Central University of Punjab, Bathinda

M.Sc. MATHEMATICS

Session 2019-2021

Department of Mathematics and Statistics

SEMESTER- I

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	**T**	**P**	
STA.506	Probability and Distribution Theory	Core	4	-	-	4
MAT.506	Real Analysis	Core	4	-	-	4
MAT.508	Linear Algebra	Foundation	4	-	-	4
MAT.509	Ordinary Differential Equations	Core	4	-	-	4
MAT.559	Number Theory	Core	4	-	-	4
XYZ	Inter-Disciplinary Elective -1 (From Other Departments	IDC	2	-	-	2
Total			22	-	-	22

Interdisciplinary courses offered by Mathematics Faculty (For PG students of other Departments)

MAT.510	Basic Mathematics (IDC)	IDC	2	-	-	**2**

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MAT.523	Algebra – I	Core	4	-	-	4
MAT.525	Differential Geometry	Core	4	-	-	4
MAT.526	Complex Analysis	Core	4	-	-	4
MAT.530	Topology	Core	4	-	-	4
MAT.553	Numerical Analysis	Foundation	3	-	-	3
MAT.554	Numerical Analysis (Practical)	Foundation	-	-	2	1
ABC	Value Added Course	VAC	1	-	-	1
XYZ	IDC course from other Departments	IDC	2	-	-	2
Total			22	-	2	23

Interdisciplinary courses offered by Department of Mathematics and Statistics (For PG students of other Departments)

MAT.528	Linear Programming Problems	IDC	2	-		2

Value added course offered by Department of Mathematics and Statistics

MAT.529	Numerical Methods (VAC)	Skill based	1	-		1

SEMESTER-III

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MAT.502	Research Methodology	Foundation	4	-	-	4
MAT.543	Seminar	Skill based	2	-	-	2
MAT.551	Algebra-II	Core	4	-	-	4
MAT.552	Calculus of Variation and Integral Equation	Core	4	-	-	4
MAT.561	Partial Differential Equations	Core	4	-	-	4
MAT.524	Measure Theory	Core	4	-	-	4
STA.557	Operations Research	Discipline Elective	4	-	-	4
MAT.563	Differentiable Manifolds					
MAT.556	Advanced Complex Analysis					
MAT.574	Advanced Numerical Analysis					
Total			26	-	-	26

SEMESTER-IV

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MAT.527	Mechanics	Core	2	-	-	2
MAT.571	Functional Analysis	Core	4	-	-	4
MAT.558	Discrete Mathematics	Discipline Elective	4	-	-	4
MAT.572	Riemannian Geometry					
MAT.577	Finite Element Analysis					
MAT.580	Fluid Dynamics					
MAT.581	Competitive Exam Course-1 (DEC)	Compulsory Foundation	2	-	-	2
MAT.582	Competitive Exam Course-2 (DEC)	Compulsory Foundation	2	-	-	2
MAT.599	Project Work	Skill based	-	-	12	6
XYZ	Value Added Course	Skill based	1	-	-	1
	Total		15	-	12	21

Total Credits for the course: 92

Evaluation Criteria for Theory classes

A. Continuous Assessment: [25 Marks]

i. Surprise Test (minimum three)- Based on Objective Type Tests (10 Marks)

ii. Term paper (10 Marks)

iii. Assignments (5 Marks)

B. Mid Semester Test: Based on Subjective Type Questions [25 Marks]

C. End Semester Test: Based on Subjective Type Questions [25 Marks]

D. End-Term Exam: Based on Objective Type Questions [25 Marks]

Evaluation Criteria for Practical classes

A. Practical file: [10 Marks]

B. Written Exam: [10 Marks]

C. Viva-Voce [5 Marks]

Course Title: Probability and Distribution Theory	L	T	P	Cr
Course Code: STA.506	4	0	0	4

Course Code: STA.506
Total Hours: 60

Learning outcomes: 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).

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

Suggested Readings:
1. E. J. Dudewicz and S. N. Mishra, *Modern Mathematical Statistics*, Wiley International Student Edition, 1988.
2. I. Miller and M. Miller, *Mathematical Statistics,* 6th Edition, Oxford & IBH Pub., 1999.
3. P. Billingsley, *Probability and Measure*, 4th Edition, John Wiley & Sons, 2012.
4. S. M. Ross, *Introduction to Probability Models*, 11th Edition, 2014.
5. V. K. Rohtagi and A. K. M. E. Saleh, *An Introduction to Probability Theory and Mathematical Statistics*, Wiley Eastern, 2010.

