Department of Mathematics

2-Year M.Sc. Course in Mathematics

Detailed Syllabi

Course Details			
Course Title: Real Analysis			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	I	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Course		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Presentation.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		
Prerequisite	NIL		

Course Objectives

- To understand the axiomatic foundation of the real number system, in particular the notion of completeness and some of its consequences.
- To understand the concepts of limits, limit points, sequence, continuity and Uniform continuity, in real line as well as in arbitrary metric spaces.
- To understand the concepts of Homeomorphisms, Compactness, connectedness, and completeness in Metric spaces.

Learning Outcomes

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

- Classify and explain open and closed sets, limit points, convergent and Cauchy convergent sequences, complete spaces, compactness, connectedness, and uniform continuity etc. in a metric space.

- Know how completeness, continuity and other notions are generalized from the real line to metric spaces.

Course Contents

UNIT I **(25% Weightage)**

Finite and infinite sets, Countable and uncountable sets, Cantor's theorem, Cardinal numbers, Schröder-Bernstein theorem, Euclidean spaces, Metric spaces, Metric induced by norm, open ball, closed ball, open and closed sets, interior, exterior, closure, boundary points and their properties,

UNIT II **(30% Weightage)**

Sequences in metric spaces, Complete Metric spaces, Completion of a metric space; relatively open sets in a subspace, Limit, Continuity and and uniform continuity in Metric spaces. Pointwise and Uniform convergence of sequences of functions, Pointwise and Uniform convergence of series of functions, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation.

UNIT III **(30% Weightage)**

Compact spaces; Heine-Borel theorem, Finite intersection property, totally bounded set, Bolzano - Weierstrass theorem, sequentially compactness; Connected sets, connected subsets of real numbers, Intermediate value theorem, connected components, totally disconnected sets, , Cantor's Intersection Theorem.

UNIT IV **(15% Weightage)**

Riemann Integral, Riemann Stielzet Integration and its properties,

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Finite and infinite sets, Countable and uncountable sets.
3-4	Cantor's theorem, cardinal numbers.
5 -6	Schröder-Bernstein theorem
7-9	Riemann integration

10-13	Riemann Steitelt integration and properties
14-15	Euclidean spaces, metric spaces, metric induced by norm.
16-19	Open ball, closed ball, open and closed sets, interior, exterior, closure, boundary points and their properties.
19-25	Sequences in metric spaces, relatively open sets in a subspace, Continuous function and Uniform continuity in Metric spaces.
26-29	Compact spaces; Heine-Borel theorem, finite intersection property, totally bounded set, Bolzano - Weierstrass theorem, sequentially compactness
30-35	Connected sets, connected subsets of real numbers, Intermediate value theorem, connected components, totally disconnected sets
35-40	Complete Metric spaces, Cantor's Intersection Theorem, Completion of a metric space.
41-45	Pointwise and Uniform convergence of sequences of functions, Uniform convergence and continuity, uniform convergence and integration, uniform convergence and differentiation.
15 Hours	*Tutorials*

Suggested Texts/References:

- R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis, 3rd edition, John Wiley & Sons, Inc., New York, 2000.
- W. Rudin, Principles of Mathematical Analysis, 5th edition, McGraw Hill Kogakusha Ltd., 2004.
- N. L. Carother, Real Analysis, Cambridge University Press, 2000.
- T. Apostol, Mathematical Analysis, 5th edition, Addison-Wesley, Publishing Company, 2001.
- S. Kumaresan, Topology of Metric Spaces, 2nd edition, Narosa Book Distributors Pvt Ltd, 2011.

Course Details			
Course Title: Linear Algebra			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	I	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Course		
Nature of the Course	Theory		

Special Nature/ Category of the Course (*if applicable*)	NA
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)

Course Objectives

- To develop the understanding of concepts through examples, counter examples and problems.
- To orient the students with tools and techniques of Linear Algebra.
- To develop a skill to solve problems.

Learning Outcomes

After completion of the course the learners should be able to:

- solve system of linear equations
- check vector space and subspace.
- determine kernel and range space of a linear transformation.
- find the matrix of linear transformation.
- check whether given matrix or transformation is diagonalizable or not.
- determine Jordan Canonical form of a matrix.
- check bilinear form.
- determine the signature of real symmetric bilinear form.
- determine the orthogonal basis in an inner product space.
- find orthonormal matrix to diagonalize a Hermition matrix.

Course Contents

UNIT I **(weightage 20%)**

System of linear equations, Linear transformation, Null space, range space, Matrix representation of a linear transformations, Effect of change of basis on Matrix representation, Similarity of matrices, rank and nullity of linear transformations.

Unit II **(weightage 25%)**

Eigen values, Eigen vectors, Characteristic polynomials of a linear transformation, Diagonalization of a matrix; Cayley Hamilton Theorem; Minimal polynomial; Invariant subspaces; Jordan Canonical forms.

.

Unit III **(weightage 25%)**

Bilinear forms on a vector space and examples, Matrix of a Bilinear from, Symmetric and Skew-symmetric bilinear forms, Definition of a Quadratic form, matrix of a quadratic form, Reduction to normal form, Orthogonal and congruent reduction., Sylvester's Law of Inertia. positive definiteness.

Unit IV **(weightage 30%)**

Inner product space: Definition and Examples, Norm of a Vector, orthogonally, Orthonormal set, Gram Schmidt orthogonalization, Orthogonal complement, adjoint of a linear transformation. Self-adjoint operator, Unitary operator, Orthogonal, Unitary, Hermitian, skew-Hermitian, symmetric and skew-symmetric matrices. Orthogonal reduction of symmetric matrices, Unitary reduction of Hermitian matrices. Polar and Singular value decomposition.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	System of linear equations
3-4	Algebra of linear transformation, Linear transformations, Matrix representation of a linear transformation
5-6	Null space, range space, rank and nullity of matrix
7-8	Rank nullity theorem, similarity of matrices
9-10	Effect of change of basis on Matrix representation, Fundamental theorem of homomorphism,
11-12	Hom(V,W) as a vector space, dual space, annihilator of a subset of a vector space
13-14	Invariant subspaces, Eigen values, Eigen vectors, Characteristic polynomials of a linear transformation,
15-16	Diagonalization of a matrix with distinct Eigen values,
17-18	Cayley Hamilton Theorem.
19-20	Jordan Canonical forms.
21-22	Bilinear forms on a vector space and examples, Matrix of a Bilinear from,
23-24	Symmetric and Skew-symmetric bilinear forms,
25-26	Definition of a Quadratic form, matrix of a quadratic form,

27-28	Reduction to normal form,
29-30	Orthogonal and congruent reduction., Sylvester's Law of Inertia.
31-32	positive definiteness.
33-34	Inner product space: Definition and Examples,
35-36	Norm of a Vector, orthogonally, Orthonormal set,
37-38	Gram Schmidt orthogonalization, Orthogonal complement
39-40	adjoint of a linear transformation. Self-adjoint operator,
41-42	Unitary operator, Orthogonal, Unitary, Hermitian, skew-Hermitian, symmetric and skew-symmetric matrices.
43-45	Orthogonal reduction of symmetric matrices, Unitary reduction of Hermitian matrices. Polar and Singular value decomposition and problems
Texts/References • K. Hoffman and R. A. Kunze, Linear Algebra, 3rd edition, Prentice Hall, 2002. • T. S. Blyth and E. F. Robertson, Further Linear Algebra, Springer, 2002 • M. Artin, Algebra, Prentice Hall of India, 1991. • G. Strang, Linear Algebra and its Applications, Thomas Brooks/Cole, 2006. • Promode Kumar Saikia, Linear Algebra, Pearson, Education, 2009.	

Ordinary Differential Equations and Laplace Transform

Course Code	………….	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	I	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	N/A		
Methods of Content Interaction	*Lectures, Tutorials,*		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades)		

	• 70% - End Term External Examination (University Examination)

Course Objectives

- Understand initial value problem
- Learn p- discriminants, c-discriminants, singular solutions
- Solve system of homogeneous system of linear differential equations with constant coefficients.
- Learn autonomous system of the linear systems with constant coefficients.
- Learn to find power series solution of linear differential equations with variable coefficients.
- Learn to use Laplace transform methods to solve differential equation

Learning Outcomes

After completion of the course the learners will be able to:

- Effectively determining p- discriminants and c-discriminants and singular solution
- Determining the concept of Wronskian.
- Demonstrate ability of solving homogenous system of linear of differential equations with constant coefficients.
- Demonstrate autonomous system
- Demonstrate understanding ordinary, regular and irregular singular points
- Demonstrate ability of solving linear differential equations with variable coefficients about ordinary points using power series method.
- Demonstrate ability of solving solve differential equations about regular singular points using Frobenius method.
- Demonstrate understanding of Eigen value problems
- Demonstrate ability of solving Sturm-Liouville problems
- Demonstrate understanding of the Laplace transforms and the inverse Laplace transform
- Demonstrate ability of obtaining Laplace transform of derivatives, integrals, periodic functions, etc.
- Demonstrate ability of solving Laplace transforms to solve initial-value problems for linear differential equations with constant coefficients.

Course Contents

UNIT I: (40% Weightage)

Introduction to initial value problem, Lipchitz conditions, Existence and Uniqueness Theorems of Picard, p-discriminants and c-discriminants, Singular solutions, Existence and Uniqueness Theorems for systems of first order equations, Global Existence and uniqueness criteria, Equivalent first order systems for higher order equations, Criteria for convertibility of a system of equation into a higher order equation in one of the unknowns, General theory for linear systems, Wronskians, Matrix methods for linear systems with constant coefficients, Autonomous Systems, Stability.

UNIT II: (20% Weightage)

Power series method for general linear equations of higher order, Solutions near an ordinary point, Regular and Logarithmic solutions near a regular singular point.

UNIT III: (25%Weightage)

Laplace transforms, Existence criteria, Properties, Transforms of standard functions, Transforms of derivatives and integrals, Derivatives and integrals of Transforms, Inverse Laplace transforms, Existence and uniqueness criteria, Exponential shifts, inverse of products of transforms, convolution theorem, Applications to Initial value problems.

UNIT IV: (15% Weightage)

Eigenvalue problems, Eigen function and expansion formula, Sturm-liouville problems, self-adjoint problems,

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1	Introduction to the initial value problems, Lipchitz conditions, Existence and Uniqueness Theorems
2-3	p- discriminants and c-discriminants, Singular solutions
4-5	Existence and Uniqueness Theorems for systems of first order equations
6-7	Global Existence and uniqueness criteria, Equivalent first order systems for higher order equations
8-9	Criteria for convertibility of a system of equation into a higher order equation in one of the unknowns
10-11	General theory for linear systems, Wronskians and method of variation of parameters
12-13	Matrix methods for linear systems with constant coefficients

14-16	About autonomous system
17-19	Phase plane
20-22	Trajectories
23	Power series method for general linear equations of higher order
24-25	Solutions near an ordinary point
26-27	Regular and Logarithmic solutions near a regular singular point
28-29	Laplace transforms, Existence criteria, Properties
30-33	Transforms of standard functions, Transforms of derivatives and integrals, Derivatives and integrals of Transforms
34-36	Inverse Laplace transforms, Existence and uniqueness criteria, Exponential shifts, inverse of products of transforms, convolution theorem
37-38	Applications to Initial value problems
39-43	Eigenvalue problems, Sturm-Liouville problems
44-45	Eigen function and expansion formula, self adjoint problems

Suggested Readings:

1. D. G. Zill, A first course in differential equations, Nineth Edition, Cengage Learning, 2008
2. E. Kreyszig, Advance Engineering Mathematics, Tenth Edition, John Wiley and Sons, 2010.
3. B. Rai, D.P. Choudhury and H.I. Freedman, A Course in Ordinary Differential Equations, Narosa Publishing House, New Delhi, 2002. 4. E. A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall of India, New Delhi, 1968. 5. L. Elsgolts, Differential Equations and Calculus of Variations, Mir Publishers, 1970. 6. G. F. Simons, Differential Equations, Tata Mc Graw Hill, New Delhi, 1972.

Course Details			
Course Title: Discrete Mathematics			
Course Code	MSMTH1003C04	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	I	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Course		
Nature of the Course	Theory/Practical		

Special Nature/ Category of the Course (*if applicable*)	Skill Based (*More than one can apply*) (*Keep this category even if one or more than one unit or some part(s) of a unit are related to these categories*)
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Self-study, Seminar, Presentations by students.
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)

Course Objectives

- Simplify and evaluate basic logic statements including compound statements, implications, inverse, converses, and contrapositives using truth tables and the properties of logic.
- Express a logic sentence in terms of predicates, quantifiers, and logical connectives.
- Apply the operations of sets and use Venn diagrams to solve applied problems; solve problems using the principle of Inclusion-Exclusion.
- Describe binary relations; determine if a binary relation is reflexive, symmetric, or transitive or is an equivalence relation; combine relations using set operations and composition.
- Use elementary number theory including the divisibility properties of numbers to determine prime numbers and composites, the greatest common divisor, and the least common multiple; perform modulo arithmetic and computer arithmetic.
- Solve counting problems by applying elementary counting techniques using the product and sum rules, permutations, combinations, the pigeon-hole principle, and the binomial expansion.
- Represent a graph using an adjacency matrix and graph theory to application problems such as computer networks.
- Determine if a graph has an Euler or a Hamilton path or circuit.

Learning Outcomes

After successful completion of this course, students should be able with:

- Constructing proofs.
- Elementary formal logic.
- Set algebra.
- Relations and functions.
- Combinatorial analysis.

- Recurrence relations.
- Graphs, digraphs, trees, Eulerian and Hamiltonian graphs.

Course Contents

UNIT I: Propositional Logic and Relations **(20 % Weightage)**

- Statements, Logical connectives, Truth tables, Equivalence, Inference and deduction, Predicates, Quantifiers.
- Relations and their compositions, Equivalence relations, Closures of relations, Transitive closure and the Warshall's algorithm, Partial ordering relation, Hasse diagram, Recursive functions.

