Physics of Atoms and Molecules*, Pearson Education , 2007.
2. A. Das, *Lectures on Quantum Mechanics*, Hindusthan Book Agency, New Delhi, 2003.

Reference Books:

1. C. Cohen-Tannoudji, B. Diu, and F. Laloe, *Quantum Mechanics Vol. 1*, Wiley- Interscience publication, 1977.
2. D. J. Griffiths, *Introduction to Quantum Mechanics*, Pearson Prentics Hall, Upper Saddle River, NJ, 2005.
3. L. I. Schiff, *Quantum Mechanics*, McGraw-Hill, New York, 1968.

Course – MMATAME309

Elasticity-I (Marks - 50)

Total lectures Hours: 50

Generalised Hooke's law Orthotropic and transversely isotropic media. Stress-strain relations in isotropic elastic solid. [4]

Saint-Venant's semi-inverse method of solution (Statement). Formulation of torsion problem and the equations satisfied by the torsion function and the boundary condition. Formulation of torsion problem as an internal Neumann problem,. Dirichlet's problem and Poisson's problem. Prandtl's stress function. shearing stress in torsion problem. Solution of torsion problem for simple sections Method of sol. of torsion problem by conformal mapping. [24]

Flexure problem : Reduction of flexure problem to Neumann problem. Solution of flexure problem for simple sections. [7]

Potential energy of deformation. Reciprocal theorem of Betti and Rayleigh. Theorem of min. Potential energy. [7]

Plane problem : plane strain, plane stress, generalised plane stress. Basic equations. Airy's stress function. Solution in terms of complex analytic function. [8]

Text Books:

1. Y. A. Amenzade – Theory of Elasticity , MIR Pub., 1984.
2. A. E. H. Love – A treatise on the Mathematical Theory of Elasticity, CUP, 1963.

Reference Book:
1. I. S. Sokolnikoff – Mathematical Theory of Elasticity, Tata Mc Graw Hill Co., 1977.
2. W. Nowacki – Thermoelasticity , Addison-Wesley, 1963.
3. Y. C. Fung- Foundations of Solid Mechanics, PHI, 1965.
4. S. Timoshenk and N. Goodies, Theory of Elasticity, Mc Grwa Hill Co., 1970.

5. N. I. Muskhelishvili- Some Basic Problems of the mathematical theory of Elasticity, 1st English Edition, Noordhoff International Publishing, 2010.

Course – MMATAME310

Non-Linear Programming –I (Marks - 50)

Total lectures Hours: 50

The non-linear programming problem and its fundamental ingredients. [1]

Linear inequalities and theorems of the alternative-Farkas' theorem. The optimality criteria of linear programming. Tucker's lemma and existence theorems. Theorems of the alternative. [6]

Convex sets-Separation theorems. [1]

Convex and concave functions- Basic properties and some fundamental theorems of convex functions. Generalisied Gordan theorem. Bohnenblust-Karlin-Shapely theorem. [6]

Saddle point optimality criteria without differentiability-The minimization and the local minimization problems and some basic results. Sufficient Optimality theorem. Fritz John saddle point necessary Optimality theorem. Slater's and Karlin's Constraint qualifications and their equivalence. The strict constraints qualification. Khun-Tucker Saddle point necessary optimality theorem. [12]

Differentiable Convex and concave functions-Some basic properties. Twice differentiable convex and concave functions. Theorems in cases of strict convexity and concavity of functions. [4]

Optimality criteria with differentiability-Sufficient Optimality theorems. Fritz John Stationary point necessary optimality theorem. The Arrow-Hurwicz-Uzawa constraint qualification. Kuhn-Tucker stationary-point necessary ptimality theorem. [10]

Duality in non-linear programming-weak duality theorem. Wolfe's duality theorem. Strict converse duality theorem. The Hanson-Huard strict converse duality theorem. Unbounded dual theorem. Duality in quadratic and linear programming. [10]

Text Books:

1. O. L. Mangasarian, *Non-Linear Programming*, McGraw Hill, New York, 1994.
2. M.S. Bazaraa, H.D. Sherali and C. M. Shetty, *Nonlinear Programming*, John Wiley & Sons. Inc., 2004.

Reference Book:

1. J.Dutta, C.R.Bector, and S. Chandra, ***Principles of Optimization Theory***, Narosa Publishers, New Delhi, India, 2004.
2. A.Mordecal, *Nonlinear Programming Analysis and Methods*, Dover Publications, 2012

Course – MMATAME311

Advanced Optimization and Operations Research-I (Marks - 50)

Total lectures Hours: 50

Convex and concave functions: Basic properties and some fundamental theorems of convex/concave functions, Differentiable convex and concave functions [3]

Generalised convex and convex functions: Quasi-convex, quasi-concave, pseudo-convex, pseudo-concave functions and related theorems [3]

Constrained optimization with equality constraints- Lagrange's multiplier method, Interpretation of Lagrange multiplier. [3]

KKT conditions for constrained optimization. [3]

Theory of nonlinear programming: Saddle point optimality criteria without differentiability, the minimization and the local minimization problems and some basic results, sufficient optimality theorem, Fritz John saddle point necessary optimality theorem, Slater's and Karlin's constraint qualifications and their equivalence, strict constraints qualification, Kuhn-Tucker saddle point necessary optimality theorem. [7]

Quadratic Programming: Wolfe's modified simplex method, Beale's method. [6]

Separable convex programming, separable programming algorithm [3]

One-dimensional optimization: Function comparison method, Fibonacci and Golden section methods for unimodal functions [5]

Unconstrained optimization: Gradient methods, Steepest descent method, conjugate gradient method, Quasi-Newton's method, Daviddon-Fletcher-Powel method [9]

Information theory: Measure of information, Entropy and its properties, Marginal, joint and conditional entropies, mutual information, communication system, information process by a channel, Shanon Fano encoding procedure. [8]

Text Books:

1. N.S. Kambo, *Mathematical Programming Techniques*, Affiliated East-West Press Pvt. Ltd., New Delhi, 2005.
2. Edwin K. P. Chang and S. Zak, *An Introduction to Optimization*, John Wiley & Sons Inc., 2004.

Reference Books:

1. M. Aokie, *Introduction to Optimization Techniques: Fundamentals and Applications of Nonlinear Programming*, The Macmillan Company, 1971.
2. Johannes Jahn, *Introduction to the Theory of Nonlinear Optimization*, Springer, 2007.
3. O. L. Mangasarian, , *Non-Linear Programming*, McGraw Hill, New York,1994.
4. C. Mohan and K. Deep, *Optimization Techniques*, New Age Science, 2009.
5. S. S. Rao, *Optimization-Theory and Applications*, Wiley Eastern Ltd., 1977.

