SYLLABUS FOR M.A/M.SC.

IN

MATHEMATICS

Under Choice Based Credit System (CBCS)

Effective from 2017-2018

The University of Burdwan
Burdwan-713104
West Bengal

THE UNIVERSITY OF BURDWAN

Syllabus of M.A/M.Sc. in Mathematics

[with effect from 2017-18]

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 – I	1:1:0	3	2
		MMATG102	Complex Analysis – I	1:1:0	3	2
		MMATG103	Topology - I	1:1:0	3	2
		MMATG104	Differential Geometry - I	1:1:0	3	2
		MMATG105	Functional Analysis - I	1:1:0	3	2
		MMATG106	Linear Algebra	1:1:0	3	2
		MMATG107	Classical Mechanics - I	3:1:0	5	4
		MMATG108	Ordinary Differential Equations	1:1:0	3	2
		MMATG109	Partial Differential Equations	1:1:0	3	2
		MMATG110	C Programming	1:1:1	5	4
Second Semester	Core	MMATG201	Real Analysis - II	1:1:0	3	2
		MMATG202	Complex Analysis -II	1:1:0	3	2
		MMATG203	Topology – II	1:1:0	3	2
		MMATG204	Differential Geometry – II	1:1:0	3	2
		MMATG205	Calculus of R^n - I	1:1:0	3	2
		MMATG206	Abstract Algebra - I	1:1:0	3	2
		MMATG207	Operations Research	3:1:0	5	4
		MMATG208	Integral Transform	1:1:0	3	2
		MMATG209	Integral Equations	1:1:0	3	2
		MMATG210	Numerical Methods	1:1:1	5	4

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 Spaces	1:1:0	3	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	MMATPME306-1	Advanced Functional Analysis-I	3:1:0	5	4
		MMATPME306-2	Advanced Abstract Algebra-I	3:1:0	5	4
		MMATPME306-3	Algebraic Topology-I	3:1:0	5	4
		MMATPME306-4	Rings of Continuous Functions-I	3:1:0	5	4
		MMATPME306-5	Advanced Complex Analysis-I	3:1:0	5	4
		MMATPME306-6	Measure and Integration-I	3:1:0	5	4
	Choose any one from the following courses for Major Elective - 2.					
	Major Elective-2	MMATAME307-1	Advanced Optimization-I	3:1:0	5	4
		MMATAME307-2	Advanced Operations Research-I	3:1:0	5	4
		MMATPME307-3	Euclidean and non – Euclidean Geometries-I	3:1:0	5	4
		MMATPME307-4	Geometric Mechanics on Riemannian Manifolds-I	3:1:0	5	4
		MMATPME307-5	Advanced Differential Geometry - I	3:1:0	5	4
		MMATPME307-6	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	1:1:0	3	2
		MMATA302	Classical Mechanics - II	1:1:0	3	2
		MMATA303	Continuum Mechanics	3:1:0	5	4
		MMATG304	Introduction to Manifolds / Theory of Electro Magnetic Fields and Relativity	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	MMATAME306-1	Boundary Layer Flows and Magneto - hydrodynamics-I	3:1:0	5	4
		MMATAME306-2	Turbulent Flows-I	3:1:0	5	4
		MMATAME306-3	Space Sciences-I	3:1:0	5	4
		MMATAME306-4	Elasticity-I	3:1:0	5	4
	Choose any one from the following courses for Major Elective - 2.					
	Major Elective-2	MMATAME307-1	Advanced Optimization-I	3:1:0	5	4
		MMATAME307-2	Advanced Operations Research-I	3:1:0	5	4
		MMATPME307-3	Euclidean and non – Euclidean Geometries-I	3:1:0	5	4
		MMATPME307-4	Geometric Mechanics on Riemannian Manifolds-I	3:1:0	5	4
		MMATPME307-5	Advanced Differential Geometry-I	3:1:0	5	4
		MMATAME307-6	Quantum Mechanics-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**	MMATMIE308-1	Introduction to Operations Research	2:0:0	2	2
		MMATMIE308-2	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	MMATP401	Abstract Algebra – III	1:1:0	3	2
		MMATP402	Calculus of R^n –II	1:1:0	3	2
		MMATP403	Topology –III	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	MMATPME406-1	Advanced Functional Analysis-II	3:1:0	5	4
		MMATPME406-2	Advanced Abstract Algebra-II	3:1:0	5	4
		MMATPME406-3	Algebraic Topology-II	3:1:0	5	4
		MMATPME406-4	Rings of Continuous Functions-II	3:1:0	5	4
		MMATPME406-5	Advanced Complex Analysis-II	3:1:0	5	4
		MMATPME406-6	Measure and Integration-II	3:1:0	5	4
	Choose any one from the following courses for Major Elective - 4.					
	Major Elective-4	MMATAME407-1	Advanced Optimization-II	3:1:0	5	4
		MMATAME407-2	Advanced Operations Research-II	3:1:0	5	4
		MMATPME407-3	Euclidean and non – Euclidean Geometries-II	3:1:0	5	4
		MMATPME407-4	Geometric Mechanics on Riemannian Manifolds-II	3:1:0	5	4
		MMATPME407-5	Advanced Differential Geometry-II	3:1:0	5	4
		MMATPME407-6	Operator Theory and Applications-II	3:1:0	5	4
	Project	MMATPSO408	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	Wavelet Analysis	2:0:0	2	2
		MMATA403	Dynamical Systems	2:0:0	2	2
		MMATA404	Introduction to Quantum Mechanics	1:1:0	3	2
		MMATG405	Graph theory / Chaos and Fractals	1:1:0	3	2
	Choose any one from the following courses for Major Elective - 3.					
	Major Elective-3	MMATAME406-1	Boundary Layer Flows and Magneto - hydrodynamics-II	3:1:0	5	4
		MMATAME406-2	Turbulent Flows-II	3:1:0	5	4
		MMATAME406-3	Space Sciences-II	3:1:0	5	4
		MMATAME406-4	Elasticity-II	3:1:0	5	4
	Choose any one from the following courses for Major Elective - 4.					
	Major Elective-4	MMATAME407-1	Advanced Optimization -II	3:1:0	5	4
		MMATAME407-2	Advanced Operations Research-II	3:1:0	5	4
		MMATPME407-3	Euclidean and Non – Euclidean Geometries-II	3:1:0	5	4
		MMATPME407-4	Geometric Mechanics on Riemannian Manifolds-II	3:1:0	5	4
		MMATPME407-5	Advanced Differential Geometry-II	3:1:0	5	4
		MMATAME407-6	Quantum Mechanics-II	3:1:0	5	4
	Project	MMATPSO408	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**.**

Course – MMATG101

Real Analysis-I (Marks – 25)

Total lectures Hours: 30

Monotone functions and their discontinuities. Functions of bounded variation and their properties. [6]

Riemann Stieltjes integral, existence and other properties. [7]

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. [10]

Measurable Functions, continuity and measurability, monotonicity and measurability, measurability of Supremum and Infimum, simple functions, sequence of measurable functions, Egorov's Theorem. [7]

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

Course – MMATG102

Complex Analysis – I (Marks – 25)

Total lectures Hours: 30

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

Zeros of analytic functions and their limit points, entire functions, Liouville's theorem. Fundamental theorem of algebra. Simply connected region and primitives of analytic functions, Morera's theorem. [15]

Recommended Books:

1. J. B. Conway, *Functions of one complex variable, 2nd Ed.*, Narosa Publishing House, New Delhi, 1997.
2. L. V. Ahlfors – *Complex Analysis- 3rd Edn*, McGraw-Hill, 1979.
3. R. V. Churchill and J. W. Brown: Complex Variables and applications.
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. E. T. Copson, *Introduction to the Theory of Function of a Complex Variable,* Oxford University press, 1970

7. K. Kodaria, *Complex Analysis,* Cambridge University Press, 2007.
8. R. Remmmert, *Theory of complex functions*, Springer-Verlag, New York, 1991.
9. W. Rudin – *Real and Complex Analysis,* Tata McGraw-Hill Education, 1987.
10. J. M. Howie: Complex Analysis

Course – MMATG103

Topology - I (Marks – 25)

Total lectures Hours: 30

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. [12]

Continuous functions, homeomorphism and topological invariants. [4]

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. [14]

Recommended 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.
3. J. Dugundji, *Topology*, Allyn and Bacon, 1966.
4. K. D. Joshi, *Introduction to General Topology,* New Age International(P) Ltd*, 1983*
5. J. L. Kelley, *General Topology*, Springer, 1975.
6. S. Willard, *General Topology*, Dover Publications, 2004

Course – MMATG104

Differential Geometry- I (Marks - 25)

Total lectures Hours: 30

Geometry of Curves:

Definition of curves in R^n with examples, Arc-length, Reparametrization, Level curves vs. parametrized curves. [6]

Curvature of plane curves and space curves, Properties of plane curves, Torsion of space curves, Properties of space curves, Serret-Frenet formulae. [5]

Simple closed curves with periods, Isoperimetric inequality, Four vertex theorem (statement only). [4]

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. [9]

First fundamental form, Length of curves on surfaces, Isometries of surfaces, Developable surfaces. [6]

Recommended Books:

1. A. Pressley, *Elementary Differential Geometry*, Springer-Verlag, 2001, London (Indian Reprint 2004).
2. M. P. Do Carmo, *Differential Geometry of Curves and Surfaces*, Prentice-hall, Inc., Englewood, Cliffs, New Jersey, 1976.
3. B. O'Neill, *Elementary Differential Geometry*, 2^{nd} Ed., Academic Press Inc., 2006.
4. V. A. Toponogov, Differential Geometry of curves and surfaces, Birkhauser, 2006.
5. Erwin Kreyszig, Differential Geometry, Dover Publications, Inc., New York, 1991.