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

L	T	P	Cr
4	0	0	4

Learning outcomes: 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.

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

Suggested Readings:
1. Tom M. Apostol, *Mathematical Analysis*, Addition –Wesley, USA, 1981.
2. R. G. Bartle, *The Elements of Real Analysis*, John Willey and Sons, New York, 1976.
3. Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, Narosa, Publishing House, New Delhi, 2014.
4. W. Rudin, *Principles of Mathematical Analysis,* 3rd Edition, McGraw Hill, Kogakusha, International student Edition, 1976.
5. E. C. Titchmarsh, *The Theory of functions,* Oxford University Press, Oxford, 2002.

Course Title: Linear Algebra	**L**	**T**	**P**	**Cr**
Course Code: MAT.508	4	0	0	4
Total Hours: 60				

Learning outcomes: 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.

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

Suggested Readings:

1. S. Luthar and I. B. S. Passi, *Algebra: Rings*, Volume 2, Narosa Publishing House, 2000.
2. J. Gilbert and L. Gilbert, *Linear Algebra and Matrix Theory,* Cengage Learning, 2004.
3. K. Hoffman and R. Kunze: *Linear Algebra,* 2nd Edition, Pearson Education (Asia) Pvt. Ltd/ Prentice Hall of India, 2004.
4. P. B. Bhattacharya, S.K. Jain and S.R. Nagpaul, *Basic Abstract Algebra,* Wiley Eastern, Delhi, 2003.
5. Bist and V. Sahai, *Linear Algebra,* Narosa, Delhi, 2002.

Course Title: Ordinary Differential Equations	**L**	**T**	**P**	**Cr**
Course Code: MAT.509	4	0	0	4
Total Hours: 60				

Learning outcomes: 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   **15 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   **15 Hours**
Total differential equations, Simultaneous differential equations, Adjoint and self adjoint equations, Green's function and its applications to boundary value problems, Strum-Liouville boundary value problem, Eigen values and Eigen functions, Sturm comparison and separation theorems.

Unit-IV   **15 Hours**
Orthogonal sets of function, Autonomous system of differential equations, Critical points and Stability for Linear systems with constant coefficients, linear plane autonomous systems, perturbed systems, Method of Lyapunov for nonlinear systems. Limit cycles of Poincare-Bendixson Theorem.

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

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. G. F. Simmons and S. G. Krantz, *Differential Equations; Theory, Techniques and Practice*, Tata McGraw Hills, 2007.
4. L. Perko, *Differential Equations and Dynamical Systems*, Springer, 2001.
5. M. D. Raisinghania, *Advanced Differential Equations*, 5th Edition, S. Chand & Company Ltd., New Delhi, 2010.
6. S. L. Ross, *Differential Equations*, 3rd Edition, Wiley, 1984.
7. W.T. Reid, *Ordinary Differential Equations*, John Wiley and Sons, New York, 1971.

	L	T	P	Cr
Course Title: Number Theory	4	0	0	4

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

Learning outcomes:
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 $ax + by = c$, $x^2 + y^2 = z^2$ and its application to $x^4 + y^4 = z^4$. Farey sequences, Continued fractions.

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

Suggested Readings:
1. W. W. Adams and L. J. Goldstein, *Introduction to Number Theory*, Prentice Hall Inc., 1976.
2. T. M. Apostol, *Introduction to Analytic Number Theory*, Springer Verlag, 1976.
3. D. M. Burton, *Elementary Number Theory*, Tata McGraw-Hill, 7th Edition, New Delhi, 2012.
4. H. Davenport, *The Higher Arithmetic: An Introduction to the Theory of Numbers*, Cambridge University Press; 8 edition, 2008.
5. G. H. Hardy and E. M. Wright, *An Introduction to the Theory of Number*, Oxford Univ. Press, U.K., 2008.

6. Niven, S. Zuckerman, and H. L. Montgomery, *Introduction to Number Theory*, Wiley Eastern, 1991.

Course Title: Basic Mathematics (IDC)	L	T	P	Cr
Course Code: MAT.510	2	0	0	2
Total Hours: 30				

Learning outcomes: 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   **8 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   **7 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   **8 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   **7 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.

