Central University of Punjab, Bathinda

Course Scheme & Syllabus

for

M.Sc. MATHEMATICS

Syllabi Applicable for admissions in M. Sc. (Mathematics), 2016

Scheme of Programme M.Sc. Mathematics

SEMESTER- I

S. No	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage C_A	M_1	M_2	E_T	T_M
1	MAT.401	Research Methodology-I	F	2	-	-	2	25	25	25	25	50
2	MAT.501	Probability and Distribution Theory	C	4	-	-	4	25	25	25	25	100
3	MAT.502	Real Analysis	C	4	-	-	4	25	25	25	25	100
4	MAT.503	Topology	C	4	-	-	4	25	25	25	25	100
5	MAT.504	Linear Algebra	C	4	-	-	4	25	25	25	25	100
6	MAT.505	Differential Equations	C	4	-	-	4	25	25	25	25	100
7	XXX	Inter-Disciplinary Elective -1 (From Other Departments	I_E	2	-	-	2	25	25	25	25	50
	Interdisciplinary courses offered by Mathematics Faculty (For PG students of other Centres)											
8	MAT.402	Basic Mathematics	I_E	2	-	-	2	25	25	25	25	50
				24	**-**	**-**	**24**	**-**	**-**	**-**	**-**	**600**

C_A**:** Continuous Assessment: Based on Objective Type Tests/ Assignments

M_1 : Mid-Term Test-1: Based on Objective Type & Subjective Type Test

M_2 : Mid-Term Test-2: Based on Objective Type & Subjective Type Test

E_T : End-Term Exam (Final): Based on Objective Type Tests

T_M : Total Marks

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

SEMESTER- II

S. No	**Course Code**	**Course Title**	**Course type**	L	**T**	**P**	**Cr**	**% Weightage** C_A	M_1	M_2	E_T	T_M
1	MAT.403	Computer Fundamentals and C Programming	F	3	0	0	3	25	25	25	25	75
2	MAT.404	Computer Fundamentals and C Programming (Lab)	F	0	0	2	1	-	-	-	-	25
3	MAT.506	Algebra – I	C	4	-	-	4	25	25	25	25	100
4	MAT.507	Measure Theory	C	4	-	-	4	25	25	25	25	100
5	MAT.508	Differential Geometry of Curves and Surfaces	C	4	-	-	4	25	25	25	25	100
6	MAT.509	Complex Analysis	C	4	-	-	4	25	25	25	25	100
7	MAT.510	Mechanics	C	2	-	-	2	25	25	25	25	50
8	XXX	Humanities for Science Students (From Other Departments)	I_E	2	**-**	**-**	2	25	25	25	25	50
Interdisciplinary course offered by Mathematics faculty for PG students other centres												
9	MAT.405	Linear Programming	I_E	2	-	-	2	25	25	25	25	50
	MAT.406	Numerical Methods		2	-	-	2	25	25	25	25	50
				22	**-**	**4**	**24**	**-**	**-**	**-**	**-**	**600**

C_A**:** Continuous Assessment: Based on Objective Type Tests/ Assignments

M_1 : Mid-Term Test-1: Based on Objective Type & Subjective Type Test

M_2 : Mid-Term Test-2: Based on Objective Type & Subjective Type Test

E_T : End-Term Exam (Final): Based on Objective Type Tests

T_M : Total Marks

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

Semester-III

S. No	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage C_A	M_1	M_2	E_T	T_M
1	MAT.405	Research Methodology-II	F	2	0	0	2	25	25	25	25	50
2	MAT.601	Algebra-II	C	4	-	-	4	25	25	25	25	100
3	MAT.602	Differential Topology	C	4	-	-	4	25	25	25	25	100
4	MAT.603	Numerical Analysis	C	3	-		3	25	25	25	25	75
5	MAT.604	Numerical Analysis (Lab)	C			2	1					25
6	MAT.599	Seminar	F	-	-	-	2	-	-	-	-	50
	MAT.605	Advanced Partial Differential Equations										
	MAT.606	Advanced Complex Analysis	E									
7	MAT.607	Mathematical Methods		4	-	-	4	25	25	25	25	100
	MAT.608	Discrete Mathematics										
	MAT.609	Number Theory										
8	MAT.610	Operations Research	E	4	-	-	4	25	25	25	25	100
				23	**-**	**2**	**24**	**-**	**-**	**-**	**-**	**600**

C_A**:** Continuous Assessment: Based on Objective Type Tests// Assignments

M_1: Mid-Term Test-1: Based on Objective Type & Subjective Type Test

M_2: Mid-Term Test-2: Based on Objective Type & Subjective Type Test

E_T: End-Term Exam (Final): Based on Objective Type Tests

T_M: Total Marks

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

Semester-IV

S. No	Course Code	Course Title	Course Type	L	T	P	Cr	% Weightage				T_M
								C_A	M_1	M_2	E_T	
1	MAT.611	Functional Analysis	**C**	4	-	-	4	25	25	25	25	100
2	MAT.612	Calculus of Variation and Integral Equations	**C**	4	-	-	4	25	25	25	25	100
3	MAT.600	Dissertation Research	**C**		-	16	8	-	-	-	-	200
4	MAT.613 MAT.614 MAT.615	Riemannian Geometry Algebraic Topology Finite Element Analysis	**E**	4	-	-	4	25	25	25	25	100
5	MAT.616 MAT.617 MAT.618	Advanced Numerical Analysis Fluid Mechanics Lie Algebra	**E**	4	-	-	4	25	25	25	25	100
				16		**16**	**24**	**-**	**-**	**-**	**-**	**600**

C_A **:** Continuous Assessment: Based on Objective Type Tests/ Assignments

M_1 : Mid-Term Test-1: Based on Objective Type & Subjective Type Test

M_2 : Mid-Term Test-2: Based on Objective Type & Subjective Type Test

E_T : End-Term Exam (Final): Based on Objective Type Tests

T_M : Total Marks

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

Semester-I

Course Title: Research Methodology-I
Course Code: MAT.401

L	T	P	Credits	Marks
2	0	0	2	50

Total Hours: 32

Course Objective: The course Research Methodology -I has been framed to introduce basic concepts of research methods and statistics.

