Central University of Punjab, Bathinda

M.Sc. MATHEMATICS

Session 2020-2022

Department of Mathematics and Statistics

School of Basic and Applied Sciences

Program Outcomes:

After completion of the program, students will be able to

- develop a broad understanding of recent mathematical theories, tools and techniques.
- apply different mathematical techniques in various fields.
- independently plan and carry out research in pure and applied mathematics.
- compete at national/international level for research/jobs in area of mathematics.

SEMESTER- I

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MAT.506	Real Analysis	Core	4	0	0	4
MAT.508	Linear Algebra	Foundation	4	0	0	4
MAT.509	Ordinary Differential Equations	Core	4	0	0	4
MAT.559	Number Theory	Core	4	0	0	4
MAT.512	Mathematical Statistics	Core	4	0	0	4
XYZ	Inter-Disciplinary Elective -1 (From Other Departments	IDC	2	0	0	2
Total			**22**	**0**	**0**	**22**

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

MAT.510	Basic Mathematics (IDC)	IDC	2	0	0	2

SEMESTER- II

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MAT.525	Differential Geometry	Core	4	0	0	4
MAT.526	Complex Analysis	Core	4	0	0	4
MAT.530	Topology	Core	4	0	0	4
MAT.531	Abstract Algebra	Core	4	0	0	4
MAT.553	Numerical Analysis	Foundation	3	0	0	3
MAT.554	Numerical Analysis (Practical)	Skill based	0	0	2	1
ABC	Value Added Course	VAC	1	0	0	1
XYZ	IDC course from other Departments	IDC	2	0	0	2
Total			**22**	**0**	**2**	**23**

Value added course offered by Department of Mathematics and Statistics

MAT.528	Linear Programming	VAC	1	0	0	1

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

MAT.529	Numerical Methods	IDC	2	0	0	2

Semester-III

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MAT.502	Research Methodology	Foundation	4	0	0	4
MAT.543	Seminar	Skill based	0	0	0	2
MAT.552	Calculus of Variation and Integral Equation	Core	4	0	0	4
MAT.563	Differentiable Manifolds	Core	4	0	0	4
MAT.561	Partial Differential Equations	Core	4	0	0	4
MAT.524	Measure Theory	Core	4	0	0	4
MAT.557	Operations Research					
MAT.562	Advanced Algebra	Discipline Elective		0	0	4
XYZ	MOOC Course		4			
Total			**24**	**0**	**0**	**26**

Semester-IV

Course Code	Course Title	Course Type	Credit Hours			Course Credits
			L	T	P	
MAT.571	Functional Analysis	Core	4	0	0	4
MAT.527	Mechanics	Core	2	0	0	2
MAT.572	Riemannian Geometry	Discipline Elective*	4	0	0	4
MAT.577	Finite Element Analysis					
MAT.580	Fluid Dynamics					
MAT.581	Competitive Exam Course-1 (DEC)	Compulsory Foundation	2	0	0	2
MAT.582	Competitive Exam Course-2 (DEC)	Compulsory Foundation	2	0	0	2
MAT.599	Project Work	Skill based	0	0	0	6
XYZ	Value Added Course	VAC	1	0	0	1
Total			**15**	**0**	**0**	**21**

Total Credits for the course: 92

***Course(s) will be offered based on the availability of subject experts.**

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: [5 Marks]
B. Practical and Written Exam: [15 Marks]
C. Viva-Voce [5 Marks]

Semester-I

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

L	T	P	Cr
4	0	0	4

Learning outcomes:
The students will be able to

- develop the knowledge of set theory and metric spaces with properties.
- Illustrate various properties of compact sets and connected sets.
- Explain concepts of convergent sequences and continuity in metric spaces.
- Study of Riemann Stieltje's Integral in detail.

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. T. 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. A. 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
Course Code: MAT.508
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes:

The students will be able to

- Review the basic notions in linear algebra that are often used in mathematics and other sciences
- Define Vector spaces, Subspaces and related results.
- Define Linear transformations and characteristic polynomials with examples.
- Illustrate various properties of canonical forms.
- Study of Inner product spaces
- Explain concepts of the Gram-Schmidt orthogonalization process.