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

Suggested Reading Books:
1. E. Kreyszig, *Advanced Engineering Mathematics*, 9th edition, John Wiley & Sons, Inc., 2006.
2. E. Kreyszig, *Advanced Engineering Mathematics*, 9th edition, John Wiley & Sons, Inc., 2006.
3. G. B. Thomas and R. L. Finney, *Calculus and Analytic Geometry*, 11th edition, Pearson India, 2015.
4. P. K. Jain, *Mathematics: Text book for class XI*, NCERT, 2006.
5. R. K. Jain and S.R.K. Iyengar, *Advanced Engineering Mathematics*, 8th Edition, Narosa Publications, 2002.

SEMESTER-II

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

L	T	P	Cr
4	0	0	4

Learning outcomes:
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**
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.

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

Suggested Readings:
1. M. Artin, *Algebra,* 2nd Edition, Prentice Hall of India, Delhi, 2011.
2. P. B. Bhattacharya, S. K. Jain and S.R Nagpal, *Basic Abstract Algebra*, Cambridge University Press, New Delhi, 2003.
3. J. A. Gallian, *Contemporary Abstract Algebra,* Narosa Publishing House, New Delhi, 2008.
4. N. S. Gopalakrishnan, *University Algebra*, John Wiley & Sons, 1986.
5. N. Herstein, *Topics in Algebra*, 2nd Edition, Wiley Eastern Limited, New Delhi, 2006.
6. S. Luthar and I. B. S. Passi, *Algebra Vol. II: Rings*, Narosa Publishing House, 1999.
7. B. S. Passi and I. S. Luthar, *Algebra Vol. I: Groups*, Narosa Publishing House, 1996.
8. S. Surjeet and Q. Zameeruddin, *Modern Algebra,* 8th Edition, Vikas Publishing House, New Delhi, 2006.

Course Title: Differential Geometry
Course Code: MAT.525
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: 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.

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

Suggested Readings:
1. A. Gray, E. Abbena, and S. Salamon, *Modern Differential Geometry of Curves and Surfaces with Mathematica*, Third edition, CRC Press, 2006.
2. Pressley, *Elementary Differential Geometry*, Second Edition, Undergraduate Mathematics Series, Springer-Verlag London Ltd., 2010.
3. O' Neill, *Elementary Differential Geometry*, Revised Second Edition, Academic Press, 2006.
4. B$\ddot{a}$r, *Elementary Differential Geometry*, Cambridge University Press, 2001.
5. M. P. Do Carmo, *Differential Geometry of Curves and Surfaces*, Revised and Updated Second Edition, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 2016.
6. R. S. Millman & G. D. Parkar, *Elements of Differential Geometry*, Englewood Cliffs, N.J. : Prentice Hall, 1977.

7. T. J. Willmore, *An Introduction to Differential Geometry*, First Edition, Dover Publications, Inc., Mineola, New York, 2012.

	L	**T**	**P**	**Cr**
Course Title: Complex Analysis	4	0	0	4

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

Learning outcomes: 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.

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

Suggested Readings:
1. L. V. Ahlfors, *Complex Analysis*, 3rd Edition, Tata McGraw-Hill, 1979.
2. R. V. Churchill & J. W. Brown, *Complex Variables and Applications*, 8th Edition, Tata McGraw-Hill, 2014.
3. S. Ponnusamy, *Foundations of Complex Analysis*, 2nd Edition, Narosa Publishing House, 2007.
4. Theodore W. Gamelin, *Complex Analysis.* UTM, Springer-Verlag 2001.
5. W. Tutschke and H.L. Vasudeva, *An Introduction to Complex Analysis, Classical and Modern Approaches*, 1st Edition, CRC Publications, 2004.

Course Title: Topology
Course Code: MAT.530
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: 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.

Unit-II   **15 Hours**
Quotient Topology: Construction of cylinder, Cone, Mobius band and Torus. Connected spaces, Connected subspaces of the real line, Components and path components, Local connectedness.

Unit-III   **15 Hours**
Compact spaces, Sequentially compact spaces, Heine-Borel theorem, Compact subspaces of the real line, Limit point compactness, Local–compactness and one point compactification. The Countability axioms: Separable spaces, Lindeloff spaces.

Unit-IV   **14 Hours**
Separation axioms: Hausdorff spaces, Regularity, Complete regularity, Normality, Urysohn lemma, Urysohn metrization theorem, Tietze extension theorem and Tychnoff theorem.