Unit-I **(08 Lecture Hours)**

Introduction: Meaning and importance of research, Different types and styles of research, Role of serendipity, Critical thinking, Creativity and innovation, Hypothesis formulation and development of research plan, Art of reading, understanding and writing scientific papers, Literature survey, Interpretation of results and discussion, Poster preparation and presentation.

Unit-II **(08 Lecture Hours)**

Library: Classification systems, e-library, Reference management, Web-based literature search engines, Intellectual property rights (IPRs).

Entrepreneurship and business development: Importance of entrepreneurship and its relevance in career growth, Types of enterprises and ownership.

Unit-III **(08 Lecture Hours)**

Statistical analysis and fitting of data: Meaning, Characteristics, Measure of central tendency, Arithmetic mean, median, mode, geometric mean, harmonic mean.

Dispersion: Meaning, Computation of dispersion, Range method, Averaging. First moment of dispersion-Mean deviation, The second moment of dispersion, Standard deviation, third moment of dispersion the quartile deviation.

Unit-IV **(08 Lecture Hours)**

Skewness, Moments and Kurtosis: Skewness, Test of skewness, objectives of skewness, distinction between skewness and dispersion, measure of skewness, kurtosis, meaning and importance, measures of moments and kurtosis

Correlation and regression analysis: Positive and negative correlation, Causation and correlation, Methods of studying correlation, Regression coefficient and the coefficient of correlation, the point of intersection of two regression lines.

Recommended Books:

1. S. Gupta, *Research Methodology and Statistical techniques*, Deep and Deep Publications (P) Ltd. New Delhi, India, 2005.
2. Sheldon M. Ross, *Probability and Statistics for Engineers and Scientists*, Elsevier Academic Press, 2009.

Suggested Readings:

1. C. R. Kothari, *Research Methodology*, New Age International, New Delhi, India, 2008.
2. R. Panneerselvam, *Research Methodology*, PHI, New Delhi, 2005.
3. S. C. Gupta and V. K. Kapoor, *Fundamentals of Mathematical Statistics*, Sultan Chand & Sons, 2014.

Course Title: Probability and Distribution Theory
Course Code: STA.501
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

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

Unit-I **(13 Lecture Hours)**

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

Unit-II **(14 Lecture Hours)**

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, Chi-square, Laplace and Lognormal.

Unit-III **(15 Lecture Hours)**

Bivariate random variable and their joint, marginal and conditional p.m. fs. and p.d.fs, correlation coefficient, conditional expectation. Bivariate normal and multinomial 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), truncated distributions, compound distributions.

Unit-IV **(14 Lecture Hours)**

Markov, Chebyshev, Holder, Jensen and Liapounov inequalities. Convergence in probability and in distribution, weak law of large numbers. Central limit problem; De-Moivre-Laplace and Lindeberg-levy forms of central limit theorem. Approximating distribution of a function of a statistic (Delta method). Transformation of statistics.

Recommended Books:

1. V. K. Rohtagi and A. K. M. E. Saleh, An Introduction to Probability Theory and Mathematical Statistics, Wiley Eastern, 2010.
2. P. L. Meyer, *Introductory Probability and Statistical Applications*, Oxford & IBH Pub., 1975.
3. I. Miller and M. Miller, *Mathematical Statistics*, 6th Edition, Oxford & IBH Pub., 1999.
4. S. N. Mishra and E. J. Dudewicz, Modern Mathematical Statistics, Wiley International Student Edition, 1988.

Suggested Readings:

1. S. M. Ross, Introduction to Probability Models, 11th Edition, 2014.
2. C. R. Rao, *Linear Statistical Inference and its Applications*, 2nd Ed., Wiley Eastern, 2002.
3. S. Johnson and S. Kotz, *Distributions in Statistics*, Vol. I, II and III, Houghton and Miffin, 1972.

Course Title: Real Analysis
Course Code: MAT.502
Total Lectures: 56

L	T	P	Credits	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 funtions, the calculus of several variables and some basic theorems.

Unit-I **(15 Lecture Hours)**

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 $\mathfrak{R}^k$, Perfect sets, Cantor set, Separated sets, Connected sets in a metric space, Connected subsets of real line. Convergent sequences (in Metric spaces), 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-II **(15 Lecture Hours)**

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 Integral, Properties of integral, Integration and differentiation, Riemann sums and Riemann integral. Fundamental theorem of Calculus, Integration of vector valued functions, Rectifiable curves.

Unit-III **(13 Lecture Hours)**

Sequence and Series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. Equicontinuous Families of Functions, The Stone-Weierstrass Theorem.

Unit-IV **(13 Lecture Hours)**

Functions of several variables, Linear transformation, Derivative is an open subject, Chain rule, Partial derivatives, Jacobian, Interchange of the order of differentiation, Derivation of higher order, Inverse function theorem, Implicit function theorem.

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.

Suggested Readings:

1. E. C. Titchmarsh, *The Theory of functions*, 2nd Edition, Oxford University Press 1961.
2. Tom M. Apostol, *Mathematical Analysis*, Addition –Wesley, 2002.
3. Ajit Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, Narosa, Publishing House, 2014.
4. R. G. Bartle, *The Elements of Real Analysis*, John Willey and Sons, 1976.

