Central University of Punjab, Bathinda

Course Scheme & Syllabus

for

M.Sc. MATHEMATICS

Scheme of Programme for M.Sc. Mathematics

SEMESTER- I

S. No	Course Code	Course Title	L	T	P	Cr
1	STA.506	Probability and Distribution Theory	4	-	-	4
2	MAT.506	Real Analysis	4	-	-	4
3	MAT.507	Topology	4	-	-	4
4	MAT.508	Linear Algebra	4	-	-	4
5	MAT.509	Differential Equations	4	-	-	4
6	XYZ	Inter-Disciplinary Elective -1 (From Other Departments	2	-	-	2
7	MAT.503	Basics of Latex	-	-	2	1
	Interdisciplinary courses offered by Mathematics Faculty (For PG students of other Departments)					
8	MAT.510	Basic Mathematics (IDC)	2	-	-	2
			22	**-**	**2**	**23**

C_A**:** Continuous Assessment: Based on Objective Type Tests (10%) / Assignments (5%)/Term Paper (10%)

M_1: Mid-Term Test-1: Based on Subjective Type Questions (25%)

M_2: Mid-Term Test-2: Based on Subjective Type Questions (25%)

E_T: End-Term Exam (Final): Based on Objective Type Questions (25%)

T_M: Total Marks

C: Core; E: Elective; F: Foundation; VAC: Value Added Course, L: Lectures; T: Tutorial; P: Practical; Cr: Credits**.** I_E**:** Interdisciplinary elective

TRANSACTION MODE: Lecture/Demonstration/Co Operative learning/ Group discussion/Team teaching/Tutorial/Problem solving/E-team teaching/Self-learning.

SEMESTER- II

S. No	Course Code	Course Title	L	T	P	Cr
1	MAT.521	Computer Fundamentals and C Programming	3	0	0	3
2	MAT.522	Computer Fundamentals and C Programming (Practical)	0	0	2	1
3	MAT.523	Algebra – I	4	-	-	4
4	MAT.524	Measure Theory	4	-	-	4
5	MAT.525	Differential Geometry of Curves and Surfaces	4	-	-	4
6	MAT.526	Complex Analysis	4	-	-	4
7	MAT.527	Mechanics	2	-	-	2
8	XYZ	Humanities for Science Students (From Other Departments)	2	-	-	2
Interdisciplinary course offered by Mathematics faculty for PG students other centres						
9	MAT.528	Linear Programming (IDC)	2	-	-	2
	MAT.529	Numerical Methods (IDC)	2	-	-	2
			23	-	**2**	**24**

C_A**:** Continuous Assessment: Based on Objective Type Tests (10%) / Assignments (5%)/Term Paper (10%)

M_1: Mid-Term Test-1: Based on Subjective Type Questions (25%)

M_2: Mid-Term Test-2: Based on Subjective Type Questions (25%)

E_T: End-Term Exam (Final): Based on Objective Type Questions (25%)

T_M: Total Marks; C: Core; E: Elective; F: Foundation; L: Lectures; T: Tutorial; P: Practical; Cr: Credits**.** I_E**:** Interdisciplinary elective

TRANSACTION MODE: Lecture/Demonstration/ Co Operative learning/ programming/Practical/ Group discussion/Team teaching /Experimentation/ Tutorial/Problem solving/Self-learning.

Semester-III

S. No	Course Code	Course Title	L	T	P	Cr
1	MAT.560	Research Methodology	4	-	-	4
2	MAT.551	Algebra-II	4	-	-	4
3	MAT.552	Calculus of Variation and Integral Equation	4	-	-	4
4	MAT.553	Numerical Analysis	3	-		3
	MAT.554	Numerical Analysis (Practical)			2	1
5	STA.557	Operations Research	4	-	-	4
6	MAT.543	Seminar-I	-	-	-	1
7	MAT.555	Differential Topology	4	-	-	4
	MAT.556	Advanced Complex Analysis				
	MAT.557	Advanced Partial Differential Equations				
	MAT.558	Discrete Mathematics				
	MAT.559	Number Theory				
			21	-	**2**	**25**

C_A**:** Continuous Assessment: Based on Objective Type Tests (10%) / Assignments (5%)/Term Paper (10%)

M_1: Mid-Term Test-1: Based on Subjective Type Questions (25%)

M_2: Mid-Term Test-2: Based on Subjective Type Questions (25%)

E_T: End-Term Exam (Final): Based on Objective Type Questions (25%)

T_M: Total Marks

C: Core; E: Elective; F: Foundation; L: Lectures; T: Tutorial; P: Practical; Cr: Credits**.** I_E**:** Interdisciplinary elective

TRANSACTION MODE: Lecture/Demonstration/ Co Operative learning/ programming / Practical /Seminar/Group discussion/Team teaching

/Experimentation/Tutorial/Problem solving/E-team teaching/Self-learning.

One MOOC course will be offered from 1st Semester to 3rd Semester Semester-IV

S. No	Course Code	Course Title	L	T	P	Cr
1	MAT.571	Functional Analysis	4	-	-	4
2	MAT.599	Project Work		-	12	6
3	MAT.544	Seminar-II			-	1
4	MAT.572	Riemannian Geometry	4	-	-	4
	MAT.573	Fluid Mechanics				
	MAT.574	Advanced Numerical Analysis				
	MAT.575	Algebraic Topology				
	MAT.576	Lie Groups and Lie Algebra				
	MAT.577	Finite Element Analysis				
5	MAT.578	Fundamentals of Analysis and Linear algebra	**-**	-	**4**	**2**
6	MAT.579	Fundamentals of Applied Mathematics	**-**	-	**4**	**2**
7	XYZ	Value Added Course	**1**	-	**-**	**1**
8	XYZ	Value Added Course 2	**1**	-	**-**	**1**
			10		**20**	**21**

C_A**:** Continuous Assessment: Based on Objective Type Tests (10%) / Assignments (5%)/Term Paper (10%)

M_1: Mid-Term Test-1: Based on Subjective Type Questions (25%)

M_2: Mid-Term Test-2: Based on Subjective Type Questions (25%)

E_T: End-Term Exam (Final): Based on Objective Type Questions (25%)

T_M: Total Marks

C: Core; E: Elective; F: Foundation; DEC: Discipline Enrichment Courses, L: Lectures; T: Tutorial; P: Practical; Cr: Credits**.** I_E**:** Interdisciplinary elective

TRANSACTION MODE: Lecture/Demonstration/Project Method/ Co Operative learning/ Seminar/Group discussion/Team teaching /Experimentation/Tutorial/Problem solving/E-team teaching/Self-learning.

Semester-I

Course Title: Probability and Distribution Theory

Course Code: STA.506

Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objectives: The course is designed to equip the students with knowledge of various probability distributions and to develop skills and understanding of various inequalities for further studies.

Unit I **(14 Hours)**

Random experiments, sample spaces (finite and infinite), events, algebra of events, three basic approaches to probability, combinatorial problems. Axiomatic approach to probability. Product sample spaces, conditional probability, Bayes' formula.

Unit II **(16 Hours)**

Bernoulli trials, random variables (discrete and continuous). Distribution Function and its properties, mean and variance. Discrete Distributions: Bernoulli, binomial, Poisson, hyper-geometric, geometric, negative binomial, uniform. Continuous Distributions: Uniform, normal, exponential, gamma, Beta, Cauchy, Weibull, Pareto, Laplace and Lognormal.

Unit III **(15 Hours)**

Bivariate random variable and their joint, marginal and conditional p.m.fs. and p.d.fs, correlation coefficient, conditional expectation. Bivariate normal distributions. Moment generating and probability generating functions. Functions of random variables and their distributions using Jacobian of transformation and other tools. Probability Integral transformation, order statistics and their distributions (continuous case only).

Unit IV **(14 Hours)**

Markov's, Chebychev's, Holder's, Jensen's and Liapounov's inequalities. Convergence in probability and in distribution, Weak law of large numbers. Central limit problem; De-Moivre-Laplace and Lindberg-Levy forms of central limit theorem. Approximating distribution of a function of a statistic (Delta method).

Recommended Books:

1. V. K. Rohtagi and A. K. M. E. Saleh, *An Introduction to Probability Theory and Mathematical Statistics*, Wiley Eastern, 2010.
2. I. Miller and M. Miller, *Mathematical Statistics,* 6th Edition, Oxford & IBH Pub., 1999.
3. S. M. Ross, *Introduction to Probability Models*, 11th Edition, 2014.

Suggested Readings:

1. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley International Student Edition, 1988.
2. P. Billingsley, *Probability and Measure*, 4th Edition, John Wiley & Sons, 2012.

Course Title: Real Analysis
Course Code: MAT.506
Total Lectures: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective: The aim of this course is to make the students learn fundamental concepts of metric spaces, Riemann-Stieltjes integral as a generalization of Riemann Integral, Sequence and series of functions and some basic theorems.

Unit-I **(15 Hours)**

Set Theory: Finite, countable and uncountable sets, Real number system as a complete ordered field, Archimedean property, supremum, infimum

Metric spaces: Definition and examples, Open and closed sets, Compact sets, Elementary properties of compact sets, k- cells, Compactness of k-cells, Compact subsets of Euclidean space $\Re^k$, Bolzano Weierstrass theorem, Heine Borel theorem, Perfect sets, Cantor set, Separated sets, Connected sets in a metric space, Connected subsets of real line.

Unit-II **(15 Hours)**

Sequences in Metric spaces: Convergent sequences, Subsequences, Cauchy sequences, Complete metric space, Cantor's intersection theorem, Category of a set and Baire's category theorem. Examples of complete metric space, Banach contraction principle.

Unit-III **(15 Hours)**

Continuity: Limits of functions (in Metric spaces), Continuous functions, Continuity and compactness, Continuity and connectedness, Discontinuities, Monotonic functions, Uniform continuity.

Riemann Stieltje's Integral: Definition and existence of Riemann Stieltje's integral, Properties of integral. Integration and Differentiation. Fundamental Theorem of Calculus, 1st and 2nd Mean Value Theorems of Riemann Stieltje's integral.

Unit-IV **(15 Hours)**

Sequences and series of functions: Problem of interchange of limit processes for sequences of functions, Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation, equicontinuous families of functions, Stone Weierstrass Theorem.

Recommended Books

1. Walter Rudin, *Principles of Mathematical Analysis,* 3rd Edition, McGraw Hill, Kogakusha, International student Edition, 1976.
2. S. C. Malik and S. Arora, *Mathematical Analysis*, New Age International Ltd., UK, 2017.