Course – MMATG105

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 C^n, C[a,b] (with sup metric and integral metric), C_0, l_p ($1 \leq p \leq \infty$), $L_2[a,b]$, 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]

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

Course – MMATG 106

Linear Algebra (Marks - 25)

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, annihilator of a subset of a vector space. [9]

Similar and congruent matrices, characteristic polynomial, minimal polynomial, diagonalization, Cayley-Hamilton theorem, 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]

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

Course– MMATG107

Classical Mechanics – I (Marks - 50)

Total lectures Hours: 50

Motion of a rigid body: Rotating coordinate system, 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]

Constrained motion: Constraints and their classification with examples, Problems in dealing with constraints, Lagrange's equation of motion of the first kind, Gibbs-Appell's principle of least action, D'Alembert's principle. [8]

Lagrangian mechanics: Degrees of freedom, Generalised coordinates, Lagrange's equations of motion of the second kind (holonomic and non-holonomic systems), Velocity dependent potential, Dissipative forces, Rayleigh's dissipation function, Generalised momenta and energy. [8]

Hamiltonian mechanics: Legendre dual transformation, Hamilton's canonical equations of motion, properties of Hamilton's function, principle of least action, Hamilton's principle, Derivation of the Euler-Lagrange's equations of motion, Derivation of the Hamilton's equations of motion, Invariance of Hamilton's principle under coordinate transformation. [8]

Calculus of Variations: Derivation of Euler-Lagrange's equation, Sufficient condition for existence of extremals, Brachistochrone problem, Geodesic, Isoperimetric problem, Approximate solution of boundary value problems (Rayleigh-Ritz method, Galenkin's method), Variational problems with moving boundaries. [10]

Small oscillations: Small oscillations in systems with more than one degree of freedom, Normal coordinates, Oscillations under constraints, Oscillations with dissipation, Forced oscillations, Anharmonic oscillator. [6]

Recommended Books:

1. H. Goldstein, *Classical Mechanics,* Narosa Publ. House, 1997.
2. V. B. Bhatia, *Classical Mechanics with introduction to nonlinear oscillation and chaos*, Narosa Publishing House, 1997.
3. N. C. Rana & P.S. Jog, *Classical Mechanics*, Tata McGraw Hill, 2001.
4. A. S. Gupta, *Calculus of Variations with Applications*, Prentice –Hall of India, 1996.
5. E. T. Whittaker – *A Treatise on the Analytical Dynamics of Particles and Rigid Bodies, C*ambridge University Press, 1993.
6. *D*. T. Green Wood – *Classical Dynamics,* Dover Publication, 2006.
7. F. R. Gantmakher – *Lectures in Analytical Mechanics,* Mir Publishers, 1970
8. J. L. Synge & B. a. Graffith, *Principles of Mechanics*, Mc. Graw-Hill Book Co. 1960.
9. I. M. Gelfand and S.V. Fomin, *Calculus of Variations*, Prentice Hall Inc, 2012.

Course – MMATG108

Ordinary Differential Equations (Marks- 25)

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]

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

Course – MMATG109

Partial Differential Equations (Marks - 25)

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]

Recommended Books:

1. T.Amarnath , *An Elementary Course in Partial Differential Equations,* Jones and Bartlell Pub., 2011.
1. I. N. Sneddon, *Elements of Partial Differential Equations,* Dover Publications, 2006.
2. G. W. Bluman, S. Kumei, *Symmetries and Differential Equations*, Springer, 1989.
3. P. Phoolan Prasad & R. Ravindran , *Partial Differential Equations,* Wiley, 1984.

Course – MMATG110

C Programming (Marks-50)

Total Lectures Hours: 50

Theory (Marks : 25)

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]

Practical (Marks : 25) **[20]**

Sessional (Algorithm & Program with output) : 5 marks
Viva Voce : 5 marks
Simple problems : 15 Marks (Algorithm: 3, Program :8, Correct output: 4)

List of practical (using C programming)

1. Finding roots of quadratic equation
2. Sorting of numbers in ascending and descending order
3. Finding the position of given number(s) from a list of numbers
4. Check whether a number is prime or not.
5. Find the prime numbers between two given numbers
6. Evaluate the values of ^nC_r and ^nP_r for given values of n and r.
7. Fibonacci sequence
8. Calculation of Series sum, like, sinx, cosx, exp(x) or other series
9. Finding value of a given polynomial at given point(s)
10. Matrix multiplication
11. Inversion of matrix
12. Solution of a system of linear equations
13. Calculation of mean and standard deviation
14. Calculation of correlation coefficient
15. Sorting of Strings
16. Sorting of structure data
17. Program by pointer
18. Reading of data from a file and printing of data to a file

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

Course – MMATG201

Real Analysis-II (Marks – 25)

Total lectures Hours: 30

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. [17]

Vitali Lemma, differentiation of monotone functions, differentiation of an integral, absolute continuity. [5]

Fourier series, Dirichlet's kernel, Riemann Lebesgue Theorem, point wise convergence of Fourier series of functions of bounded variation. [8]

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

Course – MMATG202

Complex Analysis – II (Marks – 25)

Total lectures Hours: 30

Singularities. Laurent's series expansion and classification of isolated singularities, essential singularities and Casorati-Weierstrass's theorem. Theory of residues, Cauchy's residue theorem and evaluation of improper integrals. [12]

Argument principle, Rouche's theorem and its application, Maximum modulus theorem. Schwarz's Lemma. Behaviour of a function at the point at infinity. Conformal mappings, Bilinear transformation, Riemann mapping theorem. [14]

Intordution to Analytic continuation, Monodromy theorem. [4]

Recommended Books:

1. J. B. Conway, *Functions of one complex variable, 2nd Ed.*, Narosa Publishing House, New Delhi, 1997.
2. L. V. Ahlfors – *Complex Analysis- 3rd Edn*, McGraw-Hill, 1979
3. R. V. Churchill and J. W. Brown: Complex Variables and applications.
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. E. T. Copson, *Introduction to the Theory of Function of a Complex Variable,* Oxford University press, 1970
7. K. Kodaria, *Complex Analysis,* Cambridge University Press, 2007.
8. R. Remmmert, *Theory of complex functions*, Springer-Verlag, New York, 1991.
9. W. Rudin – *Real and Complex Analysis,* Tata McGraw-Hill Education, 1987
10. J. M. Howie: Complex Analysis

Course – MMATG203

Topology - II (Marks – 25)

Total lectures Hours: 30

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

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. Local Compactness. [12]

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. [12]

Recommended 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.
3. J. Dugundji, *Topology*, Allyn and Bacon, 1966.
4. K. D. Joshi, *Introduction to General Topology,* New Age International(P) Ltd*, 1983*
7. J. L. Kelley, *General Topology*, Springer, 1975.
8. S. Willard, *General Topology*, Dover Publications, 2004

Course – MMATG204

Differential Geometry- II (Marks - 25)

Total lectures Hours: 30

Conformal mapping of surfaces, Surface area, Equalareal maps and theory of Archimedes. [5]

Curvature of surfaces, Second fundamental form, Curvature of curves on a surface, Normal and Principal curvatures, Euler's theorem, Geometric interpretation of principal curvatures. [7]

The Gaussian and Mean curvature, Pseudosphere, Flat surfaces, Surfaces of constant mean curvature, Gaussian of compact surfaces, Gauss map. [6]

Geodesics and its basic properties Geodesic equations, Geodesic on surfaces of revolution, Geodesic as shortest path, Geodesic coordinates, Minimal surfaces with examples, Holomorphic functions. Gauss's Theorema Egregium, 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). [12]

Recommended Books:

1. A. Pressley, *Elementary Differential Geometry*, Springer-Verlag, 2001, London (Indian Reprint 2004).
2. M. P. Do Carmo**,** *Differential Geometry of Curves and Surfaces***,** Prentice-hall, Inc., Englewood, Cliffs, New Jersey, 1976.
3. B. O'Neill, *Elementary Differential Geometry*, 2nd Ed., Academic Press Inc., 2006.
4. V. A. Toponogov, Differential Geometry of curves and surfaces, Birkhauser, 2006.
5. Erwin Kreyszig, Differential Geometry, Dover Publications, Inc., New York, 1991.

Course- MMATG205

Calculus of R^n - I (Marks - 25)

Total lectures Hours: 30

Topology of $\mathbb{R}^n$, Functions from $\mathbb{R}^n$ to $\mathbb{R}^m$, projection functions, component functions , limit and continuity. [10]

Derivative of functions from $\mathbb{R}^n$ to $\mathbb{R}^m$, directional derivatives and partial derivatives, partial derivatives of higher order., Chain rule, matrix representation of derivative of functions, mean value theorem, continuously differentiable functions, C^∞-functions, real analytic functions. [15]

Implicit function theorem, inverse function theorem (local and global). [5]

Recommended Books:

1. T. M. Apostol, *Calculus, Vol – II,* John Wiley Sons, 1969.
2. J. R. Munkres*, Analysis on manifolds,* Addison-Wesley Pub. Comp., 1991.
3. R. Courant and F. John, *Introduction to Calculus and Analysis, Vol – II,* Springer Verlag, New York, 2004.
4. T. Marsden, *Basic Multivariate Calculus*, Springer, 2013.
5. M.Spivak-*Calculus on Manifolds,* The Benjamin/Cummings Pub.comp.,1965.