UNIT II: Number Theory **(25 % Weightage)**

- Divisibility, The Division Algorithm, The greatest common divisors, The Euclidean algorithm, Linear Diophantine equations, Primes and their distribution, The fundamental theorem of arithmetic.
- Congruence, Chinese remainder theorem, Fermat Little theorem, Wilson theorem, Euler's Phi- function, Mobius function and Mobius inversion formula.
-

UNIT III: Combinatorics **(25 % Weightage)**

- The Pigeonhole Principle, Permutations and Combinations; Derangements, The Inclusion Exclusion Principle and Applications, Recurrence Relations and Generating functions, Catalan and Stirling numbers.
-

UNIT IV: Graph Theory **(30% Weightage)**

- Basic concepts of graphs, directed graphs and trees, Adjacency and incidence matrices, Spanning tree, Kruskal's and Prim's algorithms, Shortest Path, Dijkstra's algorithm, Planar Graphs, Graph Coloring, Eulerian and Hamiltonian graphs.
-

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Relations and their compositions, Equivalence relations.
3-4	Closures of relations, Transitive closure and the Warshall's algorithm.
5	Partial ordering relation, Hasse diagram, Recursive functions.
6-7	Statements, Logical connectives, Truth tables, Equivalence.

8-10	Inference and deduction, Predicates, Quantifiers.
11-12	Divisibility, Division algorithm, Greatest common divisors, Euclidean algorithm.
13-14	Linear Diophantine equations, Primes and their distribution, Fundamental theorem of arithmetic.
15-17	Congruence, Chinese remainder theorem, Fermat Little theorem, Wilson theorem.
18-20	Euler's Phi- function, Mobius function and Mobius inversion formula.
21-23	Pigeonhole principle, Permutations, Combinations.
24-25	Derangements, Inclusion Exclusion principle and Applications.
26-29	Recurrence Relations and Generating functions.
30-31	Catalan and Stirling numbers.
32-33	Basic concepts of graphs, directed graphs and trees,
34	Adjacency and incidence matrices.
35-36	Spanning tree, Kruskal's and Prim's algorithms.
37	Shortest Path, Dijkstra's algorithm.
38-39	Planar Graphs.
40-41	Graph Coloring.
42-43	Eulerian graphs.
44-45	Hamiltonian graphs.

Suggested References:

- J. P. Trembley and R. P. Manohar, *Discrete Mathematical structures with Applications to Computer Science,* McGraw Hill, 1975.
- D. E. Burton, *Elementary Number Theory*, Tata McGraw-Hill, 2006
- Richard A. Brualdi, *Introductory Combinatorics,* Pearson, 2004
- N. Deo, *Graph Theory with Applications to Engineering and Computer Science,* Prentice Hall of India, 1980.
- R. P. Grimaldi, *Discrete and Combinatorial Mathematics,* Pearson Education, 1999.
- C.L. Liu, *Elements of Discrete Mathematics,* McGraw-Hill, 1977.

Complex Analysis and Functions of several variables

Course Code	…………..	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	II	**Contact Hours**	45 (L) + 15 (T) Hours

Course Type	Discipline Based Core
Nature of the Course	Theory
Special Nature/ Category of the Course (*if applicable*)	N/A
Methods of Content Interaction	*Lectures, Tutorials,*
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)

Course Objectives

- Learn the functions of several variables
- Learn Mean value theorem, Taylor's theorem, Inverse functions theorem and Implicit function theorem
- Evaluate complex integrals using parameterization, fundamental theorem of calculus, Cauchy's integral theorem and Cauchy's integral formula;
- Learn Taylor series and Laurent series of a function
- Compute the residue of a function and use the residue theory to evaluate a contour integral or an integral over the real line;
- Learn conformal mapping with applications
- Study meromorphic function and its applications
- Study analytic continuation

Learning Outcomes

After completion of the course the learners will be able to:

- Demonstrate ability to justify the need for a Complex Number System and explain how is related to other existing number systems
- Demonstrate a function of complex variable and carry out basic mathematical operations with complex numbers.
- Demonstrate understanding of condition(s) for a complex variable function to be analytic and/or harmonic. .
- Understand singularities of a function, know the different types of singularities, and be able to determine the points of singularities of a function.

- Demonstrate ability to evaluate the complex integrals.
- Understand Taylor’s and Laurent’s series of the functions.
- Demonstrate ability to evaluate contour integrals or an integral over the real line using residue theory.
- Demonstrate ability to understand linear and bilinear transformations and their mappings.
- Demonstrate ability to understand Meromorphic functions and its applications.
- Demonstrate understanding of analytic continuations and its applications.

Course Contents

UNIT I: **(20% Weightage)**

Functions of several variables: Limit, Continuity and Differentiability, Higher derivatives, Mean value theorem, Taylor’s theorem, Inverse function theorem, Implicit function theorem.

UNIT II: **(20% Weightage)**

Complex line integrals, complex Integrals, Contour and Contours Integrals, The fundamental theorem of Integration, Cauchy’s Integral Theorem, Independence of path, Cauchy’s integral formula. Morera’s theorem, Liouville’s theorem, Fundamental theorem of algebra.

UNIT III: **(30 % Weightage)**

Infinite series, sequence and series of functions, Power series, Power series expansion of an analytic functions, The zeroes of an analytic function, Taylor’s and Laurent series, Singularities, Maximum Modulus Principle. Cauchy’s residues Theorem, evaluation of contour integral and integral over the real line using residue theorem.

UNIT IV: **(30%Weightage)**

Meromorphic function, Argument Principle, Rouche’s Theorem, Hurwitz’s theorem, Critical Points, Winding Numbers, Analytic continuation, Conformal mappings and Mobius Transformation.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1	Introduction to the functions of several variables
2	Directional derivatives and continuity, total derivatives
3	Total derivatives expressed in terms of partial derivatives

4	An application to complex valued functions
5-6	Mean value theorem for differentiable functions, Taylor's theorem
7-8	Inverse functions theorem
9-10	Implicit function theorem
11	Introduction to the line integration, simply and multiply connected domains, Introduction to the contour integration,
12	Cauchy's Integral Theorem (with proof) and its deduction for multiply connected domain, Independence of path
13-14	Cauchy's integral formula and its derivative form
15-18	The fundamental theorem of Integration, Morera's theorem Liouville's theorem
19-20	Infinite series, sequence and series of functions
21-22	Power series, Convergence of power series
23-26	Taylor's and Laurent series, The zeroes of an analytic function Singularities
27-28	Maximum Modulus Principle. Cauchy's residues Theorem (with proof)
29-32	Evaluation of contour integral and integral over the real line using residue theorem.
33-34	Meromorphic function, Argument Principle, Critical Points, Winding Numbers
35-36	Rouche's Theorem (with proof), Hurwitz's theorem (with proof)
37-38	Introductory idea of holomorphic function and homotopic functions
39-40	Open mapping and Inverse Function Theorems with their proofs
41-45	Conformal mappings and Mobius Transformations

Suggested References:

- T. M. Apostol, Mathematical Analysis, Narosa Publishing House, 1974.
- E. Kreyszig, Advance Engineering Mathematics, Tenth Edition, John Wiley and Sons.
- M.R. Spiegel, Schaum's Outline of Theory and Problems of Complex Variable. Mcgraw-Hill Book Company, Singapore, 1988.
- K. A. Stroud, Further Engineering Mathematics. 3rd Edition. The Bath Press, London, Great Britain, 1996.
- S. Lang, Complex Analysis, Addison Wesley Publishing Company, Ontario, Canada, 1976.
- H. A. Priestley, Introduction to Complex Analysis. Oxford University Press, Oxford, U.K., 1990.
- J. B. Conway, Functions of Complex variable, Narosa publication, 1993
- R. V. Churchill, J.W. Brown, Complex Variables and Applications, McGraw-Hill International, 2009

Course Details

Course Title: Topology			
Course Code	MSMTH2003C04	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	II	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Course		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Presentation.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		

Course Objectives

- To teach the fundamentals of point set topology
- Constitute an awareness of need for the topology in Mathematics.

Learning Outcomes

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

1. Understand to construct topological spaces from metric spaces and using general properties of neighbourhoods, open sets, close sets, basis and sub-basis.
2. Apply the properties of open sets, close sets, interior points, accumulation points and derived sets in deriving the proofs of various theorems.
3. Understand the concepts of countable spaces and separable spaces.
4. Understand the concepts and properties of the compact and connected topological spaces.

Course Contents

UNIT I **(25% Weightage)**

Definition and examples of topological spaces (including metric spaces), Open and closed sets, Subspaces and relative topology, Closure and interior, Accumulation points and derived sets, Dense sets, Neighbourhoods, Boundary, Bases and sub-bases, Alternative methods of defining a topology in terms of the Kuratowski closure operator and neighbourhood systems.

UNIT II **(25 % Weightage)**

Filter and Ultra filter, Continuous functions and homeomorphism, Quotient topology, First and second countability and separabilty, Lindelöf spaces, Separation axioms T_0, T_1, T_2, T_3, $T_{3½}$, and T_4 and their characterizations, Urysohn's lemma, Tietze's extension theorem.

UNIT III **(25 % Weightage)**

Compactness, Compactness and the finite intersection property, Local compactness, One-point compactification, Connected spaces, Connectedness of the real line, Components, Locally connected spaces, Path connectedness

UNIT IV **(25% Weightage)**

Product topology in terms of the standard sub-base and its characterizations, Product topology and separation axioms, connectedness, countability properties and compactness, Tychonoff's theorem.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Definition and examples of topological spaces (including metric spaces), Open and closed sets.
5-7	Subspaces and relative topology, Closure and interior, Accumulation points and derived sets,
8-11	Dense sets, Neighbourhoods, Boundary, Bases and sub-bases, Alternative methods of defining a topology in terms of the Kuratowski closure operator and neighbourhood systems
12-15	Filter and Ultra filter
16-19	Continuous functions and homeomorphism, Quotient topology, First and second countability and separabilty.
20-23	Lindelöf spaces, Separation axioms T_0, T_1, T_2, T_3, $T_{3½}$, and T_4 and their characterizations, Urysohn's lemma, Tietze's extension theorem.
24-26	Compactness, Compactness and the finite intersection property.
27-30	Local compactness, One-point compactification, Connected spaces,

31-34	Connectedness of the real line, Components, Locally connected spaces, Path connectedness.
35-37	Product topology in terms of the standard sub-base and its characterizations.
38-41	Product topology and separation axioms, connectedness.
42-45	Countability properties and compactness, Tychonoff's theorem.
15 Hours	*Tutorials*

Suggested Texts/References:

- J. L. Kelley, General Topology, Van Nostrand, 1995.
- K. D. Joshi, Introduction to General Topology, Wiley Eastern, 1983.
- James R. Munkres, Topology, 2nd Edition, Pearson International, 2000.
- J. Dugundji, Topology, Prentice-Hall of India, 1966.
- George F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 1963.
- S. Willard, General Topology, Addison-Wesley, 1970.

Course Details			
Course Title: Algebra I			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	II	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Course		
Nature of the Course	Theory		
Special Nature/Category of the course (if applicable)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students,		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		

Prerequisite	• Basic knowledge of Group and Ring

Course Objectives

- To develop the understanding of concepts through examples, counter examples and problems.
- To orient the students with tools and techniques of Algebra.
- To develop a skill to solve problems.

Learning Outcomes

After completion of the course the learners should be able to:

- check subring, ideal.
- understand Symmetric group, Dihedral group.
- solve problems related to Sylow theorems.
- understand difference among ID,PID,UFD and ED.
- check the irreducibility of polynomials.

Course Contents

UNIT I: **(25% Weightage)**

Review of Permutation groups, Dihedral groups, simplicity of A_n, Internal and External direct products and their relationship, Semi direct product, Subnormal and normal series, Zassenhaus' lemma, Schreier's refinement theorem, Composition series, Jordan-Hölder's theorem.

Unit II **(25% Weightage)**

Group action; Cayley's theorem, orbit decomposition; counting formula; class equation, consequences for p-groups; Sylow's theorems (proofs using group actions). Applications of Sylow's theorems, structure theorem for finite abelian groups (Statements only).

Unit III **(25% Weightage)**

Basic properties and examples of ring, domain, division ring and field; direct products of rings, characteristic of a domain, field of fractions of an integral domain, ring homomorphisms, ideals, factor rings prime and maximal ideals, principal ideal domain.

Unit IV **(25% Weightage)**

A Euclidean domain, unique factorization domain; brief review of polynomial rings over a field, reducible and irreducible polynomials, Gauss' theorem for reducibility of polynomial, Eisenstein's criterion for irreducibility polynomial, roots of polynomials.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Review of Permutation groups
3-4	simplicity of A_n
5-6	Dihedral groups,
7-8	Internal and External direct products and their relationship,
9-10	Semi direct product
11-12	Subnormal and normal series
13-14	Zassenhaus' lemma,
15-16	Schreier's refinement theorem
17-18	Composition series
19-20	Jordan-Hölder's theorem
21-22	Commutators, Solvable groups
23-24	Group action; Cayley's theorem, group of symmetries
25-26	properties; orbit decomposition; counting formula; class equation, consequences for p-groups;
27-28	Sylow's theorems (proofs using group actions). Applications of Sylow's theorems,
29-30	direct product; structure theorem for finite abelian groups; invariants of a finite abelian group (Statements only)
31-32	Basic properties and examples of ring, domain, division ring and field;
33-34	direct products of rings, characteristic of a domain, field of fractions of an integral domain,
35-36	ring homomorphisms, ideals, factor rings prime and maximal ideals,
37-38	principal ideal domain, A Euclidean domain,
39-40	unique factorization domain;
41-42	brief review of polynomial rings over a field, reducible and irreducible polynomials,
43-45	Gauss' theorem for reducibility of polynomial, Eisenstein's criterion for irreducibility of polynomial, roots of polynomials and problems.
Texts/ References	

- N. Jacobson, Basic Algebra I, 3rd edition, Hindustan Publishing corporation, New Delhi, 2002.
- Ramji Lal, Algebra 1, Springer, 2017
- I. N. Herstein, Topics in Algebra, 4th edition, Wiley Eastern Limited, New Delhi, 2003.
- J. B. Fraleigh, A First Course in Abstract Algebra, 4th edition, Narosa Publishing House,

New Delhi, 2002.