Suggested Readings

1. E. C. Titchmarsh, *The Theory of functions,* Oxford University Press, Oxford, 2002.
2. Tom M. Apostol, *Mathematical Analysis*, Addition –Wesley, USA, 1981.
3. Ajit Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, Narosa, Publishing House, New Delhi, 2014.
4. R. G. Bartle, *The Elements of Real Analysis*, John Willey and Sons, New York, 1976.

Course Title: Topology
Course Code: MAT.507
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective: The course is an introductory course on point-set topology. It is designed in such a way that the students will have a working knowledge in general topology and be able to understand more advanced topics like Algebraic Topology, Differential Topology, Riemannian Geometry and allied areas.

Unit-I **(16 Hours)**

Topological spaces: Open sets, Closed sets, Neighborhoods, Bases, Sub bases, Limit points, Closures, Interiors, Continuous functions, Homeomorphisms. Examples of topological spaces: Subspace topology, Product topology, Metric topology, Topological manifolds. Quotient Topology: Construction of cylinder, Cone, Mobius band and Torus.

Unit-II **(15 Hours)**

Connected spaces, Connected subspaces of the real line, Components and path components, Local connectedness. Compact spaces, Sequentially compact spaces, Heine-Borel theorem, Compact subspaces of the real line, Limit point compactness, Local–compactness and one point compactification.

Unit-III **(15 Hours)**

The Countability axioms: Separable spaces, Lindelöf spaces. Separation axioms: Hausdorff spaces, Regularity, Complete regularity, Normality, Urysohn lemma, Urysohn metrization theorem, Tietze extension theorem and Tychnoff theorem.

Unit-IV **(14 Hours)**

Covering spaces, Local finiteness, Refinement, The Nagata-Smirnov metrization theorem, Paracompactness, Partition of unity, The Smirnov metrization theorem.

Recommended Books:

1. J. R. Munkres, *Topology,* Second Edition, Pearson India Education services Pvt. Ltd., 2015.
2. M. A. Armstrong, *Basic Topology*, Paperback Edition, Springer, 2004.
3. S. Kumaresan, *Topology of Metric Spaces,* second edition, Narosa Publishing House New Delhi, 2015.

Suggested Readings

1. K. D. Joshi, *Introduction to General Topology*, Wiley Eastern, Delhi, 1986.
2. M. G. Murdeshwar, *General Topology*, Wiley Eastern, New Delhi, 1983.
3. G. F. Simmons, *Introduction to Topology & Modern Analysis*, McGraw Hill, Auckland, 1963.
4. James Dugundji, *Topology,* Universal Book Stall, New Delhi, 1990.
5. S. Willord, *General Topology,* Philippines: Addison Wesley Publishing Company, 1970.

Course Title: Linear Algebra
Course Code: MAT.508
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective

The main objective is to introduce basic notions in linear algebra that are often used in mathematics and other sciences. The emphasis will be to combine the abstract concepts with examples in order to intensify the understanding of the subject.

Unit I **(15 Hours)**

Vector spaces, Subspaces, Linear dependence and independence, Basis and dimensions, Coordinates, Linear transformations, Algebra of linear transformations, Isomorphism, Matrix representation of a linear transformation, Change of basis, Rank and nullity of a linear transformation. Linear functionals, Dual spaces, Transpose of a linear transformation.

Unit I **(16 Hours)**

Characteristic polynomial and minimal polynomial of a linear transformation, Characteristic values and Characteristic vectors of a linear transformation, Cayley Hamilton theorem, Invariant subspaces, Diagonalization and triangulation of a matrix, Direct sum of subspaces, Invariant Direct sums, Characteristic polynomial and minimal polynomial of block matrices.

Unit III **(15 Hours)**

Cyclic subspaces and Annihilators, Canonical forms: Jordan canonical forms, rational canonical forms. Quotient spaces, Bilinear forms, Symmetric and skew-Symmetric bilinear forms, Sylvester's theorem, quadratic forms, Hermitian forms. Reduction and classification of quadratic forms.

Unit IV **(14 Hours)**

Inner product spaces. Norms and distances, Orthonormal basis, Orthogonality, Schwartz inequality, The Gram-Schmidt orthogonalization process. Orthogonal and positive definite matrices. The Adjoint of a linear operator on an inner product space, Normal and self-adjoint operators, Unitary and orthogonal operators.

Recommended Books:

1. K. Hoffman and R. Kunze: *Linear Algebra,* 2nd Edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2004.
2. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory,* Cengage Learning, 2004.

Suggested Readings:

1. I. N. Herstein, *Topics in Algebra,* 2nd Edition, Wiley Eastern Limited, New Delhi, 2006.
2. P. B. Bhattacharya, S.K. Jain and S.R. Nagpaul, *First Course in Linear Algebra,* Wiley Eastern, Delhi, 2003.
3. V. Bist and V. Sahai, *Linear Algebra,* Narosa, Delhi, 2002.

Course Title: Differential Equations
Course Code: MAT.509
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective

The objective of this course is to equip the students with knowledge of some advanced concepts related to differential equations and to understand some basic approaches to solve the ordinary and partial differential equation.

Unit-I **(15 Hours)**

Initial value problem, boundary value problems, Lipchitz's condition, dependence of solution on initial conditions and on function. Existence and Uniqueness theorem (Picard's Method), non local existence of solutions.

General theory of homogenous and non-homogeneous linear ODEs: Solution of Linear homogeneous equations; Wronskian and linear independance, Reduction of the order of equation, Non-Homogeneous equations: Method of undetermined coefficients, Variation of parameters.

Unit-II **(14 Hours)**

Series Solutions of Second Order Linear Equations: Ordinary points, Regular and Irregular Singular points of second order linear ODEs, Power series solution near an ordinary point, Cauchy-Euler Equations, Solutions about Singular Points; The Method of Frobenius

Unit-III **(14 Hours)**

Total differential equations, Simultaneous differential equations, Adjoint and self adjoint equations, Green's function and its applications to boundary value problems, Sturm Liouville's boundary value problems. Sturm comparison and separation theorems, Orthogonal solutions.

Unit-IV **(17 Hours)**

Classification of partial differential equations (PDEs), Cauchy's problem and Characteristics for first order PDEs, Lagrange's linear PDEs, Charpit's and Jacobi's method. General solution of higher order linear PDEs with constant coefficients, separation of variables method for Laplace, Heat and wave equations.

Recommended Books:

1. L. C. Evans, *Partial Differential Equations. Graduate Studies in Mathematics*, 2nd Edition, American Mathematical Society, Indian Reprint, 2014.
2. I. N. Sneddon, *Elements of Partial Differential Equations*, McGraw-Hill, 2006.
3. S. L. Ross, *Differential Equations*, 3rd Edition, Wiley, 1984.
4. M. D. Raisinghania, *Advanced Differential Equations*, 5th Edition, S. Chand & Company Ltd., New Delhi, 2010.

Suggested Readings:

1. E. A. Coddington and N. Levinson Theory of ordinary differential equations. McGraw-Hill Book Company, Inc., New York-Toronto-London, 1955.
2. E. B. Williams and C. DiPrima Richard, *Elementary Differential Equations and Boundary Value Problems*, 8th Edition, John Wiley and Sons, New York, 2005.
3. W.T. Reid, *Ordinary Differential Equations*, John Wiley and Sons, New York, 1971.

Course Title: Basics of LaTeX
Course Code: MAT.503
Total Hours: 30

L	T	P	Cr	Marks
0	0	2	1	25

Objectives

The main objective of this course is provide a basic knowledge of LaTex and its various applications in teaching and research.

Unit-I **(8 Hours)**

Installation of the software LaTeX, Understanding LaTeX compilation and LaTeX editors, Basic syntax, Writing mathematical equations, Matrices, Tables, Inclusion of graphics into LaTeX file.

Unit-II **(8 Hours)**

Page configurations: Title, Abstract, Keywords, Chapter, Sections and Subsections, References and their citations, Labeling of equations, Table of contents, List of figures, List of tables, Page numbering, Generating index.

Unit-III **(6 Hours)**

Packages: amsmath, amssymb, amsthm, amsfonts, hyperrefer, graphic, color, xypic, latexsym, natbib, setspace, multicol, subcaption, url, verbatim, tikz, and geometry.

Classes: Article, Report, Book, Letter, Slides, Beamer.

Unit-IV **(8 Hours)**

Applications to: Writing reports, books, articles/ research papers, thesis, and official letters. Making simple and modern resumes, figures, question papers, and presentations.

Recommended Books:

1. L. Lamport. LATEX: A Document Preparation System, User's Guide and Reference Manual. 2nd Edition, Addison Wesley, New York, 1994.
2. D. F. Griffiths and D. J. Higham, *Learning LaTex, 2nd Edition,* Philadelphia, Pensylvania, SIAM, 1997.

Suggested Readings:

1. M. Goossens, F. M. Michel, and S. Alexander, The LaTeX companion, 2nd Edition, Addison-Wesley, 1994.

Course Title: Basic Mathematics (IDC)
Course Code: MAT.510
Total Hours: 30

L	T	P	Cr	Marks
2	0	0	2	50

Objective: The objective of this course is to provide the understanding of basic mathematical techniques for the post graduate students of the other departments.

Unit-I **(08 Hours)**

Sets: Basic Definitions, subsets, power set, set operations. Ordered pairs, Cartesian product of sets.

Functions and Relations: Definition of relation, domain, co-domain and range of a relation. Binary relations, equivalence relations, partition. Function as a special kind of relation from one set to another. Domain, co-domain and range of a function. composition, inverse. Real valued function of the real variable, constant, identity, Polynomial, rational, Functions.

Unit-II **(07 Hours)**

Sequence and series, Arithmetic Progression (A.P), Arithmetic Mean (A.M), Geometric Progression (G.P), general term of a G.P, sum of n terms of a G.P. Arithmetic and Geometric series, infinite G.P. and its sum. Geometric mean (G .M), relation between A.M and G.M.

Unit-III **(08 Hours)**

Need for complex numbers, especially $\sqrt{-1}$, to be motivated by inability to solve every Quadratic equation. Brief description of algebraic properties of complex numbers. Argand plane and polar representation of complex numbers, Statement of Fundamental Theorem of Algebra, n^{th} roots of unity.

Unit-IV **(07 Hours)**

Matrices and types of matrices, Operations on Matrices, Determinants of Matrix and Properties of Determinants, Minors and Cofactor and Adjoint of a square matrix, Singular and non-singular Matrices, Inverse of a Matrix, Eigen values and Eigen vectors, Cayley Hamilton theorem.

Recommended Books:

1. R.K. Jain and S.R.K. Iyengar, *Advanced Engineering Mathematics*, 8^{th} Edition, Narosa Publications, 2002.
2. G. B. Thomas and R. L. Finney, *Calculus and Analytic Geometry*, 11^{th} edition, Pearson India, 2015.