Course Title: Topology
Course Code: MAT.503
Total Hours: 56

L	T	P	Credits	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 **(12 Lecture Hours)**

Countable and uncountable sets, Infinite sets and Axiom of choice, Limsup, Liminf. Bolzano Weierstrass Theorem, Cardinal numbers and their arithmetic. Schroeder-Bernstein Theorem, Cantor's theorem and the continuum hypothesis, Zorn's Lemma, Well-ordering Theorem.

Unit-II **(16 Lecture Hours)**

Topological Spaces: Open sets, Closed sets, Neighbourhoods, 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, Moebius band, Torus. Covering spaces.

Unit-III **(14 Lecture 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-IV **(14 Lecture Hours)**

The Countability Axioms: Separable spaces, Lindelof spaces. Separation Axioms: Hausdorff spaces, Regularity, Complete regularity, Normality, Urysohn Lemma, Urysohn Metrization Theorem, Tietze Extension Theorem. Tychnoff Theorem.

Recommended Books:

1. J. R. Munkres, *Topology- A First Course*, Prentice Hall of India, New Delhi, 1975.
2. M. A. Armstrong, *Basic Topology*, Springer, Paperback Edition, 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.504
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

Objective:
The concepts and techniques from linear algebra are of fundamental importance in many scientific disciplines. 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 **(14 Lecture Hours)**

Vector Space: Vector spaces, Subspaces, Direct sum of subspaces, Linear dependence and independence, Basis and dimensions, Linear transformations, Algebra of linear transformations, Dual spaces, Matrix representation of a linear transformation, Rank and nullity of a linear transformation, Invariant subspaces. Change of basis,

Unit I **(15 Lecture Hours)**

Characteristic polynomial and minimal polynomial of a linear transformation, Cayley Hamilton theorem, Eigenvalues and eigenvectors of a linear transformation, Diagonalization and triangularization of a matrix, Characteristic polynomial and minimal polynomial of block matrices. Canonical forms, Diagonal forms, Triangular forms, Jordan canonical forms, rational canonical forms, Quotient spaces.

Unit III **(14 Lecture Hours)**

Linear functional, Dual space, Dual basis, Annihilators, Bilinear forms, Symmetric bilinear forms, Sylvester's theorem, quadratic forms, Hermitian forms. Reduction and classification of quadratic forms.

Unit IV **(13 Lecture 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. J. Gilbert and L. Gilbert: *Linear Algebra and Matrix Theory,* Cengage Learning, 2004.
2. V. Bist and V. Sahai, *Linear Algebra,* Narosa, Delhi, 2002.

Suggested Readings:

1. I. N. Herstein, *Topics in Algebra* 2nd Edition, Wiley Eastern Limited, New Delhi, 2006.
2. K. Hoffman and R. Kunze: *Linear Algebra* 2nd Edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2004.
3. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, *First Course in Linear Algebra,* Wiley Eastern, Delhi, 2003.

Course Title: Differential Equations
Course Code: MAT.505
Total Hours: 56

L	T	P	Credits	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 **(13 Lecture Hours)**

Initial value problem, Existence of solutions of ordinary differential equations of first order, Existence and Uniqueness theorem, Regular and Singular points, Singular solutions for first order ODEs, System of first order ODEs, General theory of homogenous and non-homogeneous linear ODEs, Variation of parameters, Method of undetermined coefficients, Reduction of the order of equation.

Unit-II **(14 Lecture Hours)**

Lipchitz's condition, Picards theorems, Dependence of solution on initial conditions and on function, Continuation of solutions, Non local existence of solutions. Green's function and its applications.

Unit-III **(13 Lecture Hours)**

Simultaneous differential equations, Orthogonal trajectories, Boundary value problems, Sturm Liouville's boundary value problems. Sturm comparison and separation theorems, Orthogonal solutions.

Unit-IV **(16 Lecture Hours)**

Classification of first order PDE, Classification of second order PDE, Lagrange's linear PDE, Charpit's method. Well posed and Ill-posed problems, Monge's method, General solution of higher order 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*, 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.
4. M.D. Raisinghania, *Advanced Differential Equations*, S. Chand & Company Ltd., New Delhi, 2001.

Suggested Readings:

1. E.A. Codington and N. Levinson, *Theory of Ordinary Differential Equations*, McGraw Hill, New York, 1955.
2. E. B. Williams and C. DiPrima Richard, *Elementary Differential Equations and Boundary Value Problems*, John Wiley and Sons, New York, 1967.
3. W.T. Reid, *Ordinary Differential Equations*, John Wiley and Sons, New York, 1971.

Course Title: Basic Mathematics
Course Code: MAT.402
Total Lectures: 32

L	T	P	Credits	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 Lecture Hours)**

Ordered pairs, Cartesian product of sets. Number of elements in the Cartesian product of two finite sets. Definition of relation, domain, co-domain and range of a relation. Function as a special kind of relation from one set to another. Domain, co-domain and range of a function. Real valued function of the real variable, Domain and range of these functions, constant, identity, Polynomial, rational, Functions.

Unit-II **(08 Lecture 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 Lecture 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,

Unit-IV **(08 Lecture Hours)**

Matrix and determinants, Properties of determinants, Eigen values and Eigen vectors, Derivatives, Differential equations, Order and degree of differential equations, Solution of first order differential equations. Definite integral and its properties.

Recommended Books:

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

Suggested Reading Books:

1. M.D Raisinghania, *Advanced Differential Equations*, S. Chand & Company Ltd., New Delhi, 2001.
2. E. Kreyszig, *Advanced Engineering Mathematics*, 9th edition, John Wiley & Sons, Inc., 2006.

Semester-II

Course Title: Computer Fundamentals and C Programming
Course Code: MAT.403

L	T	P	Credits	Marks
3	0	0	3	75

Total Hours: 45

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 Lecture 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 Lecture Hours)**

Computer Software: Significance of software in 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 algorithm, Flow charts, Problem solving methods, Need of programming languages.