Semester IV

Course – MMATP401

Abstract Algebra - III (Marks – 30)

Total lectures Hours: 50

Field Extensions: Algebraic extensions, Transcendental extensions, Degree of extensions, Simple extensions, Finite extensions, Simple algebraic extensions, Minimal polynomial of an algebraic element, Isomorphism extension theorem. [4]

Splitting fields : Fundamental theorem of general algebra (Kronekar theorem), Existence theorem, Isomorphism theorem, Algebraically closed field, Existence of algebraically closed field, Algebraic closures, Existence and uniqueness (up to isomorphism) of algebraic closures of a field, field of algebraic members. [6]

Separable Extension : Separable and inseparable polynomials, Separable and inseparable extensions, Perfect field, Artin's theorem. [4]

Finite Field : The structure of finite field, existence of $GF(p^n)$, Construction of finite fields, field of order p^n , primitive elements.

[6]

Normal extensions : Normal extension, automorphisms of field extensions, Galois extensions, Fundamental theorem of Galois theory. Solutions of polynomial equations by radicals, insolvability of general polynomial equation of order 5 by radicals. Roots of unity, primitive roots of unity, Cyclotomic fields, Cyclotomic polynomial, Wedderburn's theorem. Geometric constructions by straightedge and compass only. [10]

Text Books :

1. D. S. Malik, J. M. Mordeson and M. K. Sen : *Fundamentals of Abstract Algebra*, McGraw Hill , 1997.
2. T. W. Hungerford; *Abstract Algebra: An Introduction*, Spinger, 1990.

Reference Books

1. D. S. Dummit & R. M. Foote; *Abstract Algebra*, John Wiley & Sons, Canada, 2004.
2. J. Rotman; *Galois Theory (2nd Edition)*, Springer, New York, 1990.
3. P. B. Garrett; *Abstract Algebra*, Chapman & Hall/CRC, London, 2007.

Course – MMATP402

Calculus of R^n - II (Marks: 20)

Total lectures Hours: 20

The integral over a rectangle, existence of the integral, evaluation of the integral, Fubini's theorem, the integral over a bounded set, rectifiable, sets, improper integrals. Partitions of unity, change of variable theorem and its applications, diffeomorphims in R^n, wedge product, differential forms, Green's theorem, Gauss divergence theorem, generalized Stoke's theorem. [20]

Text Book:

1. J. R. Munkres, *Analysis on manifolds,* Addison-Wesley Pub. Comp., 1991.

Reference Book:

1. R. Courant and F. John, *Introduction to calculus and analysis, Volume-II*, Springer-Verlag, New York, 2004.

Course – MMATP403

Topology – II (Marks – 50)

Total lectures Hours: 50

Set Theory : Axiom of choice, Zorn's lemma, Hausdorff maximality principle, well ordering theorem and their equivalence.General Cartesian product of sets , cardinal numbers and their ordering, Schroeder-Bernstein theorem, [10]

Directed Sets, Nets, filters, subnets and convergence. [5]

Product Topology : Tychonoff product topology in terms of standard sub-base and its characterizations. Projection maps. Separation axioms on product spaces. Connectedness and compactness on product spaces, Tychonoff's theorem. Quotient topology, quotient spaces.

[10]

Compactification : Local compactness and one-point compactification. Stone-ˇCech compactification (without proof). [5]

Urysohn's metrization theorem, Uniform structure, uniform topology, uniform spaces, uniform continuity, paracompactness.

[10]

Algebraic Topology: Homotopy of paths, covering spaces, fundamental group. Fundamental group of the circle. [10]

Text Books :

1. J. R. Munkres, *Topology, A First Course*, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
2. A. Hatcher, *Algebraic Topology*, Cambridge University Press, 2003.

Reference Books:

1. G. F. Simmons, *Introduction to Topology and Modern Analysis*, Tata McGraw-Hill, 2004.
2. J. Dugundji, *Topology*, Allyn and Bacon, 1966.
3. J. L. Kelley, *General Topology*, Springer, 1975.
4. F. H. Croom, *Basic Concepts of Algebraic Topology*, Springer, NY, 1978
5. E. H. Spanier, *Algebraic Topology*, McGraw-Hill, 1966.
6. I. M. Singer and J. A. Thorpe, *Lecture Notes on Elementary Topology and Geometry*, Springer, India 2003.

7. W. S. Massey, *A Basic Course in Algebraic Topology*, Springer-Verlag, New York Inc. (1993).

Course – MMATP404

Set theory and Mathematical Logic (Marks – 25)

Total lectures Hours: 25

Set theory: Cardinal numbers: Addition, multiplication and exponentiation of cardinal numbers, the cardinal number № and c and their relation. Ordinal numbers: Initial segment, ordering of ordinal numbers, transfinite induction, addition and multiplication of ordinal numbers , sets of ordinal numbers. [10]

Mathematical logic: Statement calculus: Propositional connectives, statement form, truth functions, truth tables. [4]

Tautologies, contradiction, adequate sets of connectives . [2]

Arguments: Proving validity rule of conditional proof, Formal statement calculus, Formal axiomatic theory L, Deduction theorem and its Consequences. [7]

Quantifiers, Universal and existential; symbolizing of everyday languages. [2]

Text Books:

1. E. Mendelson, *Introduction to Mathematical Logic*, CRC Press(Taylor& Francis Gr.) 2010.
2. S. M. Srivastava, *Course on Mathematical Logic,* Springer, 2012.

Reference Books:

1. I. M. Copi, *Symbolic Logic*, Macmillan, New York, 1979.
2. A. G. Hamilton, *Logic for Mathematicians* ,Cambridge University Press, 1988
3. R. R. Stoll, *Set Theory and Logic,* Dover Publications, Inc. NewYork, 1963.

Course – MMATG405

Graph theory (Marks-25)

Total lectures Hours :

Graph: Undirected graphs. Directed, graphs- basic properties, Subgraph, Isomorphism, Walks, Paths, cycles, connected components, Distance, Bipartite graph and its characterization, radius and center, Diameter, Degree sequence. [5]

Trees, centres of trees, spanning trees, Minimal Spanning tree, Kruskal's algorithm. [5]

Eulerian Graphs and its characterization, Hamiltonian Graphs, Dirac Theorem, Ore'sTheorem, closure of a graph, uniqueness of closure. [4]

Cut vertices and cut edges, Vertex and edge connectivities, Blocks, complement of a graph, Clique Number, Independence number, Matching number. [4]

Chromatic number, Chromatic polynomial, edge colouring number, planar graphs, Statement of Kuratowski Theorem, Isomorphism properties of graphs, Eulers formula, 5 colour theorem. Statement of 4 colour theorem, Dual of a planar Graph. [7]

Text Books:

3. J. Clark and D. A. Holton: *A First Look at Graph Theory*, Allied Publishers Ltd., 1995.
4. D. S. Malik, M. K. Sen and S. Ghosh: *Introduction to Graph Theory*, Cengage Learning Asia, 2014.