Suggested Reading Books:

1. E. Kreyszig, *Advanced Engineering Mathematics*, 9th edition, John Wiley & Sons, Inc., 2006.
2. P. K. Jain, *Mathematics: Text book for class XI*, NCERT, 2006.

Semester-II

Course Title: Computer Fundamentals and C Programming
Course Code: MAT.521
Total Hours: 45

L	T	P	Cr	Marks
3	0	0	3	75

Objectives: The aim of this course is to provide adequate knowledge of fundamentals of computer along with problem solving techniques using C programming. This course provides the knowledge of writing modular, efficient and readable C programs. Students also learn the utilization of arrays, structures, functions, pointers, file handling and their applications.

Unit-I **(10 Hours)**

Computer Hardware: Definitions, Historical overview, Technological advancement in computers, Shape of today's computer, Computer as a system. CPU, Primary memory, Secondary storage devices, Input and output devices,

Unit-II **(11 Hours)**

Computer Software: Significance of software in a computer system, Categories of software – System software, Application software, Compiler, Interpreter, Utility program, Binary arithmetic for integer and fractional numbers, Operating System and its significance.
Introduction to the algorithm, Flowcharts, Problem-solving methods, Need of programming languages.

Unit-III **(12 Hours)**

C Programming: Historical development of C, C character set, Identifiers and keywords, Data types, Declarations, Statement and symbolic constants, Input-output statements, Preprocessor commands, Operators, Expressions, Library functions, Decision making and loop control statements

Unit-IV **(12 Hours)**

C Programming: Functions, Storage Classes, Arrays, Strings, Pointers, Structure and Union, File handling.

Recommended Books:

1. P. Norton, *Introduction to Computers*, Tata McGraw Hill, 2008.
2. B. W. Kernighan and D.M. Ritchie, *The C Programming Language*, 2nd Edition, PHI, New Delhi, 2011.

Suggested Readings:

1. Y. Kanetkar, *Let Us C*, 13th Edition, BPB Publications, 2013.
2. V. Rajaraman, *Fundamentals of Computers*, PHI, 2004.
3. G.B. Shelly, T.J. Cashman and M.E. Vermaat, *Introduction to Computers*, Cengage India Pvt Ltd, 2008.

Course Title: Computer Fundamentals and C Programming (PRACTICAL)

Course Code: MAT.522

L	T	P	Cr	Marks
0	0	2	1	25

Total Hours: 30

Laboratory experiments will be set in context with the materials covered in the theory.

Course Title: Algebra – I
Course Code: MAT.523
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective:
This course provides the foundation required for more advanced studies in Algebra and other branches of mathematics. The aim is also to develop necessary prerequisites for course Algebra-II.

Unit I **(15 Hours)**
Fundamental theorem of arithmetic, divisibility in Z, congruences, Chinese Remainder Theorem, Euler's Ø- function, primitive roots.
Group Theory: Review of basic concepts of Groups, Subgroups, Normal subgroups, Quotient groups, Homomorphism, Cyclic groups, Permutation groups, Even and odd permutations, Conjugacy classes of permutations, Alternating groups, Cayley's Theorem, Class equations.

Unit II **(15 Hours)**
Normal and Subnormal series, Composition series, Solvable groups, Nilpotent groups. Direct products, Fundamental theorem for finite Abelian groups, Sylow theorems and their applications, Survey of some finite groups, Groups of order p^2, pq (p and q primes)

Unit III **(14 Hours)**
Ring theory: Review of rings, Elementary properties of Rings, Zero Divisors, Nilpotent and idempotent elements, Characteristic of rings, Ideals, Ring homomorphism, Maximal and prime ideals, Nilpotent and nil ideals, Zorn's Lemma.

Unit IV **(16 Hours)**
Polynomial rings in many variables, Factorization of polynomials in one variable over a field. Unique factorization Domains. Euclidean and Principal ideal Domains. Gauss lemma, Eisenstein's irreducibility criterion, Unique factorization in R[x], where R is a Unique factorization domain.

Recommended Books:

1. J. A. Gallian, *Contemporary Abstract Algebra,* Narosa Publishing House, New Delhi, 2008.
2. I. N. Herstein, *Topics in Algebra*, 2nd Edition, Wiley Eastern Limited, New Delhi, 2006.

3. P. B. Bhattacharya, S.K. Jain and S.R Nagpal, *Basic Abstract Algebra*, Cambridge University Press, New Delhi, 2003.

Suggested Readings:

1. T. W. Hungerford, *Algebra*, Springer, New York, 1974.
2. M. Artin, *Algebra,* 2nd Edition, Prentice Hall of India, Delhi, 2011.
3. S. Surjeet and Q. Zameeruddin, *Modern Algebra,* 8th Edition, Vikas Publishing House, New Delhi, 2006.

Course Title: Measure Theory
Course Code: MAT.524
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective: The objective of this course is to introduce the fundamentals of measure theory in an abstract setting after having studied Lebesgue measure on real line so that students can understand more advanced topics in mathematics as well as statistics.

Unit-I **(15 Hours)**

Semi-algebras, Algebras, Monotone class, σ -algebras, Measure and outer measures, Caratheödory extension process of extending a measure on semi-algebra to generated σ -algebra, Completion of a measure space.

Unit-II **(15 Hours)**

Borel sets, Lebesgue outer measure and Lebesgue measure on R, Translation invariance of Lebesgue measure, Characterizations of Lebesgue measurable sets, Countable additivity, Continuity of measure and Borel-Cantelli Lemma, Existence of a non-measurable set, Measurability of Cantor set.

Unit-III **(15 Hours)**

Measurable functions on a measure space and their properties, Borel and Lebesgue measurable functions, Simple functions and their integrals, Littlewood's three principle and Egoroff's Theorem (statement only), Lebesgue integral on R and its properties.

Unit-IV **(15 Hours)**

Bounded convergence theorem, Fatou's lemma, Lebesgue monotone convergence theorem, Lebesgue dominated convergence theorem, countable additivity and continuity of integration, uniform integrability: the Vitali convergence theorem. Functions of bounded variations: Jorden's theorem, L^p spaces, Young's inequality, Minkowski's and Hölder's inequalities, Riesz-Fischer theorem (statement only).

Recommended Books:

1. H.L. Royden, *Real Analysis*, Macmillan, New York, 1988.
2. G.de Bara, *Measure Theory and Integration*, Ellis Horwood Limited, England, 2003.
3. P. R. Halmos, *Measure Theory*, 14th Edition, Springer, New York, 1994.

Suggested Readings:

1. I. K. Rana, *An Introduction to Measure and Integration,* 2nd Edition, Narosa Publishing House, New Delhi, 2005.
2. B. Krishna and A. Lahiri, *Measure Theory*, Hindustan Book Agency, 2006.
3. Terence Tao, *An Introduction To Measure Theory*, American Mathematical Society, Rhode Island, 2012.
4. G.B. Folland, *Real Analysis,* 2nd Edition, John Wiley, New York, 1999.

Course Title: Differential Geometry of Curves and Surfaces
Course Code: MAT.525
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective: To introduce students to the local and global theory of curves and surfaces so that they can embark on further studies and research in topics like Differential Topology, Algebraic Topology, Riemannian Geometry and allied areas.

Unit-I **(15 Hours)**

Curves in plane and space: Parameterized curves, Tangent vector, Arc length, Reparametrization, Regular curves, Curvature and torsion of smooth curves, Frenet-Serret formulae, Arbitrary speed curves, Frenet approximation of a space curve. Osculating plane, Osculating circle, Osculating sphere, Involutes and evolutes, Bertrand curves, Spherical indicatrices, Helices, Fundamental theorem of space curves.

Unit-II **(15 Hours)**

Isomeries of $\mathbb{R}^3$, Congruence of curves. Surfaces in $\mathbb{R}^3$**:** Definition and examples, Smooth surfaces, Tangent, Normal and orientability. Examples of surfaces: Generalized cylinder and generalized cone, Ruled surfaces, Surface of revolution and Quadric surfaces. First fundamental form, Isometries of surfaces, Conformal mapping of surfaces, Surface area, Equi-areal maps and theorem of Archemedes,

Unit-III **(15 Hours)**

Second fundamental form, Curvature of curves on a surface, Normal and principal curvatures, Meusnier's theorem, Euler's theorem, Weingarten equations and Weingarten matrix, Geometric interpretation of principal curvatures, Umbilical points. Gaussian and mean curvature, Pseudo sphere, Flat surfaces, Surfaces of constant mean curvature, Gaussian curvature of compact surfaces, Gauss map and its properties.

Unit-IV **(15 Hours)**

Geodesics: Definition and basic properties, Geodesic equations, Geodesics on a surfaces of revolution, Clairaut's theorem, Geodesics as shortest paths, Geodesic coordinates, Gauss Theorema Egregium, Gauss equations, Codazzi-Mainardi equations, Compact surfaces of constant Gaussian curvature.

Recommended Books:

1. A. Pressley, *Elementary Differential Geometry*, Second Edition, Undergraduate Mathematics Series, Springer-Verlag London Ltd., 2010.
2. M. P. Do Carmo, *Differential Geometry of Curves and Surfaces*, Revised and Updated Second Edition, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 2016.
3. B. O' Neill, *Elementary Differential Geometry*, Revised Second Edition, Academic Press, 2006.

Suggested Readings:

1. C. Bär, *Elementary Differential Geometry*, Cambridge University Press, 2001.
2. A. Gray, E. Abbena, and S. Salamon, *Modern Differential Geometry of Curves and Surfaces with Mathematica*, Third edition, CRC Press, 2006.
3. R. S. Millman & G. D. Parkar, *Elements of Differential Geometry*, Englewood Cliffs, N.J. : Prentice Hall, 1977.
4. T. J. Willmore, *An Introduction to Differential Geometry*, First Edition, Dover Publications, Inc., Mineola, New York, 2012.

Course Title: Complex Analysis
Course Code: MAT.526
Total Lectures: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective: This course is aimed to provide an introduction to the theories for functions of a complex variable. It begins with the exploration of the algebraic, geometric and topological structures of the complex number field. The concepts of analyticity, Cauchy-Riemann equations and harmonic functions are then introduced. Students will be equipped with the understanding of the fundamental concepts of complex variable theory.

Unit-I **(15 Hours)**

Review of complex number system, algebra of complex numbers, complex plane, function of a complex variable, limit, continuity, uniform continuity, differentiability, analytic function, Cauchy- Riemann equations, harmonic functions and harmonic conjugate.