Unit-III **(12 Lecture 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 Lecture 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. Kerninghan and Ritchie D.M., *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 (LAB)

Course Code: MAT.404

L	T	P	Credits	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.506
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

Objective:
This course provides the foundation required for more advanced studies in Algebra. The aim is also to develop necessary prerequisites for MAT.506 (Algebra-II).

Unit I **(15 Lecture Hours)**

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 **(14 Lecture Hours)**

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

Unit III **(13 Lecture Hours)**

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

Unit IV **(14 Lecture 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, 1974.
2. M. Artin, *Algebra*, (Second Edition) Prentice Hall of India, 2011.
3. S. Surjeet and Q. Zameeruddin, *Modern Algebra,* 8th Edition, Vikas Publishing House, New Delhi, 2006.

Course Title: Measure Theory
Course Code: MAT.507
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

Objective: The objective of this course is to introduce student's measure theory in an abstract setting after having studied Lebesgue measure on real line. Some important theorems are also studied.

Unit-I **(14 Lecture Hours)**

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

Unit-II **(14 Lecture Hours)**

Borel sets, Lebesgue outer measure and Lebesgue measure on R, Translation invariance of Lebesgue measure, Existence of a non-measurable set, Characterizations of Lebesgue measurable sets, The Cantor-Lebesgue function.

Unit-III **(14 Lecture Hours)**

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

Unit-IV **(14 Lecture Hours)**

Bounded convergence theorem, Fatou's lemma, Lebesgue monotone convergence theorem, Lebesgue dominated convergence theorem, 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, Grand Text Mathematics*, 14^{th} Edition, Springer, 1994.

Suggested Readings:

1. I. K. Rana, *An Introduction to Measure and Integration,* 2^{nd} 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, 2012.
4. G.B. Folland, *Real Analysis,* 2^{nd} Edition, John Wiley, New York, 1999.

Course Title: Differential Geometry of Curves and Surfaces
Course Code: MAT.508
Total Hours: 56

L	T	P	Credits	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, Riemannian Geometry and allied areas.

Unit-I **(14 Lecture 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, Isomeries of R^3, Congruence of curves.

Unit-II **(14 Lecture Hours)**

Surfaces in R^3**:** Smooth surfaces, Tangent, Normal and Orientability. Examples of surfaces: Generalized cylinder and cone, Ruled surfaces and Surface of revolution. First fundamental form, Isometry of surfaces, Conformal mapping of surfaces, Surface Area, Equi-areal maps and a Theorem of Archemedes,

Unit-III **(14 Lecture Hours)**

Second fundamental form, Curvature of curves on a surface, Normal and Principal curvatures, Meusnier's theorem, Euler's theorem, Geometric interpretation of principal curvatures, Umbilical points. Gaussian and Mean curvature, Flat surfaces, Surfaces of constant mean curvature, Gaussian curvature of compact surfaces, Gauss map.

Unit-IV **(14 Lecture Hours)**

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

Recommended Books:

1. A. Pressley, *Elementary Differential Geometry*, Springer (Undergraduate Mathematics Series), 2001.
2. M. P. Do Carmo, *Differential Geometry of Curves and Surfaces*, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1976.
3. B. O' Neill, *Elementary Differential Geometry*, Academic Press, 1997.

Suggested Readings:

1. C. Bär, *Elementary Differential Geometry*, Cambridge University Press, 2001.
2. A. Gray, *Differential Geometry of Curves and Surfaces*, CRC Press, 1998.
3. R. S. Millman & G. D. Prkar, *Elements of Differential Geometry*, Prentice Hall, Englewood, Clifts, NJ, 1977.
4. T. J. Willmore, *An Introduction to Differential Geometry*, Oxford University Press, London, 1965.

Course Title: Complex Analysis
Course Code: MAT.509
Total Lectures: 56

L	T	P	Credits	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 **(14 Lecture 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, Construction of analytic functions.

Unit-II **(14 Lecture 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 **(14 Lecture Hours)**

Singularities of analytic functions, Casorati-Weierstrass theorem, 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 **(14 Lecture 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. L. V. Ahlfors, *Complex Analysis*, Tata McGraw Hill, 1979.
2. S. Ponnusamy, *Foundations of Complex Analysis*, Narosa Publishing House, 2007.

Suggested Readings:

1. W. Tutschke and H.L. Vasudeva, *An Introduction to Complex Analysis: Classical and Modern Approaches*, CRC Publications, 2004.
2. R. V. Churchill & J. W. Brown, *Complex Variables and Applications*, Tata McGraw Hill, 1996.

Course Title: Mechanics
Course Code: MAT.510
Total Hours: 32

L	T	P	Credits	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 Lecture 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 **(08 Lecture 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 Lecture Hours)**
Method of point set constraints, generalized coordinates D'Alembert's principle and lagrange's equations, Applications of lagrangian formulation. Hamilton's principle, Techniques of calculus of variations.

Unit-IV **(08 Lecture Hours)**
Lagrange's equations through Hamilton's principle, Cyclic coordinates and conservation theorems, Canonical equations of Hamilton, Hamilton's equations from variational principle.

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

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.
4. Louis N. Hand and Janet D. Finch, *Analytical Mechanics*, Cambridge University Press, 1998.
5. D.E Rutherford, *Classical Mechanics*, Oliver & Boyd Ltd., 3rd Edition, 1964

Course Title: Linear Programming
Course Code: MAT.405
Total Lectures: 32

L	T	P	Credits	Marks
2	0	0	2	50

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 **(10 Lecture 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 Lecture 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 Lecture Hours)**

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

Unit-IV **(06 Lecture 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
Course Code: MAT.406
Total Lectures: 32

L	T	P	Credits	Marks
2	0	0	2	50

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

Unit-I **(08 Lecture Hours)**

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

Unit-II **(08 Lecture Hours)**

Bisection method of Balzeno, Method of false position and convergence, Newton Raphson method, Order of convergence.