Suggested Readings:
1. G. F. Simmons, *Introduction to Topology & Modern Analysis*, McGraw Hill, Auckland, 1963.
2. J. L. Kelley, *General Topology*, GTM, First Edition, Springer, 1975.
3. J. R. Munkres, *Topology,* Second Edition, Pearson India Education services Pvt. Ltd., 2015.
4. James Dugundji, *Topology,* Universal Book Stall, New Delhi, 1990.
5. M. A. Armstrong, *Basic Topology*, Paperback Edition, Springer, 2004.
6. S. Kumaresan, *Topology of Metric Spaces,* second edition*,* Narosa Publishing House New Delhi, 2015.

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

Course Title: Numerical Analysis	L	T	P	Cr
Course Code: MAT.553	3	0	0	3

Course Title: Numerical Analysis
Course Code: MAT.553
Total Hours: 45

Learning outcomes: 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.

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

Suggested Readings:
1. K. Atkinson, *An Introduction to Numerical Analysis*, 2nd Edition, John Wiley & Sons, 1989.
2. R. L. Burden and J. D. Faires, *Numerical Analysis*, 9th Edition, Cengage Learning, 2011.
3. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7th Edition, Pearson LPE, 2009.
4. R. S. Gupta, *Elements of Numerical Analysis*, 2nd Edition, Cambridge University Press, 2015.
5. 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.
6. S. S. Sastry, *Introductory Methods of Numerical Analysis*, 4th Edition, PHI,

Course Title: Numerical Analysis (Practical)	**L**	**T**	**P**	**Cr**
Course Code: MAT.554	0	0	2	1
Total Hours: 30				

Learning outcomes: 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.

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

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 2nd and 4th order Runge-Kutta methods.
14. To solve the initial value problem using modified Euler's method.
15. To solve the initial value problem using 2nd and 4th order Runge-Kutta methods.

Course Title: Linear Programming (IDC)	**L**	**T**	**P**	**Cr**
Course Code: MAT.528	2	0	0	2
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   **8 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   **8 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   **8 Hours**
Transportation and Assignment Problem: Transportation problems, Formulation of transportation problem, Feasible and optimal solution of transportation problems. Assignment problems.

Unit-IV   **6 Hours**
Theory of games: Introduction to basic concepts of game theory including strategic Games.

Suggested Readings:
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 (VAC)	**L**	**T**	**P**	**Cr**
Course Code: MAT.529	1	0	0	1
Total Lectures: 30				

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

Unit-I   **7 Hours**
Error Analysis: Relative error, Truncation error, Roundoff error, Order of approximation, Order of convergence, Propagation.

Unit-II   **8 Hours**
Roots of Nolinear Equations: Bisection method, Secant method, Newton Raphson method, Convergence and order of convergence.

Unit-III   **8 Hours**
Linear Systems of Equations: Gauss elimination and Gauss-Seidel methods.
Interpolation: Lagrange's Method, Newton's polynomials.

Unit-IV   **7 Hours**
Solution of Differential Equations: Euler's method, Heun's method, Taylor series method, Runge Kutta method.

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

Suggested Readings:
1. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7th Edition, Pearson LPE, 2009. *Computation*, 6th Edition, New Age International, New Delhi, 2015.
2. J. I. Buchaman and P. R. Turner, *Numerical Methods and Analysis,* Prentice-Hall, 1988.
3. K. Atkinson, *An Introduction to Numerical Analysis,* 2nd Edition, John Wiley & Sons, 2012.
4. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering*
5. R. S. Gupta, *Elements of Numerical Analysis*, 2nd Edition, Cambridge University Press, 2015.
6. S. S. Sastry, *Introduction Methods of Numerical Analysis*, 4th Edition, Prentice-Hall, 2005.

<center>**SEMESTER-III**</center>

Course Title: Research Methodology	L	T	P	Cr
Course Code: MAT.502	4	0	0	4

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

Learning outcomes:
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.

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

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

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

L	T	P	Cr
2	0	0	2

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

L	T	P	Cr
4	0	0	4

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

Unit-I **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-II **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-III **16 Hours**
Galois Theory: Automorphism groups, Fixed fields, Galois extensions, The fundamental theorem of Galois theory, Cyclotomic extensions, and Cyclic extensions,

Unit-IV **14 Hours**
Applications of cyclotomic extensions and Galois theory to the constructability of regular polygons, Solvability of polynomials by radicals.

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

Suggested Readings:
   1. M. Artin, *Algebra,* 2nd Edition, Prentice Hall of India, Delhi, 2011.

2. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, *First Course in Linear Algebra,* Wiley Eastern, Delhi, 2008.