Reference Books:

1. Nar Sing Deo : *Graph Theory*, Prentice-Hall, 1974.
2. J. A. Bondy and U.S.R. Murty: *Graph Theory with Applications,* Macmillan, 1976.

Course – MMATPME406

Advanced Functional Analysis-II (Marks-50)

Total lectures Hours: 50

Algebra, sub-algebra, Stone Weirstrass Theorem in c(X,R) and c(X,C), where X is a compact Hausdorff space. [6]

Representation theorem for bounded linear functionals on c[a,b] with sup norm , L_p[a,b] ($1 \leq p < \infty$) [6]

Weak topology, weak* topology, Banach Alaoglü Theorem. [8]

Weiresstrass Approximation Theorem in c[a,b], Best approximation theory in normed linear spaces,

uniqueness criterion for best approximation.
[6]

Banach Algebra, commutative Banach algebra, analytic function, invertible and non invertible elements,

properties of resolvant sets, resolvant functions.
[6]

Spectrum, compactness of spectrum, Gelfand Mazur Theorem, spectral radius and its properties,

topological divisor of zero, spectral mapping theorem for polynomials.
[8]

Quotient algebra, Banach * algebra, B* algebra, complex homeomorphism, isomorphism, ideals, maximal ideals,

radical, involution, Gelfand topology, Gelfand Neumark Theorem. [10]

Text Books :

1. W. Rudin, *Functional Analysis*, TMG Publishing Co. Ltd., New Delhi,1973**.**
2. E. Kreyszig, *Introductory Functional Analysis with Applications,* Wiley Eastern,1989.

Reference Books:

1. Brown and Page, *Elements of Functional Analysis*, Von Nostrand Reinhold Co., 1970
2. A.E. Taylor- *Functional Analysis*, John Wiley and Sons, New York, 1958.
3. G. Bachman and L. Narici, *Functional Analysis,* Academic Press, 1966

Course – MMATPME407

Advanced Abstract Algebra-II (Marks – 50)

Total lectures Hours: 50

Rings and Modules - II

Tensor Products of modules, Universal Property of the tensor product, Restriction and Extension of Scalars,Flat modules and M⊗R. [10]

Simple rings, Primitive rings, Jacobson density theorem, Wedderburn - Artin theorem on simple (left) Artinian rings. [10]

The Jacobson radical, Jacobson semisimple rings, subdirect product of rings, Jacobson semisimple rings as subdirect products of primitive rings, Wedderburn - Artin theorem on Jacobson semisimple left)Artinian rings. Simple and Semisimple modules, Semisimple rings, Equivalence of semisimple rings with acobson semisimple (left)Artinian rings, Properties of semisimple rings, Characterizations of semisimple rings in terms of modules. Algebras and their structure. [30]

Text Books :

1. D.S. Dummit and R. M. Foote, *Abstract Algebra*, Second Edition, John Wiley & Sons, Inc., 1999.
2. M. Atiyah and I. G. MacDonald, *Introduction to Commutative Algebra*, Addison-Wesley, 1969.

Reference Books:

1. S. Lang, *Algebra*, Addison-Wesley, 1993
2. T. Y. Lam, *A First Course in Non-Commutative Rings*, Springer Verlag, 2nd Edn., 2001.
3. T. W. Hungerford, *Algebra*, Springer, 1974.
4. N. Jacobson, *Basic Algebra, II*, Hindusthan Publishing Corporation, India, 1984.
5. D. S. Malik, J. M. Mordesen and M. K. Sen, *Fundamentals of Abstract Algebra*, The McGraw-Hill Companies, Inc., 1997.
6. C. W. Curtis and I. Reiner, *Representation Theory of Finite Groups and Associated Algebras*, Wiley-Interscience, NY, 1962.

Course– MMATPME408

Algebraic Topology- II (Marks-50)

Total lectures Hours: 50

Introduction of singular homology and cohomology group by Eilenberg and steenrod axioms. Existence and Uniqueness of singular homology and cohomology theory. [14]

Calculation of homology and chomology groups for circle. Projective spaces, torus relation between $H_1(X)$ and $\pi_1(X)$. [14]

Singular cohomology ring, calculation of cohomology ring for projective spaces. Fibre bundles : Definitions and examples of bundles and vector bundles and their morphisms, cross sections, fibre products, induced bundles and vector bundles and their morphisoms, cross sections, fibre products, induced bundles and vector bundles, homotopy properties of vector bundles. Homology exact sequence of a fibre bundle. [22]

Text Books :

1. W. S. Massey, A *Basic Course in Algebraic Topology*, Springer, 1991.
2. W. S. Massey, *Singular Homology Theory*, Springer, 2012.

Reference Books:

1. I. M. Singer and J. A. Thorpe, *Lecture Notes on Elementary Topology and Geometry*, Springer, India 2003.
2. G. R. Bredon –*Topology and Geometry, Springer, 1993*
3. B. Gray, *Homotopy Theory An Introduction to Algebraic Topology*, Academic Press, Inc (London) Ltd, 1975.
4. F. H. Croom, *Basic Concepts of Algebraic Topology*, Springer, NY, 1978
5. E. H. Spanier, *Algebraic Topology*, McGraw-Hill, 1966.
6. J. R. Munkres, *Topology, A First Course*, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
7. A. Hatcher, *Algebraic Topology*, Cambridge University Press, 2003**.**

Course – MMATPME409

Advanced Complex Analysis-II(50 Marks)

Total lectures Hours: 50

Spaces of continuous functions, Ascoli-Arzela theorem, Spaces of Analytic functions, Hurwitz's theorem, Riemann mapping theorem. [15]

Meromorphic function, Mittag-Leffler's theorem. [10]

Elliptic function, weirstrass's elliptic function p(z), addition theorem for p(z), differential equation satisfied by p(z), the numbers e_1, e_2, e_3. *[25]*

Text Books:

1. J. B. Conway, *Functions of one complex variable, 2nd Ed.*, Narosa Publishing House, New Delhi, 1997.
2. L. V. Ahlfors – *Complex Analysis*, McGraw-Hill, 3rd Edn., 1979

Reference Books:

1. W. Rudin – *Real and Complex Analysis*, Tata McGraw-Hill Education, 1987
2. E. C. Titchmarsh – *Theory of Functions*, Oxford University Press, 2nd Edn., 1970.
3. E. T. Copson, *Introduction to the Theory of Function of a Complex Variable*, Oxford University press, 1970
4. R. P. Boas – *Entire Functions*, Academic Press, 1954
5. H. Cartan – *Elementary Theory of Analytic Functions of One or Several Complex Variables*, Dover Publication, 1995.
6. A. I. Markusevich , *Theory of Functions of a Complex Variables*, Vol. I & II, Printice-Hall, 1965.
7. M. Dutta and L. Debnath , *Elements of The Theory of Elliptic and Associated Functions with Applications, World Press Pvt., 1965*

Course – MMATPME410

Measure and Integration-II (Marks – 50)

Total lectures Hours: 50

Signed measures, Hahn-decomposition theorem. Jordan decomposition theorem. Radon-Nidodym theorem. Radon-Nikodym derivative. Lebesgue decomposition theorem. Complex measure. Integrability of fuctions w.r.t. signed measure and complex measure.