Unit-III **(08 Lecture Hours)**

Interpolation and Polynomial Approximation, Lagrange's Method, Newton's polynomials.

Unit-IV **(08 Lecture Hours)**

Solution of Differential Equations: Euler's method, Hen'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*, Cambridge University Press, 2nd Edition, 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,* John Wiley & Sons, 2nd Edition, 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*, Prentice-Hall, 4th Edition, 2005.

Semester-III

Course Title: Research Methodology-II
Course Code: MAT.407
Total Hours: 32

L	T	P	Credits	Marks
2	0	0	2	50

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 **(08 Lecture Hours)**

Formulation of Research Problem and Hypothesis:

Research Problem: How to proceed? Necessary Conditions for formulation of research problem, Sources of research problem, Criteria of a Good Research Problem, formulation and stating the problem, Common errors.

Hypothesis: The meaning, Importance, Type of sources, Characteristics of a usable hypothesis, The use of hypothesis in different types of research, Different forms of hypothesis in different types of research, Different forms of hypothesis, Difficulties in formulation of hypothesis, Testing the hypothesis

Unit-II **(08 Lecture Hours)**

Literature Survey: References, Abstraction of a research paper, Possible ways of getting oneself abreast of current literature

Unit-III **(08 Lecture Hours)**

Documentation and Scientific Writing: Result and conclusions; Preparation of manuscript for publication of research paper, Presenting a paper in scientific seminar, thesis writing.

Structure and components of research report, Types of reports, Thesis, Research project reports, Pictures and graphs, Citation styles, Writing a review of paper, Bibliography.

Unit-IV **(08 Lecture Hours)**

Computer Applications: Use of word processing, Spreadsheet and database software. Plotting of graphs. Internet and its applications: Email, WWW., Web browsing, acquiring technical skills, drawing inferences from data

Recommended Books:

1. S. Gupta, *Research Methodology and Statistical Techniques*, Deep and Deep Publications, 1999.
2. J. Anderson, B. H. Dursten and M. Poole, *Thesis & Assignment writing*, Wiley Eastern, 1977.

Suggested Readings:

1. M. Alley, *The Craft of Scientific Writing*, 3rd Corrected Edition, Springer, 1998.
2. R. A. Day and B. Gastel, *How to Write and Publish*, 7th Revised Edition, Cambridge University Press, 2011.
3. R. Kumar, *Research Methodology-A Step by Step Guide for Beginners*, Pearson Education, 2005.

Course Title: Algebra–II
Course Code: MAT.601
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

Objective:
This course is a basic course in Algebra for students who wish to pursue research work in Algebra.

Unit-I **(13 Lecture 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 Lecture Hours)**

Modules: Difference between modules and vector Spaces, Module Homomorphism, Quotient module, Completely reducible or Semi simple modules, Free modules, Representation and rank of linear mappings, Smith normal form over a PID, Finitely generated modules over a PID, Rational canonical Form, Applications to finitely generated abelian groups.

Unit-III **(13 Lecture Hours)**

Vector spaces: Definition and basic theory, The matrix of linear transformations, Dual vector spaces, Determinants, The primary decomposition theorem, Canonical forms: Rational canonical forms, Jordan blocks and Jordan forms.

Unit-IV **(15 Lecture Hours)**

Galios Theory: Automorphism groups, Fixed fields, Galois extensions, The fundamental theorem of Galois theory, Cyclotomic extensions, and Cyclic extensions, 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, 2011.
3. D. S. Dummit and R. M. Foote, *Abstract Algebra*, 3rd Edition, John Wiley, 2011.

Suggested Readings:

1. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory,* Academic Press, 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, 2000.
5. I. Stewart, *Galois Theory,* Chapman and Hall, 2003.
6. B. Hartley and T. O. Hawkes, *Rings, Modules and Linear Algebra,* Chapman and Hall, 1970.
7. C. Musili, *Rings and Modules,* 2nd Revised Edition, Narosa Publishing House, New Delhi, 1994.

Course Title: Differential Topology
Paper Code: MAT.602
Total Hours: 56

L	T	P	Credits	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 Differential Geometry of Curves and Surfaces and Riemannian Geometry, as well as be adequately prepared for pursuing research in these topics.

UNIT-I **(14 Lecture Hours)**

The standard differential structure on the Euclidean space $\mathfrak{R}^n$. Definition of manifold as a submanifold of R^n, The standard abstract definition of manifolds using transition functions; Examples including the spheres, Real projective spaces, Higher genus surfaces. Definition of orientability of a manifold with examples (To discuss why Moebius band, Real projective plane and Klein bottle are not orientable).

UNIT-II **(14 Lecture Hours)**

Smooth maps and diffeomorphisms, the inverse function theorem, immersion and submersion, embedding, local immersion and local submersion theorems, critical and regular points (values) of a smooth map. Support of a function, bump functions, smooth version of Urysohn's Lemma for a manifold, Partition of unity.

UNIT-III **(13 Lecture Hours)**

Group actions on spaces, homogeneous spaces, orbits and isotropy subgroup. Cylinder, Torus, Mobius band and Klein's bottle as orbit spaces of a properly discontinuous group action of discrete groups on the Euclidean plane, Paracompact spaces, Sards Theorem, Whitney Embedding Theorem.

