RAMAKRISHNA MISSION VIDYAMANDIRA

BELURMATH, HOWRAH, WEST BENGAL

DEPARTMENT OF MATHEMATICS

PROGRAMME OFFERED : M.Sc. MATHEMATICS

PROGRAMME CODE : MTM

DURATION : 4 SEMESTERS

TOTAL CREDIT : 80

FULL SYLLABUS WITH COURSE OUTCOME

VALID & ONGOING AS ON 30TH JUNE, 2019

Following is the credit distribution for M.Sc. Mathematics Programme:

	Credit	**Credit**	**Credit**	**Credit**	**Total Credit**
	SEM 1	**SEM 2**	**SEM 3**	**SEM 4**	
SUB	19	19	19	19	**76**
ICSH	1	1	2	--	**4**
	20	**20**	**21**	**19**	**80**

Following is the Grade Point distribution:

% of Marks	Descriptor	Grade	Grade Point
85 - 100	OUTSTANDING	**O**	**10**
70 - 84.99	EXCELLENT	**A+**	**9**
60 - 69.99	VERY GOOD	**A**	**8**
55 - 59.99	GOOD	**B+**	**7**
50 - 54.99	ABOVE AVERAGE	**B**	**6**
40 - 49.99	AVERAGE	**C**	**5**
LESS THAN 40	FAILED	**F**	**0**

Note 1 : M.Sc. Mathematics Programme offers different elective courses and project amongst the following broad spectrum courses.

(1) Commutative Algebra,
(2) Topology and Geometry,
(3) Algebraic Topology,
(4) Differential Manifolds,
(5) Rings of Continuous Functions,
(6) Probability theory and statistics,
(7) Mechanics of Continua,
(8) Non-Relativistic Quantum Mechanics,
(9) Harmonic Analysis,
(10) Banach Algebra and operator theory

However students after choosing the area will be required to do the project either in the institution or any other industry or institute for the full 4th semester duration.

Note 2. M.Sc. Mathematics Programme students must take following course :
Value-Oriented Course (Indian Cultural and Spiritual Heritage) : 4 Credit

Note 3 : Total Credit to be earned by a student to complete M.Sc. Mathematics Programme : 80 Credit

Note 4 : Mark sheet after each semester will be given both with SGPA and detailed marks obtained by the examinee.

Note 5 : Similarly Mark sheet after the final semester will be given with CGPA and detailed marks obtained by the examinee.

Calculation of SGPA = (Total Credit X Total Grade Point = Total Credit Point);
Total Credit Points/ Total Credits

Calculation of CGPA = (Total SGPA X Total Credits in each Sem.) / Total Credits earned in all the semesters

RAMAKRISHNA MISSION VIDYAMANDIRA
M.Sc. COURSE STRUCTURE

Sem I:
Paper I: Abstract Algebra I
Paper II: Linear Algebra I
Paper III: Real Analysis I
Paper IV: General Topology
Paper V: Complex Analysis

Sem II:
Paper VI: Abstract Algebra II
Paper VII: Linear Algebra II
Paper VIII: Real Analysis II
Paper IX: Measure Theory
Paper X: Numerical Analysis-I

Sem III:
Paper XI: Classical Mechanics
Paper XII: Ordinary Differential Equations
Paper XIII: Functional Analysis
Paper XIV: Numerical Analysis-II
Paper XV: Elective I

Sem IV:
Paper XVI: Mathematical Methods
Paper XVII: Graph Theory & Combinatorics
Paper XVIII: Partial Differential Equations
Paper XIX: Elective II
Paper XX: Project

List of Elective Papers: (1) Commutative Algebra, (2) Topology and Geometry, (3) Algebraic Topology, (4) Differential Manifolds, (5) Rings of Continuous Functions, (6) Probability theory and statistics, (7) Mechanics of Continua, (8) Non-Relativistic Quantum Mechanics, (9) Harmonic Analysis, (10) Banach Algebra and operator theory.

M.Sc. Mathematics
4 Semester Course
Mapping of
Employability etc

Sl. No.	Name of the Course	Semester	Course Code	Activities with direct bearing on Employability/ Entrepreneurship/ Skill development
1	Abstract Algebra I	1	MTM-P1	Skill development: Skill of algebra is developed by group discussion or free participation of students related to nontrivial problems in class.
2	Linear Algebra I	1	MTM-P2 **New Course Vide BoS dated : 11.06.2015**	Skill development : Analytical and reasoning skills are developed by group discussion or free participation of students related to nontrivial problems in class. . Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Linear algebra, which in turn improves their skills for Teaching jobs at College Level. Also, this course will help students to get a job in software companies like math works and Two pi-radian infotech private limited and others.
3	Real Analysis I	1	MTM-P3 **New Course Vide BoS dated : 11.06.2015**	Skill development : Analytical and reasoning skills are developed by group discussion or free participation of students related to nontrivial problems in class. . Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Real Analysis, which in turn improves their skills for Teaching jobs at College Level.
4	General Topology	1	MTM-P4	Skill development : Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class. . Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Topology, which in turn improves their skills for Teaching jobs at College Level.

5	Complex Analysis	1	MTM-P5	Skill development : Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class. . Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of complex analysis, which in turn improves their skills for Teaching jobs at College Level.
6	Abstract Algebra II	2	MTM-P6	Skill development: Algebraic skills is developed by group discussion or free participation of students related to nontrivial problems in class.
7	Linear Algebra II	2	MTM-P7 **New Course Vide BoS dated : 11.06.2015**	Skill development : Analytical and reasoning skills are developed by group discussion or free participation of students related to nontrivial problems in class. . Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Linear Algebra, which in turn improves their skills for Teaching jobs at College Level.
8	Real Analysis II	2	MTM-P8 **New Course Vide BoS dated : 11.06.2015**	Skill development: Analytical and reasoning skills are developed by group discussion or free participation of students related to nontrivial problems in class.
9	Measure Theory	2	MTM-P9	Skill development: Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.

10	Numerical Analysis-I	2	MTM-P10 **New course Vide BoS dated : 13.05.2017**	Employabality :Class room discussions, problem solving sessions helps them to stress on the important areas of Numerical Analysis, which in turn improves their skills for Teaching jobs at College Level. Also, the hand-on problem solving sessions using computer in class will prepare them for the jobs that require numerical modeling like software development etc. Skill development : Analytical and reasoning skills are developed by group discussion or free participation of students related to nontrivial problems in class. . Hands on problem solving session in class using computer will help them to learn to apply various analytical methods to solve real life problems using numerical applications and programming techniques .
11	Classical Mechanics	3	MTM-P11 **New course Vide BoS dated : 13.05.2017**	Skill development: Analytical and reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.
12	Ordinary Differential Equations	3	MTM-P12	Skill development : Analytical and reasoning skills are developed by group discussion or free participation of students related to nontrivial problems in class. Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Ordinary Differential Equations, which in turn improves their skills for Teaching jobs at College Level.
13	Functional Analysis	3	MTM-P13	Skill development: Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.

14	Numerical Analysis-II	3	MTM-P14 **New course Vide BoS dated : 13.05.2017**	Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Numerical Analysis, which in turn improves their skills for Teaching jobs at College Level. Also, the hand-on problem solving sessions using computer in class will prepare them for the jobs that require numerical modeling like software development etc. Skill development :Analytical and reasoning skills are developed by group discussion or free participation of students related to nontrivial problems in class. Hands on problem solving session in class using computer will help them to learn to apply various analytical methods to solve real life problems using numerical applications and programming techniques .
21	Algebraic Number theory	3	MTM-P15-ALNT **New Course Vide BoS dated : 19.06.2014**	Skill development: Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.
22	Analytic Number theory	3	MTM-P15-AnNT **New Course Vide BoS dated : 05.12.2015**	Skill development: Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.
15	Commutative Algebra	3	MTM-P15-CAL **New Course Vide BoS dated : 19.06.2014**	Skill development: Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class

16	Operations Research	3	MTM-P15-OR	Skill development : Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class. Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Operation Research, which in turn improves their skills for Teaching jobs at College Level and jobs involving market research.
17	Rings of Continuous functions	3	MTM-P15-Rc	Skill development : Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.
19	Topology and geometry	3	MTM-P15-TG **New Course Vide BoS dated : 19.06.2014**	Skill development : Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.
20	Mathematical Methods	4	MTM-P16	Skill development : Analytical and reasoning skills are developed by group discussion or free participation of students related to nontrivial problems in class. Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Mathematical Methods, which in turn improves their skills for Teaching jobs at College Level. Also, this will enhance the opportunities of the student to find employment in the areas where differential equations is needed like in research labs, software industries, signal processing units, etc.

23	Graph Theory & Combinatorics	4	MTM-P17	Skill development : Analytical and reasoning skills are developed by group discussion or free participation of students related to nontrivial problems in class. Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Graph Theory and Combinatorics, which in turn improves their skills for Teaching jobs at College Level. Also, this course will help students to get a job in software companies like math works and Two piradian infotech private limited and others.
24	Partial Differential Equations	4	MTM-P18 **New Course Vide BoS dated : 19.06.2014**	Skill development : Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class. . Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Partial Differential equations, which in turn improves their skills for Teaching jobs at College Level. Also, this will enhance the opportunities of the student to find employment in the areas where differential equations is needed like in research labs, software industries, weather forecasting departments, signal processing units, etc.
25	Algebraic Topology	4	MTM-P19-ALT	Skill development : Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.
26	Probability theory and statistics	4	MTM-P19-PS **New Course Vide BoS dated : 19.06.2014**	Skill development : Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class. Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Probability and Statistics, which in turn improves their skills for Teaching jobs at College Level. Also, this course will help students to get a job in software companies like math works andTwo piradian infotech private limited and others.