- D. S. Dummit and R.M. Foote, Abstract Algebra, John Wiley & Sons, 2003.
- M. Artin, Algebra, Prentice Hall of India, 1994.
- P. B. Bhattacharya, S. K. Jain and S. R. Nagpal, Basic Abstract Algebra, 3rd edition,

Cambridge University Press, 2000.

- Joseph A Gallian, Contemporary Abstract Algebra, Narosa Publishing House PVT. L.T.D, 2010

Applied Mathematical Tools

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	II	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Bases Core Course		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	Vocational Studies		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Self-study, Seminar, Presentations by students.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		

Course Objectives

- To acquaint the students with knowledge of Linear Programming Problem and its applications
- To orient the students with tools and techniques for testing of hypotheses (chi square and F test)
- To acquaint the students with time series and ANOVA

- To know about applications of game theory and queuing theory

Learning Outcomes

After completion of the course the learners will be able to:

- To apply chi square and F test in daily life problems
- To apply Linear Programming, game theory and queuing theory in marketing

Course Contents

UNIT I: (25% Weightage)

Linear Programming Problem Formulation, solution by Graphical Method, Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charnes-M Method, Degeneracy, Theory of Duality, Dual-simplex method. Applications

UNIT II: (25% Weightage)

Transportation problem and its applications **:** Formulation, solution, unbalanced transportation problem .Finding basic feasible solutions-Northwest corner rule, least cost method and Vogel's approximation method. Some illustrative examples.

Game Theory and its applications : Two-person zero sum game, Game with saddle points, the rule of dominance. Some illustrative examples.

UNIT III: (25% Weightage)

Queing theory and its applications. Concepts of stochastic processes, Poisson process, Birth-death process, Queuing models: Basic components of a queuing system, Steady-state solution of Markovian queuing models with single and multiple servers (M/M/1, M/M/C, M/M/1/k, M/MC/k).

UNIT IV: (25 % Weightage)

Chi- square test and F test with applications. Analysis of Variance, assumptions and applications, ANOVA for one way and two way (using Principle of LSE). ANOVA table & its interpretation. Principles of Experimental Design. Completely randomized design (CRD): layout, analysis, advantages and disadvantages. Basics of Time series analysis. Examples based on Real life applications

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-3	Linear Programming Problem Formulation, solution by Graphical Method,

4-7	Theory of Simplex Method, Simplex Algorithm, Two phase Method, Charnes-M Method
8-10	Theory of Duality, Dual-simplex method. Applications
11-13	Formulation, solution, unbalanced transportation problem
14-17	Finding basic feasible solutions-Northwest corner rule, least cost method and Vogel's approximation method and applications
18-22	Two-person zero sum game, Game with saddle points
23-25	the rule of dominance. Some illustrative examples.
26-28	Concepts of stochastic processes, Poisson process, Birth-death process
29-31	Queuing models: Basic components of a queuing system, Steady-state solution of Markovian queuing models with single and multiple servers (M/M/1, M/M/C, M/M/1/k, M/MC/k).
32-34	Chi- square test and F test with applications
35-37	Analysis of Variance, assumptions and applications, ANOVA for one way and two way (using Principle of LSE) ANOVA table & its interpretation
38-41	Principles of Experimental Design. Completely randomized design (CRD): layout, analysis, advantages and disadvantages
42-45	Basics of Time series analysis. Examples based on Real life applications
15 Hours	*Tutorials*

- Suggested References:

- H.A.Taha, Operations Research, Sixth Edition, Mac Millen Ltd, 1997
- Kanti Swarup, P.K Gupta & Man Mohan, "Operations Research", Sultan Chand publications,
- Mathematical Statistics Freund J.E. Prentics Hall of India.
- Introduction to Probability Theory and Mathematical Statistics - V.K. Rohatgi (Wiely Estem ltd)
- Fundamentals of statistics volume-I A.M. Goon, Gupta and Das Gupta (world press Kolkotta)
- Fundamentals of Mathematical Statistics - S.C. Gupta, V K Kapoor. (Sultan chand and sons Delhi)

COURSE TITLE: Research Methodology

Course Code	………….	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	II	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core/Discipline Based Core Elective/Open Elective/Mandatory Elective Non-Credit Course (*Any one)*		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable***)**	Value Based (Human Values /Ethics/ Constitutional Values etc.)/Indian Knowledge System/ Lok Vidya/ Skill Based/ Any other (Specify) (*More than one can apply*) (*Keep this category even if one or more than one unit or some part(s) of a unit are related to these categories*)		
Methods of Content Interaction	*Lecture, Tutorials, Group discussion, seminar, presentations by students.*		
Assessment and Evaluation	● 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) ● 70% - End Term External Examination (University Examination)		

Course Objectives:

- ❖ To enable students understand what research is and what is not.
- ❖ To raise awareness of the value of scientific method.
- ❖ To discuss what a researchable problem is.
- ❖ To identify and justify the basic components of the research framework.
- ❖ To consider the kind of language to use in an academic written work.

Course Learning Outcomes:

After completion of the course the students will be able to:

- ❖ Explain what research is and what it is not, and the different definitions of research.
- ❖ Introduce the objectives of research, and set the motivation in research.
- ❖ Present some aspects of the mathematical methods.
- ❖ Discuss the criteria of good research and the different type of research.

Course Contents:

UNIT I: Foundations of Research (25 % Weightage)

Meaning of research, Objectives of research, Motivation in research, General characteristics of research, Criteria of good research, Types of research: Description Vs. Analytical, Applied Vs. Fundamental, Quantitative Vs. Qualitative, Conceptual Vs. Empirical, Action research, Understanding the language of research : Concept, Construction, Definition, Variable.

UNIT II: Research Problems and Literature Review (25 % Weightage)

What is a research problem?, Selecting a research problem, Necessity of defining the problem, Techniques involved in defining the problem, Sources of a research problem, Statement of the problem, Delimiting and Evaluating a problem, Meaning of Literature review, Need of review of Literature, Objective of review of Literature, Sources of Literature, The functions of Literature, How to conduct the review of Literature, Precautions in Library Use, Reporting review of Literature, Importance of Literature review in defining a problem.

UNIT III: Proof Methods and Report Writing (30 % Weightage)

General principle of Mathematical writing, Mathematical sentences: Definition, Theorem, Proposition, Lemma, Corollary, Proof, Conjecture, Axiom. Direct Proof, Proof by Cases, Proof by Contraposition, Proof by Contradiction, Proof by Mathematical Induction, If-and-Only-If Proof, Common mistakes in writing Mathematical solutions and proofs, Mathematical writing in LaTeX/MS Office, Beamer/PowerPoint presentations. Preparation of reports, Types of Research reports, Structure and components of Research papers, Technical reports, and Thesis.

UNIT IV: Research Ethics and IPR (20 % Weightage)

Ethics with respect to science and research, Ethical Issues related to publishing, Intellectual honesty and research integrity, Plagiarism and Self-Plagiarism. Softwares for detection of Plagiarism, Intellectual Property Rights (IPR) and patent law, Copy right, Royalty, Trade related aspects of IPR.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-10	**UNIT I: Foundations of Research**
1-4	Meaning of research, Objectives of research, Motivation in research, General characteristics of research, Criteria of good research.
5-8	Types of research: Description Vs. Analytical, Applied Vs. Fundamental, Quantitative Vs. Qualitative, Conceptual Vs. Empirical, Action research.
9-10	Understanding the language of research : Concept, Construct, Definition, Variable.
11-20	**UNIT II: Research Problems and Literature Review**
11-14	What is a research problem?, Selecting a research problem, Necessity of defining the problem, Techniques involved in defining the problem,

	Sources of a research problem, Statement of the problem, Delimiting and Evaluating a problem.
15-18	Meaning of Literature review, Need of review of Literature, Objective of review of Literature, Sources of Literature, The functions of Literature, How to conduct the review of Literature.
19-20	Precautions in Library Use, Reporting review of Literature, Importance of Literature review in defining a problem.
21-35	**UNIT III: Proof Methods and Report Writing**
21-22	General principle of Mathematical writing, Mathematical sentences: Definition, Theorem, Proposition, Lemma, Corollary, Proof, Conjecture, Axiom.
23-26	Direct Proof, Proof by Cases, Proof by Contraposition, Proof by Contradiction, Proof by Mathematical Induction, If-and-Only-If Proof, Common mistakes in writing Mathematical solutions and proofs.
27-32	Mathematical writing in LaTeX/MS Office, Beamer/PowerPoint presentations.
33-35	Preparation of reports, Types of Research reports, Structure and components of Research papers, Technical reports, and Thesis.
36-45	**UNIT IV: Research Ethics and IPR**
36-39	Ethics with respect to science and research, Ethical Issues related to publishing.
40-41	Intellectual honesty and research integrity, Plagiarism and Self-Plagiarism. Softwares for detection of Plagiarism
42-45	Intellectual Property Rights (IPR) and patent law, Copy right, Royalty, Trade related aspects of IPR.
15 Hours	*Tutorials*

Text/Reference Books:

- Kothari, C.R., Research Methodology: Methods and Techniques. New Age International Ltd, New Delhi, 2004.
- Kumar, R., Research Methodology: A Step-by-Step Guide for Beginners, TJ International Ltd, London, 2011.
- Goddard, W., Melville, S., Research Methodology: An Introduction, JUTA and Company Ltd, 2004.
- Margie, H., Essentials of Mathematics,: Introduction to Theory, Proof, and the Professional Culture, Vol. 21, American Mathematical Society, 1996.
- Wadehra, B. L., Law Relating to Patents, Trademarks, Copyright Designs and Geographical Indications, Universal Law Publishing, 2014.

Measures and Integration

Course Code		Credits	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Course		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Self-study, Seminar, Presentations by students.		
Assessment and Evaluation	● 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) ● 70% - End Term External Examination (University Examination)		

Course Objectives

- To give a very streamlined development of a course in Lebesgue integration.
- To introduce the concept of Lebesgue measure.
- To develop the theory of Lebesgue integration which gives stronger and better results as compared to the theory of Riemann integration?
- To study the measurable sets and Lebesgue measurable functions.
- To provide a basis for further studies in Analysis, Probability, and Dynamical Systems.

Course Learning Outcomes

After successful completion of this course, students should be able to:

- Describe the basic properties of Lebesgue measure and measurable functions.
- Construct the Lebesgue integral, elucidate its basic properties.
- Appreciate the existence of other useful integration theories besides Riemann's.
- Understand the basic features of Lp-spaces.

- Use the ideas of this course in unseen situation.

Course Contents

UNIT I: (20% Weightage)

Review of Riemann Integral, Its drawbacks and Lebesgue's recipe to extend it. Extension of length function, Semi-algebra and algebra of sets, Sigma Algebra, Lebesgue outer measure, Measurable sets, Measure space, complete measure space.

UNIT II: (25 % Weightage)

The Lebesgue measure on **R**, Properties of Lebesgue measure, Uniqueness of Lebesgue Measure, Measurable sets, Construction of non-measurable subsets of **R.**

UNIT III: (30 % Weightage)

Measurable functions, Lebesgue integration: The integration of non-negative functions, Fatou's Lemma. Integrable functions and their properties, Lebesgue's dominated convergence theorem.

UNIT IV: (25% Weightage)

Absolutely continuous function, Lebesgue-Young theorem (without proof), Fundamental theorem of Integral calculus and its applications, Product of two measure spaces, Fubini's theorem. Lp-spaces, Holder's inequality, Minkowski's inequality, Completion of Lp-spaces.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Review of Riemann Integral, Its drawbacks and Lebesgue's recipe to extend it.
3-4	Extension of length function.
5-6	Semi-algebra and algebra of sets.
7-8	Lebesgue outer measure.
9-10	Measurable sets.
11-12	Measure space, complete measure space.
13-15	The Lebesgue measure on **R**, Properties of Lebesgue measure.
16-17	Uniqueness of Lebesgue Measure.
18-19	Construction of non-measurable subsets of **R.**
20-24	Integration of non-negative functions.

25-27	Measurable functions.
28-29	Fatou's Lemma.
30-31	Integrable functions and their properties.
32	Lebesgue's dominated convergence theorem.
33-34	Absolutely continuous function, Lebesgue-Young theorem (without proof).
35-36	Fundamental theorem of Integral calculus and its applications.
37-39	Product of two measure spaces, Fubini's theorem.
40-43	Lp-spaces, Holder's inequality, Minkowski's inequality.
44-45	Completion of Lp-spaces.
15 Hours	*Tutorials*

Suggested References:

- Inder K. Rana, An introduction to Measure and Integration, Narosa, 1997.
- G. De Barra, Measure Theory and Integration, John Wiley and Sons, 1981.
- J. L. Kelly, T. P. Srinivasan, Measure and Integration, Springer, 1988.
- P.R. Halmos, Measure Theory, GTM, Springer, 1950.

Course Details			
Course Title: Algebra-II			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	45 (L) + 15 (T) Hours
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Presentation.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		

Course Objectives

This course focuses on theory of fields and Galois Theory. The main objective of the course is to study Galois correspondence and its applications to solvability of polynomial equations and classical problems of ruler-compass constructions. The course also aims to give the introduction to Finite fields.

Learning Outcomes

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

- Prove that a given field extension is a Galois extension.
- Identify the Galois Group of a given Galois extension and describe the action of this on the set of roots.
- Apply the Galois Correspondence to analyze specific examples of finite field extensions
- Prove that quantic is not solvable by radicals
- Prove that squaring the circle and doubling the cube is not possible by ruler and compass.
- Prove the fundamental theorem of algebra using Galois Theory.