3. D. S. Dummit and R. M. Foote, *Abstract Algebra*, 3rd Edition, John Wiley, USA, 2011.

4. J. P. Escofier, *Galois Theory*, Springer-Verlag, New York, 2000.

5. N. Herstein, *Topics in Algebra,* 2nd Edition, Wiley Eastern Limited, New Delhi, 2006.

6. S. Luthar and I. B. S. Passi, *Algebra Vol III: Modules*, Narosa Publishing House, 2002.

7. C. Musili, *Rings and Modules,* 2nd Revised Edition, Narosa Publishing House, New Delhi, 2001.

8. B. S. Passi and I. S. Luthar, *Algebra: Volume 4: Field Theory*, Narosa Publishing House, New Delhi, 2010

9. N. Stewart, *Galois Theory,* Chapman and Hall, USA, 2003.

10. B. Hartley and T. O. Hawkes, *Rings, Modules and Linear Algebra*, Chapman and Hall, USA, 1970.

Course Title: Calculus of Variation and Integral Equations	**L**	**T**	**P**	**Cr**
Course Code: MAT.552	4	0	0	4

Total Hours: 60

Learning outcomes:
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.

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

Suggested Readings:

1. H. Goldstein, *Classical Mechanics,* 2nd Edition, Narosa Publishing House, 1980.
2. J. L. Synge and B.A. Griffith, *Principle of Mechanics,* McGraw-Hill Book   Company, 1970.
3. M.D. Raisinghania, *Integral equations and boundary value problems,* 9th Edition, S. Chand Publishing, New delhi, 2016.
4. R. P. Kanwal, *Linear integral equations*, Birkhauser, Boston, 1996.
5. Rakesh Kumar and Nagendra Kumar, *Differential Equations and Calculus of Variations,* CBS Publishers and Distributors Pvt Ltd, 2013.

Course Title: Partial Differential Equations	**L**	**T**	**P**	**Cr**
Course Code: MAT.561	4	0	0	4
Total Hours: 60				

Learning outcomes:

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   **17 Hours**

Formation of PDEs: First order PDE in two and more independent variables, Classification of first order PDEs, Derivation of PDE by elimination method of arbitrary constants and arbitrary functions, Cauchy Problem for first order PDEs, Integral surface passing through given curve, Nonlinear first order PDEs, Lagrange‟s first order linear PDEs, Charpit‟s method and Jacobi‟s method for non-linear PDE of first order,

UNIT-II   **13 Hours**

PDEs of second order with variable coefficients: Classification of second order PDEs, Canonical form, Parabolic, Elliptic and Hyperbolic PDEs, Well posed problems, Superimposition principle.

UNIT-III   **16 Hours**

Fourier Series (FS): Introduction to Fourier series, Convergence of FS for continuous and piece wise continuous functions. Differentiation and Integration of FS, Fourier cosine and sine series.

Fundamental solution of Laplace Equation, Green"s function for Laplace Equation, Wave equation, Diffusion Equation, Solution of BVP in spherical and cylindrical coordinates,

UNIT-IV   **14 Hours**

Method of separation of variables for Laplace, Heat and Wave equations, Eigen values and Eigen functions of BVP, Orthogonality of Eigen function.

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

Suggested Readings:
1. L. C. Evans, *Partial Differential Equations. Graduate Studies in Mathematics*, 2nd Edition, American Mathematical Society, Indian Reprint, 2014.
2. S. J. Farlow, *Partial Differential Equations for Scientists and Engine*ers, Birkhauser, New York, 1993.
3. F. John, *Partial Differential Equations,* Springer-Verlag, New York, 1982.
4. K, Sankara, Rao, *Introduction to Partial Differential Equations*, PHI Learning, 2010.
5. Ian N. Sneddon, *Elements of Partial Differential Equations*, Dover Publications, 2013

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

L	T	P	Cr
4	0	0	4

Learning outcomes: 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   **18 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. 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-II   **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-III   **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.

Unit-IV   **12 Hours**
Functions of bounded variations: Jorden's theorem, L^p spaces, Young's inequality, Minkowski's and Hölder's inequalities, Riesz-Fischer theorem (statement only).