27	Advanced Functional Analysis	4	MTM-P19-AdFA **New course Vide BoS dated : 27.11.2017**	Skill development : Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class. Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Advanced Functional analysis, which in turn improves their skills for Teaching jobs at College Level. Further, it will help students to find employment in various areas like research labs, industrial researches, market analysis, etc.
28	Harmonic Analysis	4	MTM-P19-Har **New course Vide BoS dated : 27.11.2017**	Skill development: Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.
29	Advanced Numerical Analysis	4	MTM-P19-AdNA **New course Vide BoS dated : 27.11.2017**	Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Numerical Analysis, which in turn improves their skills for Teaching jobs at College Level. Also, the hand-on problem solving sessions using computer in class will prepare them for the jobs that require numerical modeling like software development etc. Skill development :Analytical and reasoning skills are developed by group discussion or free participation of students related to nontrivial problems in class. Hands on problem solving session in class using computer will help them to learn to apply various analytical methods to solve real life problems using numerical applications and programming techniques .
30	Non-relativistic quantum mechanics	4	MTM-P19-NQM **New course Vide BoS dated : 27.11.2017**	Skill development: Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.

31	Banach algebra and operator theory	4	MTM-P19-Banop	Skill development: Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.
32	Differential Manifolds		MTM-P15-DM **New course Vide BoS dated : 27.11.2017**	Skill development : Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class. Employabality : Class room discussions, problem solving sessions helps them to stress on the important areas of Differential Manifolds, which in turn improves their skills for Teaching jobs at College Level. This course will also be helpful to the students who seek employment in research labs and industries involving geometrical structures of physical and biological objects, for example in the areas of molecular biology (pharmacy), engineering problems, etc.
		4	MTM-P19-MCON **New Course Vide BoS dated : 05.12.2015**	Skill development: Reasoning skills is developed by group discussion or free participation of students related to nontrivial problems in class.

Course Code: MTM-P1 (Credit-4, Full Marks-50, 60hours)

Name of the Course: Abstract Algebra I

Course Outcome: To learn the basic concepts of cyclic group, normal subgroup, group homomorphism, direct products of groups, Sylow theorems and applications, ideal and ring homomorphism, ring embedding, ED, PID, UFD, prime and irreducible elements, maximal and prime ideal, Noetherian ring, Hilbert Basis Theorem. This is required for further courses in algebra.

1. Recapitulations: Basic Set Theory.
2. Binary composition, Group, Abelian group, Elementary properties of groups, Semigroup and Subgroup, Centre of a group, Permutation, Product of permutations, Inverse of a permutation, Order of a permutation, Cycles and transposition, Even and odd permutations, Symmetric group and alternating group, Integral power (multiple) of an element of a group, Order of an element, Order of a group, Cyclic group, Coset and Lagrange's theorem.

3. Normal subgroup, Quotient group, Homomorphism and its properties, Isomorphism, Kernel of a homomorphism, First Isomorphism Theorem and its applications, Automorphism, Inner Automorphism.
4. External and internal direct product of two groups and applications.
5. Group action on a set, Class equation, Cayley's Theorem, Cauchy's Theorem on finite groups, Converse of Lagrange's Theorem for finite commutative group, p-group, Sylow's Theorems and their applications.
6. Ring, Unit, Characteristic of a ring, Subring, Integral domain, Skew field, Field, Subfield, Every finite integral domain is a field.
7. Ideals of a commutative ring, Quotient ring, Ring homomorphism, First Isomorphism Theorem, Ring embedding, Every integral domain can be embedded in a field.
8. Maximal and Prime ideal and the corresponding quotient rings.
9. (a) Polynomial ring, If R is an integral domain then so is R[x], Division algorithm, Remainder theorem and factor theorem, If R is an integral domain and if f(x) is a nonzero polynomial of degree n then f(x) has at most n roots in R.

   (b) Euclidean Domain and Principal ideal domain. Every Euclidean domain is a principal ideal domain, K is a field iff K[x] is a Euclidean domain iff K[x] is a PID. Associates and greatest common divisor – simple theorems. Prime and irreducible elements, every prime element is irreducible in an integral domain and every irreducible element is prime in a principal ideal ring, Unique facrorization domain, Every irreducible element is prime in a UFD, Every PID is a UFD, If R is a UFD, then so is R[X].
10. Noetherianring and Hilbert Basis Theorem.

References

1. M. Artin, Algebra, Prentice-Hall of India, 1991.
2. PM. Cohn, Algebra, Vols. I, II & III, John Wiley &Sens, 1982, 1989, 1991.
3. N. Jacobson, Basic Algebra, Vols. I & II, W.H. Freeman, 1980 (also published by Hindustan Publishing Company).
4. S. Luther and I.B.S. Passi, Algebra, Vol. I–Groups, Vol. II–Rings, NarosaPublising House (Vol. I-1996, Vol. II-1999)
5. D.S. Malik, J.N. Mordeson, and M.K. Sen, Fundamentals of Abstract Algebra, McGraw-Hill, International Edition, 1997
6. VivekSahai and VikasBist, Algebra, Narosa Publishing House, 1999.
7. University Algebra – Gopalkrishna
8. Algrbra – Dumit and Foot

Course Code: MTM-P2 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Linear Algebra I

Course Outcome: The student will learn the concepts of Vector spaces; linear transformations; dual spaces; triangulation and diagonalization of matrices and linear transformations; direct sum decompositions of vector spaces. Further, the student will learn about inner product spaces, projections; isometries; Reisz representation theorem; normal, self-adjoint, unitary and orthogonal operators; unitarily diagonalizable matrices; spectral theorem; various canonical and bilinear forms. Thus, they will be ready to use linear algebra for various applications in multivariable analysis, numerical analysis, functional analysis, calculus, differential geometry, mechanics, linear programming problems,etc.

1. Recapitulation (with a stress towards the geometric perspective) : Vector Space, Linear transformation, Quotient space, Determinant as area/Volume, Matrix of a linear transformation : Change of base, Similarity.
2. Dual spaces and adjoint (transpose) of a linear transformation.
3. Diagonalization : The matrix aspect (a review), The linear transformation aspect (a comparison), Annihilating polynomials, Invariant subspace, Simultaneous triangulation, Simultaneous diagonalisation,
4. Direct sum decompositions, Invariant direct sums, The primary decomposition theorem.
5. Complex inner product spaces, Projection, Orthogonal projections, orthogonal matrices and isometries, Reisz representation theorem, Normal and self-adjoint operators, Unitary and orthogonal operators, Unitarily diagonalizable matrices and Spectral theorem.
6. Canonical forms (Rational canonical forms, Smith normal forms, Jordan forms).
7. Bilinear forms, Symmetric bilinear forms, Skew symmetric bilinear forms.

References

1. Linear Algebra: Hoffman and Kunze
2. Linear Algebra: Friedberg, Insel, Spence (Prentice Hall of India)
3. Linear Algebra: Kwak and Hong (Birkhauser)
4. Linear Algebra: A Geometric Approach : S. Kumaresan (Prentice Hall of India)

Course Code: MTM-P3 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Real Analysis I

Course Outcome: The student will review the various concepts of analysis on Real line (studied in the undergraduate courses). Additionally, they will learn Taylor's and Maclaurin's series; and some concepts of metric topology, viz. Completeness, Baire Category Theorem, Compactness and Connectedness. This will enable the student to take up studies on Multivariable analysis, Measure theory, Numerical Analysis. Also, this course will suffice as the one of the basic requirement courses for the courses - Functional Analysis, Ordinary Differential equations, etc.

1. Point set in $\mathbb{R}$: Natural ordering on $\mathbb{R}$,completeness property and its consequence, Archemedian Property, $\mathbb{R}$- an Archemedian totally ordered field, Well ordering property of $\mathbb{N}$ and its application to l-ary expansion of a real number, where l = 2,3,10. Intervals, open set, closed set, limit point and interior point of a set, Bolzano-Weirstrass theorem, isolated point, Perfect set, $\mathbb{R}$-a perfect set, Cantor Set and its properties. Compact subsets of $\mathbb{R}^n$.

2. Numerical Sequence and Series: Definition of a sequence, subsequence, convergence and limit point of a sequence, subsequential limits, equivalence between limit point and subsequential limit of a sequence, Cauchy sequence, limsup and liminf of a sequence in extended real number system, monotone sequence, Bolzano-Weistrass theorem, Series, convergence, root and ratio test, conditionally and absolutely convergent series, Riemann rearrangement theorem.

3. Limit and Continuity: Limit of a function, limsup and liminf of a function, algebra of limits, sequential approach, continuity of a function at a point, family of continuous functions over an interval as an algebra over , properties of continuous functions over a closed and bounded interval, Intermediate Value Property-its applications, point free definition of continuity, type of discontinuity of a function, discontinuity of a monotone function, a function f has first kind of discontinuity iff the set of discontinuities of f is countable.

4. Differentiability: Definitions of a differentiable function, geometric interpretation, Algebra of differentiable functions, Darboux properties, Rolle's theorem – its applications, Lagrange's and Cauchy's mean value theorems – their applications, L Hospital rule, Taylor's and Maclaurin's series (proof not required), Role of higher order derivatives to the nat ure of functions and its derived functions, local maxima and minima.

5.Elements of Metric Topology: Completeness and Baire Category Theorem, Compactness, Connectedness.

References

1. W Rudin: Principles of Mathematical Analysis
2. T M Apostol: Mathematical Analysis
3. C Golffman: Real Analysis
4. Bruckner, Bruckner & Thompson: Real Analysis

Course Code: MTM-P4 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: General Topology

Course Outcome: The student will learn about basics of topological spaces,countability axioms,continuous functions and homeomorphisms, separation axioms,compactness, local compactness and one point compactification,connectedness, product topology. This will enable the student for any course requiring basic topology, such as algebraic topology, multivariable analysis, differential geometry, partial differential equations, fluid mechanics, mechanics of continua, etc.

1. Zorn's Lemma and Axiom of Choice**.**Cardinal numbers: Definition: Order relation of Cardinal numbers, Equality of Cardinal numbers (Schroeder-Bernstein theorem), Addition and product of Cardinal numbers, Cardinal number of the power set of a set, Continuum Hypothesis**.**

2. Definition and examples of topological spaces. Closed sets.Closure.Dense subsets.Neighbourhoods.Interior, exterior and boundary.Accumulation points and derived sets.Bases and sub-bases.Subspaces and relative topology.

3. Continuous functions and homeomorphisms.

4. First and Second Countable spaces. Lindelof's theorem.Separable spaces.Second Countability and Separability.

5. Separation axioms T_0, T_1, T_2, $T_{3½}$, T_4; their Characterizations and basic properties. Urysohn's lemma. Tietze extension theorem.