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 II **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. I. 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. V. Bist and V. Sahai, *Linear Algebra,* Narosa, Delhi, 2002.

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

L	T	P	Credits
4	0	0	4

Learning outcomes:

The students will be able to

- Define Initial, Boundary value problems and related results.
- Review the basic concepts of ordinary differential equations.
- Study of Stability for Linear systems.
- Explain concepts of the Strum-Liouville boundary value problem.

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.

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

L	T	P	Credits
4	0	0	4

Learning outcomes:
The students will be able to

- Understand the concept of Divisibility of integers and Congruences.
- Discuss various important theorems in Number theory.
- Develop the knowledge of Number theoretic functions and explore their usage in various important results.
- Explain the representation of an integer as a sum of two or four squares.
- Describe Quadratic residues and quadratic non-residues with their importance.

Unit-I **15 Hours**

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

Unit-II **15 Hours**

Chinese remainder theorem, Fermat's little theorem, Wilson's theorem, Euler's theorem. Arithmetic functions σ(n), d(n), τ(n), μ(n), Order of an integer modulo n, primitive roots for primes, composite numbers having primitive roots.

Unit-III **15 Hours**

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

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 $x^4 + y^4 = z^2$. 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. I. Niven, S. Zuckerman, and H. L. Montgomery, *Introduction to Number Theory*, Wiley Eastern, 1991.

Course Title: Mathematical Statistics
Course Code: STA.512
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes:
The students will be able to

- Define the sample space and concept of random variables (discrete and continuous).
- Define Moment generating function and characteristic functions with examples.
- Illustrate various properties of Discrete and continuous Distributions.
- Explain concepts of sampling distribution and its standard error, Chi-square, t and F distribution.

Unit I **14 Hours**

Sample space, events and their types, three approaches to probability, combinatorics problems on probability, independent events, Bayes theorem. Bernoulli trials, concept of random variables (discrete and continuous). Distribution Function and its properties, mean and variance. Bivariate random variable and their joint, marginal and conditional p.m.fs. and p.d.fs. Independence of random variables.

Unit II **16 Hours**

Expectation, Conditional expectation, Moments, Moment generating function and its properties,, Tchebyshey's, inequalities, Markov's inequality, Jensen's inequality, Characteristic function and its elementary properties, weak and strong laws of large numbers, Central Limit theorems (i.i.d. case).

Unit III **15 Hours**

Discrete Distributions: Bernoulli, Binomial, Poisson, hyper-geometric, geometric, negative binomial, multinomial. Continuous Distributions: Uniform, normal, exponential, gamma, Beta, bivariate normal.

Unit IV **14 Hours**

Concept of sampling distribution and its standard error, Chi-square, t and F distributions and their applications. Elementary concepts in testing of statistical hypotheses, Tests of significance: tests based on normal distribution, Chi-square, t and F statistic.

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. P.L. Meyer, Introductory probability and statistical applications, Addison-Wesley Publishing Company, Inc., 1972.
5. S. M. Ross, *Introduction to Probability Models*, 11th Edition, 2014.
6. V. K. Rohtagi and A. K. M. E. Saleh, *An Introduction to Probability Theory and Mathematical Statistics*, Wiley Eastern, 2010.

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

L	T	P	Credits
2	0	0	2

Learning outcomes:

The students will be able to

- Define sets and functions with related concepts.
- Understand the concept of functions and relations.
- Relate the concept of Arithmetic progression and Geometric progression and their sum.
- Explain the description of algebraic properties of complex numbers.
- Explore the theory of Matrices and Determinants.

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

L	T	P	Credits
4	0	0	4

Learning outcomes:
The students will be able to

- learn the basic concepts of plane and space curves.
- understand the theory of surfaces in $\mathbb{R}^3$.
- Define the first and second fundamental forms.
- Illustrate various properties of curvature.
- Explain the theory of geodesics and relation between geometry and topology.

Unit-I **15 Hours**
Curves in plane and space: Parameterized curves, Tangent vector, Arc length, Reparametrization, Closed curves, Regular curves, Curvature and torsion of smooth curves, Frenet-Serret formulae, Arbitrary speed curves, Frenet approximation of a space curve, Isomeries of $\mathbb{R}^3$, The Tangent Map of an Isometry, Orientation, Congruence of curves, Simple closed curves, The isoperimetric inequality, The four vertex theorem.