[25]

Measurable Rectangles, Elementary sets. Product measures. Fubini's theorem. [10]

L_p [a,b] – spaces ($1 \le p \le \infty$). Holder and Minkowski inequality. Completeness and other properties of L_p [a, b] spaces. Dense subspaces of L_p [a, b] – spaces. Bounded linear functionals on L_p [a, b] – spaces and their representations. [15]

Text Books :

1. I. K. Rana, *An Introduction to Measure and Integration,* Narosa Publishing House, 1997.
2. G. D. Barra, *Measure Theory and Integration,* Wiley Eastern Limited, 1987.

Reference Books:

1. Hewitt and Stormberg – *Real and Abstract Analysis*, John – Wiley, N. Y., 1965.
2. H. L. Royden , *Real Analysis*, PHI, 2005
3. W. Rudin , *Real and Complex Analysis, Tata McGraw-Hill, 1993*
4. I. P. Natanson , *Theory of Functions of a Real Variable*, Vols. I & II, Ungar Publishing Company, 1974.
5. Charles Schwartz, Measure , Integration and Function spaces, World Scientific Publisher, Singapore, 1994.

Course – MMATPME412

Euclidean and non-Euclidean Geometries - II (ENEG-II) (Marks: 50)

Total lectures Hours: 50

Independence of the Parallel Postulate: Consistency of Hyperbolic Geometry, Beltrami's Interpretation, The Beltrami–Klein Model, The Poincaré Models, Perpendicularity in the Beltrami–Klein Model, A Model of the Hyperbolic Plane from Physics, Inversion in Circles, Poincaré Congruence, The Projective Nature of the Beltrami–Klein Model. [10]

Philosophical Implications, Fruitful Applications: What Is the Geometry of Physical Space? What Is Mathematics About? The Controversy about the Foundations of Mathematics, The Meaning, The Fruitfulness of Hyperbolic Geometry for Other Branches of Mathematics, Cosmology, and Art. [10]

Geometric Transformations: Klein's Erlanger Programme, Groups, Applications to Geometric problems, Motions and Similarities, Reflections, Rotations, Translations, Half-Turns, Ideal points in the Hyperbolic Plane, Parallel Displacements, Glides, Classification of Motions, Automorphisms of the Cartesian Model, Motions in the Poincaré Model, Congruence Described by Motions. [10]

Further Results in Real Hyperbolic Geometry: Area and Defect, The Angle of Parallelism, Cycles, The Curvature of the Hyperbolic Plane, Hyperbolic Trigonometry, Circumference and Area of a Circle, Saccheri and Lambert Quadrilaterals, Coordinates in the Real Hyperbolic Plane, The Circumscribed Cycle of a Triangle, Bolyai's Constructions in the Hyperbolic Plane. [10]

Elliptic and other Riemannian Geometries. Hilbert's Geometry without Real number. [10]

Text Book:

1. Marvin Jay Grenberg, *Euclidean and non-Euclidean Geometries: Development and History*, W. H. Freeman and Company, New York, 4^{th} Edn., 2008.

Reference Books:

1. R. Courant and H. Robbins,*What is mathematics?*, Oxford Univ. Press, New York, 1941.
2. C. B. Boyer and U. Merzbach, *A history of mathematics*, New York, Wiley, 2^{nd} edn., 1991.
3. H. S. M. Coxeter, *Introduction to geometry, 2nd ed.*, New York, Wiley, 2001.
4. Euclid, Thirteen Books of the Elements, 3 Vols. Tr. T. L. Heath, with annotations, New York, Dover, 1956.
5. J. G. Ratcliffe, *Foundations of hyperbolic manifolds, 2^{nd}, ed.*, New Yprk, Springer, 2006.
6. H. E. Wolfe, *Introduction to non-euclidean geometry*, New York, Holt, Rinehart and Winston, 1945.
7. V. J. Katz, *A history of mathematics: an introduction, 2^{nd} ed., Reading* , Mass: Addison-Wesely Longman, New York, 1988.

Course – MMATPME413

Geometric mechanics on Riemannian Manifolds-II (Marks 50)

Total lectures Hours: 50

Manifolds, Tangent vectors, The Differential of a Map, The Lie bracket, One-forms, Tensors, Riemannian Manifolds, Linear Connections, The Volume element. Laplace Operators on Riemannian Manifolds, Gradient vector field; Divergence and Laplacian, Applications, Pluri-harmonic functions, Uniqueness for solution of the Cauchy problem for the heat operator, The Hessian and applications, Application to the heat equation with convection on compact manifolds. [10]

Lagrangian Formalism on Riemannian Manifolds, A simple example, The pendulum equation, Euler–Lagrange equations on Riemannian manifolds, Laplace's Equation $\Delta f = 0$, A geometrical interpretation for a Δ operator, Poisson's equation, Geodesics, The natural Lagrangian on manifolds, Momentum and Work, Force and Newton's Equation, A geometrical interpretation for the potential U. Harmonic Maps from a Lagrangian Viewpoint, Introduction to harmonic maps, The energy density, Harmonic maps using Lagrangian formalism, D'Alembert principle on Riemannian manifolds. [10]

Conservation Theorems, Noether's Theorem, The role of Killing vector fields, The Energy-Momentum tensor, Definition of Energy-Momentum, Einstein tensor, Field equations, Divergence of the energy-momentum tensor, Conservation Theorems, Applications of the conservation theorems. Hamiltonian Formalism, Momenta vector fields. Hamiltonian, Hamilton's system of equations, Harmonic functions, Geodesics, Harmonic maps, Poincaré half-plane. [10]

Hamilton–Jacobi Theory, Hamilton–Jacobi equation in the case of natural Lagrangian, The action function on Riemannian manifolds, Hamilton–Jacobi for conservative systems, Action for an arbitrary Lagrangian, Examples, The Eiconal Equation on Riemannian Manifolds, Applications of Eiconal equation, Fundamental solution for the Laplace–Beltrami operator, Fundamental Singularity for the Laplacian, Laplacian momenta on a compact manifold, Minimizing geodesics. Minimal Hypersurfaces, The Curl tensor, Application to minimal hypersurfaces, Helmholtz decomposition, The non-compact case. [10]