Course– MMATG206

Abstract Algebra -I (Marks – 25)

Total lectures Hours: 30

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. [5]

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 pn (n > 0), pq, p^2q, p^2q^2 (p, q are primes); determination of all simple group of order up to 60, External and internal direct product of groups; External direct product of cyclic groups; structure theorem of finite Abelian groups. [20]

Ring : Ideal, Quotient ring; Homormorphism and Isomorphism between two rings; prime, maximal and primary ideal. [5]

Recommended Books:

1. I. N. Herstein – Topics in Algebra , Vikas Publishing House Pvt. Ltd, New Delhi, 1985.
2. D. S. Malik, J. M. Mordeson and M. K. Sen, Fundamentals of Abstract Algebra, McGraw-Hill, 1997.
3. J. B. Fraleigh, A First Course in Abstract algebra , Addison-Wesley, 1967.
4. J. A. Gallian, Contemporary Abstract algebra, Cengage Learning, 1986.
5. D. M. Burton, A First Course in Rings and Ideals, Addison-Wesley Publishing Company, 1970.
6. M. K. Sen, S. Ghosh & P. S. Mukhopadhyay – Topics in Abstract Algebra , University Press, 2006.
7. D. S. Dummit and R. M. Foote, Abstract Algebra, Second Edition, John Wiley & Sons, Inc., 1999.

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]

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

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

Unconstrained optimization [4]

Constrained optimization with equality constraints- Lagrange's multiplier method, Interpretation of Lagrange multiplier. [5]

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]

Recommended Books:

1. H. A. Taha, *Operations Research – An Introduction*, Prentice-Hall, 1997.
2. J. K. Sharma, *Operations Research: Theory and Applications*, Macmillan, 1997
3. S. D. Sharma, H. Sharma, *Operations Research: Theory, Methods and Applications*, Kedar Nath Ram Nath, 1972
4. S. S. Rao, *Optimization-Theory and Applications*, Wiley Eastern Ltd., 1977.
5. K. Swarup, P. K. Gupta, M. Mohan, *Operations Research*, Sultan Chand & Sons, 1978
6. F. S. Hillier, G. J. Lieberman, Introduction to Operations Research, McGraw-Hill, 2001
7. M. S. Bazaraa, H. D. Sherali, C. M. Shetty, *Nonlinear Programming-Theory and Algorithms*, Wiley-Interscience, 2006
8. A. K. Bhunia and L. Sahoo, *Advanced Operations Research,* Asian Books Private Limited, New Delhi, 2011.
9. M. Aokie, *Introduction to Optimization Techniques: Fundamentals and Applications of Nonlinear Programming*, The Macmillan Company, 1971.

Course – MMATG208

Integral Transform (Marks 25)

Total lectures Hours: 30

Laplace transform: Definition and its existence, Basic properties of Laplace transform, Laplace transform of derivatives and its asymptotic properties (Initial value and Finial value Theorem), Laplace transform of an integral, Inversion by analytical method and Bromwich path, Lerch's theorem, Convolution theorem, Heaviside's Series expansion, Applications to ordinary and partial differential equations. [15]

Fourier transform: Definition and basis properties, Fourier transform of some elementary functions, Fourier transform of derivatives, Inverse formula, Convolution theorem, Perseval's relation, Fourier sine and cosine transforms, Finite Fourier Transform. Applications to Heat, Wave and Laplace equations. [15]

Recommended 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.
3. E. Kreyszig, *Advanced Engineering Mathematics*, John Wiley and Sons, 2010.
4. J. W. Miles, *Integral Transforns in Applied Mathematics*, Cambriddge University Press, 2008.
5. M. R. Spiegel, *Laplace Transforms*, Mc Graw Hill, 1965.
6. I. N. Sneddon : The Use of Integral Transforms
7. N. V. Mclachlan: Operational Calculus.

Course– MMATG209

Integral Equations (Marks – 25)

Total lectures Hours: 30

Linear Integral Equation, Classification, Reduction of differential equation to integral equation and vice-versa, Eigen values and eigen functions. [4]

Fredholm integral equation of second kind with degenerate kernel. [5]

Conditions of uniform convergence and uniqueness of series solution of Fredholm and Volterra integral equations. [4]

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. [9]

Fredholm theorems and Fredholm alternative. [5]

Singular integral equation, Solution of Abel's integral equation. [3]

Recommended 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.
3. S. G. Mikhlin, Linear *Integral Equation*, Pergamon Press, 1960.
4. F. G. Tricomi, *Integral Equation*, Interscience Publishers, 1985.
5. M.D.Raisinghania, Integratal Equation & Boundary Value Problem, S. Chand, 2016.

Course – MMATG210

Numerical Methods (Marks – 50)

Total lectures Hours: 50

Theory (Marks-25)

Polynomial approximations: Spline interpolation, Cubic spline, Hermite interpolation. [6]

Numerical integration: Gauss' theory of quadrature, Gauss-Legendre formula, Euler-Maclaurin summation formula, Richardson extrapolation, Romberg integration. [7]

Initial Value Problems: Solution of Initial Value Problems for first order ordinary differential equation by multi-step predictor-corrector method- Adams-Bashforth method, Adams-Moulton method and Milne's method. [5]

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. [7]

Recommended 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.
3. A. Ralston, A First Course in Numerical Analysis, McGraw Hill, N.Y. ,1965.
4. S. S. Sastry, *Introductory methods of Numerical Analysis*, Prentice Hall India Pvt. Ltd., New Delhi, 1999.
5. Scarborough, *Numerical Mathematical Analysis,* Oxford &IBH Publishing Co., Calcutta, 1966.
6. G.D. Smith, *Numerical solution of partial differential equations*, Oxford University Pres, 1985.
7. R. Kress, *Numerical Analysis*, Springer-Verlag, 1998.
8. J. Stoer, R. Bulirsch, *Introduction to Numerical Analysis*, Springer, 1993.

Practical (Marks-25) [20]

Sessional (Algorithm & Program with output): 5 marks

Viva Voce: 5 marks

Numerical Problems : 15 marks (Algorothm: 3,Program: 8, result: 4)

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. Interpolation: Cubic Spline interpolation and Hermite interpolation
3. Integration by Romberg's method
4. Largest Eigen values of a real matrix by power Method.
5. Solution of Boundary Value Problem (BVP) for second order O.D.E. by Finite Difference Method(FDM) and Shooting Method.
6. Solution of one-dimensional heat conduction equation using two layer explicit formula.
7. Solution of one- dimensional wave equation by Finite Deference Method.

Recommended 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.
3. B. S. Gottfried, *Programming with C*, TMH, 2011.
4. K. R. Venugopal and S. R. Prasad, *Programming with C*, TMH, 1997.
5. C. Xavier, *C Language and Numerical Methods*, New Age International (P) Ltd. Pub, 2007.
6. S.K. Pundir, Numerical Methods in Science and Engineering, CBS, 2017.

Course – MMATP301

Abstract Algebra - II (Marks - 50)

Total Lectures Hours: 50

Group : Normal series; subnormal series; solvable series; composition series; nilpotent group; Jordan-Holder Theorem; Ascending central series; descending central series; commutator subgroup. [10]

Ring : Principal ideal domain; Euclidean domain; prime elements and irreducible elements; associates; greatest common divisor; least common multiple; quotient field; polynomial rings.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. [25]

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]

Recommended 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.
3. D. M. Burton; A First Course in Rings and Ideals, Addison-Wesley Publishing Company, 1970.
4. N. H. McCoy; The Theory of Rings, Chelsea Publishing Company, 1973.
5. D. S. Dummit and R. M. Foote, Abstract Algebra, Second Edition, John Wiley & Sons, Inc., 1999.

Course – MMATP302

Functional Analysis-II (Marks - 25)

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]

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]

Recommended Books:

1. E. Kreyszig, *Introductory Functional Analysis with Applications*, Wiley Eastern,1989.
2. G. Bachman & L. Narici- *Functional Analysis*, Academic Press,1966.
3. A. L. Brown and A. Page, *Elements of Functional Analysis*, Von Nostrand Reinhold Co., 1970
4. R. E. Edwards, *Functional Analysis*, Holt Rinchart and Wilson, New York,1965.
5. B.V. Limaye, *Functional Analysis*, Wiley Easten Ltd,1996
6. A.E. Taylor, *Functional Analysis*, John Wiley and Sons, New York, 1958.
7. K. Yosida, *Functional analysis*, Springer Verlag, New York,1990.
8. K. K. Jh*a, Functional Analysis,* Student's Friends, 1986.

Course – MMATP303

Topological Vector Spaces (Marks – 25)

Total Lectures Hours: 30

Convex sets, convex hull, Representation Theorem for convex hull. [5]

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. [10]

Linear operators with its continuity on topological vector spaces and homeomorphism. [4]

Closed sets, open sets with its properties, neighbourhoods, local base and its properties. [6]

Hyperplanes, separation of convex sets by hyperplanes. [5]

Recommended 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.
3. J. Horvoth-*Topological Vector spaces and Distributions*, Addison-Wesley Publishing Co., 1966
4. 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, Hamiltonian vector fields, flows and properties, sympletic transformation, Poisson bracket, examples. [10]

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]

Recommended Books:

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

Course – MMATP305

Operator Theory (Marks - 25)

Total Lectures Hours: 30

Closed Linear transformation and its properties, bounded inverse Theorem (statement only), closed graph theorem. [4]

Adjoint (conjugate) operators over normed linear spaces and their algebraic properties, Annihilators and properties of annihilators of bounded linear operator on a normed linear space. 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. [5]

Normal operators, isometric operators, unitary operators and their properties. [4]

Hermitian symmetric self adjoint operators and their properties on inner product space and Hilbert space. [5]

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

Recommended Books:

1. G. Bachman and L. Narici; *Functional Analysis,* Academic Press, 1966.
2. E. Kreyszig; *Introductory Functional Analysis with Applications,* Wiley Eastern, 1989
3. B. K. Lahiri, *Elements of Functional Analysis*, The World Press Pvt. Ltd., Kolkata, 1994.
4. B. V. Limaye, *Functional Analysis*, Wiley Eastern Ltd, New Delhi, 1981.
5. M. T. Nair, *Functional Analysis*, Prentice-Hall of India Pvt. Ltd, New Delhi, 2002.
6. K. Yosida, *Functional Analysis*, Springer Verlog, New York, 3rd Edn, 1990