UNIT-IV **(15 Lecture Hours)**

Definition and examples of Lie groups and Lie algebras, homomorphism, Left and right translations of a Lie group, Left (right) invariant vector fields, Lie algebra of a Lie group, Interpretation of the space of left (right) invariant vector fields of a Lie group G as the tangent space to G at the identity. Exponential map, One-parameter subgroups; Closed subgroups, Cartan's theorem and Adjoint representation of a Lie group.

Recommended Books:

1. Amiya Mukherjee, *Topics on Differential Topology*, Hindustan Book Agency, New Delhi, 2005.
2. S. Kumaresan, *A Course in Differential Geometry and Lie Groups (Texts and Readings in Mathematics)*, Hindustan Book Agency, 2002.
3. A. R. Shastri, *Elements of Differential Topology*, CRC, Chapman & Hall, 2011.

Suggested Readings:

1. M. W. Hirsch, *Differential Topology*, Springer-Verlag, New York, 1976.
2. J. R. Munkres, *Elementry Differential Topology*, Princeton University Press, 1966.
3. V. Guilleman and A. Pollac, *Differential Topology*, Prentice Hall, Englewood, clifts, New Jerssey, 1974.
4. G. E. Bredon, *Topology and Geometry*, Springer-Verlag, New York, 1993.

Course Title: Numerical Analysis
Course Code: MAT.603
Total Hours: 45

L	T	P	Credits	Marks
3	0	0	3	75

Objective:

The aim of this course is to teach the applications of various numerical techniques for a variety of problems occurring in daily life. At the end of the course, the students will be able to do programming in C/C++/MATLAB and understand the basic concepts in Numerical Analysis of differential equations.

Unit-I **(11 Lecture 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, Order of convergence, Newton's method for two non linear equations.

Unit-II **(11 Lecture Hours)**

Linear Systems of Equations: Gauss Elimination, Gauss-Jordan method, LU decomposition, Gauss- Seidel iteration and SOR methods.

Eigen Value Problems: Power method and Jacobi method.

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

Unit-III **(12 Lecture Hours)**

Spline and Approximation: Cubic Spline, B-Spline, Least square method, Påde approximation, Chebyshev Approximation.

Numerical Differentiation: Numerical differentiation with finite differences, Errors in numerical differentiation.

Numerical Integration: 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 Lecture 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, Predicator-Corrector 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*, Cambridge University Press, 2nd Edition, 2015.
4. K. Atkinson, *An Introduction to Numerical Analysis*, John Wiley & Sons, 2nd Edition, 1989.

Course Title: Numerical Analysis (Lab)
Course Code: MAT.604
Total Hours: 30

L	T	P	Credits	Marks
0	0	2	1	25

Objective: Laboratory experiments will be set in context with the materials covered in theory in C/C++/MATLAB.

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 root of f(x)=0 in the detected interval.
2. To find the root of f(x)=0 using Newton-Raphson and fixed point iteration methods.
3. To compute the intermediate value using the Newton's forward difference interpolation formula.
4. To compute Lagrange and divided difference interpolating polynomials.
5. To solve linear system of equations using Gauss elimination (without pivoting) method.
6. To solve linear system of equations using Gauss- seidel method.
7. To find the dominant eigen-value and associated eigen-vector by Rayleigh power method.
8. To integrate a function numerically using trapezoidal and Simpson's rule.
9. To solve the initial value problem using Euler and modified Euler's methods.
10. To solve the initial value problem using and Runge-Kutta methods.
11. To solve the initial value problem using predictor corrector methods.

Course Title: Seminar
Course Code: MAT.599
Total Hours: 56

L	T	P	Credits	Marks
0	0	4	2	50

Course Title: Advanced Partial Differential Equations
Course Code: MAT.605
Total Hours: 56

L	T	P	Credits	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 **(15 Lecture 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 **(14 Lecture 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 **(13 Lecture Hours)**
Evolution Equations: Unbounded linear operators, C_0 – Semigroups, Hille-Yosida theorem, Contraction Semigroup on Hilbert Spaces, Heat equation, Wave equation, Schrodinger equation, Inhomogeneous equations.

Unit-IV **(14 Lecture 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*, American Mathematical Society, 2nd Edition, Indian Reprint, 2014.

Course Title: Advanced Complex Analysis
Course Code: MAT.606
Total Hours: 56

L	T	P	Credits	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 **(15 Lecture 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 **(15 Lecture 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 Lecture 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 (z)], Integral formula for (z),Addition theorem and Duplication formula for (z).
Unit- IV **(13 Lecture Hours)**
Weierstrass Zeta function: Weierstrass Zeta function and their properties, Quasi periodicity of (z), Weierstrass sigma function (z) and their properties, Quasiperiodicity of (z), Associated sigma functions.

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

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

Course Title: Mathematical Methods
Course Code: MAT.607
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

Objective:
The objective of the course is to provide foundation for other related branches of Mathematics. Most of the topics covered are widely applicable in Applied Mathematics and Engineering.

UNIT-I **(14 Lecture Hours)**
Laplace Transform: Laplace transform and inversion formulas, First shifting theorem, Laplace transform of the derivatives and of the Integrals of a function, Derivatives and Integrals of Laplace transforms, Convolution products, Applications of Laplace transform in initial and boundary value problems, heat, wave and Laplace equations.

UNIT– II **(14 Lecture Hours)**
Fourier Transform: Fourier integrals, Fourier cosine and sine integrals, Inverse Fourier transform, Fourier cosine and sine transform, Complex form of the Fourier transform, Linearity of the Fourier transform. Discrete Fourier transforms (DFT), Relationship of FT and fast Fourier transforms (FFT), Applications of FT to heat conduction, vibrations and potential problems,

UNIT- III **(13 Lecture Hours)**
Fourier series: Periodic functions, Trigonometric series, Fourier series, Euler formulas, Functions having arbitrary periods, Even and Odd functions, Half-range expansions, Determination of Fourier coefficients without integration, Approximation by trigonometric polynomials, Square error.