Unit-II **15 Hours**
Surfaces in $\mathbb{R}^3$**:** Definition and examples, Smooth surfaces, Smooth maps, Tangents and derivatives, Normal and orientability. Examples of surfaces: Level surfaces, Generalized cylinder and generalized cone, Ruled surfaces, Surface of revolution, Quadric and Compact surfaces. First fundamental form, Isometries of surfaces, Conformal mapping of surfaces, Surface area, Equiareal maps and theorem of Archimedes.

Unit-III **15 Hours**
Second fundamental form, Gauss and Weingarten maps, Curvature of curves on a surface, Normal and geodesic curvatures, Meusnier's theorem, Parallel transport and covariant derivative, Gaussian and mean curvatures, Principal curvatures, Geometric interpretation of principal curvatures, Euler's theorem, Surfaces of constant Gaussian curvature, Umbilical points, Flat surfaces, Surfaces of constant mean curvature, Gaussian curvature of compact surfaces.

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 and Codazzi-Mainardi equations, Gauss

Theorema Egregium, Compact surfaces of constant Gaussian curvature, Geodesic 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. C. Bär, *Elementary Differential Geometry*, Cambridge University Press, 2001.
2. M. P. Do Carmo, *Differential Geometry of Curves and Surfaces*, Revised and Updated Second Edition, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 2016.
3. A. Gray, E. Abbena, and S. Salamon, *Modern Differential Geometry of Curves and Surfaces with Mathematica*, Third edition, CRC Press, 2006.
4. R. S. Millman & G. D. Parkar, *Elements of Differential Geometry*, Englewood Cliffs, N.J. : Prentice Hall, 1977.
5. B. O' Neill, *Elementary Differential Geometry*, Revised Second Edition, Academic Press, 2006.
6. A. Pressley, *Elementary Differential Geometry*, Second Edition, Undergraduate Mathematics Series, Springer-Verlag London Ltd., 2010.
7. T. J. Willmore, *An Introduction to Differential Geometry*, First Edition, Dover Publications, Inc., Mineola, New York, 2012.

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

L	T	P	Credits
4	0	0	4

Learning outcomes:
The students will be able to

- Recall complex number system and algebra of complex variables.
- Illustrate the concept of analytic function and discuss about the necessary and sufficient conditions for a function to be analytic.
- Understand the notion of complex line integral and related results.
- Discuss Mobius transformations and their properties.

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. 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. H.S. Kasana, *Complex Variables: Theory and Applications,* 2nd Edition, PHI Learning Pvt. Ltd, 2005.
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 students will be able to

- Describe Topological spaces with examples and related concepts in detail.
- Explain continuous functions in topology and its characterizations.
- Understand various topological properties with examples.

- Discuss various countability axioms and separation axioms with their usage to prove many important results in topology.
- Understand important theorems like Urysohn metrization theorem and Tychnoff theorem.
- 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. Nets.

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.

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

Course Title: Abstract Algebra
Course Code: MAT.531
Total Hours: 60

L	T	P	Credits
4	0	0	4

Learning outcomes:
The students will be able to

- Review the basic notions in Group theory.
- Explain the Sylow theorems .
- Review the Ring theory and ideals with examples.
- Illustrate various properties of Polynomial rings.
- Explain Eisenstein's irreducibility criterion and Unique factorization domain.

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.
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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. I. S. Luthar and I. B. S. Passi, *Algebra Vol. II: Rings*, Narosa Publishing House, 1999.
7. I. 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: Numerical Analysis
Course Code: MAT.553
Total Hours: 45

L	T	P	Credits
3	0	0	3

Learning outcomes:

The students will be able to

- Review the basic concepts of various numerical techniques for a variety of mathematical problems occurring in science and engineering.
- Explain the basic concept of errors .
- Review the numerical techniques for interpolation and approximations with examples.
- Explain the concept of numerical integration and solutions of 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*, 2^{nd} Edition, John Wiley & Sons, 1989.
2. R. L. Burden and J. D. Faires, *Numerical Analysis*, 9^{th} Edition, Cengage Learning, 2011.
3. C. F. Gerald and P. O. Wheatly, *Applied Numerical Analysis*, 7^{th} Edition, Pearson LPE, 2009.
4. R. S. Gupta, *Elements of Numerical Analysis*, 2^{nd} Edition, Cambridge University Press, 2015.
5. M. K. Jain, S.R.K. Iyengar and R.K. Jain, *Numerical Methods for Scientific and Engineering Computation*, 6^{th} Edition, New Age International, New Delhi, 2015.