Course – MMATPME306-1

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

Strict convexity and uniform convexity of a Banach space, examples and properties of strictly convex and uniformly convex Banach spaces. [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 Banach space. [6]

Recommended 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.
3. J. Diestel, *Geometry of Banach Spaces*, Springer, 1975.
4. L. Narici & E. Beckenstein, *Topological Vector spaces*, Marcel Dekker Inc, New York and Basel,1985

5. A.A. Schaffer, *Topological Vector Spaces*, Springer , 2nd Edn., 1991

Course – MMATPME306-2

Advanced Abstract Algebra-I (Marks - 50)

Total Lectures Hours: 50

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]

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

Course – MMATPME306-3

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]

Recommended Books:

1. F. H. Croom, *Basic Concepts of Algebraic Topology*, Springer, NY, 1978.
2. E. H. Spanier, *Algebraic Topology*, McGraw-Hill, 1966.
3. A. Hatcher, *Algebraic Topology*, Cambridge University Press, 2003.
4. W. S. Massey, *A Basic Course in Algebraic Topology*, Springer-Verlag, New York Inc., 1991.
5. I. M. Singer & J. A. Thorpe, *Lecture Notes on Elementary Topology and Geometry*, Springer, India 2003

Course – MMATPME306-4

Rings of Continuous Functions-I (Marks - 50)

Total Lectures Hours: 50

The ring C(X) of the real valued continuous function on a topological space X, its subrings, the subring $C^*(X)$, their Lattice structure, ring homomorphisms and lattice homomorphism. [10]

Zero-sets cozero-sets, their unions and intersection, completely separated sets, C^* embedding, Urysohn's extension theorem and C-embedding. Pseudocompactness and internal characterization of Pseudocompact spaces. [10]

Ideals, Z-filters, maximal ideals, prime ideals, prime filters and their relation. [5]

Completely regular spaces and the zero-sets, weak topologies determined by C(X) and $C^*(X)$. Stone-Čech's therem concerning adequacy of Tychonoff spaces X for investigation of C(X) and $C^*(X)$, compact subsets and C – embedding. [10]

Convergence of Z – filters, cluster points, prime Z – filters and convergence and fixed Z- filters. [5]

Fixed ideals and compactness, fixed maximal ideals of C (X) and $C^*(X)$, their characterizations, the residue class rings modulo fixed maximal ideals in C(X) and $C^*(X)$ and the field of reals. Relation between fixed maximal ideals in C(X) and $C^*(X)$. Compactness and fixed ideals. [10]

Recommended Books:

1. Richard E. Chandler, *Hausdorff Compactifications* (Marcel Dekker, Inc. 1976).
2. L. Gillmen and M. Jerison, *Rings of Continuous Functions* (Von Nostrand, 1960).

Course– MMATPME306-5

Advanced Complex Analysis-I (50 Marks)

Total Lectures Hours: 50

The functions M(r) and A(r). Theorem of Borel and Caratheodary, Convex function and Hadamard three-circle theorem, Open mapping theorem. [10]

Dirichlet series, abscissa of convergence and abscissa of absolute convergence, their representations in terms of the coefficients of the Dirichlet series. Riemann Zeta function, the product development of and the zeros of the zeta functions. [15]

Entire functions, growth of an entire function, order and type and their representations in terms of the Taylors coefficients, distribution of zeros, Picards's first theorem. Weierstrass factor theorem, the exponent of convergence of zeros. Canonical product, Hadamard's factorization theorem, Borel's theorems, Picard's second theorem. [25]

Recommended Books:

1. E. T. Copson, *Introduction to the Theory of Function of a Complex Variable,* Oxford University press, 1970.
2. E. C. Titchmarsh – *The Theory of Functions,* Oxford University Press, 2nd Edn., 1970.
3. A. I. Markusevich , *Theory of Functions of a Complex Variables*, Vol. I & II, Printice-Hall, 1965.
4. L. V. Ahlfors, *Complex Analysis,* McGraw-Hill, 3rd Edn., 1979.
5. J. B. Conway , *Functions of One Complex Variable,* Narosa Publishing House, New Delhi, 2nd Edn., 1997.
6. A.S.B. Holland, *Introduction to the theory of entire function*, Academic Press New York and London, 1973.
7. G. Valiron**,** Lectures on the general theory of integral functions, Toulouse, 1923.
8. R. P. Boas – *Entire Functions,* Academic Press, 1954.

Course – MMATPME306-6

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]

Recommended 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.
3. E. Hewitt and K. Stormberg – *Real and Abstract Analysis,* John – Wiley, N. Y., 1965.
4. I. P. Natanson – *Theory of Functions of a Real Variable*, Vols. I & II, Ungar Publishing Company, 1974.
5. H. L. Royden , *Real Analysis*, PHI, 2005
6. W. Rudin – *Real and Complex Analysis, Tata McGraw-Hill, 1993*

7. Charles Schwartz- Measure , Integration and Function spaces, World Scientific Publisher, Singapore, 1994.

Course – MMATPME307-3

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

Total Lectures Hours: 50

Euclid's Geometry: Brief Survey of the Beginnings of Geometry, The Axiomatic Method, Undefined Terms, Euclid's Postulates, The Parallel Postulate, Attempts to Prove the Parallel Postulate, Construction, Descartes' Analytic Geometry. [3]

Logic and Incidence Geometry: Elementary Logic, Logic rules, Incidence Geometry, Incidence Axioms, Models of Incidence geometry. [5]

Hilbert's Axioms and Neutural Geometry: Axioms of Betweenness, Axioms of Congruence, Axioms of Continuity, Alternate Angle theorem, Exterior Angle theorem, Saccheri and Lambert Quadrilaterals, Angle sum of a Triangle. [4]

History of the Parallel Postulate: Review, Proclus, Equidistance, Wallis, Saccheri, Clairaut's Axiom and Proclus' Theorem, Legendre, Lambert and Taurinus, Farkas Bolyai. [3]

Affine Geometry: Definition and Examples, Parallelism and Simple properties, Combinatories of finite planes, A closer look at the Affine plane A_k^2, Planes over finite fields, Affine transformations, Collineations in A_k^2, Affine coordinates, Triangles and parallelograms, Classical theorems in A_k^2. **[10]**

Projective Geometry: Introduction, Examples, Finite projective planes, projective completion, Homogeneous coordinates, Projective transformations, Collineations in P_k^2, Principle of duality, Classical Theorems in P_k^2, Projective line, Projective completion of conics. [10]

Classification of Conics: Affine classification of Conics, Projective classification of Conics, transitive Groups on Affine Conics, Transitive Groups on Affine Conics. [5]

Euclidean Geometry: Inner product Spaces, Isometries of E^2, Triangles and Parallelograms, Length Minimizing Curves in E^n, Geometry of Plane Curves. [10]

Recommended Books:

1. S. Kumaresan and G. Santhanam, An Expedition to Geometry, Hindustan Book Agency, 2005.
2. Marvin Jay Grenberg, *Euclidean and non-Euclidean Geometries: Development and History,* W. H. Freeman and Company, New York, 4th Edn., 2008.
3. G. Eric Moorhouse, Incidence Geometry, Univ. of Wyoming, Math5700-Fall2700, August, 2007.
4. C. B. Boyer and U. Merzbach*, A history of mathematics*, 2nd edn., New York, Wiley, 1991.

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

Course– MMATPME307-4

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]

Recommended Books:

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

Course – MMATPME307-5

Advanced Differential Geometry-I (Marks-50)

Total Lectures Hours: 50

Riemannian Geometry: 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, Fundamental Theorem of Riemannian geometry, Riemannian connection, Riemann Curvature tensor, Bianchi Identities, Generalized and proper generalized curvature tensors, Ricci tensor, scalar curvature, Gaussian curvature, Sectional Curvature, Schur's theorem, semisymmetric and quarter symmetric metric connections (Definitions and examples), Einstein manifolds, quasi-Einstein manifolds and their generalizations. [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 and their properties. [10]

Recommended Books:

1. Manfredo P. Do Carmo, *Riemannian Geometry,* Birkhauser, Boston, 1992**.**
2. S. Kobayashi and K. Nomizu, *Foundations of Differential Geometry*, Vol. 2, Interscience Press, Newyork, 1969.
3. T. J. Willmore, *Riemannian Geometry*, Oxford University Press, 1997.
4. K. Yano and M. Kon, *Structure on Manifold,* World Scientific Publication, Singapore, 1984.
5. J. M. Lee, *Riemannian Manifolds*, An Introduction to Curvature, Springer-Verlag, 2005.
6. P. Petersen, Riemannian Geometry, Springer Verlag, 2006. U. C. De and A. A. Shaikh, *Differential Geometry of Manifolds*, Narosa Publ. Pvt. Ltd, New Delhi, 2007.