6. Compact spaces.Continuous functions and compact sets. Basic properties of compactness. Compactness and finite intersection property. Local compactness and one pointcompactification. Compactness in metric spaces**:**Equivalence of compactness, and sequential compactness in metric spaces

7. Connected spaces. Connectedness on the real line.Components.

8. Tychonoff product topology in terms of standard sub-base and its characterizations. Projection maps. Separation axioms and product spaces.Connectedness and product spaces.Tychonoff's theorem. Embedding lemma and Tychonoff embedding.

References

l. James R. Mukres, Topology, A First Course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000
2. J. Dugundji, Topology, Allyn and Bacon, 1966 (reprinted in India by Prentice Hall of India Pvt. Ltd.)
3. George F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1963.
4. J.L. Kelley, General topology, Van Nostrand, Reinhold Co., New York, 1995.
5. L. Steen and J. Seebach, Counter examples in Topology , Holt, Rinehart and Winston, New York, 1970.
6. S. Willard, General Topology, Addison-Wesley, Reading, 1970.

Course Code: MTM-P5 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Complex Analysis

Course Outcome: To learn the concept of contour integration, Maximum modulus and relevant theorems, Taylor series, Laurent series, singularities, residue, argument principle, Rouches' theorem and its applications, conformal mapping, bilinear transformation. This will enable the student to take up studies in complex analysis, harmonic analysis, applied mathematics, physics, etc.

1. Analytic Functions, Cauchy-Riemann equations and its applications.

3. **Complex Integration:** Basic idea, ML-inequality, Winding number or Index of a curve, Cauchy-Goursat Theorem for simply-closed contour & for closed polygon. Cauchy Integral formula.Derivatives of an analytic function.Morerea's theorem.Necessary & sufficient condition for a function to be analytic in a convex domain. Mean value Theorem, Liouville's theorem, The Fundamental theorem of Algebra. Evaluation of some integrals.

4. **Uniform Convergence of sequence of functions and series of functions:** deduction of special properties of the limit function and of the sum function respectively with special reference to their analyticity. Power series-uniform convergence. A power series represents an analytic function inside its circle of convergence.

5. Taylor's series and Laurent's expansion. Zeros and Poles – basic results.Isolated singularities.Relation between zeros and poles. Zeros are Isolated points and are finite in number. Riemann's theorem.

6. Maximum Modulus Theorem, Minimum Modulus Theorem, Schwarz lemma.

7. **Residue:** Determination of Residue, Residue theorem, Evaluation of integrals. Application of logarithmic residue theorem.Meromorphic function.The Argument principle.

8. Rouche's theorem and its application. Open mapping theorem. Hurwitz Theorem

9. Branches of many valued functions with special reference to arg z, log z and z^a.

10. Linear functional transformation and conformal mapping,

References

1. Complex variables – Theory & applications – H.S. Kasana (PHI)
2. Applied complex Analysis – Rubenfeld
3. Complex Variables – Spiegel (Schaum series)
4. The Theory of function – Titchmarsh, E.C.
5. Foundations of complex Analysis – S. Ponnusamy (Narosa)
6. Function of One Complex Variable : J B Conway
7. Complex Analysis – T W Gamalin (Springer)
8. Complex Analysis – L V Ahlfors (TMH)
9. Real and Complex Analysis – W Rudin (TMH)
10. Complex Functional Theory – D E Sorason (HBA)
11. Complex Analysis in One Variable - RaghavanNarsimham, Springer.

Course Code: MTM-P6 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Abstract Algebra II

Course Outcome: To learn the concept of normal and sub normal series, various field extension, Galois theory. This course is required for higher course in field extension theory.

1. Normal and Subnormal Series, Composition Series, Jordan Holder Theorem, Solvable Groups, Nilpotent Groups, Fundamental Theorem on Finitely generated abelian Groups (Statement and Applications)

2. Extension of Fields, Algebraic and Transcendental Extensions, Rular and compass construction, Normal and Separable Extensions, Splitting Field, Finite Fields, Primitive elements., Algebraically Closed Fields, Automorphisms of Extensions,k Galois Extensions, Fundamental Theorem of Galois Theory and applications.

3. Symmetric rational functions, Separability, Cyclic extension, Cyclotomic extension, Radical extension, Simple problems.

References

1. I. Stewart, Galois Theory, 2nd edition, Chapman and Hall, 1989.
2. J.P. Escofier, Galois theory, GTM Vol. 204, Springer, 2001.
3. S. Lang, Algebra, 3rd edition, Addison-Wesley, 1993.

Course Code: MTM-P7 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Linear Algebra II

Course Outcome: The student will learn about module theory. This will enable him to take up studies in commutative algebra.

1. Modules, Submodules, Homo-Morphisms, Quotient modules, Isomorphism theorems, exact sequence of modules, Generation of modules, direct sum, Free modules, Hom (-,-) and its properties, 5-lemma.

2. Rings of fraction, Modules of fraction, Local global principle.

3. Tensor product of modules and related properties.

4. Nakayamma lemma and construction of minimal generating set of a finitely generated module over a commutative local ring with identity.

5. Projective modules and related properties (projective modules over local rings are free, Schanuel lemma).

6. Projective resolution of a module, free resolution of a module, Homology, Tor, Ext and there basic properties, Simple problems.

7. Flat modules and related properties, Faithfully flat modules.

8. Finitely generated modules over PID, Structure theorems – Invariant factor form and elementary divisor form, Primary Decomposition Theorem, Application to Abelian groups.

References

1. Algebra – Dummit and Foote

Course Code: MTM-P8 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Real Analysis II

Course Outcome: The student will learn about sequences and series of functions with special stress on Fourier series; review of Reimann integration theory with introduction to beta and gamma functions; Multivariable analysis with applications to maxima-minima problems. These will the enable the student to solve problems arising in differential equations, mechanics and develop various numerical models. Also, this course partially fulfils the basic requirements for courses on numerical analysis, partial differential equations, mathematical methods, differential geometry, mechanics, etc.

1. Limits and Convergences of sequences and series of functions, Weierstass' approximation theorem, continuity and differentiability of limit functions.

2. Fourier series : Introduction, Even and odd functions, Fourier series for functions of period 2π, Dirichlet's conditions, Convergence of Fourier series, Bessel's inequality, Reimann-Lebesgue theorem, Fourier series of a function with its periodic extension,.
Half Range Fourier Series : Construction of half range Sine series and half range Cosine series, Perseval;s identity, Examples.
Dirichlet's kernel, Fejer's kernel, Fejer's theorem, Dini's and Jordan's tests for pointwise convergence of Fourier esries.
3. Riemann Integration: Revision of fundamental properties of Riemann integration, Lebesgue's Theorem on Riemann Integrable functions. Improper Riemann integral, Absolute Convergence, Beta and Gamma functions as examples.

4. Functions of several variables: Continuity of functions of several variables, Directional Derivatives, Partial Derivatives, Differentiability, Chain Rule, Schwarz Theorem, Taylor's Theorem, Inverse function Theorem, the Implicit function Theorem, Jacobians, Extreme problems with constraints, Lagrange's multiplier method (proof may be omitted).

References

1. W Rudin: Principles of Mathematical Analysis
2. T M Apostol: Mathematical Analysis
3. C Golffman: Real Analysis
4. Bruckner, Bruckner & Thompson: Real Analysis
5. M Spivak: Calculus on Manifolds.
6. E. M. Stein, R. Shakarchi – Fourier Analysis : An Introduction

Course Code: MTM-P9 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Measure Theory

Revision Vide BoS dated : 11.06.2015

Course Outcome: The student will learn about Sigma-field and field of subsets of a set; Countably additive nonnegative measure on a sigma-field, Continuity from above and below; Measurable functions; Integration theory; L^p spaces of a measure space; Jensen's inequality for a probability space; product sigma-fields, product measures. This will enable the student to take up courses on functional analysis, advanced functional analysis, etc.

1. Sigma-field and field of subsets of a set. Sigma-field generated by a collection of sets. Example: the Borel sigma field on the line and its various generating collections. Monotone class theorem.

2. Countably additive nonnegative measure on a sigma-field. Continuity from above and below. Examples: (i) counting measure on the sigma-field of all subsets of a set, (ii) the Lebesgue measure on the real line (introduced by considering Lebesgue outer measure and restricting it to Borel sets, (iii) statement of the Caratheodory extension theorem.

3. Measurable functions. Simple functions and approximation of simple functions by a non-decreasing sequence of simple functions. Extended real valued measurable functions. The positive and negative parts of a measurable function.

4. Integral of a nonnegative simple function, of a nonnegative measurable function. Monotone convergence theorem. Integral of a real valued measurable function.

5. Linearity of integrals. Fatou's theorem. Dominated Convergence theorem (and bounded convergence theorem on finite measure spaces).

6. L^pspaces of a measure space. Cauchy- Schwarz, Holder's and Minkowski's theorems.

7. Jensen's inequality for a probability space.

8. Product sigma-fields, product measures and Fubini'sTheorm.

References

1. I.K. Rana: Integration and Measure.
2. Billingsley: Probability and Measure.

Course Code: MTM-P10 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Numerical Analysis-I

Course Outcome: **(Theory)** A student will learn about interpolation techniques; solving algebraic, transcendental and system of linear equations using numerical methods; finding approximate eigenvalues of matrices.

(**Practical)** The student will learn to code the aforesaid numerical methods using MATLAB or C programming language. This will enable the student for advanced studies in numerical analysis. Also, this will prepare the student for any employment where numerical techniques are required, for example in research labs, software industries, etc.

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(Theory - 30 marks)

1. Interpolation: Error of polynomial interpolation, Lagrange, Newton Interpolation, Hermiteand Cubic spline interpolation.

2. Differentiation: Based on Newton's forward and backward interpolation, Lagrange's formula.

3. Numerical solution of algebraical equations and transcendental equations by Bisection method, Fixed point iteration method, Newton- Raphson method, Secant method. Condition of convergence and order of convergence of the above methods, Graeffe's Root-squaring method for solving algebraic equations, Muller's method, Aitken's Δ^2 acceleration process, Bairstow's method to determine complex roots of a polynomial equation.