Course Contents

UNIT I **(20% Weightage)**

Field Extensions, finite extensions, algebraic elements, algebraic extensions, splitting fields,

Simple and multiple roots of polynomials, criterion for simple roots, Normal and Separable extensions, perfect fields

UNIT II **(25 % Weightage)**

Fixed Fields; Galois groups; Galois extensions; ruler and compass constructions; Structure theorem of finite fields; Irreducible polynomials over finite fields; primitive element theorem

UNIT III **(35 % Weightage)** Fundamental theorem of Galois Theory; Solvability by radicals, insolvability of quintics; Kummer extensions; abelian extensions; roots of unity and cyclotomic polynomials, cyclotomic extensions.

UNIT IV **(20% Weightage)**

Introduction to modules, Free modules, Digonalization of integer matrices, modules over PIDS, representation theorem for finitely generated abelian groups.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-3	Field Extensions, finite extensions, Algebraic extensions, splitting fields.

4-7	Simple and multiple roots of polynomials, criterion for simple roots.
8 -11	Normal and separable extensions
12-15	Structure of finite fields, Irreducible polynomials over finite fields, roots of unity and cyclotomic polynomials.
16-19	Algebraically closed fields and algebraic closures, Primitive element theorem, fixed fields
20-23	Galois groups, Fundamental theorem of Galois Theory, Norms and Traces.
24-27	Solvability by radicals, solvability of algebraic equations, symmetric functions.
28-31	Ruler and compass constructions, Fundamental theorem of algebra.
32-34	Abelian and Cyclic extensions, Kummer extensions.
35-37	Introduction to modules, Free modules
38-40	Digonalization of integer matrices
41-45	modules over PIDS, representation theorem for finitely generated abelian groups.
15 Hours	*Tutorials*

<u>Suggested Texts/References:</u>

- Patrick Morandi, Fields and Galois Theory, Springer (GTM), 2010.
- M. Artin, Algebra, Prentice Hall of India, 1994.
- S. Lang, Algebra, Springer.
- D. S. Dummit and R. M. Foote, Abstract Algebra, 2nd Ed., John Wiley, 2002.
- Emil Artin, Galois Theory, Dover Publication, INC.

COURSE TITLE: Development of Mathematics in India

Course Code	....	**Credits**	2
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	III	**Contact Hours**	45 (L) + 15 (T) Hours

Course Type	Discipline Based Core/Discipline Based Core Elective (*Any one)*
Nature of the Course	Theory
Special Nature/ Category of the Course (*if applicable*)	Indian Knowledge System
Methods of Content Interaction	*Lecture, Tutorials, Group discussion, Seminar, Presentations by students.*
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)

Course Objectives:

- ❖ The course aims at imparting Mathematical knowledge of Indian Mathematicians.
- ❖ The course focuses on introduction to Indian Knowledge System in Mathematics, Indian perspective of modern scientific world-view.

Course Learning Outcomes:

After completion of the course the students will be able to:

- ❖ Ability to understand, connect up, and explain basics of Indian Mathematical knowledge in the modern Mathematics perspective.

Course Contents:

UNIT I: **(50 % Weightage)**

Overview of Mathematics in India, Problems from the Sulva Sutras: Arithmetic, Geometry, Square roots. Buddhist Mathematics, Works of Baudhayana and Panini, Jain Mathematics: The Infinite, Combinatorics, Works of Mahaviracharya and Sridhara, Hemachandra and Fibonacci sequence, Hindu-Arabic numerals, Aryabhata I: Geometry and Trigonometry, Aryabhata's table of sine function.

UNIT II:

Brahmagupta's plane and solid geometry, Brahmagupta's number theory and algebra, Pythagorean triples, Pell's equation, Algebra in the works of Bhaskara II, Geometry in the works of Bhaskara II., Works of Vahamihir, Madhvan Namputri, Indian Mathematics in the colonial period and after:Works of Srinivasa Ramanujan, Komaravolu Chandrasekharan, and Harish-Chandra.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-8	**UNIT I:**
1-2	Overview of Mathematics in India.
3-4	Problems from the Sulva Sutras: Arithmetic, Geometry, Square Roots.
6-7	Buddhist Mathematics, Works of Baudhayana and Panini.
8-10	Jain Mathematics: The Infinite, Combinatorics, Works of Mahaviracharya and Sridhara, Hemachandra and Fibonacci sequence.
11-12	Hindu-Arabic numerals, Aryabhata I: Geometry and Trigonometry, Aryabhata's table of sine function.
13-23	**UNIT II:**
13-16	Brahmagupta's plane and solid geometry, Brahmagupta's number theory and algebra, Pythagorean triples, Pell's equation,.
17-19	Algebra in the works of Bhaskara II, Geometry in the works of Bhaskara II., Works of Vahamihir,
20-23	Indian Mathematics in the colonial period and after: Works of Srinivasa Ramanujan, Komaravolu Chandrasekharan, and Harish-Chandra.
7 Hours	*Tutorials*

Text/Reference Books:

- Cooke, R. L., *The History of Mathematics: A Brief Course*. John Wiley & Sons, Inc., 2014.
- Clark, Walter Eugene, ed., *The* Aryabhatiya *of Aryabhata*, University of Chicago Press, Chicago, 1930.
- Colebrooke, Henry Thomas, *Algebra with Arithmetic and Mensuration from the Sanscrit of Brahmegupta and Bhascara*, J. Murray, London, 1817.
- Datta, B., The science of the Sulba, Calcutta, 1932.
- Saraswati, T. A., Geometry in Ancient and Medieval India, Delhi, 1979.
- Andrews, G. E., *An introduction to Ramanujan's 'lost' notebook*, American Mathematical Monthly, **86**, No. 2, 89–108, 1979.

Human Values in Famous Mathematician

Course Code	…………..	**Credits**	2
L + T + P	2	**Course Duration**	One Semester
Semester	III	**Contact Hours**	30 Hours
Course Type	Discipline Based Core		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	Value Based (Human Values /Ethics/ Constitutional Values etc.)/Indian Knowledge System		
Methods of Content Interaction	*(e.g. Lecture, Tutorials, Group discussion, primary data collection & analysis, role playing, seminar, presentations by students, field work etc.)*		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		

- **Course Objectives:**
  To acquaint the students with foundational knowledge values , ethics and associate them with mathematics
- To strengthen knowledge of moral values
- To develop skills and competencies in identifying what to do and do not in social life

Course Learning Outcomes:

After completion of the course the students will be able to:

- Know lives and ethics of mathematicians and to implement in their academic personality

Course Contents:

UNIT I: Fundamentals of Value Education (18 % Weightage)

Value Education: Definition, Need, Content, Process and relevance to present day. Concept of Human Values, self introspection. Morality and Mathematics

UNIT II: Biographies of Ancient Indian Mathematicians (16 % Weightage)

A brief introduction to the lives and information on the works of the following mathematicians: Aryabhata, Varahamihira, Brahmagupta, Bhaskara I & II, Mahavira, Madhava, and Paramesvara.

UNIT III: Biographies of Remarkable Mathematicians (16 % Weightage)

A brief introduction to the lives and information on the works of the following mathematicians: Euler, Lagrange, Gauss, Cauchy, Abel, Galois, Riemann, Hardy, Noether, Ramanujan, von Neumann, Wiles, and Bhargava.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-8	**UNIT I: Fundamentals of value education**
1-2	Definition of value education
3-6	Need of value education in society
6-7	Definition of ethics, human values and its need and uses in life
8-10	Knowledge about self-introspection, Morality and mathematics
	UNIT II: Biographies of Ancient Indian Mathematicians
10-15	Biographic of famous Indian mathematicians Aryabhata, Varahamihira, Brahmagupta, Bhaskara I & II, Mahavira, Madhava, and Paramesvara
16-20	**UNIT III: Biographies of Remarkable mathematician**
16-20	Biographies Euler, Lagrange, Gauss, Cauchy, Abel, Galois, Riemann, Hardy, Noether, Ramanujan, von Neumann, Wiles, and Bhargava.
10 Hours	*Tutorials*

Essential Readings:

- 3. Puttaswamy, T. K. (2012). Mathematical Achievements of Pre-Modern Indian Mathematicians. Elsevier Inc. USA. 4. Srinivasiengar, C. N. (1988).
- The History of Ancient Indian Mathematics. The World Press Private Ltd. Calcutta. Digitized Book (2009).
- James, Ioan. (2002). Remarkable Mathematicians: From Euler to von eumann. The Mathematical Association of America. Cambridge University Press.

Partial Differential Equation and Fourier Analysis

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester

Semester	IV	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Course		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Self-study, Seminar, Presentations by students.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		

Course Objectives

- To acquaint the students with application of Fourier analysis and its application in solving PDE
- To orient the students with tools and techniques of solving PDE
- To develop skills to apply PDE in engineering problems
- To enable students understanding of geometrical interpretation of PDE

Learning Outcomes

After completion of the course the learners will be able to:

- To solve linear and non linear PDE
- To apply Fourier Transform in solving PDE
- Solve Heat and wave equations
- Formulate mechanical problems in PDE

.

Course Contents

UNIT I: (30% Weightage)

Formation of P.D.E's, P.D.E's of first order, Classification of equations and integrals, Complete, general, singular and special integrals, Lagrange Quasi- linear equations, Integral surfaces through a given curve, Linear and nonlinear First order equations and shocks, Surfaces orthogonal to a given system of surfaces, Pfaffian differential equations, Cauchy's Method of Characteristics, Compatible systems, Charpit's method and Jacobi's method.

UNIT II: (30% Weightage)

Classification of second order P.D.E.'s, Reduction to canonical forms, Linear equations with constant coefficients, Separation of variables, The method of Integral Transform, Laplace, Diffusion and wave equation in various coordinate systems.

UNIT III: (20 % Weightage)

Fourier analysis: Periodic functions, trigonometric series, Fourier series, Euler formulas, Functions having arbitrary periods, Even and odd functions, Half range expansions, Approximation by Trigonometric Polynomials, Fourier Integral.

UNIT IV: (20%Weightage)

Fourier Transform (including cosine and sine transforms), Solution of PDE using Fourier transforms, Boundary value problems on transverse vibrations of strings and heat diffusion in rods.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Formation of P.D.E's, P.D.E's of first order,
3-4	Classification of equations and integrals, Complete, general, singular and special integrals,
5-6	Lagrange Quasi- linear equations,
7-8	Integral surfaces through a given curve, Surfaces orthogonal to a given system of surfaces,
9-10	Pfaffian differential equations, and some exercise
11-12	Cauchy's Method of Characteristics, Compatible systems
13-14	Charpit's method and Jacobi's method.
15-17	Classification of second order P.D.E.'s, Reduction to canonical forms, and some examples
18-20	Linear equations with constant coefficients, Separation of variables,
21-22	The method of Integral Transform,
23-24	Nonlinear Equation of the second order (Monge's Method),

25-27	Laplace, Diffusion and wave equation in various coordinate systems.
28-30	Fourier analysis: Periodic functions, trigonometric series, Fourier series, Euler formulas
31-33	Functions having arbitrary periods, Even and odd functions, Half range expansions,
34-35	Approximation by Trigonometric Polynomials,
36	Fourier Integral.
37-39	Fourier Transform (including cosine and sine transforms),
40-42	Solution of PDE using Fourier transforms,
43-45	Boundary value problems on transverse vibrations of strings and heat diffusion in rods.
15 Hours	*Tutorials*

- Suggested References:
- N. Sneddon, *Elements of Partial Differential Equations*, McGraw Hill Publications, 1957.
- T. Amaranath, *Partial Differential Equations*, Narosa Publ, 2003
- P. Prasad and R. Ravindran, *Partial Differential Equations*, Wiley Eastern Ltd, New Delhi, 1991.
- C. R. Chester, *Techniques in Partial Differential Equations*, McGraw-Hill, New York, 1971.
- L. C. Evans, *Partial Differential Equations*, Graduate Studies in Mathematics, Vol 19, American Mathematical Society, 1999.

Course Details: Functional Analysis

Course Code	…………..	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	core		
Nature of the Course	Theory		

Special Nature/ Category of the Course (*if applicable*)	NA
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)

Course Objectives

- To acquaint the students with the principles and methods of functional

analysis.

- To orient the students with major link between mathematics and its applications.
- To develop a skill to formulate (if possible) problems.

Learning Outcomes

After completion of the course the learners should be able to:

- the basic results associated to different types of convergences in normed spaces and its applications.
- The student has knowledge of central concepts from functional analysis, including the Hahn-Banach theorem, the open mapping and closed graph theorems, the Banach-Steinhaus theorem, dual spaces, weak convergence, the Banach-Alaoglu theorem, and bounded self-adjoint operators.
- Be able to produce examples and counterexamples illustrating the mathematical concepts presented in the course.
- Understand the statements and proofs of important theorems and be able to explain the key steps in proofs.

Course Contents

Unit I **(25% Weightage)**

Normed linear spaces, Quotient norm, Banach spaces and examples, l^p spaces as Banach spaces, Bounded linear transformations on normed linear spaces, B(X,Y) as a normed linear spaces, Open mapping and closed graph theorems, Uniform boundedness principle, Banach Fixed point theorem.