Radially Symmetric Spaces, Existence and uniqueness of geodesics, Geodesic spheres, A radially non-symmetric space, The Heisenberg group, The left invariant metric, The Euler–Lagrange system, The classical action, The complex action, The volume function at the origin. Mechanical Curves, The areal velocity, Areal velocity as an angular momentum, The circular motion, The asteroid, Noether's Theorem, The first integral of energy, Physical interpretation, The cycloid, Solving the Euler–Lagrange system, The total energy, Galileo's law, Curves that minimize a potential, The gravitational potential, Minimal surfaces, The brachistochrone curve, Coloumb potential, Physical interpretation, Hamiltonian approach, Hamiltonian system. [10]

Text Book:

1. Ovidiu Calin, Der-Chen Chang, *Geometric mechanics on Riemannian manifolds*, Springer-Verlag, 2006.
2. W.M. Oliva, *Geometric Mechanics*,Springer, 2002

Course– MMATPME414

Advanced Differential Geometry-II (Marks-50)

Total lectures Hours: 50

Structures on Manifolds: Cartan's symmetric manifolds, recurrent manifolds, semisymmetric manifolds, pseudosymmetric manifolds, Einstein field equation, Schwarchild spacetimes, Robertson-Walker spacetimes. [15]

Complex Structures: Almost Complex manifolds, Nijenhuis tensor, Contravariant and covariant almost analytic vector fields, Almost Hermite manifolds, Kähler manifolds, almost Tachibana manifolds, holomorphic sectional curvature. [15]

Contact Structures: Contact manifolds, K-contact manifolds, Sasakian manifolds, Trans-Sasakian manifolds. [20]

Text Books:

1. D. E. Blair, *Contact Manifolds in Riemannian Geometry*, Birkhausher, 2005
2. U. C. De and A. A. Shaikh, Complex and Contact manifolds, Narosa Publ. Pvt. Ltd, New Delhi, 2009.
3. R. Deszcz, S. Haesen and L. Verstraelen, On Natural Symmetries: Topics in Differential Geometry (Ch. 6), Editura Academiei Române, A. Mihai and R. Miron eds., 2008.

Reference Books:

1. K. Yano and M. Kon, *Structure on Manifolds*, World Scientific, 1984.
2. A. Kushner, V. Lychagin and V. Rubtsov, Contact Geometry and nonlinear Differential equations, Cambridge University Press, 2007.
3. B. O'Neill, *Semi-Riemannian Geometry with Application to Relativity*, Academic Press, 1983.

Course– MMATPME415

Operator Theory and Applications -II (Marks-50)

Total lectures Hours: 50

Projection Operators on Hilbert spaces, product of projection operators, positive operators, product of positive operators, monotone sequences of positive operators. Square root of positive operators. [8]

Spectral Theorem for bounded normal finite dimensional operators. [4]

Infinite orthogonal direct sums, commutatively convergence of infinite series of operators, spectral theorem of compact normal operators. [6]

Spectral theory of bounded self adjoint operators: eigen values, spectrum of bounded self adjoint operators. Spectral family of bounded self adjoint linear operators and its properties, spectral theorem of bounded self adjoint operators. [14]

Unbounded linear operators on Hilbert spaces: Hellinger-Toeplitz Theorem, symmetric and self adjoint operators, Spectral properties of self adjoint operators.Wecken's lemma, spectral theorem of unitary operators, Cayley transform of self adjoint operators, spectral theorem of self adjoint operators. [14]

Multiplication operator and differentiation operator, self-adjointness of multiplication operators, unboundedness of differentiation operators , self-adjointness of differentiation operators, spectral properties of multiplication operators. [4]

Text Books :

1. G. Bachman and L.Narici, *Functional Analysis,* Academic Press, 1966
2. E. Kreyszig, *Introductory Functional Analysis with Applications*, Wiley Eastern, 1989

Reference Books:

1. B. V. Limaye, *Functional Analysis*, Wiley Eastern Ltd., 1984.
2. B. K. Lahiri, *Elements of Functional Analysis*, The World Press Pvt. Ltd, Kolkata, 1994
3. G. F. Simmons, *Introduction to topology and Modern Analysis*, McGraw-Hill, New York, 1958.
4. K. Yosida, *Functional Analysis*, Springer Verlog, New York, 3rd Edn, 1990.

Course– MMATPSO416

Project and Social Outreach Programme: Project paper will be done from any course of Sem –III & Sem – IV.

Social outreach programme will be done according to the decision of the department in every year.

Course – MMATA401

Fluid Mechanics (Marks - 50)

Total lectures Hours: 50

Irrotational motion of fluid: Irrotational motion in simply connected and multiply connected regions, Acyclic irrotational motion and some properties (Using Green's theorem). [4]

Two dimensional motion: Stream function, Complex potential, Source, sink and doublets, Complex potentials for simple source, sink and doublet, Circle theorem, Uniform flow past a circle, Image of a source with respect to a plane boundary, image of a source outside a circle, image of a doublet outside a circle. [10]

Circulation about a cylinder: Motion of translation and rotation of circular cylinder in an infinite liquid, Blasius theorem, Kutta-Joukowski's theorem. [5]

Axi-symmetric motion: Axi-symmetric motion, Stokes' stream function, Three-dimensional motion, Source, sink, doublet in three dimension. [5]

Vortex motion: Permanence of vortex lines and filaments, Equation of surface formed by the streamlines and vortex lines in the case of steady motion, Helmholtz's theorems, System of vortices, Rectilinear vortices, Vortex pair and doublets, Image of vortex with respect to a circle, A single infinite row of vortices, Karman's vortex sheet, Pair of stationary vortex filament behind a circular cylinder in a uniform flow. [8]

Viscous incompressible fluid flow: Viscous incompressible fluid flow: Field equations (Euler and Navier-Stokes' Equations), Boundary conditions, Reynolds number, Poisueile flow, Couette flow, Flow through parallel plates, Flow through pipes of circular and elliptic cross sections Vorticity transport equation, Energy dissipation due to viscosity. [8]

Waves: Surface condition of gravity waves, Cisotti's equation, Complex potential, Small height gravity waves, Progressive waves-Cases of deep and shallow water, Stationary waves-possible wave lengths in a rectangular tank, Paths of particles for different waves, Energy for different waves . [7]

Group velocity: Group velocity and its dynamical significance. [3]

Text Books:

1. G. K. Batchelor , *An Introduction to Fluid Dynamics*, Cambridge University Press, 2005.
2. P. K. Kundu and I. M. Cohen , *Fluid Mechanics*, 4th Edition, Academic Press, 2008.