4. Solution of systems of linear equations using Gauss elimination method,Gauss-Jordan method, LU decomposition, Cholesky method,Gauss-Jacobi iterative method, Gauss-Seidal iterative method, Condition of convergence in the above iterative methods, Methods of Relaxation and Over-relaxation.

5. Matrix eigen value problems: Jacobi method for symmetric matrices, Householder's method for symmetric matrices, Rutishauser method for arbitrary matrices, Power method.

(Practical- 20 marks)

The following problems should be done on computer using **C / MATLAB language**:

1. Interpolation: Newton's forward and backward interpolation, Lagrange's interpolation, Inverse interpolation, Cubic Spline.

2. Differentiation: Based on Newton's forward and backward interpolation, Lagrange's formula.

3. Numerical solution of algebraical equations and transcendental equations by Bisection method, Fixed point iteration method, Newton- Raphson method, Secant method,Graeffe's Root-squaring method for solving algebraic equations, **Muller's method**, Aitken's Δ^2 acceleration process, Bairstow's method to determine complex roots of a polynomial equation.

4. Solution of system of linear equations: Gauss elimination method, **Gauss-Jordan method**, LU decomposition, **Cholesky method**,**Gauss-Jacobi iterative method**,Gauss-Seidal iterative method.

References

1. F. B. Hilderbrand: Introduction to Numerical Analysis, Mcgraw-Hill, 1974.
2. J.B. Scarborough: Numerical Mathematical Analysis, Johns Hopkins Press, 1966.
3. A. Ralston: A First Course in Numerical Analysis, Mcgraw-Hill, 1985.
4. J. Butcher: The Numerical Analysis for Ordinary Differential Equations, Wiley, 2008.
5. K. E. Atkinson: An Introduction to Numerical Analysis.
6. S. S. Sastry: Introductory Methods of Numerical Analysis.
7. M. K. Jain, S. R. K. Iyengar and R. K. Jain: Numerical Methods for Scientific and Engineering Computation.

8. Richard L. Burden, J. Douglas Faires and Annette M. Burden: Numerical Analysis
9. W. H. Press, S. A. Teukolsky, W. T. Vetterling and Brian P. Flannery : Numerical Recipes in C.
10. E. Balaguruswamy : Numerical methods.

Course Code: MTM-P11 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Classical Mechanics

Course Outcome: To learn the concepts of Lagrangian, Hamiltonian, Hamilton's principle, principle of least action, Noether's theorem, Brackets, Euler's dynamical equation, Eulerian angles, motion of a symmetrical top, small oscillation. This course serves as the basics required by the student to work on physical problems arising in the mechanical world. Further, this will help a student to take up studies in advanced mechanics.

Degree of freedom, Generalized Coordinates,Unilateral and bilateral constraints, Holonomic and non-holonomic system, Scleronomic and Rheonomic systems, Principle of virtual work, D'Alembert's principle, Lagrange's equations of first and second kind (holonomic and non-holonomic system), Euler-Lagrange's equation, velocity-dependent potentials, Rayleigh's dissipation function, Cyclic or ignorable coordinates, Energy conservation in Lagrangian formulation.

Hamilton's principle, Necessary and sufficient conditions of Hamilton's principle, Legendre transformation,Hamilton's canonical equation of motion, Derivation of Hamilton's equation of motion from Lagrange's equations and Hamilton's principle, Derivation of Lagrange's equation from Hamilton's principle,Extension of Hamilton's principle to systems with constraints,Routhian, Principle of least action,Noether's Theorem, Brachitochrone for uniform force field,Hamilton's Principle Function, Hamilton's Characteristic Function, Lagrange's and Poisson brackets, Invariance of Lagrange's and Poisson brackets, integral invariants of Poincare, Canonical transformations, Differential forms and generating functions,Liouville's theorem, Jacobi's Identity, Poisson's Theorem, Jacobi-Poisson Theorem.

Hamilton-Jacobi equation, Solution to the time dependent Hamilton-Jacobi equation, Conditions for Separability of Coordinates, Solution of one dimensional simple harmonic oscillator problem by Hamilton-Jacobi method,Action Angle Variables, Adiabatic Invariance.

Principle of linear momentum, Principle of angular momentum, Euler's dynamical equations, Eulerian angles, Motion of a symmetrical top, Theory of small oscillations.

References

1. Classical Mechanics - N. C. Rana and P. S. Joag, TATA-McGraw Hill Publishing Company Ltd.
2.Classical Mechanics - H. Goldstein, C. P. Poole and J. Safko, Pearson
3.Analytical Mechanics - Louis N. Hand and Janet D. Finch
4. Principles of Mechanics - Synge and Griffith
5. Classical Dynamics - D. Greenwood, Prentice Hall of India,
6.A Text Book of Dynamic-F. Chorlton
7. Mathematical Methods of Classical Mechanics- V. I. Arnold
8. Classical Mechanics- Alexei Deriglazov
9. Classical Mechanics- Dieter Strauch
10. Theoretical Mechanics- N. G. Chetaev

Course Code: MTM-P12 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Ordinary Differential Equations

Course Outcome: This will help the student to solve various problems arising in the physical world which can be expressed in terms of ODEs (for example problems in kinematics,
evolution, etc.). This forms one of the basic requirements for partial differential equations, further studies in mechanics, etc.

1. Preliminaries – Initial Value problem and the equivalent integral equation, mth order equation in d-dimensions as a first order system, concepts of local existence, existence in the large and uniqueness of solutions with examples.

2. Basic Theorems – Ascoli-Arzela Theorem. A Theorem on convergence of solutions of a family of initial-value problems.

3. Picard-Lindelof Theorem – Peano's existence Theorem and corollary. Maximal intervals of existence. Extension Theorem and corollaries. Kamke's convergence Theorem. Kneser's Theorem (Statement only).

4. Differential inequalities and Uniqueness – Gronwall's inequality. Maximal and minimal solutions. Differential inequalities. A Theorem of Winter. Uniqueness Theorems. Nagumo's and Osgood's criteria.

5. EgrespointstandLyapunov functions. Successive approximations.

6. Variation of constants, reduction to smaller systems. Basic inequalities, constant coefficients. Floquet Theory. Adjoint systems, Higher order equations.

7. Linear second order equations – Preliminaries. Basic facts. Theorems of Sturm. Sturm Liouvilee Boundary value Problems.

References

1. P. Hartman, Ordinary Differential Equations, John Wiley (1964).
2. E.A. Coddington and N. Levinson, Theory of Ordinary Differential Equations, McGraw-Hill, NY (1955).
3. G.F. Simmons : Differential Equaitons.

Course Code: MTM-P13 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Functional Analysis

Revision Vide BoS dated : 17.12.2016

Course Outcome: A student will review the concepts of metric spaces; learn about the basics of functional analysis – normed linear spaces, Banach spaces, Hahn Banach theorems, Hilbert spaces, Riesz representation theorem, operators on Hilbert spaces. This will enable the student to take up advanced courses on operator theory, functional analysis, partial differential equations, numerical PDEs, etc.

1. Review of (i) Complete Metric Spaces. (ii) Completion of a Metric Space. (iii) Baire category theorem and applications. (iv) Banach Fixed Point Theorem.
2. Normed linear spaces, Banach spaces and examples. Quotient space of normed linear spaces and its completeness, equivalent norms, Riesz lemma, basic properties of finite dimensional normed linear spaces and compactness.Bounded linear transformations, normed linear spaces of bounded linear transformations, Hahn-Banach theorem for real linear spaces, complex linear spaces and normed linear spaces, consequences of HahnBanach theorem, dual spaces with examples. Open mapping and Closed Graph theorems, Uniform Boundedness Principle and some of its consequences, reflexive spaces.
3. Inner product spaces. Hilbert spaces, Orthonormal sets, Bessel’s inequality, complete orthonormal sets and Parseval's identity, Structure of Hilbert spaces. Projection theorem, Riesz representation theorem, Reflexivity of Hilbert spaces.
4. Adjoint of an operator on a Hilbert space, Commutativity of operators on Hilbert spaces, Self-adjoint, positive, projection, normal and unitary operators.

References

l. G. Bachman and L. Narici. Functional Analysis.Academic Press, 1966.
2. N. Dunford and J.T. Schwartz, Linear Operators, Part-I.Interscience, New York, 1958.
3. C. Goffman and G. Pedric, First Course in Functional Analysis, Prentice Hall of India, New Delhi, 1987.
4. P.K.Jain, O.P.Ahuja and Khalil Ahmad, Functional Analysis, New Age International (P) Ltd. & Wiley Eastern Ltd., New Delhi, 1997.
5. B.V.Limaye, Functional Analysis, Wiley Eastern Ltd.
6. G.F.Simmons, Introduction to Topology and Modern Analysis. McGraw-Hill Book Company, New York. 1963.
7. A.E.Taylor. Introduction to Functional Analysis.John Wiley and Sons.New York, 1958.
8. J.B.Conway, A Course in Functional Analysis, Springer-Verlag, New York, 1990.
9. Walter Rudin, Functional Analysis, Tata McGraw-Hill Publishing Company Ltd.,
10. B.K. Lahiri: Elements of Functional Analysis.

Course Code: MTM-P14 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Numerical Analysis-II

Course Outcome: (Theory) A student will learn about numerical techniques to approximate integrals; solve ordinary and partial differential equations.

(**Practical)** The student will learn to code the aforesaid numerical methods using MATLAB or C programming language. This course will enable the student for advanced studies in numerical analysis, numerical methods in partial differential equations. Also, this will enhance the opportunities of the student to find employment in the areas where numerical techniques are required, for example in research labs, software industries, weather forecasting departments, signal processing units, etc.

(Theory - 20 marks)

1. Integration: Trapezoidal, Simpson's 1/3 rule,Weddle's rule, Gauss-Legendre quadrature, Method of undetermined parameters. Richardson's extrapolation technique and Romberg integration formula.

2. Least square polynomial approximation.

3. Numerical solution of ODE: Initial value problems: Taylor's series method, Picard method, Euler's method, Modified Euler's method, Outlines of Runge- Kutta 4^{th} order method, Milne's method, Adams- Bashforth method, Adams-Multan method.