Unit II **(25% Weightage)**

Hahn-Banach theorem and its applications, Dual space, Separability, Reflexivity, Finite dimensional norm linear space, Reisz lemma, Weak and weak* convergence of operators,

Unit III **(25% Weightage)**

Inner product spaces, Hilbert spaces, Orthogonal sets, Bessel's inequality, Complete orthonormal sets and Parseval's identity, Structure of Hilbert spaces, Projection theorem, Riesz representation theorem, Riesz-Fischer theorem,

Unit IV **(25% Weightage)**

Adjoint of an operator on a Hilbert space, Reflexivity of Hilbert spaces, Self-adjoint operators, Positive, projection, normal and unitary operators and their basic properties.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Normed linear spaces, Quotient norm
3-4	Banach spaces and examples
5-6	l^p spaces as Banach spaces
6-9	**Tutorial**
10-11	Bounded linear transformations on normed linear spaces, B(X,Y) as a normed linear spaces,
12-13	Open mapping
14-15	closed graph theorems
16-17	Uniform boundedness principle
18-20	**Tutorial**
21-23	Hahn-Banach theorem and its applications
24-26	Dual space,
27-29	Finite dimensional norm linear space, Reisz lemma,
30-32	Separability, Reflexivity**,**
33-35	**Weak and weak* convergence of operators**
36-37	Inner product spaces, Hilbert spaces
38-39	Orthogonal sets, Bessel's inequality, Complete orthonormal sets and Parseval's identity, Structure of Hilbert spaces
40-41	Projection theorem, Riesz representation theorem, Riesz-Fischer theorem

42-45	**Tutorial**
45-48	Adjoint of an operator on a Hilbert space, Reflexivity of Hilbert spaces,
49-52	Self-adjoint operators, Positive, projection
53-55	normal and unitary operators and their basic properties.
55-60	**Tutorial**

Texts/ References

- G. Bachman and L. Narici, Functional Analysis, Academic Press, 1966.
- J. B. Conway, A First Course in Functional Analysis, Springer, 2000.
- R. E. Edwards, Functional Analysis, Holt Rinehart and Winston, 1965.
- C. Goffman and G. Pedrick, First Course in Functional Analysis, Prentice-Hall of India,
- 1987.
- B. V. Limaye, Functional Analysis, New Age International, 1996.
- G. F. Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill, 1963.
- W. Rudin, Principles of Mathematical Analysis, 5th edition, McGraw Hill Kogakusha Ltd., 2004.
- M. Thamban Nair, Functional Analysis First Course, PHI, 2021

Numerical Methods and Statistics

Course Code	………….	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective/ Discipline Based Core Elective /Open Elective/Mandatory Elective		
Nature of the Course	Theory		

Special Nature/ Category of the Course (*if applicable*)	N/A
Methods of Content Interaction	*Lectures, Tutorials,*
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)

Course Objectives

- Learn Sampling theory
- Learn hypothesis testing for large and small samples
- Study Chi-Square distribution and goodness of fit
- Learn Neyman-Pearson lemma and likelihood ratio test
- Learn the tools and techniques of solving algebraic and transcendental equations
- Learn different interpolation schemes
- Study numerical methods to solve ordinary differential equations

Learning Outcomes

After completion of the course the learners will be able to:

- Demonstrate ability to understand a Central Limit Theorem
- Demonstrate ability to test hypothesis for single and two large samples
- Demonstrate ability to test hypothesis using t and F distributions
- Demonstrate ability to apply Chi - Square test for goodness of fit
- Demonstrate ability to apply Neyman-Pearson lemma and llikelihood ratio test
- Understand the error analysis and convergence of numerical schemes
- Demonstrate ability to solve algebraic and transcendental equations
- Demonstrate ability to solve ordinary differential equations
- Understanding of numerical integration and demonstrate ability to solve integrals n

Unit-I (25% weightage)

Numerical Integration: Newton-Cotes Formulas, numerical schemes along with error estimates, Euler-Maclaurin formula. Numerical techniques for solution of Ordinary differential equations, Incremental methods, Euler's and Improved Euler's methods etc. method along with error bounds, Predictor-Corrector methods of Adams-Bashforth-Moulton and Milne's types with error estimates.

UNIT II: (25%Weightage)

Numerical Linear Algebra, Gaussian elimination and Gauss-Jordan methods for solving systems of linear equations, LU decomposition and solutions of linear systems and matrix inversion using these decompositions, Gauss-Jacobi and Gauss-Seidel Iterative methods and their convergence, Estimation of eigenvalues and eigenvectors, Gerschgorin's circles, Power method for the first and second dominant eigenvalues along with convergence criteria.

UNIT III: (25 % Weightage)

Introduction to the sampling distribution, bounds on probability Weak and Strong law of large numbers. , Central Limit theorem, Methods of Finding Estimators: Point Estimation (Method of Maximum Likelihood, Method of Moments); Interval Estimation (Estimation of mean, standard error of estimate);.

UNIT IV: (25%Weightage)

Hypothesis testing: Confidence interval, Level of Significance Type I and Type II errors; single large sample test, Two large sample test; t-test (paired and unpaired), F-test, Chi-Square test and goodness of fit; Concepts of Hypothesis Testing: Neyman-Pearson lemma, Likelihood Ratio Test.

Course Content

1	Numerical Integration,Newton-Cotes Formulas,
2-4	Simpson's 1/3 and 3/8- rules along with error estimates, Euler-Maclaurin formula
5-7	Numerical techniques for solution of Ordinary differential equations, Incremental methods, Euler's and Improved Euler's methods,
8	Fourth order Runge-Kutta method along with error bounds,
9-10	Predictor-Corrector methods of Adams-Bashforth-Moulton and Milne's types with error estimates.
11-14	Numerical Linear Algebra, Gaussian elimination and Gauss-Jordan methods for solving systems of linear equations,
15-18	LU and Cholesky decomposition and solutions of linear systems and matrix inversion using these decompositions,
19-21	Gauss-Jacobi and Gauss-Seidel Iterative methods and their convergence,
22	Estimation of eigenvalues and eigenvectors
23-24	Gerschgorin's circles, Power method for the first and second dominant eigenvalues along with convergence criteria.
25	Introduction to the sampling distribution, Central Limit theorem, bounds on probability Weak and Strong law of large numbers
26-28	Methods of Finding Estimators: Point Estimation (Method of Maximum Likelihood, Method of Moments);
30-31	Interval Estimation (Estimation of mean, maximum error of estimate); Confidence interval, Type I and Type II errors
32-33	Hypothesis testing: single large sample test
34-35	Two large sample test
36-39	t-test (paired and unpaired), F-test
40-42	Chi-Square test and goodness of fit
43-45	Concepts of Hypothesis Testing: Neyman-Pearson lemma, Likelihood Ratio Test.

Project

Prerequisites: Reasonably good understanding about M.Sc. first year courses; especially those

related to the project topic.

Goal: The project is of one semester duration and carries 4 credits. A student will choose a topic (either a research paper or some other advanced material related to but beyond the first year courses). The student will then learn the material under the supervision of a teacher. It is expected that the student will meet the supervisor regularly (at least once per week) and present the material that he/she has learnt and keep his/her supervisor updated with his/her progress. The student is also expected to write an expository essay of about 10 to 15 pages on the project topic and also present it to a panel of examiners at the end of the term.

Grading Scheme: The student's performance will be evaluated based on the presentations (working seminars to the supervisor), project essay and final presentation and the grading scheme for this course will be announced prior to the beginning of the project course.

Syllabi of Elective Courses From Table 1

Course Details			
Course Title: Algebraic Geometry			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.		
Assessment and Evaluation	30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 70% - End Term External Examination (University Examination)		
Prerequisite			

Course Objectives

- To develop the understanding of concepts through examples, counter examples and problems.
- To orient the students with tools and techniques of Algebraic Geometry
- To develop a skill to solve problems.

Learning Outcomes

After completion of the course the learners should be able to:

- understand zariski topology
- understand affine varieties
- understanding of plane curves

Course Contents

UNIT I **(25% Weightage)**

Affine algebraic sets, Zariski topology, algebraic set and ideal correspondence,

Hilbert's nullstellensatz, affine varieties.

UNIT II **(25% Weightage)**

Polynomial maps, the coordinate ring functor, rational maps and birational equivalence,

dimension and product of affine varieties.

UNIT III **(25% Weightage)**

Projective algebraic sets and projective varieties, projective closures, rational functions and morphisms, Segre embedding and Veronese embedding. Tangent spaces, smooth and singular points, algebraic characterizations of the blowing-up a point on a variety.

dimension of a variety,

UNIT IV **(25% Weightage)**

Plane curves, rational curves, multiple points, intersection numbers, Bezout's theorem, Max Noether's fundamental theorem.

<u>Content Interaction Plan:</u>

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Affine algebraic sets , Zariski topology,
3-4	algebraic set and ideal correspondence
5-6	Hilbert’s nullstellensatz
7-8	affine varieties
9-10	Polynomial maps,
11-12	the coordinate ring functor
13-14	rational maps and birational equivalence
15-16	dimension and product of affine varieties
17-18	Projective algebraic sets and projective varieties,
19-20	projective closures,
21-22	rational functions and morphisms,
23-24	Segre embedding and Veronese embedding.
25-26	Tangent spaces
27-28	smooth and singular points
29-30	algebraic characterizations of the blowing-up a point on a variety.
31-32	dimension of a variety,
33-34	Plane curves
35-36	rational curves
37-38	multiple points,
39-40	intersection numbers,
41-42	Bezout’s theorem
43-45	Max Noether’s fundamental theorem.

Books Recommended:

1. C. Musli, Algebraic Geometry for Beginners, TRIM-20, Hindustan Book Agency, 2001.

2. W. Fulton, Algebraic Curves, An Introduction to Algebraic Geometry, W.A. Benjamin, 1969.

3. K. Hulek, Elementary Algebraic Geometry , SML, vol 20, American Mathematical Society, 2003.

4. M. Ried, Undergraduate Algebraic Geometry, LMS Student texts 12, Crambridge University Press, 1988.

Course Details			
Course Title: Algebraic Number Theory			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Presentation.		
Assessment and Evaluation	30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 70% - End Term External Examination (University Examination)		

Course Objectives

- To show how tools from algebra can be used to solve problems in number theory.
- To study Dedekind domains, Norm and Classes of ideals
- To study Class groups and class number

Learning Outcomes

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

- be able to compute norms and discriminants and to use them to determine the integer rings in algabraic number fields;
- be able to factorize ideals into prime ideals in algebraic number fields in straightforward examples;
- understand the proof of Minkowski's Theorem on lattices, and be able to apply it, for example, to prove that all positive integers are the sum of four squares.

Prerequisites: Algebra-I (MTH553), Algebra-II (MTH 602)

Course Contents

UNIT I **(15% Weightage)**

Rudiments of Field extensions, Trace and Norm, Discriminant and Resultant of Polynomials, Steinitz' Theorem, Transcendence Bases,

UNIT II **(15 % Weightage)**

Algebraic Integers, Integral elements, Integrally closed Domains, Rings of Algebraic integers, Arithmetic in **Z**[i], Integers of Quadratic number fields, Integers of Cyclotomic fields, Integral basis, Discriminant of quadratic and cyclotomic fields.

UNIT III **(35 % Weightage)**

Decomposition of Ideals, Dedekind domains, Norm and Classes of ideals. Units of quadratic and cyclotomic fields, Dirichlet's Theorem on Group of units of algebraic integers of **Q**(ζ) with ζ a primitive p^{th} root of unity.

UNIT IV **(35% Weightage)**

Extension of Ideals, Decomposition of prime numbers in quadratic and cyclotomic fields, Decomposition of Prime ideals in Galois extensions, Ramificaions, Theory of Kronecker and Weber on Abelian extensions, Class group and class number.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Rudiments of Field extensions, Trace and Norm
5-8	Discriminant and Resultant of Polynomials, Steinitz' Theorem, Transcendence Bases
9 -12	Algebraic Integers, Integral elements, Integrally closed Domains, Rings of Algebraic integers
13-16	Arithmetic in **Z**[i], Integers of Quadratic number fields, Integers of Cyclotomic fields

17-20	Integral basis, Discriminant of quadratic and cyclotomic fields.
21-24	Decomposition of Ideals, Dedekind domains.
25-28	Norm and Classes of ideals. Units of quadratic and cyclotomic fields.
29-32	Dirichlet's Theorem on Group of units of algebraic integers of **Q**(ζ) with ζ a primitive p^{th} root of unity.
33-36	Extension of Ideals, Decomposition of prime numbers in quadratic and cyclotomic fields.
37-40	Decomposition of Prime ideals in Galois extensions, Ramificaions.
41-45	Theory of Kronecker and Weber on Abelian extensions, class groups and class number
15 Hours	*Tutorials*

Suggested Texts/References:

Texts/References

1. P. Ribenboim, *Classical Theory of Algebraic Numbers*, Springer Universitext.
2. Ian Stewart, and David Tall, Algebraic Number theory, Chapmann & Hall

2. N. Borevich and I. Shafarevich, *Number Theory*, Academic Press.

3. S. Lang, *Algebraic Number Theory*, Springer-Verlag, New York, 1994.

4. M. Rosen and K. Ireland, *A Classical Introduction to Number Theory*, Graduate Texts in Mathematics, Springer, 1982.

Course Objectives

- To acquaint the students with the Algebraic Topology
- To orient the students with major link between Algebraic Topology and its applications.

Learning Outcomes

After completion of the course the learners should be able to:

- The basic results associated to Algebraic Topology.
- produce examples illustrating the mathematical concepts presented in the course.
- Understand the statements and proofs of important theorem and be able to explain the key steps .

Course Contents

Unit I **(weightage 25%)**

Homotopic maps, homotopy type, retraction and deformation retract, Fundamental group. Calculation of fundamental groups of n-sphere, n ≥1, of the cylinder, the torus, and the punctured plane

Unit II **(weightage 25%)**

Course Details			
Course Title: Algebraic Topology			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		
Prerequisite	• Topology, Algebra		

Notion of free group and Fundamental group of figure eight,Applications: the Brouwer fixed-point theorem, the fundamental theorem of algebra.

Unit III **(weightage 25%)**

Covering projections, the lifting theorems, relations with the fundamental group, classification of covering spaces, universal covering space.