Reference Books:

1. S.W. Yuan , *Foundations of Fluid Mechanics,* Prentice – Hall International, 1970.
2. J. L. Bansal, *Viscous Fluid Dynamics*, Oxford and IBH Publishing Co., 1977.
3. I. S. Sokolnikoff , *Mathematical theory of Elasticity*, Tata Mc Grow Hill Co., 1977.

Course – MMATA402

Dynamical Systems (Marks - 30)

Total lectures Hours: 30

History of dynamical system, mathematical definition, different types of dynamical systems with examples, phase variable and phase space, continuous and discrete dynamical systems, Flows and maps, orbits, fixed points, periodic points and their stabilities, Attractors and Repellors. [6]

Phase plane analysis, hyperbolic concept of hyperbolicity, stable, unstable and center subspaces. [6]
Lyapunov and asymptotic stability,Local and global stability, Hartmann-Grobman theorem (statement only), stable manifold theorem, Lyapunov function, Lyapunov theorem on stability, periodic orbits, limit cycles, attracting and invatriant sets, Poincare-Bendixson theorem, Poincare map, Lienard's theorem (statement only) and applications. Bifurcation theory, Saddle-Node, Pitch-Fork and Transcritical bifurcations for one-dimensional continuous systems, Hopf-bifurcation, Analysis of Lorentz system. [12]

Some important maps:Logistic map, Tent map, Baker map, Shift map and their properties. [6]

Text Books:

1. P. Glendinning, *Stability,Instability and Chaso,* Cambridge University Press, 1994.
2. Robert C. Hilborn, *Chaos and Nonlinear Dynamics,* Oxford University Press, 2001.
3. Steven H. Strogatz, *Nonlinear Dynamical and Chaos*, Perseus Books , Indian Edition, 2007.

Reference Books:

1. D W Jordan and P. Smith, *Nonlinear Ordinary Differential Equattions*, Clarenden Press.
2. A. Medio and M. Lines, *Nonlinear Dynamics,* C. U. P.

3. M. W. Hirsch and S. Smale, *Differential Equations, Dynamical Systems*, Academic, 1974.
4. R. L. Devaney, *An Introduction to Chaotic Dynamical Systems*, Addition-Wesley, 1989

Course – MMATA403

Chaos and Fractals (Marks – 20)

Total lectures Hours: 20

Sensitive dependence on initial conditions (SDIC), Topological transivity, Topological mixing, Topological conjugacy and semi-conjugacy for maps, Chaos, mathematical definition of chaotic system, chaotic orbits, dynamics of logistic map, Lyapunov exponents, Invariant measure, Ergodic maps, Invariant measure for logistic map, Period three implies chaos.
[12]

Definition of fractals, self-similar fractal with examples, von-Koch curve, Cantor set, Dimension of self-similar fractals, Box dimension.
[8]

Text Books:

1. P. Glendinning, *Stability,Instability and Chaso*, Cambridge University Press, 1994.
2. Robert C. Hilborn, *Chaos and Nonlinear Dynamics*, Oxford University Press, 2001.
3. Steven H. Strogatz, *Nonlinear Dynamical and Chaos*, Perseus Books , Indian Edition, 2007.

Reference Books:

1. D. W. Jordan and P. Smith, *Nonlinear Ordinary Differential Equattions*, Oxford University Press, 1999.
2. Ferdinand Verhulst, *Nonlinear Differential Equations and Dynamical Systems*, Springer, 1996.
3. A. Medio and M. Lines, *Nonlinear Dynamics: A Primer*, Cambridge University Press, 2001.
4. M. W. Hirsch and S. Smale, *Differential Equations, Dynamical Systems*, Academic, 1974.
5. R. L. Devaney, *An Introduction to Chaotic Dynamical Systems*, Addition-Wesley, 1989.

Course – MMATA404

Quantum Mechanics (Marks -25)

Total lectures Hours: 25

Origins of quantum theory: Inadequacies of classical mechanics; Planck's quantum hypothesis; Photoelectric effect; Compton experiment; Bohr model of hydrogenic atoms, Wilson-Sommerfeld quantization rule, Correspondence principle, Stern-Gerlach experiment (brief description and conclusion only). [5]

Wave aspect of matter: de Broglie hypothesis; mater waves; uncertainty principle; double-slit experiment; Concept of wave function; Gedanken experiments. [4]

Schrodinger equation: Time-dependent Schrodinger equation; Statistical interpretation – conservation of probability, equation of continuity, expectation value, Ehrenfest theorem; Formal solution of Schrodinger equation – time-independent Schrodinger equation, stationary state, discrete and continuous spectra, parity. [4]

Solutions of Schrodinger equation in one-dimension: Infinite potential box; Step potential; Potential barrier; Potential well. [3]

Linear harmonic oscillator in one-dimension: Classical description; Schrodinger method of solution; Energy levels and wave functions; Planck's law. [3]

Hydrogenic atoms: Schrodinger equation for hydrogenic atoms; Solution in spherical polar coordinates; Spherical Harmonics, Energy levels and wave functions; Radial probability density. [3]

Mathematical foundations of quantum mechanics: Concept of wave function space and state space; Observables; Postulates of quantum mechanics; Physical interpretations of the postulates – expectation values, Ehrenfest theorem, uncertainty principle. [3]

Text Books:

2. B. H. Bransden and C. J. Joachain, *Quantum Mechanics*, Prentics Hall, 2005.
3. D. J. Griffiths, *Introduction to Quantum Mechanics*, Pearson Prentics Hall, Upper Saddle River, NJ, 2005.

Reference Books:

1. S. N. Ghoshal, *Quantum Mechanics*, S Chand & Company Ltd, Kolkata, 2002.
2. L. I. Schiff, *Quantum Mechanics*, McGraw-Hill, New York, 1968.

Course – MMATAME406

Boundary Layer Flows and Magneto-hydrodynamics II (Marks - 50)

Total lectures Hours: 50

Basic ideas of electro-magnetic fields, basic laws. Electromagnetic induction : Faradays law, inductance ; energy in magnetic field. Maxwell's equations:Electrodynamics before Maxwell-Ampire –Maxwell equation;Maxwell's equation,- in vacuum , in matter, physical significance,boundary conditions ;Energy transfer and Poynting theorem. [6]

Basic equations in MHD: Physical description of electrically conducting fluids, Maxwell's electromagnetic field equations, Basic MHD equations- Continuity Equation, Equations of motion, Energy flow, Lorentz force, Ohm's law. [6]

MHD approximations: The low frequency dynamics of the electromagnetic field, Conservation Laws for MHD: Mass, Momentum, Energy. [6]

Dimensional analysis and Lundquist criterion: Dimensionless forms of basic equations, Lundquist criterion, Convection dominated flow. [5]

Propagation of waves: Alfven's theorem and its interpretation, Diffusion dominated case, Physical interpretation of Lorentz force, Alfven waves. [5]

Incompressible steady MHD flow: Parallel steady flow, one-dimensional steady viscous flow, Hartmann flow, Couette flow. [8]

Unsteady MHD flow: Unsteady unidirectional motion (MHD Rayleigh problem) [4]

Magnetohydrostatics: Pinch effect, Linear pinch, Stability of pinch configuration. [4]

Force free-field: Force free-field and its general solution, Toroidal and Poloidal fields. [3]

Dynamo Problem: Dynamo theory, Symmetric fields, Cowling's theorem, Isorotation-Ferraro's law of isorotation. [3]

Text Books:

1. V.C.A. Ferraro & C. Plumpton, *An introduction to Magneto-Fluid Mechanics*, Clarendon Press, 1966.
2. T.G. Cowling, *Magnetohydrodynamics*, Intersicence Publishers Ltd., 1956.