Unit-II **(15 Hours)**

Complex line integral, Cauchy's theorem, Cauchy-Goursat theorem, Cauchy's integral formula and its generalized form, Index of a point with respect to a closed curve, Cauchy's inequality. poisson's integral formula, Morera's theorem. Liouville's theorem, Contour integral, power series, Taylor's series, higher order derivatives, Laurent's series.

Unit-III **(15 Hours)**

Singularities of analytic functions, Fundamental theorem of algebra, zeroes of analytic function, poles, residues, residue theorem and its applications to contour integrals, branches of many valued functions with arg z, log z, and z^{a}. Maximum modulus principle, Schwarz lemma, open mapping theorem.

Unit-IV **(15 Hours)**

Meromorphic functions, the argument principle, Rouche's theorem, Mobius transformations and their properties and classification, definition and examples of conformal mappings.

Recommended Books:

1. Theodore W. Gamelin, *Complex Analysis*. UTM, Springer-Verlag 2001.
2. L. V. Ahlfors, *Complex Analysis*, 3rd Edition, Tata McGraw-Hill, 1979.

3. S. Ponnusamy, *Foundations of Complex Analysis*, 2nd Edition, Narosa Publishing House, 2007.

Suggested Readings:

1. W. Tutschke and H.L. Vasudeva, *An Introduction to Complex Analysis, Classical and Modern Approaches*, 1st Edition, CRC Publications, 2004.
2. R. V. Churchill & J. W. Brown, *Complex Variables and Applications*, 8th Edition, Tata McGraw-Hill, 2014.

Course Title: Mechanics
Course Code: MAT.527
Total Hours: 30

L	T	P	Cr	Marks
2	0	0	2	50

Objectives:
This course is designed for the M.Sc. students, but it is also useful for science or engineering students in related areas. The main goal of the course is to introduce the concept of mechanics and its applications and to learn the fundamentals of this important topic.

Unit-I **(08 Hours)**
General force system, equipollent force system, equilibrium conditions, reduction of force systems, couples, moments and wrenches, necessary and sufficient conditions of rigid bodies, general motion of rigid body.

Unit-II **(07 Hours)**
Moments and products of inertia and their properties, moving frames of references and frames in general motion, Euler's dynamical equations, motion of a rigid body with a fixed point under no force.

Unit-III **(08 Hours)**
D'Alembert's principle, Lagrange's equations, from D'Alembert's principle, procedure for formulation of Lagrange's equations, applications of Lagrangian formulation. Hamilton's principle, techniques of calculus of variations.

Unit-IV **(07 Hours)**
Generalized momentum and cyclic coordinates, conservation of linear momentum, conservation of angular momentum, Hamiltonian function H and conservation of energy: Jacobi's integral, Hamilton's equations, Hamilton's equations in different coordinate systems.

Recommended Books:

1. K. Sankra Rao, *Classical Mechanics*, 1st Edition, Prentice Hall of India, 2005.
2. M.R. Speigal, *Theoretical Mechanics*, 1st Edition, Schaum Outline Series, 1967.
3. N.C. Rana and P.S. Joag, *Classical Mechanics,* 1st Edition, Tata McGraw-Hill, New Delhi, 1991.

4. J.C. Upadhyaya, *Classical Mechanics,* 2nd Edition, Himalaya Publishing House, Pvt. Ltd., New Delhi, 2017.

Suggested Readings:

1. F. Gantmacher, *Lectures in Analytic Mechanics*, MIR Publishers, Moscow, 1975.
2. P.V. Panat, *Classical Mechanics*, Narosa Publishing House, New Delhi, 2005.
3. Louis N. Hand and Janet D. Finch, *Analytical Mechanics,* 1st Edition, Cambridge University Press, 1998.
4. D.E Rutherford, *Classical Mechanics*, 3rd Edition, Oliver & Boyd Ltd., 1964.

Course Title: Linear Programming (IDC)
Course Code: MAT.528

L	T	P	Cr	Marks
2	0	0	2	50

Total Hours: 30

Objective: The objective of this course is to provide the understanding of Linear Programming for the post graduate students of the other departments.

Unit-I **(08 Hours)**

Formulation of linear programming problems (LPP). Graphical solution to LPPs. Cases of unique and multiple optimal solutions. Unbounded solutions and infeasibility and redundant constraints.

Unit-II **(08 Hours)**

Feasible solution, basic feasible solutions, Optimal solution, Convex sets, Solution of LPP with Simplex methods. The dual problem. Formulation of the dual.

Unit-III **(08 Hours)**

Transportation and Assignment Problem: Transportation problems, Formulation of transportation problem, Feasible and optimal solution of transportation problems. Assignment problems.

Unit-IV **(06 Hours)**

Theory of games: Introduction to basic concepts of game theory including strategic Games.

Recommended Books:

1. H. A. Taha, *Operations Research - An Introduction,* Macmillan Publishing Company Inc., New York, 2006.
2. K . Swarup, P. K. Gupta and Man Mohan, *Operations Research*, Sultan Chand & Sons, New Delhi, 2001.

Course Title: Numerical Methods (IDC)
Course Code: MAT.529
Total Lectures: 30

L	T	P	Cr	Marks
2	0	0	2	50

Objective: The objective of this course is to provide the understanding and use of numerical methods for the postgraduate students of other departments.

Unit-I **(07 Hours)**

Error Analysis: Relative error, Truncation error, Roundoff error, Order of approximation, Order of convergence, Propagation.

Unit-II **(08 Hours)**

Roots of Nolinear Equations: Bisection method, Secant method, Newton Raphson method, Convergence and order of convergence.

Unit-III **(08 Hours)**

Linear Systems of Equations: Gauss elimination and Gauss-Seidel methods.
Interpolation: Lagrange's Method, Newton's polynomials.

Unit-IV **(07 Hours)**

Solution of Differential Equations: Euler's method, Heun's method, Taylor series method, Runge Kutta method.

Recommended Books:

1. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7th Edition, Pearson LPE, 2009.
2. R. S. Gupta, *Elements of Numerical Analysis*, 2nd Edition, Cambridge University Press, 2015.
3. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Age International, New Delhi, 2015.

Suggested Reading:

1. K. Atkinson, *An Introduction to Numerical Analysis,* 2nd Edition, John Wiley & Sons, 2012.
2. J. I. Buchaman and P. R. Turner, *Numerical Methods and Analysis,* Prentice-Hall, 1988.
3. S. S. Sastry, *Introduction Methods of Numerical Analysis*, 4th Edition, Prentice-Hall, 2005.

Semester-III

Course Title: Research Methodology
Course Code: MAT.502
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objectives

The objective of this course is to equip the students with knowledge of some basic as well as advanced concepts related to research. The course covers preparation of research plan, reading and understanding of scientific papers, scientific writing, research proposal writing, ethics, plagiarism etc.

Unit-I **(14 Hours)**

Introduction: Meaning, Objectives, Characteristics, Significance, and Types of Research; Research Approaches, Research Methods vs. Research Methodology, Research Process, and Criteria of Good Research.

Unit-II **(16 Hours)**

Literature Survey and Review: Meaning of Literature Survey and Review, Sources of Literature, Methods of Literature Review, and Techniques of Writing the Reviewed Literature. **Formulating Research Problem:** Understanding a Research Problem, Selecting the Research Problem, Steps in Formulation of a Research Problem, Formulation of Research Objectives, and Construction of Hypothesis.

Unit-III **(14 Hours)**

Research Design: Meaning of and Need for Research Design, Characteristics of a Good Research Design, Different Research Designs, Basic Principles of Experimental Designs, Data Collection, Processing, and Interpretation.

Unit-IV **(16 Hours)**

Report Writing: Types of Reports – Technical and Popular Reports, Significance of Report Writing, Different Steps in Writing Report, Art of Writing Research Proposals, Research Papers, Project Reports, and Dissertations/Thesis; Basics of Citation and Bibliography/Reference Preparation Styles; Report Presentation: Oral and Poster Presentations of Research Reports.

Recommended Books:

1. Kothari, C.R. and G. Garg (2014): *Research Methodology*: Methods and Techniques, 3rd ed., New Age International Pvt. Ltd. Publisher
2. Kumar, R. (2014): *Research Methodology – A Step-By-Step Guide for Beginners*, 4th ed., Sage Publications

Suggested Readings:

1. Anderson, J. (2001): *Thesis and Assignment Writing*, 4th ed., Wiley, USA
2. Dawson, Catherine, (2014): *Practical Research Methods,* New Delhi, UBS Publishers' Distributors.
3. Gray, David E. (2004): *Doing Research in the Real World*. London, UK: Sage Publications.

Course Title: Algebra–II
Course Code: MAT.551
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective

This course is a advance course in Algebra for students who wish to pursue research work in Algebra.

Unit-I **(15 Hours)**

Field Theory: Basic concepts of field theory, Extension of fields, algebraic and transcendental extensions. Algebraically closed fields, Splitting fields, Separable and inseparable extensions, Normal extension, Multiple roots, Finite fields, Perfect fields.

Unit-II **(15 Hours)**

Modules: Definition and Examples, Submodules, Direct sum of submodules, Free modules, Difference between modules and vector spaces, Quotient modules, Homomorphism, Simple modules, Modules over PID

Unit-III **(14 Hours)**

Galios Theory: Automorphism groups, Fixed fields, Galois extensions, The fundamental theorem of Galois theory, Cyclotomic extensions, and Cyclic extensions,

Unit-IV **(16 Hours)**

Applications of cyclotomic extensions and Galois theory to the constructability of regular polygons, Solvability of polynomials by radicals.

Recommended Books:

1. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, *First Course in Linear Algebra,* Wiley Eastern, Delhi, 2008.
2. M. Artin, *Algebra,* 2nd Edition, Prentice Hall of India, Delhi, 2011.
3. D. S. Dummit and R. M. Foote, *Abstract Algebra*, 3rd Edition, John Wiley, USA, 2011.

Suggested Readings:

1. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory,* Academic Press, California, 2004.
2. I. N. Herstein, *Topics in Algebra,* 2nd Edition, Wiley Eastern Limited, New Delhi, 2006

3. V. Bist and V. Sahai, *Linear Algebra,* Narosa, Delhi, 2002.
4. J. P. Escofier, *Galois Theory*, Springer-Verlag, New York, 2000.
5. I. N. Stewart, *Galois Theory,* Chapman and Hall, USA, 2003.
6. B. Hartley and T. O. Hawkes, *Rings*, *Modules and Linear Algebra*, Chapman and Hall, USA, 1970.
7. C. Musili, *Rings and Modules,* 2nd Revised Edition, Narosa Publishing House, New Delhi, 1994.