Course– MMATPME307-6

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]

Recommended Books:

1. G. Bachman and L. Narici; *Functional Analysis,* Academic Press, 1966.
2. E. Kreyszig; *Introductory Functional Analysis with Applications,* Wiley Eastern, 1989
3. B. K. Lahiri, *Elements of Functional Analysis*, The World Press Pvt. Ltd., Kolkata, 1994.
4. B. V. Limaye, *Functional Analysis*, Wiley Eastern Ltd, New Delhi, 1981.
5. M. T. Nair, *Functional Analysis*, Prentice-Hall of India Pvt. Ltd, New Delhi, 2002.
6. K. Yosida, *Functional Analysis*, Springer Verlog, New York, 3rd Edn, 1990

MMATA301

Methods of Applied Mathematics (Marks - 25)

Total lectures Hours: 30

Generalized Functions: Basic concepts – Linear functional, test functions; generalized functions – regular and singular generalized functions, translation of a generalized function, scale of expansion or contraction, differentiation of a generalized functions; Sequence and series of generalized functions, Fourier transforms and integrals of generalized functions; limit of generalized functions, Differential equations in generalized functions. [8]

Operator equations on Hilbert Spaces: Self-adjointness, invertibility, boundedness and unboundedness of inverse operators, compactness of operators with illustrative examples, spectral value, eigen-value problems, spectral theorem for compact self-adjoint operator (statement only), solvability of operator equations. [8]

Integral equations with Hilbert-Schmidt kernel : Basic concepts, existence of solution, examples. [2]

Ordinary Differential Equations and Differential Operators: Adjoint of a differential operator, Legendre operator and Legendre polynomials, Associated Legendre operator and associated Legendre functions, Chebyshev operator and Chebyshev polynomials, Jacobi operator and Jacobi polynomials, Laguerre operator and Laguerre polynomials, Associated Laguerre operator and associated Laguerre functions, Bessel operator and Bessel functions, Hermite operator and Hermite polynomials, Regular Sturm-Liouville system – eigen values, equivalent integral equation; Inverse Differential Operators and Green's Functions, Properties of Green's Functions, Construction and Uniqueness of Green's Functions Bilinear expansion of Green's function, solution of inhomogeneous equation. [12]

Recommended 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.
3. Lokenath Debnath, Piotr Mikusinski, *Introduction to Hilbert spaces with applications*, Academic Press, 2005.
4. Ram P. Kanwal, *Generalized Functions Theory and Technique,* Academic Press, 1983.
5. S. Hassani, *Mathematical Physics*, Springer, 2001.
6. G. Bachman, L. Narici, *Functional Analysis*, Dover Publications, 2003

MMATA302

Classical Mechanics – II (Marks:25)

Total lectures Hours: 30

Motion of a particle relative to rotating earth, Coriolis force, Deviation of freely falling body from vertical, Foucault's pendulum. [7]

Gauge function for Lagrangian, Invariance of the Euler-Lagrange equations (under coordinate transformation, Galilean transformation), Generalised momenta and energy, Cyclic coordinates, Routh process for ignorable coordinates, Symmetry properties and conservation laws. [5]

Canonical transformations: Definition, examples and properties of canonical transformations, Generating functions, Liouville's theorem, Conservation (area) property of Hamiltonian flows, Poisson bracket (definition and properties), Poisson's theorems, Condition of canonicality in terms of Poisson bracket, Lagrangian bracket, Poisson's bracket of angular momentum, Infinitesimal canonical transformations, Hamilton-Jacobi theory, Hamilton's principle and characteristic functions, Noether's theorem, Classical field equations (Lagrangian form and Hamiltonian form). [18]

Recommended Books:

10. H. Goldstein, *Classical Mechanics,* Narosa Publ. House, 1997.
11. V. B. Bhatia, *Classical Mechanics with introduction to nonlinear oscillation and chaos*, Narosa Publishing House, 1997.
12. N. C. Rana & P.S. Jog, *Classical Mechanics*, Tata McGraw Hill, 2001.
13. E. T. Whittaker – *A Treatise on the Analytical Dynamics of Particles and Rigid Bodies, C*ambridge University Press, 1993.
14. *D*. T. Green Wood – *Classical Dynamics,* Dover Publication, 2006.
15. F. R. Gantmakher – *Lectures in Analytical Mechanics,* Mir Publishers, 1970
16. J. L. Synge & B. a. Graffith, *Principles of Mechanics*, Mc. Graw-Hill Book Co. 1960.
17. I. M. Gelfand and S.V. Fomin, *Calculus of Variations*, Prentice Hall Inc, 2012.

MMATA303

Continuum Mechanics (Marks - 50)

Total lectures Hours: 50

Continuum: Continuum hypothesis, Continuous media, Body, Configuration, Material and spatial time derivatives. [3]

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]

Wave motion: General features, phase velocity, group velocity, wave packet. [3]

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. [8]

Recommended Books:

1. A. C. Eringen, *Mechanics of Continua*, Wiley, 1967.
2. I. S. Sokolnikoff , *Mathematical theory of Elasticity*, Tata Mc Grow Hill Co., 1977.
3. S.W. Yuan , *Foundations of Fluid Mechanics*, Prentice – Hall International, 1970.
4. J. L. Bansal, *Viscous Fluid Dynamics,* Oxford and IBH Publishing Co., 1977.
5. R. N. Chatterjee, *Mathematical Theory of Continuum Mechanics*, Narosa Publishing House, New Delhi, 1999.
6. D. S. Chandrasekharaiah and L. Debnath, *Continuum Mechanics,* Academic Press, 1994.

MMATG304

Theory of Electro Magnetic Fields and Relativity (Marks - 50)

Total Lectures Hours: 50

Electrostatic field $\vec{E}$: Coulomb law, principle of superposition, divergence and curl of $\vec{E}$, boundary conditions; Electrostatic potential – Poission equation, energy in electrostatic field, electric dipole, conductor and insulator; $\vec{E}$ in dielectric media – electric polarization, divergence of displacement vector, energy in dielectric media. [7]

Magnetostatic field $\vec{B}$: Electric current, equation of continuity, Ohm's law, Lorentz force law, Biot-Savart law, divergence and curl of $\vec{B}$, boundary conditions; Magnetic vector potential – multi-pole expansion, magnetic dipole; $\vec{B}$ in matter – magnetization, auxiliary field $\vec{H}$, curl of $\vec{H}$. [7]

Electromagnetic induction: Faraday's law; inductance; energy in magnetic field. [4]

Maxwell's equations: Electrodynamics before Maxwell – Ampere-Maxwell equation; Maxwell's equations - in vacuum, in matter, physical significance, boundary conditions; Energy transfer and Poynting theorem. [7]

Electromagnetic waves: Plane wave solution of Maxwell's equations - electromagnetic waves in vacuum; Reflection and transmission of plane electromagnetic waves at the boundary between two linear media. [7]

General solution of Maxwell's equations: Electromagnetic potentials – gauging of potentials, representation of fields in terms of potentials; Retarded potentials; Jefimenko's equations; Dipole radiation; Radiation by point charges. [8]

Special relativity: Nature of light; Postulates of special relativity; Lorentz transformation – Lorentz-Fitzgerald contraction, time dialation, relativistic Doppler effect, transformation of velocities; Relativistic mass and energy; Force and acceleration in relativity; Lorentz group – boosts; Four-vectors and tensors; Relativistic particle dynamics; Relativistic electrodynamics - transformations of electric and magnetic fields and invariance of Maxwell's equations; Relativistic Lagrangian. [11]

Recommended Books:

1. Griffiths D. J., Introduction to electrodynamics (3rd Edition), *PHI Learning Private Limited, New Delhi* (2012).

2. V. B. Bhatia, *Classical Mechanics with introduction to nonlinear oscillation and chaos*, Narosa Publishing House, 1997.

3. Coulson A. A., Electricity, *Oliver and Boyd, Edinberg & London* (1974).

4. Einstein A., Relativity: The Special and the General Theory, *General Press* (2013)

MMATA305

Boundary Value Problems (Marks - 25)

Total lectures Hours: 30

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. [5]

Multi-dimensional Green's functions: Multi-dimensional delta function; Green's functions for the Laplacian; Fundamental solution; Integral equation and Green's function. [4]

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. [6]

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). [6]

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. [5]

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

Recommended Books:

1. I. Stackgold, *Green's Functions and Boundary Value Problems*, John Wiley & Sons, New York, 1979.

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

3. Philip M. *Morse and* H. *Feshbach*, *Methods of Theoretical Physics, Part I & II*, McGraw-Hill Book Company, 1953.

4. G. F. Roach, *Green's Function,* Cambridge University Press, 2nd Edn., 1982.

MMATAME306-1

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]

Recommended Books:

1. J. L. Bansal, *Viscous Fluid Dynamics*-2nd Edition, Oxford and IBH Publishing Co, 1977.
2. H. Schlichting, *Boundary Layer Theory*, Springer, 2003.
3. F. Chorlton, *Text Book of Fluid Dynamics*, Van Nostrand Reinhold Co., London, 1990.
4. S.W. Yuan , *Foundations of Fluid Mechanics*, Prentice – Hall International, 1970.
5. P. K. Kundu, *Fluid Mechanics*, Academic Press, 1990.

MMATAME306-2

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) , Stoke's flow problems, 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, Jet flows. [15]

Recommended 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.
4. J.O. Hinze: Turbulence, 2e, McGraw-Hill, New York, 1977.
5. S.B.Pope: Turbulent Flows, Cambridge University Press, 2000.

MMATAME306-3

Space Sciences-I (Marks - 50)

Total lectures Hours: 50

Special relativity: The principles of special relativity

Transformation of coordinates and velocities: (a) Lorentz transformation, (b) transformation of velocities, (c) Lorentz boost inan arbitrary direction [10]

Four-vectors: Four-velocity and acceleration. Spherically symmetric geometry

Metric of a spherically symmetric spacetime: (a) Static geometry and Birkoffs theorem, (b) Interior solution to the Schwarzschild metric, (c) Embedding diagrams to visualize geometry, Vaidya metric of a radiating source, Orbits in the Schwarzschild metric: Precession of the perihelion [16]

Experimental Tests, Classical Kepler motion, Advance of the perihelion of mercury, Bending of light, Gravitational red shifts, Solaroblateness. [10]

Openheimer – Volkoff limit, Gravitational lensing , Quasars , Pulsars, Supernova. 4. Openheimer Snydder non static dust model, Gravitational collapse. 5. Accretion into compact objects, Boltzmann formula, Saha Ionization equation, H-R diagram.