4. Numerical Solution of PDE: Solution of Laplace's equation by Gauss-Seidal method, Iterative methods for the solution of one dimensional heat equation, Wave equation (outline).

(Practical - 30 marks)

The following problems should be done on computer using **C / MATLAB language**:

1. Integration: Trapezoidal, Simpson's 1/3 rule,Weddle's rule, Gauss-Legendre quadrature, Romberg integration formula.

2. Matrix eigen value problems: Jacobi method for symmetric matrices, Householder's method for symmetric matrices, Rutishauser method for arbitrary matrices, Power method.

1. Problems of curve fitting: $y = a + bx$, $y = a + bx+cx^2$ by Least square method.

2. Numerical solution of first order ODE: Euler method, Modified Euler method, 4^{th} order Runge-Kutta method, Milne's method, Adams-Multan method.

3. Numerical Solution of PDE: Solution of Laplace's equation by Gauss-Seidal method, Iterative methods for the solution of one dimensional heat equation, Wave equation.

4. Linear difference equation.

References

1. F. B. Hilderbrand: Introduction to Numerical Analysis, Mcgraw-Hill, 1974.
2. J.B. Scarborough: Numerical Mathematical Analysis, Johns Hopkins Press, 1966.
3. A. Ralston: A First Course in Numerical Analysis, Mcgraw-Hill, 1985.
4. J. Butcher: The Numerical Analysis for Ordinary Differential Equations, Wiley, 2008.
5. K. E. Atkinson: An Introduction to Numerical Analysis.
6. S. S. Sastry: Introductory Methods of Numerical Analysis.
7. M. K. Jain, S. R. K. Iyengar and R. K. Jain: Numerical Methods for Scientific and Engineering Computation.

8. Richard L. Burden, J. Douglas Faires and Annette M. Burden: Numerical Analysis.
9. W. H. Press, S. A. Teukolsky, W. T. Vetterling and Brian P. Flannery : Numerical Recipes in C.
10. E. Balaguruswamy : Numerical methods.

Course Code: MTM-P16 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Mathematical Methods

Course Outcome: This will help student to learn about Fourier transformation, generalized functions and integral equation. This is required for study in advance course in the respective topics and it is useful in various applied mathematics courses. Also, this will enhance the opportunities of the student to find employment in the areas where differential equations is needed like in research labs, software industries, signal processing units, etc.

1.Fourier transform: Dirichlet's conditions, Fourier transform of derivatives of a function. Riemann-Labesgue's theorem. Fourier inversion theorem. Convolution theorem Parseval's relation. Evaluation of definite integrals by Fourier inversion theorem and Parseval theorem, Fourier sine and cosine transform, Multiple Fourier transform**.** Application of Fourier Tranaform for solving Integral Equations. Application in solving partial differential equations: heat equation and equations of vibration problems, Finite Fourier transform and some ideas of computational techniques of Fourier transform. **[20 Marks]**

2. **Generalized function:** Space of test functions. Generalized functions as functionals. Regular and singular points of a generalized function [Distributions]. Delta-convergent sequence. Plemelj's formula. Derivative of a generalized function. Generalized functions of slow growth, Fourier transform of generalized functions. [**15 Marks]**

3. Integral equation: Reduction of boundary value problem of ordinary differential equation to an integral equation. Fredholm integral equation: solution by the method of successive approximation. Iterated Kernels.Neumann series.Existence and uniqueness of solution of Fredholm equation. Equations with degenerate kernel: eigen values and eigen solutions. Voltera integral equation: solution by the method of iteration. Existence and uniqueness of solution.Solution of Abel equation.Solution of Voltera equation of convolution type by Laplace transform. **[15 Marks]**

References

1. The use of Integral transforms - I.N. Sneddon Tata McGraw - Hindustan Publishing Co. Ltd
2. Integral transforms for Engineers and Applied Mathematicians - L.C. Andrews & B.K. Shivamoggi - Macmilla Publishing Company.
3. Equations of Mathematical Physics - V.S. Vladimirov - Mir Publishers, Moscow.
4. Linear Integral Equations - S.G. Mikhlin - Hindustan Publishing Corp. (India)

Course Code: MTM-P17 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Graph Theory &Combinatorics
Revision Vide BoS dated : 17.12.2016

Course Outcome: A student will learn aboutcounting Theory and its applications , fundamental concepts , graphs with special properties, trees, directed graphs, coloring of graphs, planarity of graphs, combinatorics**.** This will help students in cryptology, logic and advance study in graph theory.

1. **Counting Theory and its Applications :** Counting, Pigeon Hole Principle, Inclusion and Exclusion Principle.

2. **Fundamental Concepts :** Basic Definitions. Graphs, Vertex, degree, Walks, Paths, Trails, Cycles, Circuits, Subgraphs, Induced subgraph, Cliques, Components, Adjacency Matrices, Incidence matrices, Isomorphisms.

3. **Graphs with special properties :**Complete Graphs, Bipartite Graphs, Connected Graphs, Eulerian Circuits, Hamiltonian (Spanning) Cycles.

4. **Trees :** Basic properties, distance, diameter. Spanning trees of a connected graph, Depth first search (DFS) and Breath first search (BFS) Algorithms, Minimal spanning tree, Shortest path problem, Kruskal's Algorithm, Prim's Algorithm, Dijkstra's Algorithm.

5. **Directed Graphs :**Definitions and examples. Vertex degrees. Eulerian Digraphs. Orientations and Tournaments, Network and Flow problem, Max Flow - Min Cut Theorem.

6. **Coloring of Graphs :** Vertex coloring : proper coloring, k-colorable graphs, chromatic number, upper bounds, Cartesian product of graphs, Structure of k-chromatic graphs, Mycielski's Construction, Clique number. Independent (stable) set of vertices, Independence number, Clique covering, Clique covering number.

7. **Planarity of Graphs :** Drawing graphs in a plane, Planar Graphs, Euler's Formula, Maximal Planar Graphs. Kouratowski's Theorem (Statement only). Coloring of planar graphs, Edge-contraction, Five color theorem, Four color Theorem (Statement only). Crossing Number.

8. **Combinatorics:** Definition. Pigeonhole Principle. Permutation and Combination. Binomial Coefficients. The Inclusion-Exclusion Principle and application stirling numbers. Recurrence relation and Generating functions.

References

1. Introduction to Graph Theory, Douglas B. West, Prentice-Hall of India Pvt. Ltd., New Delhi 2003.
2. Graph Theory, F. Harary, Addison-Wesley, 1969.
3. Basic Graph Theory, K.R. Parthasarathi, Tata McGraw-Hill Publ. Co. Ltd., New Delhi, 1994.

4. Graph Theory Applications, L.R. Foulds, Narosa Publishing House, New Delhi, 1993.
5. Graph Theory with Applications, J.A. Bondy and U.S.R. Murty, Elsevier Science, 1976.
6. Graphs and Digraphs, G. Chartrand and L. Lesniak, Chapman and Hall, 1996.
7. Theory of Graphs, O. Ore, AMS Colloq. 38, Amer Math. Soc., 1962
8. Graph Theory, R. Gould, Benjamin/Cummings, 1988.
9. Graph Theory, J. Gross and J. Yellen, CRC Press, 1999.
10. Graph Theory with Applications to Engineering and Computer Science, NarsinghDeo, Prentice-Hall of India Pvt. Ltd., New Delhi, 1997.
11. V. Krishnamurthy, Combinatorics, Theory and Applications, East-West Press, 1985.

Course Code: MTM-P18 (Credit-4, Full Marks-50, 60 hours)

Name of the Course: Partial Differential Equations

Course Outcome: A student will learn about first order quasi-linear, second order semi linear and linear partial differential equations; Cauchy problem, Dirichletand Neumann problems; particularly Laplace, heat and wave equations in one and two dimensions. Also they learn about some special functions like Hermite, Legendre polynomials, Bessel, harmonic and Hyper geometric functions. This course is required for various courses in applied mathematics and further study in the respective area**.** Also, this will enhance the opportunities of the student to find employment in the areas where differential equations is needed like in research labs, software industries, weather forecasting departments, signal processing units, etc.

1. Cauchy Problem, Cauchy Problem for a quasilinear 1st order PDE, General solution of a 1st order quasilinear PDE, classification of semilinear 2nd order PDE in two independent variables (Hyperbolic, Parabolic, Elliptic), Cauchy Problem & characteristic curve of 2nd order semi linear PDE, one-dim Wave Equation, 2nd order linear PDE in 3 or more independent variables, Cauchy Problem, Adjoint& self-adjoint linear PDE of 2nd order in n independent variables, Initial value Problem, D' Alembert's solution, stability of solution, Riemann-Volterra solution of one-dim Wave equation, two-dim Wave Equation, Laplace Equation.

2. Method of separation of variables, special functions such as Bessel functions, Legendre functions.

3. Hypergeometric function, Hermite Polynomials, Leguerre Polynomials, three-dim Wave Equation, Helmholtz's Equation, Helmholtz's first theorem, Kirchoff's first Theorem, Poincare's solution of Wave equation, Poisson's solution of Wave equation, Green's function for PD operator,

4. Dirichlet Problem, Neumann Problem, Harmonic function, Spherical means, Gauss MVT, Max-Min Principle of harmonic functions, Uniqueness theorem, Harmonic functions and potentials, Green's function &Dirichlet Problem, solution of Dirichlet Problem for a disc, solution of Dirichlet Problem for a sphere, Green’s function of 2nd kind and Neumann Problem, Separable solution of Laplace Equation, Neumann Problem for a sphere, Dirichlet problem for a half-space.

5. Heat Equation, Initial Value Problem, Max-Min Principle, Uniqueness of solution.

References

1. Elements of partial differential equations - I.N. Sneddon, (McGRAW-HILL)
2. An elementary course in partial differential equations, T. Amaranath, (Narosa publishing house)
3. Partial differential equations in physics, Arnold Sommerfeld, (Levant Books)
4. A treatise on the theory of Bessel Functions - G.N. Watson
5. Ordinary and Partial Differential Equations - M.D. Raisinghania

Elective papers

Course Code: MTM-P15-ALNT (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Algebraic Number theory
Course Outcome: The students will learn the basic concept of Cyclotomic fields, Kummer-Dedekind criterion, Dirichlet's Unit theorem, completion of number fields. This will enable the student to take up further studies/research in this area.