Course Title: Calculus of Variation and Integral Equations

Course Code: MAT.552

Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective

The objectives of the course calculus of variations and integral equations is to develop knowledge of the basic tenets of the theory of integral equations and mastery of the respective solutions of problems and exercises, knowledge of the main provisions of the calculus of variations and the ability to use the concepts and methods of the theory in solving problems arising in theoretical and mathematical physics.

Unit-I **(15 Hours)**

Functional, variation of functional and its properties, fundamental lemma of calculus of variation, Euler's-Lagrange equation of single independent and single dependent variable and application. necessary and sufficient conditions for extrema. Brachistochrone problem, functional involving higher order derivatives.

Unit-II **(15 Hours)**

Sturm-Liouville's theorem on extremals, one sided variations, Hamilton's principle, Hamilton's canonical equation of motion, The principle of least action, Langrange's equations from Hamilton's principle. variational methods, for boundary value problems in ODE's & PDE's, isoperimetric problems.

Unit-III **(15 Hours)**

Volterra equations: Integral equations and algebraic system of linear equations. L_2 kernels and functions of Volterra equation. Volterra equations of first and second kind. Volterra integral equation and linear differential equation.

Unit-IV **(15 Hours)**

Fredholm Equations: solution by the method of successive approximations. Solution of Fredholm integral equation for degenerate kernel, solution by the successive approximations, neumann series and resolvent kernel.

Recommended books:

1. R. P. Kanwal, *Linear integral equations*, Birkhauser, Boston, 1996.
2. M.D. Raisinghania, *Integral equations and boundary value problems,* 9th Edition, S. Chand Publishing, New delhi, 2016.

Suggested Readings:

1. J. L. Synge and B.A. Griffith, *Principle of Mechanics,* McGraw-Hill Book Company, 1970.
2. H. Goldstein, *Classical Mechanics,* 2nd Edition, Narosa Publishing House, 1980.
3. Rakesh Kumar and Nagendra Kumar, *Differential Equations and Calculus of Variations,*
   CBS Publishers and Distributors Pvt Ltd, 2013.

Course Title: Numerical Analysis

L	T	P	Cr	Marks
3	0	0	3	75

Course Code: MAT.553
Total Hours: 45

Objective:
The aim of this course is to teach the applications of various numerical techniques for a variety of mathematical problems occurring in science and engineering. At the end of the course, the students will be able to understand the basic concepts of errors, and numerical methods for the solutions of nonlinear equations, linear systems, interpolation and approximations, numerical integration and differential equations.

Unit-I **(11 Hours)**

Error Analysis: Definition and sources of errors, Propagation of errors, Sensitivity and conditioning, Stability and accuracy, Floating-point arithmetic and rounding errors.

Numerical Solutions of Algebraic Equations: Bisection method. Fixed-point iteration, Newton's method, Secant method, Convergence and order of convergence

Unit-II **(12 Hours)**

Linear Systems of Equations: Gauss elimination and Gauss-Jordan methods, Jacobi and Gauss- Seidel iteration methods.

Polynomial Interpolation: Interpolating polynomial, Lagrange and Newton divided difference interpolation, Error in interpolation, Finite difference formulas, Hermite Interpolation.

Unit-III **(11 Hours)**

Spline and Approximation: Cubic Spline, Least square method, Påde approximation

Eigen Value Problems: Power method.

Numerical Differentiation and Integration: Numerical differentiation with finite differences, Trapezoidal rule, Simpson's 1/3 - rule, Simpson's 3/8 rule, Error estimates for Trapezoidal rule and Simpson's rule, Gauss quadrature formulas.

Unit-IV **(11 Hours)**

Numerical Solution of Ordinary Differential Equations: Solution by Taylor series, Picard method of successive approximations, Euler's method, Modified Euler method, Runge- Kutta methods. Finite difference method for boundary value problems.

Recommended Books:

1. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Age International, New Delhi, 2015.
2. R.L. Burden and J. D. Faires, *Numerical Analysis*, 9th Edition, Cengage Learning, 2011.

Suggested Readings:

1. S. S. Sastry, *Introductory Methods of Numerical Analysis*, 4th Edition, PHI, 2015.
2. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7th Edition, Pearson LPE, 2009.
3. R. S. Gupta, *Elements of Numerical Analysis*, 2nd Edition, Cambridge University Press, 2015.
4. K. Atkinson, *An Introduction to Numerical Analysis*, 2nd Edition, John Wiley & Sons, 1989.

Course Title: Numerical Analysis (Practical)

Course Code: MAT.554
Total Hours: 30

L	T	P	Cr	Marks
0	0	2	1	25

Objective

Laboratory experiments will be set in context with the materials covered in theory in C/C++/MATLAB. The students will be able to do programming in C/C++/MATLAB for basic numerical methods of each unit in numerical analysis course MAT.553.

Laboratory Work: Programming exercises on numerical methods using C/C++/MATLAB languages.

1. To detect the interval(s) which contain(s) root of equation f(x)=0 and implement bisection method to find the root of f(x)=0 in the detected interval.
2. To compute the root of equation f(x)=0 using Secant method.
3. To find the root of equation f(x)=0 using Newton-Raphson and fixed point iteration methods.
4. To compute the intermediate value using Newton's forward difference interpolation formula.
5. To apply Lagrange method for a data set.
6. To construct divided difference table for a given data set and hence compute the intermediate values.
7. To solve a linear system of equations using Gauss elimination (without pivoting) method.
8. To solve a linear system of equations using the Gauss-Seidel method.
9. To find the dominant eigenvalues and associated eigenvector by Rayleigh power method.
10. To integrate a function numerically using trapezoidal and Simpson's rule.
11. To solve the initial value problem using Euler method.
12. To solve the initial value problem using modified Euler's method.
13. To solve the initial value problem using 2^{nd} and 4^{th} order Runge-Kutta methods.

Course Title: Operations Research

L	T	P	Cr	Marks
4	0	0	4	100

Course Code: STA.557
Total Hours: 60

Objective:
The objective of this course is to acquaint the students with the concept of convex sets, their properties, Linear and nonlinear programming problems. The results, methods and techniques contained in this paper are very well suited to the realistic problems in almost every area

Unit-I **(14 Hours)**
Mathematical formulation of linear programming problem, Linear Programming and examples, Convex Sets, Hyper plane, Open and Closed half-spaces, Feasible, Basic Feasible and Optimal Solutions, Extreme Point & graphical methods. Simplex method, Big-M method, Two phase method, Determination of Optimal solutions, Unrestricted variables.

Unit-II **(16 Hours)**
Duality theory, Dual linear Programming Problems, Fundamental properties of dual problems, Complementary slackness, Unbounded solution in Primal. Dual Simplex Algorithm, Sensitivity analysis: Discrete changes in the cost vector, requirement vector and Co-efficient matrix.

Unit-III **(16 Hours)**
The General transportation problem, Duality in transportation problem, Loops in transportation tables, Solution of transportation problem, Test for optimality, Degeneracy, Transportation algorithm (MODI method), Minimization transportation problem. Assignment Problems: Mathematical formulation of assignment problem, Hungarian method for solving assignment problem, Traveling salesman problem.

Unit -IV **(14 Hours)**
Elementary queuing and inventory models: Steady-state solutions of Markovian queuing models: M/M/1, M/M/1 with limited waiting space, M/M/C, M/M/C with limited waiting space, M/G/1.

Recommended books:

1. H. A. Taha, *Operations Research - An Introduction*, Macmillan Publishing Company Inc., New York, 2006.
2. K. Swarup, P. K. Gupta, and M. Mohan, *Operations Research*, Sultan Chand & Sons, New Delhi, 2001.

Suggested Readings:

1. S. M. Sinha, *Mathematical Programming, Theory and Methods,* Delhi: Elsevier, 2006.
2. N. S. Kambo, *Mathematical Programming Techniques*, Affiliated East-West Press Pvt. Ltd., 1984, Revised Edition, New Delhi, 2005.
3. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 1987.

Course Title: Seminar-I
Course Code: MAT.543
Total hours: 30

L	T	P	Cr	Marks
0	0	2	1	25

Objective: The objective of the seminar is to develop presentation and communication skills in the students so that they can cope with future challenges in teaching, research and applications.

Course Title: Differential Topology
Paper Code: MAT.555
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective: To introduce students to the basics of Differential Topology so that they are able to appreciate better the topics covered in allied courses like Algebraic Topology, Riemannian geometry and Riemann-Finsler geometry as well as be adequately prepared for pursuing research in these topics.

UNIT-I **(15 Hours)**

Topological manifolds, Charts, Atlases, Smooth manifolds, Examples of smooth manifolds, Manifolds with boundary, Smooth functions on a manifold, Smooth maps between manifolds, Diffeomorphism, Smoothness in terms of components, Examples of smooth maps, Partial derivatives, and the Inverse function theorem.

UNIT-II **(15 Hours)**

Tangent space and tangent bundle, The Differential of a map, Chain rule, Bases for the tangent space at a point, Curves in a manifold, Submersions, Immersions and embeddings, Smooth covering maps, Critical and regular points, Submanifolds, Rank of a smooth map, Submersion and immersion theorems, Bump functions and partition of unity, Sard's theorem, The Whitney embedding theorem(statement only).

UNIT-III **(15 Hours)**

Vector fields and Lie bracket. Topological groups, Lie groups: Definition and examples, The product of two Lie groups, Lie subgroups, One parameter subgroups and exponential map, Homomorphism and isomorphism in Lie groups, Lie transformation groups, The tangent space and Left invariant vector fields of a Lie group.

UNIT-IV **(15 Hours)**

Tensor algebra, Differential forms, Cotangent spaces, pullback of l-forms, k-forms, Exterior product, Differential forms on a circle, Exterior derivative, Exterior algebra and Lie derivative, Global formulas for the Lie and exterior derivatives.

Recommended Books:

1. J. M. Lee, *Introduction to Smooth Manifolds*, GTM, Vol. 218, Springer, New York, 2003.
2. L. W. Tu, *An Introduction to Manifolds*, Second edition, Springer, 2011.
3. S. Kumaresan, *A Course in Differential Geometry and Lie Groups (Texts and Readings in Mathematics),* Hindustan Book Agency, 2002.

Suggested Readings:

1. S. S. Chern, W. H. Chen and K. S. Lam, *Lectures on Differential Geometry*, World Scientific Publishing Co. Pvt. Ltd., 2000.
2. W. M. Boothby, *An Introduction to Differentiable Manifolds and Riemannian Geometry*, 2nd edition, Academic Press, New York, 2003.
3. N. J. Hicks, *Notes of Differential Geometry*, D. Van Nostrand Reinhold Company, New York, 1965.
4. L. Conlon, *Differentiable Manifolds*, 2nd edition, Birkhauser Boston, Cambridge, MA, 2001.
5. F. Warner, *Foundations of Differentiable Manifolds and Lie Groups*, Springer, New York, 1983.