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

Suggested Readings:
1. G.de Bara, *Measure Theory and Integration*, Ellis Horwood Limited, England, 2003.
2. G.B. Folland, *Real Analysis,* 2nd Edition, John Wiley, New York, 1999.
3. P. R. Halmos, *Measure Theory*, 14th Edition, Springer, New York, 1994.
4. B. Krishna and A. Lahiri, *Measure Theory*, Hindustan Book Agency, 2006.
5. K. Rana, *An Introduction to Measure and Integration,* 2nd Edition, Narosa Publishing House, New Delhi, 2005.
6. H. L. Royden, *Real Analysis*, Macmillan, New York, 1988.

Course Title: Operations Research	L	T	P	Cr
Course Code: STA.557	4	0	0	4

Course Title: Operations Research
Course Code: STA.557
Total Hours: 60

Learning outcomes:
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.

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

Suggested Readings:
1. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 1987.
2. H. A. Taha, *Operations Research - An Introduction*, Macmillan Publishing Company Inc., New York, 2006.

3. K. Swarup, P. K. Gupta, and M. Mohan, *Operations Research*, Sultan Chand & Sons, New Delhi, 2001.
4. N. S. Kambo, *Mathematical Programming Techniques*, Affiliated East- West Press Pvt. Ltd., 1984, Revised Edition, New Delhi, 2005.
5. S. M. Sinha, *Mathematical Programming, Theory and Methods,* Delhi: Elsevier, 2006.

Course Title: Differentiable Manifolds
Paper Code: MAT.563
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes: 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, 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.

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**
Differential forms, Cotangent spaces, pullback of 1-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.

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

Suggested Readings:
1. F. Warner, *Foundations of Differentiable Manifolds and Lie Groups*, Springer, New York, 1983.
2. J. M. Lee, *Introduction to Smooth Manifolds*, GTM, Vol. 218, Springer, New York, 2003.
3. L. Conlon, *Differentiable Manifolds*, 2nd edition, Birkhauser Boston, Cambridge, MA, 2001.
4. L. W. Tu, *An Introduction to Manifolds*, Second edition, Springer, 2011.
5. N. J. Hicks, *Notes of Differential Geometry*, D. Van Nostrand Reinhold Company, New York, 1965.
6. S. Kumaresan, *A Course in Differential Geometry and Lie Groups (Texts and Readings in Mathematics),* Hindustan Book Agency, 2002.
7. S. S. Chern, W. H. Chen and K. S. Lam*, Lectures on Differential Geometry*, World Scientific Publishing Co. Pvt. Ltd., 2000.
8. W. M. Boothby, *An Introduction to Differentiable Manifolds and Riemannian Geometry*, 2nd edition, Academic Press, New York, 2003.

	L	**T**	**P**	**Cr**
Course Title: Advanced Complex Analysis	4	0	0	4

Course Code: MAT.556

Total Hours: 60

Learning outcomes:
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.

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

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

Course Title: Advanced Numerical Analysis	**L**	**T**	**P**	**Cr**
Course Code: MAT.574	4	0	0	4
Total Hours: 60				

Learning outcomes: 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.

Suggested Readings:
1. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7th Edition, Pearson LPE, 2009.
2. K. Atkinson, *An Introduction to Numerical Analysis*, John Wiley & Sons, 2nd Edition, 1989.

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.
4. R. S. Gupta, *Elements of Numerical Analysis*, 2nd Edition, Cambridge University Press, 2015.
5. R.L. Burden and J. D. Faires, *Numerical Analysis*, 9th Edition, Cengage Learning, 2011.
6. S.D. Conte and Carl D. Boor, *Elementary Numerical Analysis: An Algorithmic Approach,* Tata McGraw Hill, 2005.

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

L	T	P	Cr
4	0	0	4

Learning outcomes: 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: Nomed Spaces, with examples of Function spaces $L^p($ [a,b] $)$,C([a,b]) and C^1([a,b]), Sequence Spaces l^p, c , c_0, c_{00} Banach spaces and examples, finite dimensional normed spaces and subspaces, compactness and finite dimension

Unit-II   **15 Hours**
Bounded linear transformations, Normed linear spaces of bounded linear transformations, Dual spaces with examples.
Three Main Theorems on Banach Space: Banach Steinhauns theorem (Uniform boundedness theorem) and some of its consequences, Open mapping and closed graph theorems.

Unit-III   **14 Hours**
Hahn-Banach theorem for real linear spaces and its consequences, Reflexive spaces, Solvability of linear equations in Banach spaces.

Unit-IV   **17 Hours**
Geometry of Hilbert spaces: Inner product spaces, orthonormal sets, Approximation and optimization, Projections and Riesz Representation theorem. Bounded Operators on Hilbert spaces: Bounded operators and adjoints; normal, unitary and self adjoint operators, Spectrum and Numerical Range.