S. S. Sastry, *Introductory Methods of Numerical Analysis*, 4^{th} Edition, PHI,

Course Title: Numerical Analysis (Practical)
Course Code: MAT.554
Total Hours: 30

L	T	P	Credits
0	0	2	1

Learning outcomes:
The students will be able to

- Explain continuous functions in topology and its characterizations.
- Understand the C/C++/MATLAB languages with examples.
- Understand programming in C/C++/MATLAB for basic numerical methods.

Evaluation Criteria for Practical classes
A. Practical file: [15 Marks]
B. Practical Exam: [75 Marks]
C. Viva-Voce [10 Marks]

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

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

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,

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

Course Title: Linear Programming (VAC)
Course Code: MAT.528
Total Hours: 15

L	T	P	Credits
1	0	0	1

Learning outcomes:
The students will be able to

- Discuss the linear programming problem with formulation.
- Apply different methods to solve linear programming problem.
- Understand the concept of Duality theory and Sensitivity analysis.
- Explain transportation problem and assignment problem with their mathematical formulation.

Unit-I **4 Hours**
Formulation of linear programming problems (LPP). Graphical solution to LPPs. Cases of unique and multiple optimal solutions.

Unit-II **4 Hours**
Feasible solution, basic feasible solutions, Optimal solution, Convex sets, Solution of LPP with Simplex methods.

Unit-III **3 Hours**
The dual problem. Formulation of the dual. Dual Simplex method

Unit-IV **4 Hours**

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

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

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.
3. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, McGraw-Hill, New York, 2001.

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

L	T	P	Credits
2	0	0	2

Learning outcomes:

The students will be able to

- Explain the basic concept of errors .
- Review the basic concepts of various numerical techniques for a variety of mathematical problems occurring in science and engineering.
- Review the numerical techniques for interpolation and approximations with examples.
- Explain the concept of numerical solutions of differential equations.

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 Reading:

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.

Semester-III

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

L	T	P	Credits
4	0	0	4

Learning outcomes:

The students will be able to

- Explain the various terms like as objective, meaning of research, significance research etc. which is used in research.
- Review the basic concepts of literature survey and formulation research problems.
- Basic concepts of the research design.
- Review the basic concepts of the research writing problems.

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	Credits
2	0	0	2

Learning outcomes:.

Upon successful completion of this course, the student will be able to:

1. Understand the aspects of seminar presentation.
2. presentation and communication skills.

3. complete with the future challenges in teaching, research and application.

Evaluation Criteria:

The evaluation criteria for "Seminar" shall be as follows:

S. No.	Criteria	Marks
1.	Content of presentation	20
2.	Presentation & Communication Skills	20
3.	Handling of queries	10
Total		50

Course Title: Calculus of Variations and Integral Equations
Course Code: MAT.552
Total Hours: 60

L	T	P	Credits
4	0	0	4

Learning outcomes:

The students will be able to

- Explain the basic concept of Functional.
- Review the basic concepts of variational methods, for boundary value problems in ODE's & PDE's.
- Explain the basic concept of isoperimetric problems.
- Explain the basic concept of Volterra and Fredholm Integral Equations.
- Illustrate various properties of Volterra and Fredholm Integral Equations.

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

L	T	P	Credits
4	0	0	4

Learning outcomes:

The students will be able to

- Explain the basic concept of smooth manifolds and smooth functions.
- Review the basic concepts of Submersions, Immersions and embeddings, Smooth covering maps and Bump functions.
- Explain the concepts of Vector fields, Lie brackets and Lie groups.
- Define the differential forms, exterior derivative, exterior algebra and Lie derivative.