Course Title: Advanced Complex Analysis
Course Code: MAT.556
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objectives:
This course is designed to enable the readers to understand further deeper topics of Complex Analysis and will provide basic topics needed for students to pursue research in pure Mathematics.

Unit–I **(16 Hours)**

Harmonic function: definition, relation between a harmonic function and an analytic function, examples, harmonic conjugate of a harmonic function, poisson's integral formula, mean value property, the maximum & minimum principles for harmonic functions, Dirichlet problem for a disc and uniqueness of its solution, characterization of harmonic functions by mean value property.

Unit–II **(16 Hours)**

Analytic continuation: direct analytic continuation, analytic continuations along arcs, homotopic curves, the monodromy theorem, analytic continuation via reflection. Harneck's principle. Open mapping theorem, normal families, the riemann mapping theorem, Picard's theorem.

Unit–III **(14 Hours)**

Weierstrass Elliptic functions: periodic functions, simply periodic functions, fundamental period, Jacobi's first and second question, doubly periodic functions, elliptic functions, pair of primitive periods, congruent points, first and second Liouville's theorem, relation between zeros and poles of an elliptic function, definition of Weierstrass elliptic function (z) and their properties, the differential equation satisfied by (z) [i.e., the relation between (z) and ($\bar{z}$)], Integral formula for (z), addition theorem and duplication formula for (z).

Unit- IV **(14 Hours)**

Weierstrass Zeta function: Weierstrass zeta function and their properties, quasi periodicity of (z), Weierstrass sigma function (z) and their properties, associated sigma functions.

Recommended Books:

1. J. B. Conway, *Functions of One Complex Variable*, 2nd Edition, Springer-Verlag International, USA, 1978.
2. L.V. Ahlfors, *Complex Analysis: An Introduction to the Theory of Analytic Functions of One Complex Variable*, 3rd Edition, McGraw-Hill, Higher Education, New Delhi, 1979.

Suggested Readings:

1. S. Lang**,** *Complex Analysis*, 4th Edition, Springer, New York, 2003.
2. R. Walter, *Real and Complex Analysis*, 3rd Edition, McGraw-Hill Book Co., New Delhi, 1986.
3. S. Ponnusamy, *Foundations of Complex Analysis*, 2nd Edition, Narosa Publication House, New Delhi, 1995.

Course Title: Advanced Partial Differential Equations
Course Code: MAT.557
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objectives

The objective of this course is to equip the students with knowledge of some advanced concepts related to partial differential equations and to understand some basic approaches to mathematical oriented PDEs.

Unit-I **(16 Hours)**

Distribution: Test functions and distributions, examples, operations on distributions, supports and singular supports, convolution, fundamental solutions, fourier transform, Schwartz space, tempered distributions.

Sobolev Spaces: Basic properties, approximation by smooth functions, extension theorems, compactness theorems, dual spaces, functional order spaces, trace spaces, trace theory, inclusion theorem.

Unit-II **(15 Hours)**

Weak solutions of elliptic boundary value problems: variational problems, weak formulation of elliptic PDE, regularity, Galerkin method, Maximum principles, eigenvalue problems, Introduction to finite element methods.

Unit-III **(14 Hours)**

Evolution Equations: unbounded linear operators, C_0 – semigroups, Hille-Yosida theorem, contraction semigroup on Hilbert spaces, heat equation, wave equation, Schrödinger equation, inhomogeneous equations.

Unit-IV **(15 Hours)**

Calculus of Variations: Euler-Lagrange equation, second variation, existence of minimizers (coactivity, lower semi-continuity, convexity), regularity, constraints (nonlinear eigenvalue problems, variational inequalities, harmonic maps, incompressibility), critical points (mountain pass theorem and applications to elliptic PDE).

Recommended Books

1. S. Kesavan, *Topics in Functional Analysis and Application*, Wiley-Eastern, New International, New Delhi, 1999.

2. L. C. Evans, *Partial Differential Equations. Graduate Studies in Mathematics*, 2nd Edition, American Mathematical Society, Indian Reprint, 2014.

Suggested Books

1. Rao, K. S., *Introduction to Partial Differential Equation*, 2nd Edition, PHI Learning Pvt. Ltd. 2010.
2. Amarnath, T., *An Elementary Course in Partial Differential Equations*, 2nd Edition, Narosa Publishing House 2012.
3. Sneddon, I. N., *Elements of Partial Differential Equations*, McGraw-Hill Book Company, New York 1988.

Course Title: Discrete Mathematics

L	T	P	Cr	Marks
4	0	0	4	100

Course Code: MAT.558
Total Hours: 60

Objectives

The objective of this course is to acquaint the students with the concepts in Discrete Mathematics. It includes the topics like logics, graph theory, trees and Boolean algebra.

Unit-I **(14 Hours)**

Mathematical reasoning; Basic logical operations, conditional and bi-conditional statements, tautologies, contradiction, quantifiers, prepositional calculus. recursively defined sequences. solving recurrence relations: generating functions. basics of counting and the Pigeon-hole Principle.

Unit-II **(15 Hors)**

Set Theory: Paradox in set theory, Inductive definition of sets and proof by induction; Peono postulates; **Relations:** representation of relations by graphs, properties of relations, equivalence relations and partitions, partial orderings, linear and well-ordered sets;

Unit-III **(16 Hours)**

Graphs and Planar Graphs: basic terminology, special types of graphs. the handshaking theorem, paths and circuits shortest paths. connectivity of graphs. isomorphism of graphs. homeomorphic graphs. Eulerian and Hamiltonian graphs. planar and non-planar graphs. Euler's formula. Graph coloring.

Unit-IV **(15 Hours)**

Trees: Basic terminology. Binary trees. Tree traversing: preorder, postorder and inorder traversals. Minimum spanning trees, Prim's and Kruskal's alogrithm. Boolean aIgebras: Boolean functions, Logic gates, Lattices and algebraic structures.

Recommended books

1. K. H. Rosen, *Discrete Mathematics and its Applications*, 7th Edition, McGraw-Hill, New Delhi, 2007.
2. K. D. Joshi, *Foundation of Discrete Mathematics,* John Wiley & Sons, New Delhi, 1989.

Suggested Readings:

1. D. S. Malik, and M. K. Sen, *Discrete Mathematical Structures Theory and Applications*, 2nd Edition, Thomson/Course Technology, 2004.
2. C. L. Liu, *Elements of Discrete Mathematics*, 4th Edition, McGraw-Hill, New Delhi, 1986.

Course Title: Number Theory
Course Code: MAT.559
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective

The objective of this course is to teach the fundamentals of different branches of Number Theory, namely, Geometry of Numbers and Analytic Number Theory.

Unit-I **(15 Hours)**

Divisibility of Integers, Greatest common divisor, Euclidean algorithm. The fundamental theorem of arithmetic, Congruences, Residue classes and reduced residue classes.

Unit-II **(15 Hours)**

Indices and its applications, Quadratic residues, Euler's criterion, Product of quadratic residues and quadratic non-residues, The Legendre symbol and its properties, Gauss's lemma, Quadratic reciprocity law, Jacobi symbol and its properties.

Unit-III **(15 Hours)**

Chinese remainder theorem, Fermat's little theorem, Wilson's theorem, Euler's theorem. Arithmetic functions $\sigma(n)$, $d(n)$, $\tau(n)$, $\mu(n)$, Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots.

Unit-IV **(15 Hours)**

Representation of an integer as a sum of two and four squares. Diophantine equations ax +by =c, x2+y2=z2 and its application to x4+y4=z4. Farey sequences, Continued fractions.

Recommended books:

1. David, M. Burton, *Elementary Number Theory*, Tata McGraw-Hill, 7th Edition, New Delhi, 2012.
2. I. Niven, S. Zuckerman, and H. L. Montgomery, *Introduction to Number Theory*, Wiley Eastern, 1991.

Suggested Readings:

1. T. M. Apostol, *Introduction to Analytic Number Theory*, Springer Verlag, 1976.

2. G. H. Hardy and E. M. Wright, *An Introduction to the Theory of Number*, Oxford Univ. Press, U.K., 2008.
3. W. W. Adams and L. J. Goldstein, *Introduction to Number Theory*, Prentice Hall Inc., 1976.

Semester-IV

Course Title: Functional Analysis
Course Code: MAT.571
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective: The objective of this course is to introduce basic concepts, methods of Functional Analysis and its Applications. It is a first level course in Functional Analysis.

Unit-I **(14 Hours)**

Fundamentals of Normed Linear Spaces: Normed Linear spaces, Banach spaces and examples, finite dimensional normed spaces and subspaces, compactness and finite dimension. Quotient space of normed linear spaces and its completeness.

Unit-II **(15 Hours)**

Weak convergence and bounded linear transformations, Normed linear spaces of bounded linear transformations, Dual spaces with examples.

Three Main Theorems on Banach Space: Uniform boundedness theorem and some of its consequences, Open mapping and closed graph theorems.

Unit-III **(15 Hours)**

Hahn-Banach theorem for real linear spaces and its consequences, Complex linear spaces and normed linear spaces, Reflexive spaces, Solvability of linear equations in Banach spaces.

Unit-IV **(16 Hours)**

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, Adjoint of an operator on a Hilbert space, Reflexivity of Hilbert Spaces, Self-adjoint operators, normal and Unitary operators.

Recommended books:

1. B. V. Limaye, *Functional Analysis,* New Age International (P) Ltd, New Delhi, 1996.
2. E. Kreyszig, *Introductory Functional Analysis with Application*, Willey, 2007.

Suggested Readings:

1. S. K. Berberian, *Introduction to Hilbert Spaces,* AMS Chelsea Publishing, Rhode Island, 1996.
2. C. Goffman, and G. Pedrick, *First Course in Functional Analysis*, Prentice Hall of India, New Delhi, 1983.
3. F. K. Riesz, and B. S. Nagy, *Functional Analysis*, Dover Publications, 1990.
4. A. H. Siddiqui, *Functional Analysis*, Tata-McGraw Hill, New Delhi, 1987.

Course Title: Project Work
Course Code: MAT.599
Total Hours: 180

L	T	P	Cr	Marks
0	0	12	6	150

Objective: The objective of the Project work is to develop research and independent thinking skills, presentation and communication skills in the students so that they can cope with the future challenges in teaching, research and applications.

Course Title: Seminar-II
Course Code: MAT.544
Total Hours: 30

L	T	P	Cr	Marks
0	0	2	1	25

Objective: The objective of the seminar is to develop presentation and communication skills in the students so that they can compete with the future challenges in teaching, research and applications.