Reference Book:

1. J.A. Shercliff , *A text book of Magnetohydrodynamics*, Pergaman Press, 1965.

Course – MMATAME407

Turbulent Flows-II (Marks-50)

Total lectures Hours: 50

Statistical approach: Introductory concepts, double correlation between velocity components; longitudinal and lateral correlations, correlations in homogeneous turbulence, self-similarity, derivation of Karman-Howarth equation , decay of isotropic turbulence, self-preserving solutions of Karman-Howarth equation, Loitsionsky's invariant. [15]

The scales of turbulent motion: Energy cascade, Kolmogorov hypotheses, the spectrum of turbulence, energy spectrum, restatement of Kolmogorov hypotheses, structure functions, Taylor's one-dimensional energy spectrum, energy relations in turbulent motions, velocity spectra, Kolmogorov spectra, inertial subrange. [12]

Free shear layer turbulent flows: Jet flows. [5]

Wall and boundary layer flows: Channel flow: mean velocity profiles, Couette flow: two-layer structure of the velocity field and the logarithmic overlap law, description of turbulent boundary layer flows, mean-momentum equations, two-layer hypothesis, overlap region. [10]

Turbulence models: Algebraic turbulence models, Cebeci and Smith model, Two-equation models (i) $k-\varepsilon$ model, (ii) $k-\omega$ model, remarks of turbulence modeling. [8]

Text books:

(1) S.W.Yuan: Foundations of Fluid Mechanics, Prentice-Hall International, 1970.
(2) D.J. Tritton: Physical Fluid Dynamics, second edition, Oxford Science Publications, 1988.
(3) H. Schilchting: Boundary layer theory, Springer, 2003.
(4) A. Davidson: Turbulence: An introduction to Scientists and Engineers, Oxford, 2004.

Reference books:

(1) S.B.Pope: Turbulent Flows, Cambridge University Press, 2000
(2) G. K. Batchelor: The theory of Homogeneous Turbulence, Cambridge University press, 1953.

J.O. Hinze: Turbulence, 2e, McGraw-Hill, New York, 1977.

Course – MMATAME408

Quantum Mechanics -II (Marks - 50)

Total lectures Hours: 50

Scattering theory: Basic concepts – types of scattering, channels, thresholds, cross sections; Classical description – equation of trajectory, cross sections, Hard-sphere scattering, Rutherford scattering; Quantum description – cross sections, Laboratory frame and centre of mass frame, optical theorem. [5]

Method of partial waves for potential scattering: Description of the method; Phase shift; Convergence of partial wave series; Zero-energy scattering - scattering length, S-matrix, K-matrix, T-matrix; Relation between phase shift and potential; relation to cross sections – optical theorem. [5]

Integral equation of potential scattering: Description of the method; Lippmann-Schwinger equation; Integral representation of scattering amplitude. [5]

Scattering by Coulomb potential: Scattering state solution in parabolic coordinates; Cross sections; Modified Coulomb potentials. [4]

Approximate methods for potential scattering: Born series – first and second Born amplitudes; Validity of FBA; eikonal approximation – description, scattering amplitude, cross sections WKB approximation: WKB method - connection formula; Validity; α -emission; Bound state in a potential well. [6]

Variational methods in potential scattering: Differential form – Kohn variational method, inverse Kohn variational method, Hulhen variational method, Kohn-Hulthen variational method; Schwinger variational principle – scattering amplitude, phase shift, bound principle. [5]

Quantum statistics: Fundamental assumption; Most probable configuration; Maxwell-Boltzmann distribution, Fermi-Dirac distribution and Bose-Einstein distribution; Black body spectrum. [5]

Time-dependent perturbation theory: first-order perturbation; harmonic perturbation; transitions to continuum states; absorption and emission; Einstein's coefficients; Fermi's golden rule; selection rules; Rayleigh scattering; Raman scattering. [5]

Elements of field quantization: Classical field equations – Lagrangian and Hamiltonian form; Quantization of field - Schrodinger equation; Relativistic fields - Klein-Gordon field, Dirac field; Quantization of electromagnetic field. [5]

Text Books:

1. B. H. Bransden and C. J. Joachain, *Quantum Mechanics*, Prentics Hall (2005); *Physics of Atoms and Molecules*, Pearson Education, 2007.
2. A. Das, *Lectures on Quantum Mechanics*, Hindusthan Book Agency, New Delhi , 2003.

Reference Books:

1. C. Cohen-Tannoudji, B. Diu, and F. Laloe, *Quantum Mechanics Vol. 1*, Wiley- Interscience publication , 1977.
2. D. J. Griffiths, *Introduction to Quantum Mechanics*, Pearson Prentics Hall, Upper Saddle River, NJ , 2005.

Course – MMATAME409

Elasticity-II

Total lectures Hours: 50

Vibration problems : Longitudinal vibration of thin rods, Torsional vibration of a solid circular cylinder and a solid sphere. Free Rayleigh and Love waves.
[10]

Thermoelasticity : Stress-strain relations in Thermo elasticity. Reduction of statistical thermo-elastic problem to a problem of isothermal elasticity. Basic equations in dynamic thermo elasticity. Coupling of strain and temperature fields. [25]

Magneto-elasticity : Interaction between mechanical and magnetic field. Basic equations Linearisation of the equations. [15]

References :

1. Y. A. Amenzade – Theory of Elasticity (MIR Pub.)
2. A. E. H. Love – A treatise on the Mathematical Theory of Elasticity, CUP, 1963.
3. I. S. Sokolnikoff – Mathematical Theory of Elasticity, Tata Mc Graw Hill Co., 1977.
4. W. Nowacki – Thermoelasticity (Addison Wesley)
5. Y. C. Fung- Foundations of Solid Mechanics, PHI, 1965.
6. S. Timoshenk and N. Goodies, Theory of Elasticity, Mc Grwa Hill Co., 1970.
7. N. I. Muskhelishvili- Some Basic Problems of the mathematical theory of Elasticity, P. Noordhoff Ltd., 1963.