1. Integral elements in algebraic number fields (definition and basic properties) and integral closure.
2. Integers of a quadratic field and their units.
3. Quadratic reciprocity law.
4. Norm, trace.
5. Cyclotomic fields.
6. Review of Noetherian rings and modules (basics).
7. Dedekind domains, fractional ideals
8. Proof that ring of integers of an algebraic number field is a Dedekind domain.
9. Norms of ideals, Prime ideal decomposition in an extension L/K of number fields - ramification theory and the formula \sum e_if_i equals [L:K].
10. Kummer-Dedekind criterion.
11. Definition of ideal class group and finiteness of class number.
12. Minkowski's lemma on convex bodies.
13. Dirichlet's Unit theorem.
14. Definition of p-adic metric. Ostrowski's theorem.
15. Completion of Q with respect to the p-adic metric.
16. Valuations - Archimedean and non-Archimedean (definition and basic properties).
17. Completion of number fields.

References

1. D.Marcus.
2. P.Samuel.
3. G.Janusz.
4. Ireland & Rosen.
5. AthiyaMcdonald.
6. Algebraic Number Theory by JurgenNeukirch.

Course Code: MTM-P15-AnNT (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Analytic Number theory
Course Outcome: A student will learn about basics of number theory - unique factorization, Chinese reminder theorem and its applications, p-adic numbers, structure of U(Z/nZ), finite Abelian groups and their Characters: Dirichlet's Characters, Quadratic Gauss Sum and Quadratic Reciprocity Law; Arithmetical functions, Dirichlet product, Mobius inversion, Derivatives, Generalized convolutions, Euler's summation formula, Average growth of Arithmetic functions: Big oh, small oh notations, Application: Lattice points visible from origin, Abel's summation formula, Elementary theorems on the Distribution of Primes: Growth of pi(x), Tchebychef's theorem, Shapiro's Tauberian theorem, Selberg's identity and Asymptotic formula; Continued (Finite & Infinite) Fractions and Pell's equations. This will enable the student to take up higher studies in the area of analytic number theory.

Elementary Number Theory
Introduction, Divisibility, Unique Factorization, Congruence and residues, Chinese Reminder Theorem and its applications, p-adic numbers, Structure of U(Z/nZ), Finite Abelian Groups and their Characters: Dirichlet's Characters, Quadratic Gauss Sum and Quadratic Reciprocity Law, Sums of two and four squares.

Introduction to Analytic Number Theory
Arithmetical functions, Dirichlet product, Mobius inversion, Derivatives, Generalized convolutions, Euler's summation formula, Average growth of Arithmetic functions: Big oh, small oh notations, Application: Lattice points visible from origin, Abel's summation formula, Elementary theorems on the Distribution of Primes: Growth of pi(x), Tchebychef's theorem, Shapiro's Tauberian theorem, Selberg's identity and Asymptotic formula.

Special Topics

1) Continued (Finite & Infinite) Fractions and Pell's equations.
2) Elementary Proof of Dirichlet Theorem on Primes (if time permits)

<u>ReferenceS</u>

1. Elementary Number Theory: David M. Burton
2. An Introduction to Number Theory: Ivan Niven, Herbert S. Zuckerman & Hugh L. Montgomery
3. A Classical Introduction to Modern Number Theory: Kenneth Ireland & Michael Rosen
4. Introduction to Analytic Number Theory: Tom M. Apostol.

Course Code: MTM-P15-CAL (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Commutative Algebra
Course Outcome: A student will learn about rings and ideals, Jacobson Radicals, Extension and contraction; modules, Noetherian and Artinian Rings; Prime decomposition, Integral Dependence, The Hilbert Nullstllensatz, Noethernormalisation; Completion, Valuation rings. This will enable the student to take up further research in the area of commutative algebra.

1. Rings and Ideals, Nilradical and Jacobson Radicals, Prime avoidance lemma, Extension and contraction, Operations on Ideals.

2. Modules: Recapitulations: Submodules, Operation on modules, Exact sequences, Free modules, Tensor product of modules, Restriction and extension of scalars, Projective modules, Flat modules, Injective modules, Modules over P.I.D, Nakayamma lemma, Rings and modules of Fraction, Local properties.

3. Chain condition, Noetherian and Artinian Rings.

4. Assiociated Primes and primary decomposition.

5. Integral Dependence,Going up and Going down theorem,The Hilbert Nullstllensatz, Noether normalisation.

6. Completion, Artin Rees lemma, Krull intersection theorem, Valuation rings.

References

1. Atiyah, M., MacDonald, I.G., Introduction to Commutative Algebra, Addision - Wesley, 1969.
2. Lang, S., Algebra, Addison - Wesley, 1993.
3. Lam, T.Y., A First Course in Non-Commutative Rings, Springer Verlag.
4. Jacobson, N., Basic Algebra, Hindusthan Publishing Corporation, India.
5. I. Kaplansky, Commutative rings. The University of Chicago Press, 1974.
6. Gopalakrishnan, N.S., Commutative Algebra, Oxonian Press Pvt. Ltd., New Delhi, 1988.

Course Code: MTM-P15-DM (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Differential Manifolds
Course Outcome: A student will learn about basics of differential geometry; manifolds, smooth structures, smooth maps, tangent, cotangent and vector bundles; submersion, immersion, embeddings; Lie groups; abstract tensors on manifolds. This will prepare the student for advanced courses in Reimanian Geometry, partial differential equations, fluid mechanics, theory of relativity, numerics on geometrical shapes, theory of relativity, etc. This course will also be helpful to the students who seek employment in research labs and industries involving geometrical structures of physical and biological objects, for example in the areas of molecular biology (pharmacy), engineering problems, etc.

Course Requirements: Real Analysis I & II, Linear Algebra, General Topology.

1. Manifolds : Basic definitions, examples. Topological manifolds, smooth structures, local coordinate representations, manifolds with boundary.

2. Smooth maps : Smooth functions and maps, Lie groups, bump functions and partition of unity.

3. Tangent bundle : Tangent vectors, push forwards, tangent vectors to a curve, tangent space to a manifold with boundary, tangent bundle, vector fields.

4. Cotangent bundle :Covectors, tangent covectors on manifolds, cotangent bundle, differential of a function, pull backs, line integrals, conservative covector fields.

5. Submanifolds : Submersions, Immersions and Embeddings, embedded submanifolds, Inverse function theorem, level sets.

6. Tensors : Definition, algebra of tensors, tensor fields on manifolds, symmetric tensors.

Books for references :

1. Introduction to smooth manifolds – John M. Lee.
2. A course in tensors with applications to Riemannian geometry – R. S. Mishra, Pothishala (Pvt.) Ltd.
3. Structures on a differentiable manifold and their applications – R. S. Mishra, ChandramaPrakashan, Allahabad.
4. Differential geometry of manifolds – U. C. De and A. A. Shaikh, Narosa Publishing house Pvt. Ltd.
5. Tensor calculus – B. Spain, John Willey and Sons.
6. A comprehensive introduction to differential geometry, Volume I – M. Spivak, Publish or Perish, Inc.

Course Code: MTM-P15-OR (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Operations Research
Course Outcome: A student will learn the basic concept of simplex method, duality and sensitivity analysis, network analysis, dynamic programming, integer programming, elementary queuing theory, inventory models, nonlinear programming**.** This will enable the student to take up further research in the area of operation research.

1. Operations Research and its scope. Necessity of Operations Research in Industry.
2. Linear Programming: Simplex Method. Theory of the Simplex Method.Duality and Sensitivity Analysis.
   Other Algorithms for Linear Programming: Dual Simplex Method. Parametric Linear Programming.Upper Bound Technique.Linece Goal Programming.
3. Network Analysis: Network Simplex Method. Project Planning and Control with PERT-CPM.
4. Dynamic Programming: Deterministic Dynamic Programming and Applications.
5. Integer Programming: Branch and Bound Technique. Cutting plane Algorithm.
6. Elementary queuing Theory: Steady-state Solutions of markovian Models. M/M/1, M/M/1 with limited waiting space, M/M/e, M/M/e with limited waiting space, M/G/1.
7. Inventory Models: Order Quantity Decisions and concept of EOQ. Inventory Models without shortages. Inventory Control Models with shortages EOQ Models with Quantity Discounts.
8. Nonlinear Programming: One and Multivariable Unconstrained Optimization. Conver Function. Kuhn-Tucker Conditions for Constrained Optimization.Convex Programming.Gradient Method.Steepest Descent Method.
9. Sequencing: Introduction. n jobs and two machines. n jobs and three machines.**[3]**

References

1. F.S. Hillier and G.J. Lieberman. Introduction to Operations Research, McGraw Hill International Edition.
2. G. Hadley. Linear Programming, Narosa Publishing House.
3. G. Hadley. Nonlinear and Dynamic Programming, Addision-Wesley, Reading Mass.
4. M. Bazaraa, John.J. Jarvis and H.D. Sherali. Linear Programming and Network Flows, John Wiley & Sons, New York.
5. H.A. Taha. Operation Research - An Introduction, Indian Edition.

Course Code: MTM-P15-Rc (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Rings of Continuous functions
Course Outcome: A student will learn about C-embedding and C*-embedding, Urysohn's extension theorem; Ideals of C(X) and z-filters on X, z-ideals and prime ideals; the result that C(X) is isomorphic to C(Y) for a completely regular space Y and any space X; Fixed and free ideals; C(X) determines X when X is compact; Convex and absolutely convex ideals; Real compact spaces; Stone-Cechcompactification. This will enable the student to take up research in the area of Rings of continuous function.

1.The rings C(X) and C*(X), Zero-sets and cozero-sets, Completely separated sets, C-embedding and C*-embedding, Urysohn's extension theorem and other related theorems.

2.Ideals of C(X) and z-filters on X, z-ideals and prime ideals.

3.For any space X, C(X) is isomorphic to C(Y) for a completely regular space Y, Compact sets in a completely regular space, Urysohn's lemma.