Course Title: Riemannian Geometry
Course Code: MAT.572
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective: The objective of the course is to introduce students to the basic concepts of Riemannian geometry to prepare them for further studies and research in Riemannian geometry, Finsler geometry, Mathematical Physics and their applications in allied areas.

Unit-I **(16 Hours)**

Review of differentiable manifolds and vector fields with examples, Covariant differentiation of vector fields and affine connection, Riemannian metric, Riemannian manifolds, Riemannian connection, Fundamental theorem of Riemannian geometry via Koszul's formula.

Unit-II **(14 Hours)**

Tensors and tensor fields (Riemannian metric as the most significant example), Tensorial property, Covariant differentiation of tensor fields, Riemann curvature tensor, Ricci tensor, Definition of sectional, Ricci and scalar curvatures, Isometries, notion of covering spaces, pull-back metrics via diffeomorphisms.

Unit-III **(16 Hours)**

Covariant differentiation of a vector field along a curve with specific examples, Arc length and energy of a piecewise smooth curve, Geodesics as length minimizing curves, First variation of arc length, To show that geodesics are critical points of the fixed end point first variation formula, Exponential map, Geodesic completeness, Geodesic normal coordinates, Hopf-Rinow theorem (statement only), Geodesic variations, Jacobi fields and Gauss lemma.

Unit-IV **(14 Hours)**

Second variation formula, the index form (Jacobi fields as minimizers of the index form), Global differential geometry, spaces of constant sectional curvature, Bonnet-Myers theorem, Cartan-Hadamard theorem, Cartan's theorems (on determination of metric by curvature).

Recommended Books:

1. M. P. Docarmo, *Riemannian Geometry*, Birkhausker Boston, 1992.
2. S. Kumaresan, *A Course in Differential Geometry and Lie Groups (Texts and Readings in Mathematics),* Hindustan Book Agency, 2002.

3. J. M. Lee, *Riemannian Manifolds: An Introduction to Curvature*, GTM, Springer, 1st Edition, 1997.

Suggested Readings:

1. Marcel Berger, *A Panoramic View of Riemannian Geometry*, Springer; 1st Edition, 2003. Corr. 2nd printing, 2007.
2. S. S. Chern, W. H. Chen and K. S. Lam, *Lectures on Differential Geometry*, World Scientific Publishing , 2000.
3. W. M. Boothby, *An Introduction to Differentiable Manifolds and Riemannian Geometry*, 2nd Edition, Academic Press, New York, 2003.
4. B. O' Neill, *Semi-Riemannian Geometry with Applications to Relativity*, Academic Press, New York, 1983.

Course Title: Fluid Mechanics

L	T	P	Cr	Marks
4	0	0	4	100

Course Code: MAT.573
Total Hours: 60

Objective
The objective of this course is to introduce to the fundamentals of the study of fluid motion and to the analytical approach to the study of fluid mechanics problems.

Unit-I **(15 Hours)**
Real fluids and ideal fluids, velocity of fluid at a point, streamlines, path lines, streak lines, velocity potential, vorticity vector, local and particle rate of change, equation of continuity, irrotaional and rotational motion, acceleration of fluid, conditions at rigid boundary.

Unit-II **(15 Hours)**
Euler's equation of motion, Bernoulli's equation, applications, potential theorems, axially symmetric flows, impulsive motion, Kelvin's theorem of circulation, equation of vorticity.

Unit-III **(15 Hours)**
Two dimensional flows: complex velocity potential, Milne Thomson circle theorem and applications, theorem of Blasius, vortex rows, Karman vortex street.

Unit-IV **(15 Hours)**
Some three dimensional flows: sources, sinks and doublets, images in rigid planes, images in solid sphere, Stoke's stream function.

Recommended books:

1. F. Chorlton, *Text Book of Fluid Dynamics*, Indian Edition, CBS Publishers, New Delhi, 2004.
2. L. D. Landau, and E. M. Lipschitz, *Fluid Mechanics*, Pergamon Press Ltd., London, 1987.
3. G. K. Batchelor, *An Introduction to Fluid Mechanics*, Cambridge University Press, New York, 1967.

Suggested Reading:

1. P. K. Kundu, and I. M. Cohen. *Fluid Mechanics*, Hardcover (India) Pvt.Ltd., Delhi, 2003.
2. G.K. Batechelor, *An Introduction to Fluid Dynamics*, Cambridge Press, 2002
3. H. Schlichting and K. Gersten, *Boundary Layer Theory,* 8th Edition , Springer, , 2004
4. L. Rosenhead, *Laminar Boundary Layers*, Dover Publications, 1963.
5. P.G. Drazin, and W. H. Reid, *Hydrodynamic Stability*, Cambridge Press, 2004

Course Title: Advanced Numerical Analysis
Course Code: MAT.574
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objectives: The objective of the course is to familiarize the students about some advanced numerical techniques e.g. solving systems of nonlinear equations, linear system of equations, eigenvalue problems, interpolation and approximation techniques and their use in differentiation and integration, differential equations etc.

UNIT- I **(16 Hours)**

Non-Linear Equations: Methods for multiple roots, Muller's, Iteration and Newton-Raphson method for non-linear system of equations, and Newton-Raphson method for complex roots.

Polynomial Equations: Descartes' rule of signs, Birge-Vieta, Bairstow and Giraffe's methods.

System of Linear Equations: LU Decomposition methods, SOR method with optimal relaxation parameters.

UNIT-II **(14 Hours)**

Eigen-Values of Real Symmetric Matrix: Similarity transformations, Gerschgorin's bound(s) on eigenvalues, Jacobi, Givens and Householder methods.

Interpolation and Approximation: B - Spline and bivariate interpolation, Gram-Schmidt orthogonalisation process and approximation by orthogonal polynomial, Legendre and Chebyshev polynomials and approximation.

UNIT- III **(14 Hours)**

Differentiation and Integration: Differentiation and integration using cubic splines, Romberg integration and multiple integrals.

Ordinary Differential Equations: Shooting and finite difference methods for second order boundary value problems.

UNIT- IV **(16 Hours)**

Partial Differential Equations: Finite difference methods for Elliptic, Parabolic and Hyperbolic partial differential equations.

Recommended Books:

1. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7th Edition, Pearson LPE, 2009.
2. R. S. Gupta, *Elements of Numerical Analysis*, 2nd Edition, Cambridge University Press, 2015.
3. R.L. Burden and J. D. Faires, *Numerical Analysis*, 9th Edition, Cengage Learning, 2011.

Suggested Readings:

1. K. Atkinson, *An Introduction to Numerical Analysis*, John Wiley & Sons, 2nd Edition, 1989.
2. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Age International, New Delhi, 2015.
3. S.D. Conte and Carl D. Boor, *Elementary Numerical Analysis: An Algorithmic Approach*, Tata McGraw Hill, 2005.

Course Title: Algebraic Topology
Course Code: MAT.575
Total Hours: 60

L	T	P	Cr	Marks
4	0	0	4	100

Objective: The objective of this course is to introduce the concept of Algebraic topology so that the student's can pursue research in this field and its allied areas.

Unit-I **(14 Hours)**

The Fundamental group: Homotopy of paths, Homotopy classes, The Fundamental group, Change of base point, Topological invariance, Covering spaces, The Fundamental group of the circle and product spaces.

Unit-II **(14 Hours)**

Retractions and fixed points, No Retraction Theorem, The Fundamental theorem of Algebra, The Borsuk-Ulam theorem, The Bisection theorem, Deformation Retracts and Homotopy type, Homotopy invariance.

Unit-III **(16 Hours)**

Direct sums of Abelian Groups, Free products of groups, Uniqueness of free products, Least normal subgroup, Free groups, Generators and relations, The Seifert-Van Kampen theorem, The Fundamental group of a wedge of circles.

Unit-IV **(16 Hours)**

Classification of covering spaces: Equivalence of covering spaces, the general lifting lemma, the fundamental group of a covering space. The universal covering space, Covering transformation, Existence of covering spaces.

Recommended Books:

1. James R. Munkres, *Elements of Algebraic Topology*, Perseus Books, 1995.
2. A. Hatcher, *Algebraic Topology*, Cambridge University Press, 2002.
3. Satya Deo, *Algebraic Topology: A Primer (Texts and Readings in Mathematics),* Hindustan Book Agency, 2003.

Suggested Readings:

1. M. A. Armstrong, *Basic Topology,* UTM Springer, 2000.
2. E. H. Spanier, *Algebraic Topology (2nd edition*), Springer-Verlag, New York, 2000.
3. J. J. Rotman, *An Introduction to Algebraic Topology*, *Text in Mathematics, No. 119*, Springer, New York, 2004.

4. W. S. Massey, *A Basic Course in Algebraic Topology,* SPRINGER (SIE), 2007.
5. M. J. Greenberg and J. R. Harper, *Algebraic Topology:* A First Course, 2nd Edition, Addison-Wesley Publishing Co, 1997.

Course Title: Lie Groups and Lie Algebra

L	T	P	Cr	Marks
4	0	0	4	100

Course Code: MAT.576
Total Hours: 60

Objective:
The aim of this course is to make the students learn basic concepts of Lie groups and Lie algebra, so as to enable the students to understand further topics related to the solution of differential equations.

Unit I **(15 Hours)**
Differential Manifolds: Topological manifolds, Charts, Atlases and smooth structure, Smooth maps and diffeomorphism, Tangent space, Tangent map, Vector fields and 1-forms.

Unit II **(15 Hours)**
Lie Groups: Definition and examples, Linear Lie groups, Lie group homomorphism, Lie algebra and the exponential map, Adjoint representation, Homogeneous spaces, Baker-Campbell-Hausdorff formula.

Unit III **(15 Hours)**
Lie Algebras: Definition and examples, Classical Lie algebras, Solvable and nilpotent Lie algebras, Lie and Engel theorems, Semi-simple and reductive algebras, Semi-simplicity of Classical Lie algebras

Unit IV **(15 Hours)**
Killing form, Jordan decomposition, Engel's Theorem, Cartan subalgebra and Root space decomposition, Geometry of Root systems, Simple roots and Weyl group, Classification of root systems, Examples

Recommended Books:

1. J. E. Humphreys, *Introduction to Lie Algebras and Representation Theory,* Graduate Text in Mathematics, 9, Springer-Verlag, 1980.
2. N. Jacobson, *Lie Algebras,* Wiley-Interscience, New York, 1962.
3. J. P. Serre, *Lie Algebras and Lie Groups,* Benjamin, New York, 1965.
4. N. Bourbaki, *Lie Groups and Lie Algebras*, Springer Science & Business Media, 1998.