Unit IV **(weightage 25%)**

The Borsuk-Ulam theorem, free groups, Seifert–Van Kampen theorem and its applications.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Homotopic maps, homotopy type
5-7	retraction and deformation retract, Fundamental group.
8-10	Calculation of fundamental groups of n-sphere, n ≥1, of the cylinder, the torus, and the punctured plane
11-15	Tutorial
16-20	Notion of free froup and Fundamental group of figure eight
21-23	The fundamental theorem of algebra
24-28	Fundamental group of figure eight
28-33	Tutorial
34-40	Covering projections
41-43	The lifting theorems, relations with the fundamental group,
44-45	Classification of covering spaces, universal covering space.
46-50	Tutorial
51-53	The Borsuk-Ulam theorem
54-56	free groups, Seifert–Van Kampen theorem and its applications.
57-60	Tutorial

Texts/ References

- M. A. Armstrong, Basic Topology, Springer-Verlag, 1983.
- Satya Deo, Algebraic Topology, a primer, Hindustan Book Agency, TRIM Series, 2006.
- W.S. Massey, A Basic Course in Algebraic Topology, Springer-Verlag, 2007.
- J.J. Rotman, An Introduction to Algebraic Topology, Springer-Verlag, 1988.

E.H. Spanier, Algebraic Topology, Springer-Verlag, 1989.

Calculus of variation and Integral Equation

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Course		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Self-study, Seminar, Presentations by students.		
Assessment and Evaluation	● 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) ● 70% - End Term External Examination (University Examination)		

Course Objectives

- To make familiar students with integral equations
- To make familiar Variational problems
- To orient the students with tools and techniques of solving Integral equations
- To develop skills to apply Integral equations in engineering problems

Learning Outcomes

After completion of the course the learners will be able to:

- To solve various types of Integral equations
- To convert BVP into Integral equations
- apply Integral equations in engineering problems

Course Contents

UNIT I: (20% Weightage)

Euler's equations, Functional dependence on higher-order derivatives, Functional dependence on functions of several dependent variables, Isoperimetric problems.

UNIT II: (30% Weightage)

Variational problems with moving boundaries, One sided variations, Extermals with Corners, Variational problems with subsidiary conditions, Direct method: Rayleigh-Ritz method, Galerkin's method..

UNIT III: (30 % Weightage)

Classification of Integral equations, Integral Equation with separable kernels, Iterative method for Fredholm's equation of second kind, Fredholm alternating theory, Volterra type integral equation, Integral equations of first kind, Convolution type Integral Equations.

UNIT IV: (20%Weightage)

Symmetric Kernels, Singular Integral Equation, Non-linear Volterra equations, Hilbert Schmidt theory, Application to mixed boundary value problems.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-2	Euler's equations
3-5	Functional dependence on higher-order derivatives
6-9	Functional dependence on functions of several dependent variables.
10-12	Variational problems with moving boundaries
12-14	One sided variations, Extermals with Corners,
14-15	Variational problems with subsidiary conditions
15-16	Isoperimetric problems
17-20	Rayleigh-Ritz method
21-22	Galerkin's method.
23-24	Classification of Integral equations
25-26	Integral Equation with separable kernels,

27-29	Iterative method for Fredholm's equation of second kind,
30-32	volterra type integral equation, Integral equations of first kind,
33-35	Convolution type Integral Equations
36-38	Symmetric Kernels
38-39	Singular Integral Equation,
40-41	Non-linear Volterra equations
42-43	Hilbert Schmidt theory,
44-45	Application to mixed boundary value problems.
15 Hours	*Tutorials*

- Suggested References:

- S. Gupta, *Calculus of Variations*, Prentice Hall of India Pvt. Ltd., 2003.
- I. M. Gelfand and S. V. Francis, *Calculus of Variations*, Prentice Hall, New Jersey, 2000.
- L. G. Chambers*, Integral Equations*, International Text Book Company Ltd., London, 1976.
- F. G. Tricomi, *Integral Equations*, Interscience, New York, 1957.

. • R. P. Kanwal, *Linear Integral Equation: Theory and Technique*, Birkhauser, 1997

Course Details			
Course Title: Commutative Algebra			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades)		

	• 70% - End Term External Examination (University Examination)
Prerequisite	• Linear Algebra and Algebra I

Course Objectives

- To develop the understanding of concepts through examples, counter examples and problems.
- To orient the students with tools and techniques of Commutative Algebra.
- To develop a skill to solve problems.

Learning Outcomes

After completion of the course the learners should be able to:

- understand ideal, rings and module over ring.
- understand tensor product of modules
- calculate exact sequences.
- understand localization of rings

Course Contents

UNIT I: **(25% Weightage)**

Preliminaries on rings and ideals, local and semilocal rings, nilradical and Jacobson radical, operations on ideals, extension and contraction ideals, modules and module homomorphisms, submodules and quotient modules, operations on submodules; annihilator of a module, generators for a module, finitely generated modules, Nakayama's lemma,

Unit II: **(25% Weightage)**

Exact sequences. Existence and uniqueness of tensor product of two modules, tensor product of n modules, restriction and extension of scalars exactness properties of tensor products flat modules,

Unit III **(25% Weightage)**

Multiplicatively closed subsets, saturated subsets; ring of fractions of a ring, localization of a ring, module of fractions and its properties, extended and contracted ideals in a ring of fractions, total ring of fractions of a ring.

Unit IV **(25% Weightage)**

Primary ideals, p-primary ideals, Primary decomposition, Minimal primary decomposition, uniqueness theorems, Primary submodules of a module.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Preliminaries on rings and ideals, local and semilocal rings,
3-4	nilradical and Jacobson radical,
5-6	operations on ideals, extension and contraction ideals,
7-8	modules and module homomorphisms,
9-10	submodules and quotient modules, operations on submodules;
11-12	annihilator of a module, generators for a module, finitely generated modules, Nakayama's lemma,
13-14	exact sequences.
15-16	Existence and uniqueness of tensor product of two modules,
17-18	tensor product of n modules, restriction and extension of scalars exactness
19-20	properties of tensor products flat modules,
21-22	Multiplicatively closed subsets, saturated subsets
23-24	ring of fractions of a ring, localization of a ring,
25-26	module of fractions and its properties,
27-28	extended and contracted ideals in a ring of fractions,
29-30	total ring of fractions of a ring.
31-32	Primary ideals
33-34	p-primary ideals
35-36	Primary decomposition,
37-38	Minimal primary decomposition,
39-40	Minimal primary decomposition,
41-42	uniqueness theorems,
43-45	Primary submodules of a module. Primary submodules of a module.

Texts/References

1. M. F. Atiyah and I. G. Macdonald, Introduction to Commutative Algebra, Addison Wesley, 2000.
2. M. Reid, Undergraduate Commutative Algebra, London Math. Soc. Student Texts, No. 29\, 1995.
3. I. S. Luther and I. B. S. Passi, Algebra (Volume 2: Rings), Narosa Publishing House, New Delhi,1999.
4. I. S. Luther and I. B. S. Passi , Algebra (Volume 3: Modules), Narosa Publishing House, New Delhi, 1999.
5. S. Lang, Algebra, Addison-Wesley Publishing Company, London, 2000.
6. D. Eisenbud, Commutative Algebra.

Course Details			
Course Title: Differential Geometry			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.		
Assessment and Evaluation	· 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) · 70% - End Term External Examination (University Examination)		
Prerequisite	Prerequisites: Linear Algebra (MTH 502) and Algebra (MTH 553)		

Course Objectives

- To develop the understanding of concepts through examples, counter examples and problems.
- To orient the students with tools and techniques of differential geometry.
- To develop a skill to solve problems.

Learning Outcomes

After completion of the course the learners should be able to:

.

Course Contents

Unit I **(25% Weightage)**

Graph and level sets, vector fields, the tangent space, surfaces, orientation, the Gauss map, geodesics, parallel transport, the Weingarten map.

Unit II **(25% Weightage)**

Curvature of plane curves, arc length and line integrals, curvature of surfaces, parametrized surfaces, surface area and volume, surfaces with boundary, the Gauss-Bonnet Theorem.

Unit III **(25% Weightage)**

Riemannian geometry of surfaces, Parallel translation and connections, structural equations and curvature, interpretation of curvature.

Unit IV **(25% Weightage)**

Geodesic Coordinate systems, isometries and spaces of constant curvature.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Graph and level sets
3-4	vector fields
5-6	the tangent space

7-8	Surfaces
9-10	Orientation
11-12	the Gauss map,
13-14	Geodesics
15-16	parallel transport
17-18	the Weingarten map
19-20	Curvature of plane curves
21-22	arc length and line integrals, curvature.
23-24	curvature of surfaces
25-26	parametrized surfaces
27-28	surface area and volume
29-30	surface area and volume
31-32	surfaces with boundary
33-34	the Gauss-Bonnet Theorem.
35-36	Riemannian geometry of surfaces,
37-38	Parallel translation and connections
39-40	structural equations and curvature,
41-42	interpretation of curvature.
43-45	Geodesic Coordinate systems isometries and spaces of constant

Texts/References

1. W. Kuhnel, Differential Geometry-curves-surfaces-Manifolds, AMS 2006.

2. A. Mishchenko and A. Formentko, A course of Differential Geometry and Topology, Mir Publishers Moscow, 1988.

3. A. Pressley, Elementary Differential Geometry, SUMS, Springer, 2004.

4. I. A. Thorpe, Elementary Topics in Differential Geometry. Springer, 2004

Distribution Theory

Course Code	....	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester

Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		
Prerequisite	• Functional Analysis, Measure theory, Metric Space		

Course Objectives

- To acquaint the students to solve a wide range of applications, mainly those involving differential equations.
- To orient the students with major link between mathematics and its applications.

Learning Outcomes

After completion of the course the learners should be able to:

- The basic results associated with generalized function.
- Different type of functional spaces.
- Tempered distributions and Fourier Transform
- Sobolev spaces

Course Contents

Unit I (weightage 25%)

Test function and distribution, Covergence of distribution, operation on distribution, Local properties of distribution,

Unit II (weightage 25%)

Distributional derivatives. Distributions of compact support. Direct product of distributions, convolutions and their properties. Fundamental solutions of linear differential operators.

Unit III (weightage 25%)

Space of rapidly decreasing functions, Tempered distributions. Fourier transform on $L^1(R^n)$. Sobolev space $H^{m,p}(\Omega)$, $H^s(R^n)$

Unit IV (weightage 25%)

Properties of $H^s(R^n)$, Weak solution

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-3	Test function and distribution
4-8	Covergence of distribution, operation on distribution,
9-13	Local properties of distribution,
13-15	Tutorial
16-20	Distributional derivatives. Distributions of compact support.
21-25	Direct product of distributions, convolutions and their properties.
25-30	Fundamental solutions of linear differential operators
30-34	Tutorial
35-42	Space of rapidly decreasing functions, Tempered distributions. Fourier transform on $L^1(R^n)$. Sobolev space $H^{m,p}(\Omega)$, $H^s(R^n)$

43-47	Fourier transform on $L^1(R^n)$. Sobolev space $H^{m,p}(\Omega)$, $H^s(R^n)$
48-52	Sobolev space $H^{m,p}(\Omega)$, $H^s(R^n)$
53-58	Properties of $H^s(R^n)$, Weak solution
59-60	Tutorial

Texts/ References

- S. Kesavan, Topics in Functional Analysis and Applications, Wiley Eastern, 1989.
- R. S. Pathak, A Course in Distribution Theory and Applications, Narosa Publishing House, 2001.
- F. G. Friedlander, Introduction to the Theory of Distributions, Cambridge University Press, 1982.

Fluid Mechanics

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Self-study, Seminar, Presentations by students.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		

Course Objectives

- To acquaint the students with concepts of fluid motion and its governing equations
- To enable students in understating of kinematics of fluid
- To develop students understanding of fluid flow under various physical configurations and boundary conditions.

Learning Outcomes

After completion of the course the learners will be able to:

To understand Lagrangian and Eulerian description of fluid motion To understand modeling of fluid flow

To solve flow equations in some special cases

Course Contents

UNIT I: (30% Weightage)

Lagrangian and Eulerian description of fluid motion, Motion of a continuum, Velocity and Acceleration, Stream lines, Path lines, Steady motion, Kinematics of vorticity and circulation. Equation of continuity (Cartesian, general vector form, cylindrical and spherical coordinates), Euler's equation of motion, Bernoulli's equation Motion in two dimensions-Stream function, Irrotational motion, Velocity and Complex potentials, Cauchy-Riemann's equations, Sources and Sinks.

UNIT II: (30% Weightage)

Kinematics of Deformation; Rate of strain tensor, Body and Surface forces, Stress Principle of Cauchy; Newtonian fluids, Constitutive equations for Newtonian fluids; Navier- Stokes equations in Vector and general Tensor forms, Navier-Stokes equations in orthogonal coordinate systems (particularly in Cartesian, cylindrical and spherical coordinate systems).

UNIT III: (20 % Weightage)

Dynamical Similarity, Role of Reynolds number in Fluid dynamics; Some Exact solutions– Steady flow between parallel plates, Couette flow between coaxial rotating cylinders, Steady flow between pipes of uniform cross-section, Small Reynolds number flow, Stokes equations, steady flow past a sphere

UNIT IV: (20%Weightage)

Boundary layer concept, 2-dimensional boundary layer equations, separation phenomena; boundary layer on a semi-infinite plane, Blasius solution; boundary layer thickness, Karman's Integral method.