4. Fixed and free ideals, fixed maximal ideals of C(X) and C*(X), Characterization of compact spaces X by ideals of C(X) and C*(X), Two compact spaces X and Y are homeomorphiciff C(X) and C(Y) are isomorphic.

5. Convex and absolutely convex ideals, Infinitely large and infinitely small elements, Real and hyper-real ideals, Realcompact spaces.

6. Stone-Cechcompactification : Construction of βX and related theorems, The spaces βN, βQ and βR.

References

1. Rings of continuous functions – L. Gillman and M. Jerison
2. The Stone-Cechcompactification – Russell C. Walker

Course Code: MTM-P15-TG (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Topology and geometry
Course Outcome: A student will learn the basics of algebraic topology – homotopy, fundamental groups, convexity, simplex, simplical complex, free groups, covering spaces, lifting of homotopy maps; and differential geometry – co-ordinate charts, smooth manifolds, C^k manifolds, tangent spaces, cotangent spaces, submersion, immersion, tangent bundle, vector fields, exterior algebra, differential forms, simplical homology, homology for familiar spaces (circle, torus, projective space and Klain bottle etc), coboundary maps and cohomology computations induced maps and its functoriality. This will prepare a student for further studies in geometry and subjects like differential equations, mechanics, where these topics have applications. This course will also enhance the job opportunities in the areas of computational geometry, industrial research areas where shape geometry is required for example machine designing, fluid flows, etc.

Algebraic Topology

Introduction by mentioning the limitations of classification of Euclidean subspaces via compactness and connectedness.Homotopy of maps, homotopy equivalence, contractible spaces, homotopy of paths, fundamental groups, same homotopy type of spaces have isomorphic fundamental groups, homeomorphic spaces have isomorphic fundamental groups, induced map and its functorial properties. Retract, deformation retract and strong deformation retract, its properties. Fundamental group of product spaces.**[15]**

Convex subsets of Euclidean space, convex hull, simplex, open simplex and closed simplex, simplicial complex, examples, subcomplex, skeleton, barycentre, examples, existence of barycentric sub division (statement only), simplicial map and simplicial approximations (Statement only), fundamental group of a simplicial complex. **[8]**

Free groups, free abelian groups, free product, simple examples, simplified version of Van-Kampen theorem (statement only) for computation of fundamental groups of figure eight, sphere, torus, wedge of circles. **[5]**

Covering spaces, simple examples, path lifting and its uniqueness, lifting of path homotopy computation of fundamental group of unit circle, action of fundamental group of base space on the fibre, lifting criterion, classification of covering spaces.**[12]**

Differential Geometry

Differentiable maps on Euclidean spaces. Review of implicit and inverse function theorem on Euclidean spaces. Locally Euclidean spaces, Introduction to differentiable manifold, examples, examples via regular values.C^k-manifolds, coordinate systems, charts, differentiable maps. Tangent space of smooth manifold, equivalent definitions, examples, derivative of a map, regular values, submersions, immersions and its local forms. Tangent bundle, smooth vector fields, integral curves of smooth vector fields. cotangent spaces. Exterior algebra and differential forms and its local expressions, closed forms exact forms. **[20]**

Simplicial homology: Oriented simplex, chain complex, boundary maps, simplicial homology, computation of homology for familiar spaces (circle, torus, projective space and Klain bottle etc), coboundary maps and cohomology computations induced maps and its functoriality. **[10]**

de-Rhamcohomology, Poincare lemma, induced maps and its functorial properties, volume forms, oriented manifolds, existence of smooth partitions of unity (statement only), every smooth manifold can be made orientable. De-Rham's Theorem (statement only). **[10]**

References

1. M.P.DoCarmo : Differential geometry of Curves and surfaces.
2. U.C.Dey : Differential Geometry of Curves and Surfaces in E^3.
3. F. W. Warner : Foundations of Differential manifolds and Lie Groups, Springer.
4. S. Kumaresan : A Course on differential geometry and Lie Groups, Hindustan Book Agency.
5. W.M Boothby : An Introduction to Differential Manifolds and Riemannian Geometry and Lie Groups, Academic Press/ Reed Elsevier India.

Course Code: MTM-P19-AdFA (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Advanced Functional Analysis
Course Outcome: A student will learn about the distribution theory, Sobolev spaces, trace theorems; Second order elliptic equations, weak formulation, maximum principles, elementary variational inequalities, linear evolution problems, energy methods. This will prepare the students for solving physical, chemical and socio-economic problems that can be formulated using partial differential equations. Thus, it will help students to find employment in various areas like research labs, industrial researches, market analysis, etc.

1. Distribution theory, Sobolev spaces, embedding theorems, Rellich's lemma, trace theorems.

2. Second order elliptic equations – formulation of Dirichlet, Neumann and Oblique derivative problems, weak formulation, Lax-Milgram lemma, existence and regularity up to the boundary, maximum principle, elementary variational inequality.

3. Linear evolution equations, existence of weak solutions, energy methods.

References :

1. Adams :Sobolev Spaces.
2. Kesavan : Topics in Functional Analysis and applications.
3. Evans : Partial Differential Equations
4. Brezis : Functional Analysis, Sobolev spaces and partial differential equations.

Course Code: MTM-P19-AdNA (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Advanced Numerical Analysis
Course Outcome: A student will learn about advanced techniques on finite element and finite volume methods and to develop MATLAB codes to solve real life problems using these techniques. This will prepare the students for solving physical, chemical and engineering problems that can be formulated using partial differential equations. Thus, it will help students to find employment in various areas like research labs, industrial researches, software industries, etc.

(Theory, Full marks 30)

1. Finite difference schemes
   i. Stability, consistency and order of accuracy of numerical schemes.
   ii. Lax-Fredrichs, Lax-Wendroff, explicit and implicit schemes, Crank-Nicolson method, multi-dimensional problems.
   iii. Godunov, EnquistOsher, Roe's schemes, convergence results, numerical viscosity.
   iv. Upwind schemes of Vanleer, ENO schemes, Central schemes, Relaxation methods.

2. Finite Volume Methods. One dimensional scalar conservational laws, basic theory,Riemann problem and entropy condition.

3. Finite Element Methods for linear partial differential equations.
i. Elliptic equations - weak formulation, Lax-Milgram lemma, Galerkin approximation, basis function, energy methods and error estimates, Cea's estimate and BabuskaBrezzi theorem.
ii. Parabolic Equations – Galerkin Approximations, error estimates, a posteriori errorestimates for elliptic and parabolic equations.
iii. $h_p$elements, least square finite element method.

(Practical, Full marks 20)

1. Finite difference schemes
   a. Lax-Fredrichs, Lax-Wendroff, explicit and implicit schemes, Crank-Nicolson method, multi-dimensional problems.
   b. Godunov, EnquistOsher, Roe's schemes, convergence results, numerical viscosity.
   c. Upwind schemes of Vanleer, ENO schemes, Central schemes, Relaxation methods.

2. Finite Volume Methods. One dimensional scalar conservational laws, Riemann problem.

3. Finite Element Methods for linear partial differential equations - h_p elements.

References :

1. Burden, Faires and Raynolds : Numerical Analysis.
2. Young and Gregory : Survey of Numerical Methods, volume 1 and 2.
3. Strikwerda : Finite difference schemes and pdes.
4. Sod : Numerical methods in fluid dynamics.

5. Iserles : First course in numerical analysis of differential equations.
6. Godlewski and Raviart – hyperbolic conservation law,
7. Godlewski and Raviart – Numerical approximationof hyperbolic system of conservation laws.
8. Le Veque – Numerical methods for conservation laws,
9. Le Veque – Finite volume methodsfor hyperbolic problems.
10. Ern and Guermond : Theory and practice of Finite Elements.

Course Code: MTM-P19-ALT (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Algebraic Topology
Course Outcome: A student will learn about Identification space, Fundamental Groups and covering spaces, Van Campen Theorem, Homology, The Equivalence of Simplicial and Singular Homology. Degree, Cellular Homology. This will enable the student to take up further studies/research in this area.

1. **Identification space.**Identification topology.Construction of Torus.Mobius band.Kelin bottle.Projective space.Pn. Cones and suspension.General theorems.

2. **Fundamental Groups and covering spaces**. Homotopy of paths.The Fundamental Group.Covering spaces.The fundamental group of circle.Retractions and fixed points.The fundamental theorem of algebra.The BoursakUlam Theorem. Deformation retracts and homotopy type. The fundamental group of Sn and some standard surfaces.

3. **Van Campen Theorem**. Direct sums of Abelian groups.Free product of groups.Free groups. Van Campen Theorem. Fundamental group of wedge of circles.

4. **Homology. Δ** Complexes.Simplicial Homology. Singular Homology.Homotopy Invariance.Exact Sequences and Excision.The Equivalence of Simplicial and Singular Homology.Degree, Cellular Homology.Mayer-Vietoris Sequences.Homology with Coefficients.Axioms for Homology.Homology and Fundamental Group.

References

1. Algebraic Topology. Allen Hatcher.

2. Topology. James R.Munkres.

3. Fundamental Groups and covering spaces. ElonLages Lima.

4. Lecture Notes on Elementary Topology and Geometry: Singer and Thorpe.

Course Code: MTM-P19-Banop (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Banach algebra and operator theory
Course Outcome: The main content of this course is basic Banach Algebra theory and as its application spectral theory of a normal operator on Hilbert space. This is an extremely important subject in Advanced functional analysis and operator theory. Besides the Banach algebra theory has many remarkable applications in Harmonic analysis and complex analysis. So the course is useful for anyone who is intended to do research in these areas.

1. Review of finite dimensional spectral theory as a motivation for the course.
2. Banach Algebra: Abstract Banach algebra, example of Banach algebras, complex homomorphism and their properties, Basic properties of spectrum, spectral radius formula, Gelfand-Mazurtheorem, symbolic calculus and its application, spectral mappingtheorem.
3. Commutative Banach Algebra: Maximal ideal, its relation with complex homomorphism, Gelfand transform, involution, C*-algebra, Gelfand-Naimark theorem.
4. Bounded operators on Hilbert space: Basic definitions and properties related to operators onHilbert space, resolution of identity, spectral theorem, symbolic calculas fornormal operators, its application e.g. square root of positive operator, polar decompositionof an operator.
5. (If time permits) Positive functionals, characterization of C*-algebra: Gelfand-Naimark-Segal construction.