Suggested Readings:

1. K. J. Alexander, *An Introduction to Lie Groups and Lie Algebras*, Cambridge University Press.
2. S. Kumaresan, *Differential Geometry and Lie Groups*, Hindustan Book Agency.
3. B. Hall, *Lie Groups, Lie Algebras and Representations: An Elementary Introduction*, Second Edition, Springer.
4. P. J. Olver, *Application of Lie Groups to Differential Equations*, Second Edition, Springer.

Course Title: Finite Element Analysis

L	T	P	Cr	Marks
4	0	0	4	100

Course Code: MAT.577
Total Hours: 60

Objective

The aim of this course is to make the students learn fundamental concepts of finite elements so as to enable the students to understand further topics related to solution of differential equations. Finite element analysis is a helpful tool to solve a variety of problems of science and engineering related to fluid flows, structures etc.

Unit-I **(14 Hours)**

General theory of finite element methods, Difference between finite element and finite difference, Review of some integral formulae, Concept of discretization, Convergence requirements, Different coordinates, One dimensional finite elements, shape functions, stiffness matrix, connectivity, boundary conditions, equilibrium equation, FEM procedure.

Unit-II **(16 Hours)**

Generalization of the finite element concepts-weighted residual and variational Approaches (Ritz method, Galerkin method, collocation method etc.) Numerical integration, Interpolation formulas and shape functions, Axis symmetric formulations, solving one-dimensional problems.

Unit-III **(14 Hours)**

Two dimensional finite element methods, Element types: triangular, rectangular, quadrilateral, sector, curved, isoperimetric elements and numerical integration, two dimensional boundary value problems, connectivity and nodal coordinates, variational functions, triangular elements and area coordinates, transformations, cylindrical coordinates.

Unit-IV **(16 Hours)**

Three dimensional finite elements, higher order finite elements, element continuity, plate finite elements, Application of finite element methods to elasticity problems and heat transfer problems.

Recommended Books:

1. C. S. Desai, *Introductory Finite Element Method*, CRC Press, Boca Raton, 2001.

2. G. D. Smith, *Numerical Solution of Partial Differential Equations*, Clarendon Press, Oxford, 1986.

Suggested Readings:

1. B. B. Bradie, *A Friendly Introduction to Numerical Analysis,* Pearson, New Delhi, 2005.

2. J. N. Reddy, *An Introduction to Finite Element Methods,* McGraw-Hill Higher Education, New Delhi, 2005.

3. D. Braess, Schumaker and Larry L. *Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics,* Cambridge University Press, New York, 2001.

Course Title: Fundamentals of Analysis and Linear Algebra
Course Code: MAT.578
Total Hours: 60

L	T	P	Cr	Marks
0	0	4	2	50

Objectives:
This course is designed in such a way that the students can prepare themselves for competitive examinations like CSIR-UGC NET, SLET, GATE and other similar type of examinations.

Unit I **(14 Hours)**

Analysis: Elementary set theory, finite, countable and uncountable sets, Real number system as a
complete ordered field, Archimedean property, supremum, infimum. Sequences and series, convergence, limsup, liminf. Bolzano Weierstrass theorem, Heine Borel theorem. Continuity, uniform continuity, differentiability, mean value theorem. Sequences and series of functions, uniform convergence. Riemann sums and Riemann integral, Improper Integrals.

Unit II **(16 Hours)**

Advance Analysis: Monotonic functions, types of discontinuity, functions of bounded variation, Lebesgue measure, Lebesgue integral. Functions of several variables, directional derivative, partial derivative, derivative as a linear transformation, inverse and implicit function theorems.
Metric spaces, compactness, connectedness. Normed linear Spaces. Spaces of continuous functions as examples.
Topology: Basis, dense sets, subspace and product topology, separation axioms, connectedness and compactness.

Unit III **(14 Hours)**

Linear Algebra: Vector spaces, subspaces, linear dependence, basis, dimension, algebra of linear transformations. Algebra of matrices, rank and determinant of matrices, linear equations. Eigenvalues and eigenvectors, Cayley-Hamilton theorem. Matrix representation of linear transformations. Change of basis, canonical forms, diagonal forms, triangular forms, Jordan forms. Inner product spaces, orthonormal basis. Quadratic forms, reduction and classification of quadratic forms

Unit IV **(16 Hours)**

Complex Analysis: Algebra of complex numbers, the complex plane, polynomials, power series, transcendental functions such as exponential, trigonometric and hyperbolic functions. Analytic functions, Cauchy-Riemann equations. Contour integral, Cauchy's theorem, Cauchy's integral formula,

Liouville's theorem, Maximum modulus principle, Schwarz lemma, Open mapping theorem. Taylor series, Laurent series, calculus of residues. Conformal mappings, Mobius transformations.

Recommended Books:

1. Walter Rudin, *Principles of Mathematical Analysis,* 3rd Edition, McGraw Hill, Kogakusha, International student Edition, 1976.
2. S. C. Malik, *Mathematical Analysis*, Wiley Eastern Ltd., 2010.
3. J. R. Munkres, *Topology- A First Course,* Prentice Hall of India, New Delhi, 1975.
4. M. A. Armstrong, *Basic Topology*, Springer, Paperback Edition, 2004.
5. K. Hoffman and R. Kunze: *Linear Algebra* 2nd Edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2004.
6. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory,* Cengage Learning, 2004.
7. P. B. Bhattacharya, S.K. Jain and S.R. Nagpaul, *First Course in Linear Algebra,* Wiley Eastern, Delhi, 2003.
8. H.L. Royden, *Real Analysis*, Macmillan, New York, 1988.
9. G.de Bara, *Measure Theory and Integration*, Ellis Horwood Limited, England, 2003.
10. L. V. Ahlfors, *Complex Analysis*, Tata McGraw Hill, 1979.
11. S. Ponnusamy, *Foundations of Complex Analysis*, Narosa Publishing House, 2007.
12. Ajit Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, Narosa, Publishing House, 2014.
13. S. Kumaresan, *Topology of Metric Spaces,* second edition, Narosa Publishing House New Delhi, 2015.
14. K. D. Joshi, *Introduction to General Topology*, Wiley Eastern, Delhi, 1986.

Course Title: Fundamentals of Applied Mathematics

Course Code: MAT.579

Total Hours: 60

L	T	P	Cr	Marks
0	0	4	2	50

Objectives:

This course is designed in such a way that the students can prepare themselves for competitive examinations like CSIR-UGC NET, SLET, GATE and other similar type of examinations.

Unit I **(16 Hours)**

Algebra: Permutations, combinations, pigeon-hole principle, inclusion-exclusion principle, derangements. Fundamental theorem of arithmetic, divisibility in Z, congruences, Chinese Remainder Theorem, Euler's Ø- function, primitive roots. Groups, subgroups, normal subgroups, quotient groups, homomorphisms, cyclic groups, permutation groups, Cayley's theorem, class equations, Sylow theorems. Rings, ideals, prime and maximal ideals, quotient rings, unique factorization domain, principal ideal domain, Euclidean domain. Polynomial rings and irreducibility criteria. Fields, finite fields, field extensions, Galois Theory.

Unit II **(14 Hours)**

Ordinary Differential Equations (ODEs):

Existence and uniqueness of solutions of initial value problems for first order ordinary differential equations, singular solutions of first order ODEs, system of first order ODEs. General theory of homogenous and non-homogeneous linear ODEs, variation of parameters, Sturm-Liouville boundary value problem, Green's function.

Partial Differential Equations (PDEs):

Lagrange and Charpit methods for solving first order PDEs, Cauchy problem for first order PDEs. Classification of second order PDEs, General solution of higher order PDEs with constant coefficients, Method of separation of variables for Laplace, Heat and Wave equations.

Unit III **(16 Hours)**

Numerical Analysis:

Numerical solutions of algebraic equations, Method of iteration and Newton-Raphson method, Rate of convergence, Solution of systems of linear algebraic equations using Gauss elimination and Gauss-Seidel methods, Finite differences, Lagrange, Hermite and spline interpolation, Numerical differentiation and integration, Numerical solutions of ODEs using Picard, Euler, modified Euler and Runge-Kutta methods.

Classical Mechanics:
Generalized coordinates, Lagrange's equations, Hamilton's canonical equations, Hamilton's principle and principle of least action, Two-dimensional motion of rigid bodies, Euler's dynamical equations for the motion of a rigid body about an axis, theory of small oscillations.

Unit IV **(14 Hours)**

Calculus of Variations:
Variation of a functional, Euler-Lagrange equation, Necessary and sufficient conditions for extrema. Variational methods for boundary value problems in ordinary and partial differential equations.

Linear Integral Equations:
Linear integral equation of the first and second kind of Fredholm and Volterra type, Solutions with separable kernels. Characteristic numbers and eigen functions, resolvent kernel.

Recommended Books:

1. L. C. Evans, *Partial Differential Equations. Graduate Studies in Mathematics*, American Mathematical Society, 2nd Edition, Indian Reprint, 2014.
2. I. N. Sneddon, *Elements of Partial Differential Equations*, McGraw-Hill, 2006.
3. S. L. Ross, *Differential Equations*, Wiley, 1984.I. Miller and M. Miller, *Mathematical Statistics,* 6th Edition, Oxford & IBH Pub., 1999.
4. M. D. Raisinghania, *Advanced Differential Equations*, S. Chand & Company Ltd., New Delhi, 2001.
5. J. A. Gallian, *Contemporary Abstract Algebra,* Narosa Publishing House, New Delhi, 2008.
6. I. N. Herstein, *Topics in Algebra*, 2nd Edition, Wiley Eastern Limited, New Delhi, 2006.
7. P. B. Bhattacharya, S.K. Jain and S.R Nagpal, *Basic Abstract Algebra*, Cambridge University Press, New Delhi, 2003.
8. R. P. Kanwal, *Linear Integral Equations*, Birkhauser, Boston, 1996.
9. A. Pinckus, and S. Zafrany, *Fourier series and Integral Transform*, Cambridge University Press, New York, 1997.
10. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Age International, New Delhi, 2015.
11. R.L. Burden and J. D. Faires, *Numerical Analysis*, 9th Edition, Cengage Learning, 2011.

12. G. D. Smith, *Numerical Solution of Partial Differential Equations*, Oxford: Clarendon Press, 1986.

13. R. S. Gupta, *Elements of Numerical Analysis*, Cambridge University Press, 2nd Edition, 2015.

14. M. K. Jain, S.R.K. Iyengar and R. K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6th Edition, New Age International, New Delhi, 2015.

Course Title: Value Added Course
Course Code: XYZ
Total Hours: 15

L	T	P	Cr	Marks
1	0	0	1	25