[14]

Recommended Books:

1. Jayant Narlikar , *An Introduction to Cosmology*, Cambridge University Press, 2002),3rd Edition
2. Jayant Narlikar, *An Introduction to Relativity*, Cambridge University Press, 2010.
3. Eric Poisson*, A Relativist's Toolkit: The Mathematics of Black-Hole Mechanics*, Cambridge University Press, 2007
4. Arnab Rai Choudhuri , *Astrophysics for Physicists*, Cambridge University Press, 2010
5. R. M. Wald, *General Relativity*, The University of Chicago Press, 1984
6. T. Padmanabhan*, Gravitation: Foundation and Frontiers*, Cambridge University Press, 2014
7. T. Padmanabhan, *An Invitation to Astrophysics*, World Scientific, 2006

MMATAME306-4

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]

Recommended 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.
3. I. S. Sokolnikoff – Mathematical Theory of Elasticity, Tata Mc Graw Hill Co., 1977.
4. W. Nowacki – Thermoelasticity , Addison-Wesley, 1963.
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, 1st English Edition, Noordhoff International Publishing, 2010.

MMATAME307-1

Advanced Optimization -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 [5]

KKT conditions for constrained optimization. [6]

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

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]

One-dimensional optimization: Function comparison method, Fibonacci and Golden section methods for unimodal functions [6]

Unconstrained optimization: Gradient methods, Steepest descent method, conjugate gradient method, Quasi-Newton's method, Daviddon-Fletcher-Powel method [12]

Constrained optimization : Methods of feasible direction and cutting hyperplane method. [8]

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

MMATAME307-2

Advanced Operations Research-I (Marks: 50)

Total lectures Hours: 50

Inventory Control: Probabilistic models (with and without lead time) [8]

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. [12]

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. [14]

KKT conditions for constrained optimization [6]

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

Sequencing: Sequencing problems, Solution of sequencing problems, Processing n jobs through two machines, Processing n jobs through three machines, Optimal solutions, Processing of two jobs through m machines, Graphical method of solution, Processing n jobs through m machines. [4]

Recommended Books:

1. H. A. Taha, *Operations Research – An Introduction*, Prentice-Hall, 1997.
2. J. K.. Sharma, *Operations Research: Theory and Applications*, Macmillan, 1997
3. S. D. Sharma, H. Sharma, *Operations Research: Theory, Methods and Applications*, Kedar Nath Ram Nath, 1972
4. S. S. Rao, *Optimization-Theory and Applications*, Wiley Eastern Ltd., 1977.
5. K. Swarup, P. K. Gupta, M. Mohan, *Operations Research*, Sultan Chand & Sons, 1978
6. F. S. Hillier, G. J. Lieberman, Introduction to Operations Research, McGraw-Hill, 2001
7. M. S. Bazaraa, H. D. Sherali, C. M. Shetty, *Nonlinear Programming-Theory and Algorithms*, Wiley-Interscience, 2006
8. A. K. Bhunia and L. Sahoo, *Advanced Operations Research,* Asian Books Private Limited, New Delhi, 2011.
9. M. Aokie, *Introduction to Optimization Techniques: Fundamentals and Applications of Nonlinear Programming*, The Macmillan Company, 1971.

MMATAME307-6

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 $|n\rangle$ 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]

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

Course – MMATP401

Abstract Algebra - III (Marks – 25)

Total Lectures Hours: 30

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(pn), Construction of finite fields, field of order pn , 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]

Recommended Books:

1. D. S. Malik, J. M. Mordeson and M. K. Sen : Fundamentals of Abstract Algebra, McGraw Hill , 1997.
2. D. S. Dummit & R. M. Foote; Abstract Algebra, John Wiley & Sons, Canada, 2004.
3. T. W. Hungerford; Abstract Algebra: An Introduction, Spinger, 1990.
4. J. Rotman; Galois Theory (2nd Edition), Springer, New York, 1990.
5. P. B. Garrett; Abstract Algebra, Chapman & Hall/CRC, London, 2007.

Course – MMATP402

Calculus of R^n - II (Marks: 25)

Total Lectures Hours: 30

The integral over a rectangle, the Riemann condition, set of measure zero in $\mathbb{R}^n$, existence of the integral, evaluation of the integral, Fubini's theorem. [8]

The integral over a bounded set and properties of the integral, rectifiable sets and their properties. [5]

Improper integral and its properties, existence of improper integral, evaluation of improper integral. [8]

Change of variables, partitions of unity, change of variables theorem and its applications. [5]

Statement and applications of Green's theorem, Divergence theorem, Generalized Stoke's theorem. [4]

Recommended Books:

1. J. R. Munkres, *Analysis on manifolds*, Addison-Wesley Pub. Comp., 1991.
2. R. Courant and F. John, *Introduction to calculus and analysis, Volume-II*, Springer-Verlag, New York, 2004.

Course – MMATP403

Topology – III (Marks – 50)

Total Lectures Hours: 50

Directed Sets, Nets, subnets, Filter, subfilter, Ultrafilter, Universal net, convergence of filter and nets, connections between filter and nets. Characterizations of continuity of a function and cluster point of a set in terms of filters and nets. [10]

Product Topology, Separation axioms on product spaces. Alexander subbase theorem, Connectedness and compactness on product spaces, Tychonoff's theorem. Quotient topology, quotient spaces. [10]

Compactification: Local compactness and one-point compactification. Stone-ˇCech compactification and its characterization in terms of extension property. Partial ordered set K(X) of the T_2 - Compactifications of a Tychonoff space X, K(X) complete lattice if X is locally compact, T_2. [10]

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]

Recommended 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.
3. G. F. Simmons, Introduction to Topology and Modern Analysis, Tata McGraw-Hill, 2004.
4. J. Dugundji, Topology, Allyn and Bacon, 1966.
5. J. L. Kelley, General Topology, Springer, 1975.
6. F. H. Croom, Basic Concepts of Algebraic Topology, Springer, NY, 1978
7. E. H. Spanier, Algebraic Topology, McGraw-Hill, 1966.
8. I. M. Singer and J. A. Thorpe, Lecture Notes on Elementary Topology and Geometry, Springer, India 2003.
9. W. S. Massey, A Basic Course in Algebraic Topology, Springer-Verlag, New York Inc. (1993).
10. Richard E. Chandler, Hausdorff Compactifications (Marcel Dekker, Inc. 1976).
11. K. D. Joshi, Introduction to General Topology, Wiley International Limited, 1984.

Course – MMATP404

Set theory and Mathematical Logic (Marks – 25)

Total Lectures Hours: 30

Set theory: Axiom of choice, Zor n’s lemma, Hausdorff maximality principle, well ordering theorem and their equivalence, Cardinal numbers, Schroeder-Bernstein theorem, 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. [15]

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

Tautologies, contradiction, adequate sets of connectives and some of its basic propositions. [2]

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

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

Recommended Books:

1. E. Mendelson, *Introduction to Mathematical Logic*, CRC Press(Taylor& Francis Gr.) 2010.
2. S. M. Srivastava, *Course on Mathematical Logic,* Springer, 2012.
3. I. M. Copi, *Symbolic Logic*, Macmillan, New York, 1979.
4. A. G. Hamilton, *Logic for Mathematicians* ,Cambridge University Press, 1988
5. R. R. Stoll, *Set Theory and Logic,* Dover Publications, Inc. NewYork, 1963.

Course – MMATG405

Graph theory (Marks-25)

Total Lectures Hours : 30

Graph: Undirected graphs and directed graphs with examples and some basic properties, Examples and properties of Subgraph, Isomorphism, Walks, Paths, cycles, connected components, Distance, Bipartite graph and its characterization, radius and center, Diameter, Degree sequence. [7]

Trees, centres of trees, spanning trees, Minimal Spanning tree, Kruskal's algorithm. [6]

Eulerian Graphs and its characterization, Hamiltonian Graphs, Dirac Theorem, Ore'sTheorem, closure of a graph, uniqueness of closure. [5]

Cut vertices and cut edges, Vertex and edge connectivities, Blocks, complement of a graph, Clique Number, Independence number, Matching number. [5]

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]

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

Course – MMATPME406-1

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_0 , c[a,b] with sup norm , L_p [a,b] ($1 \leq p \leq \infty$). [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]

Recommended Books:

1. W. Rudin, *Functional Analysis*, TMG Publishing Co. Ltd., New Delhi,1973**.**

2. E. Kreyszig, *Introductory Functional Analysis with Applications,* Wiley Eastern,1989.
3. Brown and Page, *Elements of Functional Analysis*, Von Nostrand Reinhold Co., 1970
4. A.E. Taylor- *Functional Analysis*, John Wiley and Sons, New York, 1958.
5. G. Bachman and L. Narici, *Functional Analysis*, Academic Press, 1966

Course – MMATPME406-2

Advanced Abstract Algebra-II (Marks – 50)

Total Lectures Hours: 50

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

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

Course– MMATPME406-3

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]

Recommended Books:

1. W. S. Massey, A *Basic Course in Algebraic Topology*, Springer, 1991.
2. W. S. Massey, *Singular Homology Theory*, Springer, 2012.
3. I. M. Singer and J. A. Thorpe, *Lecture Notes on Elementary Topology and Geometry*, Springer, India 2003.
4. G. R. Bredon –*Topology and Geometry, Springer, 1993*
5. B. Gray, *Homotopy Theory An Introduction to Algebraic Topology,* Academic Press, Inc (London) Ltd, 1975.
6. F. H. Croom, *Basic Concepts of Algebraic Topology*, Springer, NY, 1978
7. E. H. Spanier, *Algebraic Topology*, McGraw-Hill, 1966.
8. J. R. Munkres, *Topology, A First Course*, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
9. A. Hatcher, *Algebraic Topology*, Cambridge University Press, 2003.