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, Examples of smooth maps, Diffeomorphism, Smoothness in terms of components, 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, Rank of a smooth map, Submersions, Immersions and embeddings, Critical and regular points, Submersion and immersion theorems, Smooth covering maps, Submanifolds: Embedded submanifolds, Immersed submanifolds, 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**

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

L	T	P	Credits
4	0	0	4

Course Title: Partial Differential Equations
Course Code: MAT.561
Total Hours: 60

Learning outcomes:
The students will be able to

- Review the basic concepts of Partial differential equations (PDE).
- Explain the methods for solving nonlinear first order PDEs .
- Classify the second order PDEs into Parabolic, Hyperbolic and Elliptic.
- Explain the concept of Fourier sine and cosine series.
- Study the method of separation of variables for solving Laplace, Heat and Wave equations

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.

Recommended Reading:

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	Credits
4	0	0	4

Learning outcomes:
The students will be able to

- Understand the concept of algebras, σ –algebras and borel sets.
- Define Lebesgue outer measure and Lebesgue measure on R with their characterizations.
- Explain measurable functions and their properties.
- Discuss important theorems related to Lebesgue integral.
- Get in-depth understanding of L^p spaces.

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: Jordan'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 Barra, *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. I. 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
Course Code: MAT.557
Total Hours: 60

L	T	P	Credits
4	0	0	4

Learning outcomes:

The students will be able to

- Discuss the concept of convex sets and linear programming problem with formulation.
- Apply different methods to solve linear programming problem.
- Understand the concept of Duality theory and Sensitivity analysis.
- Explain transportation problem and assignment problem with their mathematical formulation.
- Apply methods to test the optimality of transportation problem.
- Develop understanding of Queuing and inventory models.

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: Advanced Algebra
Course Code: MAT.562
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning outcomes:

The students will be able to

- Understand the basic concept of Modules with examples.
- Explain the Field theory.
- Understand the concept of Gailos theory.

- Apply the cyclotomic extensions and Galois theory to the constructability of regular polygons
- Develop understanding of Queuing and inventory models.

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. I. N. Herstein, *Topics in Algebra,* 2nd Edition, Wiley Eastern Limited, New Delhi, 2006.
6. I. 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. I. B. S. Passi and I. S. Luthar, *Algebra: Volume 4: Field Theory*, Narosa Publishing House, New Delhi, 2010
9. I. 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: MOOC Course
Course Code: XYZ
Total Hours: 60

L	T	P	Credits
4	0	0	4

Semester-IV

Course Title: Functional Analysis
Course Code: MAT.571

L	T	P	Credits
4	0	0	4

Total Hours: 60
Learning outcomes:
The students will be able to

- Describe the basic notion of normed linear spaces and Banach spaces with examples.
- Explain Bounded linear transformations and Dual spaces with related examples.
- Discuss three main theorems on Banach spaces
- Understand the concept of Reflexive spaces
- Define inner product spaces and Elaborate Geometry of Hilbert spaces

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 for Hilbert spaces.f 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. A. H. Siddiqui, *Functional Analysis*, Tata-McGraw Hill, New Delhi, 1987.
7. W. Rudin, *Functional Analysis*, McGraw Hill Education; 2 edition, 2017.

Course Title: Mechanics
Course Code: MAT.527

L	T	P	Credits
2	0	0	2

Total Hours: 30

Learning outcomes:

The students will be able to

- Define the concepts of Lagrangian Mechanics.
- Explain the theory of Hamiltonian Mechanics and related properties.
- Discuss Small Oscillations for Conservative System.
- Understand the concept of Poisson Brackets and Lagrange Bracket.

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	Credits
4	0	0	4

Learning outcomes:

- Review the concepts of differentiable manifolds and covariant differentiation of vector fields

- Explain the theory of Tensors and tensor fields.
- Discuss the Jacobi fields and Gauss lemma.
- Understand the concept of Global differential geometry and related properties.

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. M. Berger, *A Panoramic View of Riemannian Geometry*, Springer; 1st Edition, 2003. Corr. 2nd printing, 2007.
2. W. M. Boothby, *An Introduction to Differentiable Manifolds and Riemannian Geometry*, 2nd Edition, Academic Press, New York, 2003.
3. S. S. Chern, W. H. Chen and K. S. Lam, *Lectures on Differential Geometry*, World Scientific Publishing , 2000.
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. J. M. Lee, *Riemannian Manifolds: An Introduction to Curvature*, GTM, Springer, 1st Edition, 1997.
7. B. O' Neill, *Semi-Riemannian Geometry with Applications to Relativity*, Academic Press, New York, 1983.