Content Interaction Plan:

Lecture cum Discussion **(Each session of 1 Hour)**	**Unit/Topic/Sub-Topic**

1-2	Lagrangian and Eulerian description of fluid motion,
3-4	Motion of a continuum, Velocity and Acceleration, Stream lines, Path lines
5-6	Steady motion, Kinematics of vorticity and circulation.
7-8	Equation of continuity (Cartesian, general vector form, cylindrical and spherical coordinates),
9-10	Euler's equation of motion, Bernoulli's equation Motion in two dimensions-Stream function
11-12	Irrotational motion, Velocity and Complex potentials,
13-14	Cauchy-Riemann's equations, Sources and Sinks.
15-17	Kinematics of Deformation; Rate of strain tensor, Body and Surface forces,
18-20	Stress Principle of Cauchy; Newtonian fluids, Constitutive equations for Newtonian fluids,
21-22	Navier- Stokes equations in Vector and general Tensor forms,
23-27	Navier-Stokes equations in orthogonal coordinate systems (particularly in Cartesian, cylindrical and spherical coordinate systems).
28-30	Dynamical Similarity, Role of Reynolds number in Fluid dynamics, Some Exact solutions–Steady flow between parallel plates,
31-33	Couette flow between coaxial rotating cylinders, Steady flow between pipes of uniform cross-section,
34-35	Small Reynolds number flow, Stokes equations,
36	Steady flow, past a sphere.
37-39	Boundary layer concept, 2-dimensional boundary layer equations
40-42	separation phenomena; boundary layer on a semi-infinite plane, Blasius solution;
43-45	boundary layer thickness, Karman's Integral method.
15 Hours	*Tutorials*

- <u>Suggested References:</u>

Bachelor G. K., *An introduction to fluid dynamics*, Cambridge University Press.

F. Chorlton, *Text book of Fluid Dynamics*, CBS Publishers

W. H. Besant and A. S. Ramsey, *A Treatise on Hydrodynamics*, CBS Publishers

Z. U. A. Warsi, *Fluid Dynamics*, CRC Press, 1999 Yuan S. W. *Foundation of fluid Mechanics*.

Graph Theory

Course Code	…………..	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	*Lecture, Tutorials, Group discussion, Self-study, Seminar, Presentations by students.*		
Assessment and Evaluation	● 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) ● 70% - End Term External Examination (University Examination)		
Prerequisite	NIL		

Course Objectives:

- ❖ To present all basic concepts of graph theory.
- ❖ To present graph properties (with simplified proofs) and formulations of typical graph problems.
- ❖ To apply graph theory based tools in solving practical problems.

Course Learning Outcomes:

After completion of the course, the successful students will be able to:

- ❖ Understand and explore the basic notions of graph theory.
- ❖ Apply this knowledge of graph theory in (especially) computer science applications.

- ❖ Analyze the significance of graph theory in different engineering disciplines.
- ❖ Demonstrate algorithms used in interdisciplinary engineering domains.
- ❖ Represent real-life situations with mathematical graphs.
- ❖ Evaluate or synthesize any real-world applications using graph theory.

Course Contents

UNIT I: Introductory Ideas **(25 % Weightage)**

Basic definitions and examples, Degrees, Regular graphs, Degree sequences and graphical sequences, Handshaking Theorem, Graph Isomorphisms, Automorphism groups, Subgraphs, Spanning and Induced subgraphs, Adjacency and Incidence matrices.

UNIT II: Connected graphs and Trees **(25 % Weightage)**

Walks, Trails and paths, Acyclic graphs, Connected graphs, Girth, Distance and diameter, Bipartite graphs, Eulerian and Hamiltonian graphs, Trees and their properties, Characterization of trees, Centers of trees, Rooted trees, Binary trees, Spanning trees, Minimum cost spanning trees, Algorithm of Kruskal's and Prim's.

UNIT III: Connectivity and Matchings **(25 % Weightage)**

Cut-vertices and bridges, Blocks, Connectivity, k-connected graphs, Independent sets of edges, Matchings, Perfect matchings, Matchings in bipartite graphs, Hall's Theorem and its applications, Maximum and maximal matchings, Matchings in a general graph.

UNIT III: Graph colorings and Planar graphs **(25 % Weightage)**

Cliques and Independent sets of vertices, Coloring of Graphs, Chromatic number and chromatic index, Chromatic polynomials, Graph drawing on the surface, Planar graphs, Euler's formula and its applications, Five-Color theorem and Four-Color conjecture, Kuratowski's theorem, Duality.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-11	**UNIT I: Introductory Ideas**

1-3	Basic definitions and examples, Degrees, Regular graphs.
4-6	Degree sequences and graphical sequences, Handshaking Theorem.
7-9	Graph Isomorphisms, Automorphism groups,
10-11	Subgraphs, Spanning and Induced subgraphs, Adjacency and Incidence matrices.
12-23	**UNIT II: Connected graphs and Trees**
12-15	Walks, Trails and paths, Acyclic graphs, Connected graphs, Girth, Distance and diameter.
16-17	Bipartite graphs, Eulerian and Hamiltonian graphs.
18-21	Trees and their properties, Characterization of trees, Centers of trees, Rooted trees, Binary trees.
22-23	Spanning trees, Minimum cost spanning trees, Algorithm of Kruskal's and Prim's.
24-34	**UNIT III: Connectivity and Matchings**
24-27	Cut-vertices and bridges, Blocks, Connectivity, k-connected graphs,
28-30	Independent sets of edges, Matchings, Perfect matchings, , Maximum and maximal matchings.
31-34	Matchings in bipartite graphs, Hall's Theorem and its applications, Matchings in a general graph.
35-45	**UNIT IV: Graph colorings and Planar graphs**
35-36	Cliques and Independent sets of vertices, Coloring of Graphs,
37-38	Chromatic number and chromatic index,
39	Chromatic polynomials.
40-42	Graph drawing on the surface, Planar graphs, Euler's formula and its applications.
43	Five-Color theorem and Four-Color conjecture.
44-45	Kuratowski's theorem, Duality.
15 Hours	*Tutorials*

<u>Suggested Texts/ References:</u>

- G. Chartrand, P. Zhang, *A First Course in Graph Theory,* Dover Publications, New York, 2012.

- S. M. Cioaba, M. Ram Murty, *A First Course in Graph Theory and Combinatorics*, TRIM, Hindustan Book Agency, 2009.
- R. Diestel, *Graph Theory*, Graduate Texts in Mathematics, Springer, 1997.
- B. Bollobas, *Graph theory an Introductory Course*, GTM 63, Springer-Verlag, New york, 1979.
- J. H. Van Lint, R.M. Wilson, *A Course in Combinatorics*, Cambridge University press, 1992.
- F. Harary, *Graph Theory*, Narosa Publishing House.

Course Details			
Course Title: Group Theory			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		
Prerequisite	• Algebra I		

Course Objectives

- To develop the understanding of concepts through examples, counter examples and problems.
- To orient the students with tools and techniques of Group Theory.
- To develop a skill to solve problems.

Learning Outcomes

After completion of the course the learners should be able to:

- understand classical groups, free groups solvable and nilpotent groups.
- find orders, centers in classical groups.
- understand central product.
- Simplicity of Projective special linear group.

Course Contents

UNIT I: **(25% Weightage)**

Unit I Basic structure of General Linear Group, Special linear group and Projective special linear group, Simplicity of Projective special linear group, Bruhat decomposition in general linear group.

Unit II **(25% Weightage)**

Free groups, Generators and relations, Todd Coxeter Algorithm, Semidirect product, Free product of groups, Generalized free products, Presentation of group, Finitely presented group, Central product.

Unit III **(30% Weightage)**

Lower and Upper central series, Nilpotent group, p-group, Characterizations of finite nilpotent group, Fitting theorem, Fitting subgroup, Frattini subgroup, The Burnside basis theorem, Extra special p-groups.

Unit IV **(20% Weightage)**

Derived Series, Solvable groups, Properties of Solvable groups. Nilpotent groups are solvable, Solvability of groups of order $p^m q$, Solvability of groups of order $p^2 q^2$, Solvability of groups of order pqr, Solvability of groups of order less than 60.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Basic structure of General Linear Group,

3-4	Special linear group and
5-6	Projective special linear group
7-8	Simplicity of Projective special linear group,
9-10	Bruhat decomposition in general linear group
11-12	Bruhat decomposition in general linear group
13-14	Free groups
15-16	Generators and relations
17-18	Todd Coxeter Algorithm
19-20	Semidirect product, Free product of groups
21-22	Generalized free products, Presentation of group
23-24	Finitely presented group, Central product.
25-26	Lower and Upper central series, Nilpotent group, \$p\$-group,
27-28	Characterizations of finite nilpotent group
29-30	Fitting theorem, Fitting subgroup,
31-32	Frattini subgroup
33-34	The Burnside basis theorem
35-36	Extra special \$p\$-groups.
37-38	Solvable groups and its properties
39-40	Groups of order $p^m q$ are solvable Groups of order p^2 q^2 are solvable
41-42	. Groups of order \$pqr\$ are solvable.
43-45	Solvability of groups of order less than equal to 60.

· Texts/References

· Michael Artin, Algebra, Prentice- Hall of India, 1991.

· J. J. Rotman, Theory of Groups: An Introduction, Allyn and Bacon, 1973.

· D. J. S. Robinson, A course in theory of groups, Springer, 1996.

· M. Suzuki, Group Theory-I, Springer, 1986.

· J. L. Alperin, R.B. Bell, Groups and Representations, Springer, 1995.

Course Title: Introduction to Finite Fields and Coding theory			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Presentation.		
Assessment and Evaluation	30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 70% - End Term External Examination (University Examination)		
Prerequisite	Algebra-I		

Course Objectives

- To give the introduction to finite fields
- To study results related to polynomials over finite fields
- To give the introduction to coding theory and applications of finite fields to coding theory
-

Learning Outcomes

Upon completion of this course, the student will be able to understand basic structure of finite fields, polynomials and irreducible polynomials over finite fields and different types of codes; Hamming codes, cyclic codes and BCH codes etc.

Course Contents

UNIT I **(25% Weightage)**

Characterization of finite fields, Roots of Irreducible Polynomials, Trace, Norms, and Bases, Roots of Unity and Cyclotomic polynomials, Representation of elements of finite fields, Order of polynomials and primitive polynomials.

UNIT II **(25 % Weightage)**

Irreducible polynomials, Construction of irreducible polynomials, Linearized polynomials, Binomials and trinomials Factorization of polynomials over small finite fields, factorization of polynomials over large finite fields, Calculation of roots of polynomials.

UNIT III **(25 % Weightage)**

The coding problem, Linear codes, generator and parity check matrices, dual codes, weights and distances, new codes from old codes, Permutation equivalent codes.

UNIT IV **(25% Weightage)**

Hamming codes, basic theory of cyclic codes, idempotent and multipliers, zeros of a cyclic codes, minimum distance of cyclic codes, BCH Codes.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Characterization of finite fields
3-4	Roots of Irreducible Polynomials
5 -8	Trace, Norms, and Bases, Roots of Unity and Cyclotomic polynomials
9-11	Representation of elements of finite fields, Order of polynomials and primitive polynomials.
12-16	Irreducible polynomials, Construction of irreducible polynomials, Linearized polynomials, Binomials and trinomials
17-22	Factorization of polynomials over small finite fields, factorization of polynomials over large finite fields, Calculation of roots of polynomials.
23-26	The coding problem, Linear codes.
27-30	Generator and parity check matrices, dual codes, weights and distances.
31-33	New codes from old codes, Permutation equivalent codes.
34-35	Hamming codes, basic theory of cyclic codes
35-40	Idempotent and multipliers, zeros of a cyclic codes, minimum distance of cyclic codes

15 Hours	*Tutorials*

Suggested Texts/References:

1. Rudolf Lidl and Harald Niederreiter, Finite Fields and their Applications, *Cambridge University Press, 1994.*

2. S. Ling and C. Xing: *Coding Theory - A First Course*, *Cambridge University Press, 2004.*

3. E. R. Berlekamp: *Algebraic Coding Theory*, *Aegean Park Press, 1984.*

4. S. Roman, Fields and Galois Theory, *Springer GTM.*

Course Details			
Course Title: Lie Algebra			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/Category of the course (if applicable)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students,		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		
Prerequisite	• Linear Algebra (MTH 502)		

Course Objectives

- To develop the understanding of concepts through examples, counter examples and problems.
- To orient the students with tools and techniques of Lie Algebra.
- To develop a skill to solve problems.

Learning Outcomes

After completion of the course the learners should be able to:

- understand classical Lie Algebras, ,
- understand Jordan-Chevalley decomposition
- understand classification of rank 2 root systems

Course Contents

UNIT I **(25 % Weightage)**

Definition and examples of Lie Algebra, examples of classical Lie Algebras, derivation of Lie

Algebras, abelian Lie Algebra, Lie subalgebras, ideals and homomorphisms, normalizers and centralizers of a Lie subalgebras, representation of Lie algebras (definition and some examples), automorphisms of a Lie algebra, solvable algebra, solvable radical, nilpotent algebra, Engel's Theorem.

UNIT II **(25 % Weightage)**

Semi-simple Lie algebra, Lie's Theorem, Jordan-Chevalley decomposition (existence and uniqueness) Cartan's trace criterion for solvability, Killing form and criterion for semi-simplicity, Simple ideals, inner derivations, abstract Jordan-Chevalley decomposition, definition and examples of Lie algebra modules, Schur's Lemma, Casimir elements of representation, Weyl's Theorem preservation of Jordan decomposition.

UNIT III **(25 % Weightage)**

Representation of sl(2,C), weights, highest weight, maximal vectors, classification of irreducible modules, toral and maximal toral subalgebra, root space decomposition and properties of roots.

UNIT IV **(25 % Weightage)**

Abstract root system (definition, examples and basic properties), Weyl group, root strings bases and their existence, Weyl chambers, classification of rank 2 root systems.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Definition and examples of Lie Algebra, examples of classical Lie Algebras,
3-4	derivation of Lie Algebras,
5-6	Lie subalgebras, ideals and homomorphisms,
7-8	normalizers and centralizers of a Lie subalgebras,
9-10	representation of Lie algebras (definition and some examples),
11-12	automorphisms of a Lie algebra, solvable algebra, solvable radical,
13-14	nilpotent algebra, Engel's Theorem.
15-16	Semi-simple Lie algebra, Lie's Theorem,
17-18	Jordan-Chevalley decomposition (existence and uniqueness)
19-20	Cartan's trace criterion for solvability,
21-22	Killing form and criterion for semi-simplicity,
23-24	Simple ideals, inner derivations, abstract Jordan-Chevalley decomposition,
25-26	definition and examples of Lie algebra modules,
27-28	Schur's Lemma, Casimir elements of representation
29-30	Weyl's Theorem preservation of Jordan decomposition.
31-32	Representation of sl(2,C), weights, highest weight,
33-34	maximal vectors, classification of irreducible modules,
35-36	toral and maximal toral subalgebra, root space decomposition and properties of roots.
37-38	Abstract root system (definition, examples and basic properties),
39-40	Weyl group,
41-42	root strings bases and their existence,
43-45	Weyl chambers, classification of rank 2 root systems.