Course– MMATPME406-4

Rings of Continuous Functions- II (Marks-50)

Total Lectures Hours: 50

Partially ordered rings, convex ideals, absolutely convex ideals, properties of convex ideals, lattice ordered rings, total orderedness of the residue class rings modulo prime ideals in C(X) and C*(X), real ideals, hyper-real ideals in C(X). Limit ordinal, non-limit ordinals, compactness of the spaces of the ordinals, first uncountable ordinals space and its "one point compactification" and relation between the rings of continuous function on them, Characterization of real ideals. [15]

Cluster point and convergence of Z–filters on a dense subset of a Tychonoff space. Characterization of C*- embedded dense subset of a Tychonoff space. Construction of Stone- Čech compactification. More specific properties of βN and βQ and βR. [15]

Characterization of maximal ideas in C*(X) and C(X). Gelfand-Kolmogorov theorem. Structure space of a commutative ring - another description of βX. The Banach-Stone theorem. [10]

Realcompact space, Hewitt Realcompactification of X, different characterization of realcompact spaces, Different properties of realcompact spaces, For realcompact space X, C(X) determines X. Tychonoff Plank. [10]

Recommended Books:

1. Richard E. Chandler, Hausdorff Compactifications (Marcel Dekker, Inc. 1976).
2. L. Gillmen and M. Jerison, Rings of Continuous Functions (Von Nostrand, 1960).

Course – MMATPME406-5

Advanced Complex Analysis-II (Marks-50)

Total Lectures Hours: 50

Harmonic functions, Characterization of Harmonic functions by mean- value property. Poisson's integral formula. Dirichlet problem for a disc. [10]

Doubly periodic functions. Weirstrass elliptic function p(z), addition theorem for p(z), differential equation satisfied by p(z), the numbers e_1, e_2, e_3. [16]

Meromorphic functions. Definitions of the functions N(r,a), m(r,a) and T(r,f). Nevanlinna's first fundamental theorem. Cartan's identity and convexity theorems. Orders of growth. Order of meromorphic function. Comparative growth growth of logM(r) and T(r). Nevanlinna's second fundamental theorem. Estimation of S(r) (Statement only). Nevanlinna's theorem on defiant functions. Nevanlinna's five-point uniqueness theorem. Milloux theorem. [24]

Recommended Books:

1. E. C. Titchmarsh – *Theory of Functions,* Oxford University Press, 2nd Edn., 1970.
2. E. T. Copson, *Introduction to the Theory of Function of a Complex Variable,* Oxford University press, 1970.
3. A. I. Markusevich , *Theory of Functions of a Complex Variables*, Vol. I & II, Printice-Hall, 1965.
4. W. Kaplan, *An introduction to analytic functions.*
5. H. Cartan, *Theory of Analytic Functions,* Dover Publication, 1995.
6. M. Dutta and L. Debnath , *Elements of The Theory of Elliptic and Associated Functions with Applications, World Press Pvt., 1965.*
7. W. K. Hayman, *Meromorphic functions*, Oxford University Press, 1964.
8. L. Yang, *Value distribution theory*, Springer-Verlag Berlin Heidelberg, 1993.

Course – MMATPME406-6

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 ($1 \leq p \leq \infty$). 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]

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

Course – MMATPME407-3

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

Total Lectures Hours: 50

The Discovery of Non-Euclidean Geometry: History and 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? [3]

Independence of the Parallel Postulate: Beltrami's Interpretation, The Beltrami–Klein Model, Perpendicularity in the Beltrami–Klein Model, The Projective Nature of the Beltrami–Klein Model. [3]

Geometric Transformations: Klein's Erlanger Programme, Groups, Applications to Geometric problems, Motions and Similarities, Reflections, Rotations, Translations, Half-Turns. [5]

Hyperbolic Plane geometry: Introduction, Poincare Upper Half-Plane, Poincare disk model, Poincare ball model. Line Elements on Open Subsets of R^2, Poincare Metrics on H^2, Length Minimizing Curves in H^2, The Distance Function on H^2, Triangles in H^2, H^2 is Two Point Homogeneous, Isometries of H^2, Drawing of hyperbolic surfaces, by using Mathematica/Mapple/MatLab software. [20]

Spherical Plane Geometry: Introduction, The Sphere S^2, Triangles in S^2, Action of SO(3) on S^2, SO(3) Preserves Length, Isometries of S^2, Euler's Theorem, S^2 is Two Point Homogeneous. [14]

Elliptic and Other Riemannian Geometries: Elliptic geometry, Riemannian Geometries. [5]

Recommended Books:

1. S. Kumaresan and G. Santhanam, An Expedition to Geometry, Hindustan Book Agency, 2005.
2. Marvin Jay Grenberg, *Euclidean and non-Euclidean Geometries: Development and History,* W. H. Freeman and Company, New York, 4th Edn., 2008.
3. R. Courant and H. Robbins,*What is mathematics?,* Oxford Univ. Press, New York, 1941.
4. C. B. Boyer and U. Merzbach, *A history of mathematics,* New York, Wiley, 2nd edn., 1991.
5. H. S. M. Coxeter*, Introduction to geometry, 2nd ed.,* New York, Wiley, 2001.
6. Euclid, Thirteen Books of the Elements, 3 Vols. Tr. T. L. Heath, with annotations, New York, Dover, 1956.
7. J. G. Ratcliffe, *Foundations of hyperbolic manifolds, 2nd, ed.,* New Yprk, Springer, 2006.
8. H. E. Wolfe, *Introduction to non-euclidean geometry,* New York, Holt, Rinehart and Winston, 1945.
9. V. J. Katz, *A history of mathematics: an introduction, 2nd ed., Reading* , Mass: Addison-Wesely Longman, New York, 1988.

Course – MMATPME407-4

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]

Recommended Books:

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

Course– MMATPME407-5

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., Introduction to submanifolds of complex structures. [15]

Contact Structures: Contact manifolds, K-contact manifolds, Sasakian manifolds, Kenmotsu manifolds, Trans-Sasakian manifolds and their submanifolds. [20]

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

Course– MMATPME407-6

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, Spectral properties of arbitrary self adjoint operators. Wecken's lemma, spectral theorem of unitary operators, Cayley transform of self adjoint operators, spectral theorem of arbitrary self adjoint operators. [14]

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

Recommended Books:

1. G. Bachman and L.Narici, *Functional Analysis*, Academic Press, 1966
2. E. Kreyszig, *Introductory Functional Analysis with Applications*, Wiley Eastern, 1989
3. B. V. Limaye, *Functional Analysis*, Wiley Eastern Ltd., 1984.
4. B. K. Lahiri, *Elements of Functional Analysis*, The World Press Pvt. Ltd, Kolkata, 1994
5. G. F. Simmons, *Introduction to topology and Modern Analysis*, McGraw-Hill, New York, 1958.
6. K. Yosida, *Functional Analysis*, Springer Verlog, New York, 3^{rd} Edn, 1990.

MMATA401

Fluid Mechanics (Marks - 50)

Total lectures Hours: 50

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]

Irrotational motion of fluid: Irrotational motion, Velocity potential, Circulation, Kelvin's circulation theorem, Irrotational motion in simply connected and multiply connected regions, Kelvin's theorem of minimum kinetic energy, Acyclic irrotational motion and some properties (Using Green's theorem) [6]

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. [4]

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]

Recommended Books:

1. G. K. Batchelor , *An Introduction to Fluid Dynamics*, Cambridge University Press, 2005.
2. P. K. Kundu and I. M. Cohen , *Fluid Mechanics*, 4^{th} Edition, Academic Press, 2008.
3. S.W. Yuan , *Foundations of Fluid Mechanics*, Prentice – Hall International, 1970.
4. J. L. Bansal, *Viscous Fluid Dynamics*, Oxford and IBH Publishing Co., 1977.
5. I. S. Sokolnikoff , *Mathematical theory of Elasticity*, Tata Mc Grow Hill Co., 1977.

MMATA402

Wavelet Analysis (Marks - 25)

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. [8]

Multiresolution analysis (MRA), Bandlimited functions. [7]

Applications to wavelet transform for physical systems. [5]

Recommended Books:

1. David F. Walnut, *An Introduction to Wavelet Analysis*, Birkhauser, 2008.
2. L. Debnath, *Wavelet Transforms and Their Applications*, Birkhauser Boston, 2002.
3. C. Sidney Burrus, Ramesh A. Gopinath and Haitao Guo, *Introduction to Wavelets and Wavelet Transforms*, PHI, 1998.

MMATA403

Dynamical Systems (Marks - 25)

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, evolution, orbits, fixed points, linear stability, Analysis of one-dimensional flows, periodic points and their stabilities, Attractors and Repellors. [6]

Phase plane analysis, hyperbolic fixed point, 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, period-doublins bifurcation, Hopf-bifurcation, Analysis of Lorentz system. [12]

Study on some important maps:Logistic map, Tent map, Baker map, Shift map, Henon map and their properties. [6]

Recommended Books:

1. G. C. Layek, An introduction to Dynamical systems and Chaos, Springer, 2015.
2. P. Glendinning, *Stability,Instability and Chaso,* Cambridge University Press, 1994.
3. Robert C. Hilborn, *Chaos and Nonlinear Dynamics*, Oxford University Press, 2001.
4. Steven H. Strogatz, *Nonlinear Dynamical and Chaos*, Perseus Books , Indian Edition, 2007.
5. D W Jordan and P. Smith, *Nonlinear Ordinary Differential Equattions*, Clarenden Press.
6. A. Medio and M. Lines, *Nonlinear Dynamics*, C. U. P.
7. M. W. Hirsch and S. Smale, *Differential Equations, Dynamical Systems*, Academic, 1974.
8. R. L. Devaney, *An Introduction to Chaotic Dynamical Systems*, Addition-Wesley, 1989

MMATA404

Introduction to Quantum Mechanics (Marks -25)

Total lectures Hours: 30

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). [6]

Wave aspect of matter: de Broglie hypothesis; mater waves; uncertainty principle; double-slit experiment; Concept of wave function; Gedanken experiments. [5]

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. [5]

Solutions of Schrodinger equation in one-dimension: Infinite potential box; Step potential; Potential barrier; Potential well. [4]

Linear harmonic oscillator in one-dimension: Classical description; Schrodinger method of solution; Energy levels and wave functions; Planck's law. [4]

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]

Recommended Books:

1. B. H. Bransden and C. J. Joachain, *Quantum Mechanics*, Prentics Hall, 2005.
2. D. J. Griffiths, *Introduction to Quantum Mechanics*, Pearson Prentics Hall, Upper Saddle River, NJ, 2005.
3. S. N. Ghoshal, *Quantum Mechanics*, S Chand & Company Ltd, Kolkata, 2002.
4. L. I. Schiff, *Quantum Mechanics*, McGraw-Hill, New York, 1968.