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

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. E. Kreyszig, *Introductory Functional Analysis with Application*, Willey, 2007.

4. B. V. Limaye, *Functional Analysis,* New Age International (P) Ltd, New Delhi, 1996.
5. F. K. Riesz, and B. S. Nagy, *Functional Analysis*, Dover Publications, 1990.
6. H. Siddiqui, *Functional Analysis*, Tata-McGraw Hill, New Delhi, 1987.
7. W. Rudin, *Functional Analysis*, McGraw Hill Education; 2 edition, 2017.

Course Title: Mechanics	**L**	**T**	**P**	**Cr**
Course Code: MAT.527	2	0	0	2

Total Hours: 30

Learning outcomes:
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   **8 Hours**
Lagrangian Mechanics: Generalized coordinates, Holonomic and non-holonomic systems, Scleronomic and rhenomic systems, Generalized potential, Lagrange's equations of motion of first kind and second kind, Energy equation for conservative field.

Unit-II   **7 Hours**
Hamiltonian Mechanics: Hamilton variables, Hamilton canonical equation, Cyclic coordinates, Canonical transformations, Hamilton's principle, Principle of least action.

Unit-III   **8 Hours**
Small Oscillations for Conservative System: Small oscillations of conservative system, Lagrange's equation for small oscillations, Nature of roots of frequency equation, Principle oscillations. Normal coordinates Hamilton-Jacobi equation and Jacobi theorem.

Unit-IV   **7 Hours**
Poisson Brackets and Lagrange Bracket: Poisson brackets, Poisson's identity, Jacobi - Poisson theorem, Lagrange bracket, Condition of canonical character of transformation in terms of Lagrange bracket and Poisson brackets.

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

Suggested Readings:
1. F. Gantmacher, *Lectures in Analytic Mechanics,* Mir Publisher, Moscow, 1975.
2. H. Goldstien, C. Ppoole and J.L. Sofco, *Classical Mechanics,* 3rd Edition, Addison Wesely, 2002.
3. J.C. Upadhyaya, *Classical Mechanics,* 2nd Edition, Himalaya Publishing House, Pvt. Ltd., New Delhi, 2017.
4. J.E. Marsden, *Lectures on Mechanics,* Cambridge University Press, 1992.
5. K. Sankra Rao, *Classical Mechanics,* 1st Edition, Prentice Hall of India, 2005.
6. L.D. Landau and E.M. Lipshitz, *Mechanics,* Pergamon Press, Oxford, 1976.
7. M.R. Speigal, *Theoretical Mechanics,* 1st Edition, Schaum Outline Series, 1967.
8. N.C. Rana and P.S. Joag, *Classical Mechanics,* 1st Edition, Tata McGraw-Hill, New Delhi, 1991.

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

L	T	P	Cr
4	0	0	4

Learning outcomes: 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, Relativity theory and Cosmology.

Unit-I   **16 Hours**
Review of differentiable manifolds and vector fields, 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, 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).

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

Suggested Readings:

1. B. O' Neill, *Semi-Riemannian Geometry with Applications to Relativity*, Academic Press, New York, 1983.
2. J. M. Lee, *Riemannian Manifolds: An Introduction to Curvature*, GTM, Springer, 1st Edition, 1997.
3. M. Berger, *A Panoramic View of Riemannian Geometry*, Springer; 1st Edition, 2003. Corr. 2nd printing, 2007.
4. M. P. Docarmo, *Riemannian Geometry*, Birkhausker Boston, 1992.
5. S. Kumaresan, *A Course in Differential Geometry and Lie Groups (Texts and Readings in Mathematics),* Hindustan Book Agency, 2002.
6. S. S. Chern, W. H. Chen and K. S. Lam*, Lectures on Differential Geometry*, World Scientific Publishing , 2000.
7. W. M. Boothby, *An Introduction to Differentiable Manifolds and Riemannian Geometry*, 2nd Edition, Academic Press, New York, 2003.

Course Title: Discrete Mathematics	L	T	P	Cr
Course Code: MAT.558	4	0	0	4
Total Hours: 60				

Learning outcomes:
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 Hours**
Set Theory: Paradox in set theory, Inductive definition of sets and proof by induction; Peano 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.