UNIT- IV: **(15 Lecture Hours)**

Applications of ODEs: Applications of differential equations to vibrations of mass in a spring, Free undamped motion, Free damped motion, Forced motion, Resonance phenomenon and Electric circuit problems. **Series Solutions**: Power series solutions, Bessel and Legendre differential equations, Generating functions and recurrence relations.

Recommended Books:
1. E. Kreyszig, *Advanced Engineering Mathematics*, Wiley India Pvt. Ltd., 8^{th} Edition, 2001.
2. R.K. Jain and S.R.K. Iyengar, *Advanced Engineering Mathematics*, Narosa Publishing, 4^{th} Edition, 2014.

Suggested Readings:
1. J. H. Davis, *Methods of Applied Mathematics with a MATLAB Overview*, Birkhäuser, Inc., Boston, MA, 2004.
2. M.D. Raisinghania, *Advanced Differential Equations*, S. Chand & Company Ltd., 2001
3. S.L. Ross, *Differential Equations*, Wiley, 1984.

Course Title: Discrete Mathematics
Course Code: MAT.608
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

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 **(13 Lecture 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 **(14 Lecture Hours)**

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 **(15 Lecture 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 **(14 Lecture 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*, McGraw Hill, Delhi, 2007.
2. K. D. Joshi, *Foundation of Discrete Mathematics,* J. Wiley & Sons, Delhi, 1989.

Suggested Readings:

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

Course Title: Number Theory
Course Code: MAT.609
Total Hours: 56

L	T	P	Credits	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 **(14 Lecture Hours)**

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

Unit-II **(14 Lecture 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 **(14 Lecture 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 **(14 Lecture 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. Zuckeman, and H. L. Montgomery, *Introduction to Number Theory*, Wiley Eastern, 1991.

Suggested Readings:

1. T. N. Apostal, *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.

Course Title: Operations Research
Course Code: MAT.610
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

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 Lecture Hours)**

Operations Research and its Scope, Necessity of Operations Research in industry 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 **(14 Lecture Hours)**

Duality theory, Dual linear Programming Problems, Fundamental properties of dual problems, Complementary slackness, Unbounded solution in Primal. Dual Simplex Algorithm, Sensitivity analysis.

Unit-III **(14 Lecture 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 and Sequencing.

Unit -IV **(14 Lecture Hours)**

Replacement problem, replacement of items that Deteriorate, replacement of items that fails completely. Job Sequencing Problems; Introduction and assumption, Processing of n jobs through two machines, Processing of n jobs through three machines and m machines, Processing two jobs through n machines.

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.

Semester-IV

Course Title: Functional Analysis
Course Code: MAT.611
Total Hours: 56

L	T	P	Credits	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 **(13 Lecture 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 **(14 Lecture 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 **(14 Lecture 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 **(15 Lecture 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: Calculus of Variation and Integral Equations
Course Code: MAT.612
Total Hours: 56

L	T	P	Credits	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 **(14 Lecture Hours)**

Linear Functional, Euler's - Lagrange's equations of single independent and single dependent variable and application. Necessary and Sufficient Conditions for Extrema. Brachistochrone problem, Functional involving higher order derivatives. Variational methods for boundary value problems in ordinary and partial differentioal eqauation.

Unit-II **(14 Lecture Hours)**

Isoperimetric problems, Geodesics, Geodesics on a sphere of radius 'a', variational problem with several variables, functionals dependent on one or two functions, derivation of basic formula, variational problems with moving boundaries, Broken extremals: Weierstrass –Erdmann conditions.

Unit-III **(14 Lecture Hours)**

Volterra Equations: Integral equations and algebraic system of linear equations. Volterra equation L2 kernels and functions. Volterra equations of first and second kind. Volterra integral equation and linear differential equation.

Unit-IV **(14 Lecture Hours)**

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

Recommended books:

1. R. P. Kanwal, *Linear Integral Equations*, Birkhauser, Boston, 1996.
2. A. Pinckus, and S. Zafrany, *Fourier series and Integral Transform*, Cambridge University Press, New York, 1997.

Suggested Readings:

1. J. L. Synge and B.A. Griffith, *Principle of Mechanics*, McGraw-Hill Book Company, 1970.
2. H. Goldstein, *Classical Mechanics,* Narosa Publishing House, 2nd Edition, 1980.
3. Zafar Ahsan, *Lecture Notes on Mechanics, Department of Mathematics,* AMU, 1999.
4. R. P. Kanwal, *Linear Integral Equations*, Birkhauser, Boston, 1996.
5. A. Pinckus, and S. Zafrany, *Fourier series and Integral Transform*, Cambridge University Press, New York, 1997.

Course Title: Dissertation Research
Course Code: MAT.600
Total Hours: 112

L	T	P	Credits	Marks
0	0	16	8	200

Course Title: Riemannian Geometry
Course Code: MAT.613
Total Hours: 56

L	T	P	Credits	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 **(15 Lecture Hours)**

Differentiable manifolds, Examples: Spheres (in higher dimensions), Product of manifolds (construction of cylinder, Torus, n-torus as a product of manifolds). Smooth maps on a manifold, smooth map between two manifolds. Tangent space, Tangent bundle, Vector fields and Lie bracket. Covariant differentiation of vector fields and affine connection. Riemannian metric, Riemannian manifolds, Fundamental Theorem of Riemannian Geometry via Koszul Formula.

Unit-II **(13 Lecture 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 **(15 Lecture 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-Renow Theorem (statement only), Geodesic variations, Jacobi fields and Gauss lemma.

Unit-IV **(13 Lecture 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, Cartan-Hadmard Theorem, Cartan's Theorems (on determination of metric by curvature).