Course – MMATAME410

Non-Linear Programming –II (Marks - 50)

Total lectures Hours: 50

Quasiconvex, strictly quasiconvex and pseudoconvex functions- Differentiability properties. Strictly quasiconvex and strictly quasiconcave functions. Karamardian theorem. Global minimum(maximum). Pseudoconvex and pseudoconcave functions. Relationship between pseudoconvex functions and strictly quasiconvex functions. Differentiable convex functions and pseudoconvex functions.
[10]

Optimality and duality for generalized convex and concave functions-Sufficient optimality theorem. Generalized Kuhn-Tucker Sufficient Optimality theorem. Generalized Fritz John stationary-point necessary optimality theorem, Kuhn-Tucker necessary Optimality conditions under the weak constraint qualifications. Duality. [12]

Optimality and duality in the presence of nonlinear equality constraints-Sufficient optimality criteria.Minimum–principle necessary optimality criteria: X^0 not open. Minimum principle necessary optimality theorem. Fritz John and Kuhn-Tucker stationary-point necessary optimality criteria: X^0 open. Duality with nonlinear equality Constraints. [12]

Non-smooth Optimization: Lagrangian Relaxation and Duality, Convex non-differentiable functions, subgradient methods, penalized Bundle methods, Applications. [16]

Text Books:

1. O. L. Mangasarian, *Non-Linear Programming*, McGraw Hill, New York, 1994.
2. M. S. Bazaraa, H. D. Sherali and C. M. Shetty, *Nonlinear Programming*, John Wiley & Sons. Inc., 2004.

Reference Book:

1. J. F. Bonnans, J. C. Gilbert, C. Lemarechal and C. A. Sagastizabal, *Numerical Optimization*, Springer, 2006.

Course – MMATAME411

Advanced Optimization and Operations Research-II (Marks - 50)

Total lectures Hours: 50

Queuing theory: Machine repairing problem, power supply model, Non-Poisson queuing models-M/ E_k /1, M/G/1, mixed queuing mode M/D/1, cost models in queuing system. [10]

Dynamic programming: Basic features of dynamic programming problems, Bellman's principle of optimality, multistage decision process-forward and backward recursive approaches, Dynamic programming approach for solving (i) linear and non-linear programming problems, (ii) routing problem, (iii) reliability optimization problem, (iv) inventory control problem, (v) cargo loading problem (vi) Allocation problem [12]

Geometric Programming: Unconstrained and constrained geometric programming. [6]

Optimal Control: Performance indices, methods of calculus of variations, transversally conditions, simple optimal control problems of mechanics, Bang-Bang control, Pontryagin's principle. [9]

Reliability: Definition of reliability, Measures of reliability, system reliability, system failure rate, reliability of different systems, like series, parallel, series parallel, parallel-series, k-out-of-n, etc., idea of reliability optimization. [6]

Replacement and Maintenance Models: Failure mechanism of items, replacement of items deteriorates with time, replacement policy for equipments when value of money changes with constant rate during the period, replacement of items that fail completely-individual replacement policy and group replacement policy, other replacement problems-staffing problem, equipment renewal problem. [7]

Text Books:

1. H. A. Taha, *Operations Research – An Introduction,* Prentice-Hall, 1997.
2. Johannes Jahn, *Introduction to the Theory of Nonlinear Optimization*, Springer, 2007.

Reference Books:

1. N. S. Kambo, *Mathematical Programming Techniques,* Affiliated East-West Press Pvt. Ltd., New Delhi, 2005.
2. C. Mohan and K. Deep, *Optimization Techniques*, New Age Science, 2009.
3. S. S. Rao, *Optimization-Theory and Applications,* Wiley Eastern Ltd., 1977.
4. A. K. Bhunia and L. Sahoo, *Advanced Operations Research*, Asian Books Private Limited, New Delhi, 2011.

Course– MMATPSO416

Project and Social Outreach Programme: Project paper will be done from any topic on Mathematics and Applications. Social outreach programme will be done according to the decision of the department in every year.

Minor Elective Course

Course – MMATMIE316

Operations Research (Marks – 25)

Total lectures Hours: 25

Integer Programming: Gomory's cutting plane algorithm (All integer and mixed integer algorithms) [4]

Unconstrained optimization [3]

Constrained optimization with equality constraints- Lagrange's multiplier method, Interpretation of Lagrange multiplier. [4]

Kuhn-Tucker conditions for constrained optimization. [3]

Queueing Theory: Basic features of queueing systems, operating characteristics of a queueing system, arrival and departure (birth & death) distributions, inter-arrival and service times distributions, transient, steady state conditions in queueing process. Poisson queueing models- M/M/1, M/M/C for finite and infinite queue length. [6]

Project Network scheduling by PERT and CPM: PERT/CPM network components and precedence relationships, critical path analysis, probability in PERT analysis [5]

Text Books:

1. H. A. Taha, *Operations Research – An Introduction,* Prentice-Hall, 1997.
2. Edwin K. P. Chang and S. Zak, *An Introduction to Optimization*, John Wiley & Sons Inc., 2004.

Reference Books:

1. S. S. Rao, *Optimization-Theory and Applications*, Wiley Eastern Ltd., 1977.

2. J. K. Sharma, *Operations Research : Theory and Applications*, Mcmillan, 2007.

3. A. K. Bhunia and L. Sahoo, *Advanced Operations Research*, Asian Books Private Limited, New Delhi, 2011.

Minor Elective Course

Course – MMATMIE317

Introduction to Graph Theory (25 Marks)

Total Lecture Hours : 25

Graphs : Undirected graphs, Directed graphs, Basic properties, Walk, Path, Cycles, Connected graphs, Components of a graph, Complete graph, Complement of a graph, Bipartite graphs, Necessary and sufficient condition for a Bipartite graph. [10]

Euler graph: Euler Graph and its characterization, Königsberg Bridge Problem. [5]

Planar graph: Planar Graph, Face-size equation, Euler's formula for a planar graph. To show : the graphs K_5 and $K_{3,3}$ are non-planar, Kuratowski Theorem (Statement only). [5]

Tree: Trees with basic properties, Spanning tree, Rooted tree, Binary tree , Minimal Spanning tree, Kruskal's algorithm. [5]

Text Books:

1. J. Clark and D. A. Holton: *A First Look at Graph Theory*, Allied Publishers Ltd., 1995.
2. D. S. Malik, M. K. Sen and S. Ghosh: *Introduction to Graph Theory*, Cengage Learning Asia, 2014.

Reference Books:

3. Nar Sing Deo : *Graph Theory*, Prentice-Hall, 1974.
4. J. A. Bondy and U.S.R. Murty: *Graph Theory with Applications,* Macmillan, 1976.