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

L	T	P	Credits
4	0	0	4

Learning outcomes:
The students will be able to
- Understand the general theory of finite element methods.
- Explain Generalization of the finite element method for concepts-weighted residual and variational Approaches for Ritz method, Galerkin method, and collocation method.
- Discuss the element properties for two dimensional problems.
- Discuss the element properties for three dimensional problems.

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: Fluid Dynamics
Course Code: MAT.580
Total Hours: 60

L	T	P	Credits
4	0	0	4

Learning outcomes:
The students will be able to

- Review the basic concepts of the study of fluid motion.
- Define the following terms for fluid motion like as Euler's equation of motion, axially symmetric flows, impulsive motion etc.
- Discuss the two dimensional fluid flow for milne thomson circle and Blasius theorems.
- Understand the concept of three dimensional flow for rigid planes, images in solid sphere and Stoke's stream function.

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 Reading:

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: Competitive Exam Course-1
Course Code: MAT.581
Total Hours: 60

L	T	P	Credits
2	0	0	2

Learning outcomes:

Students will be able to

- Review the basic concepts of Analysis.
- Understand the basic concepts of Advance Analysis and Topology.
- Apply the techniques of Linear Algebra for solving problems.
- Review the concepts in Complex Analysis.

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. A. 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.

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

L	T	P	Credits
2	0	0	2

Learning outcomes:
Students will be able to

- Review the basic concepts of Algebra.
- Understand the basic concepts of ordinary and partial differential equations.
- Apply the numerical techniques for solving nonlinear algebraic equations and differential equations.
- Interpret the Variational methods for boundary value problems in ordinary and partial differential equations

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. A. 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. I. 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: Project Work
Course Code: MAT.599
Total Hours: 180

L	T	P	Credits
0	0	0	6

Learning outcomes:.
Upon successful completion of this course, the student will be able to:
1. Understand the aspects of the Review writing and seminar presentation.
2. Write a review of existing scientific literature with simultaneous identification of knowledge gaps.
3. Identify the predatory publications and open access publications.
4. develop an understanding for scientific research.

Evaluation Criteria:
The evaluation criteria for "Project Work" shall be as follows:

S. No.	Criteria	Marks
1.	Literature review report	80
2.	Content of presentation	30
3.	Presentation Skills	25
4.	Handling of queries	15
Total		**150**

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

L	T	P	Credits
1	0	0	1

Course Title: Multivariable Calculus (VAC)
Course Code: MAT.578
Total Hours: 15

L	T	P	Credits
1	0	0	1

Learning outcomes:
Students will be able to

- Review the basic concepts of differentiability in R^n.
- Understand the basic concepts of integration in R^n.
- Discuss the Differential forms on R^n.
- Apply the Divergence theorem and Stokes' formula for solving some integrations.

Unit-I **4 Hours**
Functions in R^n, Differentiability in R^n , directional derivatives, Total derivative, Chain rule, Inverse function theorem, Implicit function theorem,

Unit-II **3 Hours**
Integaration on R^n , Riemann integral of real-valued functions on Euclidean spaces, change of variables.

Unit-III **4 Hours**
Differential forms on R^n, closed and exact forms, Poincaré lemma, Classical Green's theorem.

Unit-IV **4 Hours**
Divergence theorem and Stokes' formula as applications of general form of Stokes' theorem.

Suggested Readings:

1. S. R. Ghorpade and B. V. Limaye, *A course in Calculus and Real Analysis*, Springer, New York, 2006.
2. S. Kumaresan, *A Course in Differential Geometry and Lie groups*, Hindustan Book Agency, Trim 22, 2002.
3. Walter Rudin, *Principles of Mathematical Analysis*, Third Edition, McGraw Hill International Editions, Mathematical Studies 1976; Paper-back Indian Edition 2017.
4. M. Spivak, *Calculus on Manifolds*, W. A. Benjamin, co. 1965.