MMATG405

Chaos and Fractals (Marks – 25)

Total lectures Hours: 20

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

Quantifying Chaos: Sharkovskii order, Smale Horse-Shoe map. [12]

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

Recommended 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.
4. D. W. Jordan and P. Smith, *Nonlinear Ordinary Differential Equattions*, Oxford University Press, 1999.

5. Ferdinand Verhulst, *Nonlinear Differential Equations and Dynamical Systems*, Springer, 1996.
6. A. Medio and M. Lines, *Nonlinear Dynamics: A Primer,* Cambridge University Press, 2001.
7. M. W. Hirsch and S. Smale, *Differential Equations, Dynamical Systems*, Academic, 1974.
8. R. L. Devaney, *An Introduction to Chaotic Dynamical Systems*, Addition-Wesley, 1989.
9. G. C. Layek, An introduction to Dynamical systems and Chaos, Springer, 2015.

MMATAME406-1

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 Mass, Momentum, Energy in MHD. [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]

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

MMATAME406-2

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, Dynamical invariant in turbulence. [15]

The scales of turbulent motion: Richardson – Kolmogorov Cascading, Energy cascade, Spectral Analysis of turbulence, Kolmogorov hypotheses, structure functions, the spectrum of turbulence, energy spectrum equation, Kolmogorov two-third law, four-fifth law, restatement of Kolmogorov hypotheses , Taylor's one-dimensional energy spectrum, energy relations in turbulent motions, velocity spectra, Kolmogorov spectra, inertial subrange. [12]

Turbulent 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, one equation model, Two-equation models (i) $k-\varepsilon$ model, (ii) $k-\omega$ model, remarks on turbulence modeling. [8]

Turbulence Intermittency: Log-Normal model, Novikov-Stewart Model, Mandelbrot Random curdling model, The β-(beta) model. [5]

Recommended Books:

1. U. Frisch, Turbulance, the Legacy of A. N. Kolmogorav, CUP, 1995.
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.
4. H. Schilchting: Boundary layer theory, Springer, 2003.
5. A. Davidson: Turbulence: An introduction to Scientists and Engineers, Oxford, 2004.
6. S. B. Pope: Turbulent Flows, Cambridge University Press, 2000
7. G. K. Batchelor: The theory of Homogeneous Turbulence, Cambridge University press, 1953.
8. J.O. Hinze: Turbulence, 2e, McGraw-Hill, New York, 1977.

MMATAME406-3

Space Sciences-II (Marks - 50)

Total lectures Hours: 50

Past and future Cauchy development, Cauchy surface. DeSitter and anti-de Sitter space-times. [10]

Robertson-Walker spaces. Spatially homogeneous space-time models. The Schwarzschild and ReissnerNordstrom solutions. Kruskal diagram. [10]

Causal structure. Orientability. Causal curves. Causality conditions. Cauchy developments. Global hyperbolicity. [10]

The existence of Geodesics. The Causal boundary of space-time. Asymptotically simple spaces. [10]

Supernova. Chandrasekhar Limit. Super Chandrasekhar Limit. [10]

Recommended Books:

1. Hawking and Ellis, *The large scale structure of space-time,* Camb. Univ. Press.

2. R.M. Wald, *General Relativity*, Chicago Univ. Press,.

3. B.F. Schultz. *A first course in general relativity*, Camb. Univ. Press) .

4. S. Weinberg, *Gravitation and Cosmology*, John Wiley and Sons.

5. Raychaudhury, Banerji and Banerjee, *General Relativity, Astrophysics and Cosmology* , Springer-Verlag.

6. M. Luduigsen, *General Relativity*, Camb. Univ. Press.

7. R d'Inverno, *Introducing Einstein's Relativity*, Clarendon Press, Oxford.

MMATAME406-4

Elasticity-II (Marks - 50)

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]

Recommended Books:

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.

MMATAME407-1

Advanced Optimization -II (Marks - 50)

Total lectures Hours: 50

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. [8]

Optimal Control Theory**:** Introduction to Optimal Control: Control and Optimal Control, Examples, The Basic Optimal Control Problem, Variational Calculus; Optimal Control with Unbounded Continuous Controls: The Hamiltonian, Extension to Higher Order Systems; Bang-Bang Control, Pontryagin's Principle, Switching Curves, Transversality Conditions; Applications of Optimal Control in Economic Growth, Exploited Populations, and Advertising Policies. [12]

Stochastic Programming : Chance Constraint programming technique. [6]

Computational optimization: Fundamentals of Genetic Algorithm & Particle Swarm optimization [12]

Recommended Books:

1. C. Mohan and K. Deep, *Optimization Techniques*, New Age Publishing, 2009.
2. S. S. Rao, *Optimization-Theory and Applications*, Wiley Eastern Ltd., 1977.
3. A. K. Bhunia and L. Sahoo, *Advanced Operations Research*, Asian Books Private Limited, New Delhi, 2011.
4. Michalawich, Z. (1996), Genetic algorithms + Data structures = evolution Programs, Springer Verlag, Berlin, Third Edition, 1996.
5. Andrea E. Olsson, Particle Swarm Optimization: Theory, Techniques and Applications, Nova Science Publishers, 2011.
6. M. Aokie, *Introduction to Optimization Techniques: Fundamentals and Applications of Nonlinear Programming*, The Macmillan Company, 1971.

MMATAME407-2

Advanced 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 model M/D/1, cost models in queuing system. [12]

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]

Optimal Control Theory: Introduction to Optimal Control: Control and Optimal Control, Examples, The Basic Optimal Control Problem, Variational Calculus; Optimal Control with Unbounded Continuous Controls: The Hamiltonian, Extension to Higher Order Systems; Bang-Bang Control, Pontryagin's Principle, Switching Curves, Transversality Conditions; Applications of Optimal Control in Economic Growth, Exploited Populations, and Advertising Policies. [12]

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. [7]

Replacement: 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]

Recommended Books:

1. H. A. Taha, *Operations Research – An Introduction*, Prentice-Hall, 1997.
2. J. K.. Sharma, *Operations Research: Theory and Applications*, Macmillan, 1997
3. S. D. Sharma, H. Sharma, *Operations Research: Theory, Methods and Applications*, Kedar Nath Ram Nath, 1972.
4. K. Swarup, P. K. Gupta, M. Mohan, *Operations Research*, Sultan Chand & Sons, 1978.
5. F. S. Hillier, G. J. Lieberman, Introduction to Operations Research, McGraw-Hill, 2001.
6. A. K. Bhunia and L. Sahoo, *Advanced Operations Research,* Asian Books Private Limited, New Delhi, 2011.
7. K.C. Kapur, L.R. Lamberson, *Reliability in Engineering Design*, Willey, 1977.
8. K. C. Kapur, *Reliability Engineering*, Wiley, 2014.
9. K. K. Aggarwal, *Reliability Engineering*, Springer, 1993.
10. S. Barnett, Introduction to Mathematical Control Theory, Oxford University Press, 1975
11. I. Macki, A. Strauss, *Introduction to Optimal Control Theory*, Springer, 1982.
12. A.S. Gupta, *Calculus of Variations with Applications*, PHI, New Delhi, 2005.
13. D.Burghes, A. Graham, *Control and Optimal Control Theories with Applications*, Horwood Publishing Limited, 2004

MMATAME407-6

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: Quantization of field - Schrodinger equation; Relativistic fields - Klein-Gordon field, Dirac field; Quantization of electromagnetic field. [5]

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

MMATPSO408

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.

MMATMIE308-1

Introduction to Operations Research (Marks – 25)

Total lectures Hours: 20

Linear Programming Problems, Graphical Approach for Solving some Linear Programs, Convex Set [4]
Unconstrained optimization [2]
Constrained optimization with equality constraints- Lagrange's multiplier method, Interpretation of Lagrange multiplier. [4]
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 for infinite queue length. [6]
Game theory: formulation of two person zero sum games, solving two person zero sum games, games with mixed strategies. [4]

Recommended Books:

1. H. A. Taha, *Operations Research – An Introduction,* Prentice-Hall, 1997.
2. P. M. Karak, Liner Programming and Theory of Games, New Central Book Agency, 2011
3. Edwin K. P. Chang and S. Zak, *An Introduction to Optimization,* John Wiley & Sons Inc., 2004.
4. S. S. Rao, *Optimization-Theory and Applications*, Wiley Eastern Ltd., 1977.
5. J. K. Sharma, *Operations Research : Theory and Applications*, Mcmillan, 2007.
6. A. K. Bhunia and L. Sahoo, *Advanced Operations Research,* Asian Books Private Limited, New Delhi, 2011.

7. M. S. Bazaraa, J. J. Jarvis, H. D. Sherali, *Linear Programming and Network Flows*,Wiley, 2009.
8. G. B. Dantzig, *Linear programming and extensions*, Princeton University Press, 1963.

MMATMIE308-2

Introduction to Graph Theory (25 Marks)

Total Lecture Hours : 20

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. [8]

Euler graph: Euler Graph and its characterization, Königsberg Bridge Problem [4]

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). [4]

Tree: Trees with basic properties, Spanning tree, Rooted tree, Binary tree , Minimal Spanning tree, Kruskal's algorithm. [4]

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