Recommended Books:

1. J. M. Lee, *Riemannian Manifolds: An Introduction to Curvature*, GTM, Springer, 1st Edition, 1997.
2. B. O' Neill, *Semi-Riemannian geometry with Applications to Relativity*, Academic Press, New York, 1983.
3. M. P. Docarmo, *Riemannian geometry*, Birkhausker Boston, 1992.

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 Co. Pte. Ltd., 2000.
3. W. M. Boothby, *An Introduction to Differentiable Manifolds and Riemannian geometry*, 2nd Edition, Academic Press, New York, 2003.

Course Title: Algebraic Topology
Course Code: MAT.614
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

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

Unit-I **(14 Lecture 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.

Unit-II **(13 Lecture 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 **(15 Lecture 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 **(15 Lecture Hours)**

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

Recommended Books:

1. James R. Munkres, *Elements of Algebraic Topology*, Perseus Books, 11 December 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: Finite Element Analysis
Course Code: MAT.615
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

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 **(13 Lecture 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 **(15 Lecture 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 **(13 Lecture 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, theory of elasticity, variational functions, triangular elements and area coordinates, transformations, cylindrical coordinates.

Unit-IV **(15 Lecture 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, Computer procedures for Finite element analysis.

Recommended Books:

1. C. S. Desai, *Introductory Finite Element Method*, Boca Raton: CRC Press, 2001.
2. G. D. Smith, *Numerical Solution of Partial Differential Equations*, Oxford: Clarendon Press, 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*, Delhi: McGraw-Hill Higher Education, 2005.
3. D. Braess, Schumaker and Larry L. *Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics,* New York: Cambridge University Press, 2001.

Course Title: Advanced Numerical Analysis
Course Code: MAT.616

L	T	P	Credits	Marks
4	0	0	4	100

Total Hours: 56

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, Eigen value problems, Interpolation and Approximation techniques and their use in differentiation and integration, differential equations etc.

UNIT- I **(15 Lecture 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:** Triangularization, Cholesky and Partition methods, SOR method with optimal relaxation parameters.

UNIT-II **(13 Lecture Hours)**

Eigen-Values of Real Symmetric Matrix: Similarity transformations, Gerschgorin's bound(s) on eigenvalues, Givens, Householder and Rutishauser 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 **(13 Lecture 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, Applications of cubic spline to ordinary differential equation of boundary value type.

UNIT- IV **(15 Lecture 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*, Cambridge University Press, 2nd Edition, 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, S.D. and Carl D. Boor, Elementary Numerical Analysis: An Algorithmic Approach, Tata McGraw Hill 2005.

Course Title: Fluid Mechanics
Course Code: MAT.617
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

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 **(14 Lecture 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, irrigational and rotational motion, acceleration of fluid, conditions at rigid boundary.

Unit-II **(14 Lecture Hours)**

Euler's equation of motion, Bernoulli's equation, their applications, Potential theorems, Axially symmetric flows, impulsive motion, Kelvin's theorem of circulation, equation of vorticity.

Unit-III **(14 Lecture Hours)**

Some Three Dimensional Flows: sources, sinks and doublets, images in rigid planes, images in solid sphere, Stoke's stream function.

Unit-IV **(14 Lecture Hours)**

Two Dimensional Flows: complex velocity potential, Milne Thomson circle theorem and applications, theorem of Blasius, vortex rows, Karman Vortex Street.

Recommended books:

1. F. Charlton, *Text Book of Fluid Dynamics*, CBS Publishers, Indian Edition, Delhi, 2004
2. Landau, and E. N. 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. Kundu, and Cohen. *Fluid Mechanics*, Harcourt (India) Pvt.Ltd., Delhi, 2003.
2. G.K. Batechelor, *An Introduction to Fluid Dynamics*, Cambridge Press, 2002
3. H. Schliting and K. Gersten, *Boundary Layer Theory*, Springer, 8th Edition, 2004
4. Rosenhead, *Laminar Boundary Layers*, Dover Publications, 1963
5. P.G. Drazin, and W. H. Reid, *Hydrodynamic Stability*, Cambridge Press, 2004

Course Title: Lie Algebra
Course Code: MAT.618
Total Hours: 56

L	T	P	Credits	Marks
4	0	0	4	100

Objective:
The aim of this course is to make the students learn fundamental concepts of Lie Groups and Lie Algebras so as to enable the students to understand further topics related to solution of differential equations. It widely used to solve a variety of problems of science and engineering related to fluid flows, structures etc.

Unit-I **(13 Lecture Hours)**
Definition and examples of Lie algebras, Classical Lie algebras, Derivations of a Lie algebra, Abelian Lie algebra, Lie subalgebras, Ideals and homomorphisms, Normalizers and centralizers of a Lie sub algebra, Representations of Lie algebras (definition and some examples), Automorphisms of a Lie algebra.

Unit-II **(15 Lecture Hours)**
Solvable algebra, Solvable radical, Nilpotent algebra, Engel's Theorem, Semi-simple Lie algebra, Lie's Theorem, Jordan-Chevalley decomposition (existence and uniqueness), Cartan trace criterion for solvability, Killing form and criterion for semi simplicity.

Unit-III **(13 Lecture Hours)**
Simple ideals, Inner derivations, Abstract Jordan-Chevalley decomposition, Lie algebra modules, Schur's Lemma, Casimir elements of a representation, Weyl's Theorem for preservation of Jordan-decomposition.

Unit-IV **(15 Lecture Hours)**
Representation of sl(2, C): weights, highest weight, maximal vectors, classification of irreducible modules, toral and maximal toral subalgebra, root space decomposition and properties of roots. Abstract root systems, Weyl group, Root strings, Bases and their existence, Weyl chambers, Classification of rank 2 root systems.

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.