References :
[1] Functional Analysis - W. Rudin
[2] A course in abstract harmonic analysis - G. B. Folland

Course Code: MTM-P19-Har (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Harmonic Analysis
Course Outcome: A student will learn about Fourier series on the Circle group, its convergence; decay conditions, regularity conditions; Cesaro summability, Abel summability and its application to Dirichlet's problem on a disc; Fourier series of an L^p function, Euclidean Fourier transform, Interpolation theorem, Schwartz Space, tempered distributions. This will help the student to take up studies in the advanced topics on partial differential equations, numerical analysis, etc. This course will also enhance a student's opportunity in employment in various research labs, software industries, industries involving solving of differential equations (like automobile, hydraulic, petroleum, etc.).

1. Fourier series on the Circle group: Definition of Fourier coefficient of a integrablefunction on the circle group, associated Fourier series, relation between the properties ofa function with those of the Fourier coefficients, uniqueness of Fourier series i.e. a functionvanishes if and only if all of its
Fourier coefficients vanish.
2. Point wise and uniform convergence of a Fourier series: Point wise or uniform convergenceof Fourier series under the hypothesis that the Fourier coefficients satisfy differentkind of decay conditions or the function satisfies different type of regularity conditions. Inparticular, Dirichlet's Theorem, Jordan's Theorem, Dirichlet-Dini criterionetc. Exampleof functions whose Fourier series diverges when the related hypothesis are violated.For example Du Bois-Reymond Theorem.
3. Cesaro summability of Fourier series: The Dirichlet and Fejer kernels, their properties,Fejer's Theorem regarding the Cesaro summability of Fourier series
4. Abel summability of Fourier series and its application to Dirichlet's problem on a disc: Poisson's kernel, Poisson's integral, Poisson's Theorem i.e. Fourier series of a continuousfunction is Abel summable, solution of the Laplace equation on a disc (Dirichlet'sproblem).
5. Fourier series of anL^p function: Riemann-Lebesgue lemma for an integrable function, Plancherel's Theorem for L^2 function, Fourier series of an L^p function convergence to the function in the L^p norm, provided $1 < p < 1$. But this is not true if $p = 1$.
6. Euclidean Fourier transform: Basic properties of Fourier transform, recovering afunction from the Abel and Gauss means of its Fourier transform, Inversion formula, Plancherel's theorem, Paley-Wiener theorem.
7. Interpolation theorem, Hausdorff-Young inequality for Fourier transforms, its proofusing interpolation theorem.
8. (If time permits) Schwartz Space, tempered distributions and their Fourier transform.

References:
[1] Functional Analysis - W. Rudin
[2] A course in abstract harmonic analysis - G. B. Folland

Course Code: MTM-P19-MCON (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Mechanics of Continua
Course Outcome: The student will learn the concept of stress and strain and their analysis for solid bodies. Also students will have the concept of fluid dynamics, kinematics of fluid flow. This course will help the students in advance courses on solid mechanics and fluid mechanics.

Solid Mechanics (25 marks)

Forces in a continuum, Stresses, Stress tensor, GeneralisedHooke's Law, Principle of conservation of mass, Equation of motion, Symmetry of stress tensor, Stress transformation laws, Principal stress and Principal axes of stresses, Stress invariant, Cauchy's stress quadraic, Shearing stresses, Mohr's stress circle, Relation between stress and strain.

Deformation, Two description : Lagrangian and Eulerian, Analysis of strain and strain tensor, Infinitesimal strain and small deformation, Geometrical interpretation of infinitesimal strain components, Finite strain tensor, dilatation, strain transformation laws, Principal strain and Principal axes of strains, Strain invariants, Compatibility condition.

Plane stress and Plane Strain.

Fluid Mechanics(25 marks)

General Description: Some Basic Properties of The Fluids, Viscous (Real) and Inviscid (Perfect, Ideal) Fluid, Viscosity, Newtonian and Non-Newtonian fluids.

Some important types of flows:
1. Laminar (Stream line) and Turbulent flows.
2. Steady and Unsteady flows.
3. Uniform and Non-Uniform flows.
4. Rotational and Irrotational flows.
5. Barotropic flow.

Some useful result of vector analysis, some orthogonal coordinate systems:
1. Cartesian.
2. Spherical polar.
3. Cylindrical polar coordinates.

Kinematics of Fluid Motion: Euler's and Lagrange's method of describing Fluid motion, Velocity and Acceleration of a Fluid particle. The equation of Continuity (or Equation of Conservation of Mass) by Euler's and Lagrange's method, Conditions at the Boundary Surface, Stream Line and Path line, Filament Line, Velocity Potential, Vorticity Vector, Vortex Line, Rotational and Irrotational Motion. Lagrange's and Euler's Equation of Motion of inviscid Fluids, Impulsive Action.

Bernoulli's Theorem: Bernoulli's Equation, Euler's Momentum Theorem, D'Alembert's Paradox, Cauchy's Integral.

Motion in Two Dimensions: Stream or Current Function, Sources and Sinks, Doublets (or Dipoles) in Two Dimensions, Images, Image of a Source (or Sink) with respect to a Straight Line and Circle, Image of a Doublet with regard to a Straight Line and Circle, Milne-Thompson's Circle Theorem, Blasius Theorem.

References

1. Y.C.Fung- A First Course in Continuum Mechanics.
2. R.N.Chatterjee – Continuum Mechanics.
3. A.C.Eringin- Mechanics of Continuua.
4. G.E.Mase – Continuum Mechanics.
5. L.I.Sedov – A Course in Continuum Mechanics.
6. M.Filonenko-Brodich – Contimuum Mechanics.
7. D.S.ChandrasekhariahandL.Debnath – Continuum Mechanics.
8. W.Prager – Mechanics of Continuous Media.
9. Sokolnikov- Theory of Elasticity
10. Love- Theory of Elasticity

Course Code: MTM-P19-NQM (Credit: 4, Full Marks: 50, 60 hours)

Name of the Course: Non-Relativistic Quantum Mechanics

Course Outcome: A student will learn the basic concepts of the postulates of quantum mechanics, solution of Schrodinger's equation (1dimension), use of operators to solve different mechanical problems and symmetry in quantum mechanics. This course is the basic requirement for higher studies in quantum mechanics.

Course required: Classical Mechanics and Functional Analysis.

Postulates of Quantum Mechanics, De Broglie's Wave, Heisenberg's principle of uncertainty. Probabilistic description, Schrödinger equation: Square well potential, One dimensional harmonic oscillator, Minimum uncertainty product. Momentum Eigen functions, Box normalization, Orbital angular moment, Different approaches to quantum mechanics: Schrödinger representation, Heisenberg approach, Harmonic oscillator and Angular momentum operator, Hydrogen atom,

Symmetry in Quantum Mechanics: Unitary displacement operator, Equation of motion, Symmetry and degeneracy, Matrix elements for displaced states. Time displacement. Proper rotation group, Geometrical isomorphism, Infinitesimal rotations. Spin of a vector particle. Commutation relations for the generators, Choice of a representation, Values of m, f(j), and λ_m. Angular momentum matrices. Connection with spherical harmonics. Spin angular momentum. Covering group. Unitary and special unitary groups in two dimensions. The groups U(n) and SU(n) Generators of U(n) and SU(n). The SU(3) group. Representation in terms of coordinates and momenta.

Complex vector space and Dirac Notation, Bra-space: Inner product, outer product: associated axiom, Matrix representation , Uncertainty principle.

Reference:

1. L.I.Schiff: " Quantum Mechanics" (Mc Graw Hill)
2. R. Shankar. "Principles of Quantum mechanics"
3. P.J.E. Peebles "Quantum Mechanics " (Prentice Hall)
4. L.H.Ballentine "Quantum Mechanics " (World Scientific)
5. Y.R.Waghmare: " Fundamentals of Quantum Mechanics" (Wheeler Publications)
6. P.A.M Dirac: "The Principles of Quantum Mechanics".

Course Code: MTM-P19-PS (Credit: 4, Full Marks: 50, 60 hours)
Name of the Course: Probability theory and statistics
Course Outcome: A student will learn about probability spaces, random variables, distributions, correlation, regression, central limit theorem, measures, conditional probability, estimation and hypothesis testing. This will enable a student to go for further studies in probability, statistics, quantum mechanics, probability measures, economics, etc. This course will also enhance the employment opportunity of a student in the areas where statistical inferences are required, for example in economic planning, market survey, future estimation and trend, share market, etc.

1. Probability spaces, events and sigma-fields, random variables and distribution functions.
2. Discrete and continuous random variables, expectation, variance and moments of random variables.
3. Random vector, joint distribution and independence, covariance, correlation and regression.
4. Generating functions, characteristic function and inversion formula.
5. Convergence of random variables and vectors, central limit theorem.
6. Absolutely continuous measures, Radon-Nikodym derivative, conditional probability and expectation, Bayes formula.
7. Methods of estimation, sufficiency and completeness, unbiased estimators, Rao-Blackwell and Lehmann-Scheffe theorems, Rao-Cramer lower bound, maximum likelihood estimator, method of moments, Bayes and minimax estimators, consistency and asymptotic normality of estimators.
8. Hypothesis testing, Neyman-Pearson lemma and most powerful tests, uniformly most powerful
   tests, monotone likelihood ratio property, unbiased tests, likelihood ratio tests, confidence intervals, hypothesis testing in the multivariate and multiparameter situations.

References

1. Introduction to the Theory of Probability and its Applications (Vols. 1 and 2) – W. Feller.
2. Introduction to Probability Theory – P. G. Hoel, S. C. Port and C. J. Stone.
3. Probability and Measure – P. Billingsley.
4. Mathematical Statistics – P. J. Bickel and K. A. Doksum.
5. Statistical Inference – G. Casella and R. L. Berger.
6. Theory of Point Estimation – E. L. Lehmann.
7. Testing Statistical Hypothesis – E. L. Lehmann.
8. Linear Statistical Inference – C. R. Rao.