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

Suggested Readings:
1. C. L. Liu, *Elements of Discrete Mathematics*, 4th Edition, McGraw-Hill, New Delhi, 1986.
2. D. S. Malik, and M. K. Sen, *Discrete Mathematical Structures Theory and Applications*, 2nd Edition, Thomson/Course Technology, 2004.
3. K. D. Joshi, *Foundation of Discrete Mathematics,* John Wiley & Sons, New Delhi, 1989.
4. K. H. Rosen, *Discrete Mathematics and its Applications*, 7th Edition, McGraw-Hill, New Delhi, 2007.

Course Title: Fluid Dynamics

Course Code: MAT.580
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes:
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.

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

Suggested Readings:
1. F. Chorlton, *Text Book of Fluid Dynamics*, Indian Edition, CBS Publishers, New Delhi, 2004.
2. G. K. Batchelor, *An Introduction to Fluid Mechanics*, Cambridge University Press, New York, 1967.
3. G.K. Batechelor, *An Introduction to Fluid Dynamics*, Cambridge Press, 2002
4. H. Schlichting and K. Gersten, *Boundary Layer Theory,* 8th Edition , Springer, , 2004
5. L. D. Landau, and E. M. Lipschitz, *Fluid Mechanics*, Pergamon Press Ltd., London, 1987.

6. L. Rosenhead, *Laminar Boundary Layers*, Dover Publications, 1963.
7. P. K. Kundu, and I. M. Cohen. *Fluid Mechanics*, Hardcover (India) Pvt.Ltd., Delhi, 2003.
8. P.G. Drazin, and W. H. Reid, *Hydrodynamic Stability*, Cambridge Press, 2004

Course Title: Finite Element Analysis
Course Code: MAT.577
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes:
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.

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

Suggested Readings:
1. B. Bradie, *A Friendly Introduction to Numerical Analysis,* Pearson, New Delhi, 2005.
2. C. S. Desai, *Introductory Finite Element Method*, CRC Press, Boca Raton, 2001.
3. D. Braess, Schumaker and Larry L. *Finite Elements: Theory, Fast Solvers, and Applications in Solid Mechanics,* Cambridge University Press, New York, 2001.
4. G. D. Smith, *Numerical Solution of Partial Differential Equations*, Clarendon Press, Oxford, 1986.
5. J. N. Reddy, *An Introduction to Finite Element Methods,* McGraw-Hill Higher Education, New Delhi, 2005.

Course Title: Competitive Exam Course-1	**L**	**T**	**P**	**Cr**
Course Code: MAT.581	2	-	-	2
Total Hours: 60				

Learning outcomes:
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.

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

	L	**T**	**P**	**Cr**
Course Title: Competitive Exam Course-2	2	-	-	2

Course Title: Competitive Exam Course-2
Course Code: MAT.582
Total Hours: 30

Learning outcomes:
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   **8 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   **7 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   **8 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   7 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 eigenfunctions, resolvent kernel.

Suggested Readings:
1. Pinckus, and S. Zafrany, *Fourier series and Integral Transform*, Cambridge University Press, New York, 1997.
2. G. D. Smith, *Numerical Solution of Partial Differential Equations*, Oxford: Clarendon Press, 1986.
3. N. Sneddon, *Elements of Partial Differential Equations*, McGraw-Hill, 2006.
4. J. A. Gallian, *Contemporary Abstract Algebra,* Narosa Publishing House, New Delhi, 2008.
5. L. C. Evans, *Partial Differential Equations. Graduate Studies in Mathematics*, American Mathematical Society, 2nd Edition, Indian Reprint, 2014.
6. M. D. Raisinghania, *Advanced Differential Equations*, S. Chand & Company Ltd., New Delhi, 2001.
7. 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.
8. P. B. Bhattacharya, S.K. Jain and S.R Nagpal, *Basic Abstract Algebra*, Cambridge University Press, New Delhi, 2003.
9. R. L. Burden and J. D. Faires, *Numerical Analysis*, 9th Edition, Cengage Learning, 2011.
10. R. P. Kanwal, *Linear Integral Equations*, Birkhauser, Boston, 1996.
11. R. S. Gupta, *Elements of Numerical Analysis*, Cambridge University Press, 2nd Edition, 2015.
12. S. L. Ross, *Differential Equations*, Wiley, 1984.I. Miller and M. Miller, *Mathematical Statistics,* 6th Edition, Oxford & IBH Pub., 1999.

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

L	T	P	Cr
1	-	-	1

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

L	T	P	Cr
-	-	12	6

Learning outcomes: 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.

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