Texts/References

1. J. E. Humphreys, Lie algebra and Representation Theory, Graduate Text in Mathematics 9, Springer, New York 1978.

2. K. Erdmann and M.J. Wildon Introduction to Lie Algebras, Springer Undergraduate series, Springer-Verlag, London 2006.

3. N. Jacobson, Lie algebras, Dover, New York, 1962.

Course Details			
Course Title: Mathematical Cryptography			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Presentation.		
Assessment and Evaluation	30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 70% - End Term External Examination (University Examination)		

Course Objectives

- To understand basics of number theory
- To study computational aspects of Number Theory
- To study Cryptographic applications of Number Theory.
-

Learning Outcomes

At the end of the course, the student will be able:

- to understand some computational application of number theory
- to understand algorithm for primality testing and integer factorization
- to understand public key cryptography and elliptic curves

Prerequisite: Nil

Course Contents

UNIT I **(25% Weightage)**

Primitive Roots, Quadratic reciprocity, Arithmetic functions. Asymptotaic notations Machine models and complexity theory, computing with large integers, basic integer arithmetic, computing in Zn, faster integer arithmetic.

UNIT II **(25 % Weightage)**

Primality Testing and factorization algorithms, Pseudo-primes, Fermat's pseudo-primes, Pollard's rho method for factorization, Continued fractions

UNIT III **(25 % Weightage)**

Public Key Cryptography, Diffie-Hellmann key exchange, RSA crypto-system, Discrete logarithm-based crypto-systems, Signature Schemes and Hash functions, Digital signature standard, RSA Signature schemes, Knapsack problem.

UNIT IV **(25% Weightage)**

Elliptic curves - basic facts, Elliptic curves over R, C, Q, finite fields, Group Law, Elliptic curve cryptosystems, Primality testing and factorizations.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Brief review divisibility and congruence
3-4	Brief review Fermat's little theorem, Wilson theorem and applications
5 -8	Number Theoretic functions, Mobious inversion formula, Greatest Integer Function, Eulers Phi function and its properties
9 -11	Primitive roots, primitive roots for primes, Composite numbers having primitive roots
12-14	Eulers criterion for quadratic congruence, Legendre symbol, Quadratic reciprocity
15-19	Asymptotaic notations Machine models and complexity theory, computing with large integers, basic integer arithmetic, computing in Zn, faster integer arithmetic.

20- 29	Primality Testing and factorization algorithms, Pseudo-primes, Fermat's pseudo-primes, Pollard's rho method for factorization, Continued fractions
30-34	Public Key Cryptography, Diffie-Hellmann key exchange, RSA crypto-system, Discrete logarithm-based crypto-systems,
35-38	Signature Schemes and Hash functions, Digital signature standard, RSA Signature schemes, Knapsack problem.
39-45	Elliptic curves - basic facts, Elliptic curves over R, C, Q, finite fields, Group Law, Elliptic curve cryptosystems, Primality testing and factorizations.
15 Hours	*Tutorials*

Suggested Texts/ References

1. N. Koblitz, *A Course in Number Theory and Cryptography*, Springer 2006.

2. Victor Shoup, *A Computational Introduction to Number Theory and Algebra*, Cambridge University Press, 2008.

3. D. M. Bressoud: *Factorization and Primality Testing*, Springer-Verlag, New York, 1989.

4. I. Niven, H.S. Zuckerman, H.L. Montgomery, *An Introduction to theory of Numbers*, Wiley, 2006.

4. Jonathan Katz, Yehuda Lindell, *Introduction to Modern Cryptography*, Chapman & Hall/CRC Press 2007.

5. Jill Pipher, Jeffrey Hoffstein, Joseph H. Silverman, An Introduction to Mathematical Cryptography, Springer, 2008

6. Douglas R. Stinson, *Cryptography: Theory & Practice*, Second Edition, CRC Press, 2002.

Course Details			
Course Title: Mechanics			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		

Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.
Assessment and Evaluation	30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 70% - End Term External Examination (University Examination)
Prerequisite	Calculus, vector Calculus

Course Objectives

- To acquaint the students with the principles of Mechanics
- To orient the students with major link between mechanics theory and its applications.
- To develop a skill to formulate (if possible) problems and its solution

Learning Outcomes

After completion of the course the learners should be able to:

- The basic results associated to different types partial differential equations.
- The student has knowledge of central concepts from parabolic, elliptic and Hyperbolic Partial differential equations.
- Be able to produce examples illustrating the mathematical concepts presented in the course.
- Understand the statements and proofs of important method and be able to explain the key steps.

Course Contents

Unit I **(25% Weightage)**

D' Alembert's Principle, System of Particles -Energy and Momentum methods, Use of Centroid. Motion of a Rigid Body - Euler's Theorem, Angular momentum and kinetic energy.

Unit II **(25% Weightage)**

Euler's equation of motion of rigid body with one point fixed, Eulerian angles, motion of a symmetrical top, Generalized coordinates, Velocities and momenta, Holonomic and non-holonomic systems,.

Unit III **(25% Weightage)**

Lagrange's equations of motion, Conservative forces, Lagrange's equations for impulsive forces, Theory of small Oscillations of conservative holonomic dynamical system, Hamilton's equations of motion.

Unit IV **(25% Weightage)**

Finite Variational Principle and Principle of Least Action, Contact transformations, Generating functions, Poisson's Brackets, Hamilton Jacobi equation.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-6	System of Particles -Energy and Momentum methods, Use of Centroid. Motion of a Rigid Body - Euler's Theorem
7-10	Angular momentum and kinetic energy.
11-15	Euler's equation of motion of rigid body with one point fixed Eulerian angles, motion of a symmetrical top
16-18	Generalized coordinates, Velocities and momenta,
19-21	Solutions of Dirichlet, Neuman and mixed type problems.
22-25	Holonomic and non-holonomic systems, D' Alembert's Principle.
26-28	Lagrange's equations of motion, Conservative forces,
29-31	Lagrange's equations for impulsive forces,
32-35	Theory of small Oscillations of conservative holonomic dynamical system
36-38	Hamilton's equations of motion
39-41	Finite Variational Principle and Principle of Least Action
42-45	Contact transformations, Generating functions Poisson's Brackets Hamilton Jacobi equation

Texts/ References

- H. Goldstein, Classical Mechanics, Narosa Publishing House, 1980.
- F. Charlton, Text book of Dynamics, 2nd edition, CBS Publishers, 1985.
- R.G. Takwale& P.S. Puranik, Introduction to Classical Mechanics, Tata McGraw Hill Publishing Co., New Delhi.

E.T. Whittaker, A Treatise on Analytical Dynamics of Particles and Rigid Bodies, Cambridge University Press, 1993.

Course Title: Number Theory			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Presentation.		
Assessment and Evaluation	30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 70% - End Term External Examination (University Examination)		

Course Objectives

- To study the basics of Number Theory
- To give the introduction to elliptic curve cryptography
- To give the introduction to combinatorial and additive number theory

Learning Outcomes

Upon completion of this course, the student will be able to understand basics of several branches of Number Theory like Algebraic, combinatorial, Analytic and elliptic curves.

Prerequisite: Nil

Course Contents

UNIT I **(25% Weightage)**

Multiplicative functions, Functions τ, σ, and μ and their multiplicativity, Mobius inversion formula and its converse, Group structure under convolution product and relations between various standard functions, primitive roots, Quadratic Residues, Legendre symbols, Gauss' lemma, Quadratic Reciprocity Law and applications, Jacobi symbol.

UNIT II **(25 % Weightage)**

Diophantine equations: $ax + by = c$, $x^2 + y^2 = z^2$, $x^4 + y^4 = z^2$, Sums of squares, Waring's problem, Binary quadratic forms over integers. Farey sequences, Rational approximations, Hurwitz'Theorem.

UNIT III **(25 % Weightage)**

Simple continued fractions, Infinite continued fractions and irrational numbers, Periodicity, Pell's equation. Distribution of primes, Function $\pi(x)$, Tschebyschef 's theorem, Bertrand's postulate. Partition function, Ferrer's Graph, Formal power series, Euler's identity, Euler's formula for $\phi(n)$, Jacobi's formula.

UNIT IV **(25% Weightage)**

The congruent number problem, Elliptic curves, The addition law on a elliptic curves, the group of rational points, the group of points modulo p, integer points on elliptic curve. Algebraic numbers and algebraic integers, The fundamental theorem of arithmetic in k(1), k(i), Quadratic fields.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Multiplicative functions, Functions τ, σ, and μ and their multiplicativity,
3-4	Mobius inversion formula and its converse
5 -6	Group structure under convolution product and relations between various standard functions,
7-9	Primitive roots
10-13	Quadratic Residues, Legendre symbols, Gauss' lemma, Quadratic Reciprocity Law and applications, Jacobi symbol.
14-15	Diophantine equations: $ax + by = c$, $x^2 + y^2 = z^2$, $x^4 + y^4 = z^2$
16-19	Sums of squares, Waring's problem
19-25	Binary quadratic forms over integers. Farey sequences,
26-29	Rational approximations, Hurwitz'Theorem.
30-33	Simple continued fractions, Infinite continued fractions and irrational numbers, Periodicity, Pell's equation.

Course Title: Numerical Solutions of Partial differential Equations			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		
Prerequisite	• Linear Algebra, Primary numerical Analysis, Matrix		

34-39	Distribution of primes, Function π(x), Tschebyschef 's theorem, Bertrand's postulate. Partition function, Ferrer's Graph, Formal power series, Euler's identity, Euler's formula for ϕ(n), Jacobi's formula.
40-45	The congruent number problem, Elliptic curves, The addition law on a elliptic curves, the group of rational points, the group of points modulo p, integer points on elliptic curve. Algebraic numbers and algebraic integers, The fundamental theorem of arithmetic in k(1), k(i), Quadratic fields.
15 Hours	*Tutorials*

Suggested Texts/References

1. I. Niven and T. Zuckermann, *An Introduction to the Theory of Numbers*, Wiley Eastern.

2. G. H. Hardy and E.M. Wright, *Theory of Numbers*, Oxford University Press & E.L.B.S.

3. D. E. Burton, *Elementary Number Theory*, Tata McGraw-Hill.

5. T. M. Apostal, *Analytic Number Theory*.

•

Course Objectives

- To acquaint the students with the principles and methods of Numerical Analysis
- To orient the students with major link between mathematics theory and its applications.
- To develop a skill to formulate (if possible) problems and solution by numerical method.

Learning Outcomes

After completion of the course the learners should be able to:

- The basic results associated to different types partial differential equations.
- The student has knowledge of central concepts from parabolic, elliptic and Hyperbolic Partial differential equations.
- Be able to produce examples illustrating the mathematical concepts presented in the course.
- Understand the statements and proofs of important method and be able to explain the key steps .

Course Contents

UNIT I **(25% Weightage)**

Numerical solutions of parabolic PDE in one space: two and three levels explicit and implicit difference schemes, Convergence and stability analysis.

Numerical solution of parabolic PDE of second order in two space dimension: implicit methods, alternating direction implicit (ADI) methods, Nonlinear initial BVP.

UNIT II **(25% Weightage)**

Difference schemes for parabolic PDE in spherical and cylindrical coordinate systems in one dimension, Numerical solution of hyperbolic PDE in one and two space dimension: explicit and implicit schemes, ADI methods, Difference schemes for first order equations.

UNIT III **(25% Weightage)**

Numerical solutions of elliptic equations, approximations of Laplace and biharmonic operators Solutions of Dirichlet, Neuman and mixed type problems.

UNIT IV **(25% Weightage)**

Finite element method: Linear, triangular elements and rectangular elements.

<u>Content Interaction Plan:</u>

<u>Lecture cum Discussion</u>	

(Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Numerical solutions of parabolic PDE in one space: two and three levels explicit and implicit difference schemes, Convergence and stability analysis.
5-10	Numerical solution of parabolic PDE of second order in two space dimension: implicit methods, alternating direction implicit (ADI) methods, Nonlinear initial BVP.
10-18	Tutorial
19-25	Difference schemes for parabolic PDE in spherical and cylindrical coordinate systems in one dimension,
26-35	Numerical solution of hyperbolic PDE in one and two space dimension: explicit and implicit schemes, ADI methods, Difference schemes for first order equations.
36-44	Tutorial
45-50	Numerical solutions of elliptic equations, approximations of Laplace and biharmonic operators
50-52	Solutions of Dirichlet, Neuman and mixed type problems.
53-55	Tutorial
56-59	Finite element method: Linear, triangular elements and rectangular elements.
60	Tutorial

Texts/ References

- M. K. Jain, S. R. K. Iyenger and R. K. Jain, Computational Methods for Partial Differential Equations, Wiley Eastern, 1994.
- M. K. Jain, Numerical Solution of Differential Equations, 2nd edition, Wiley Eastern.
- D. V. Griffiths and I. M. Smith, Numerical Methods of Engineers, Oxford University
- Press, 1993.
- C. F. General and P. O. Wheatley Applied Numerical Analysis, Addison- Wesley, 1998.

Course Objectives

Course Details			
Course Title: Operations Research			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		
Prerequisite	• Linear Algebra, Statistics, Matrix		

- To acquaint the students with the principles and methods of Operations Research
- To orient the students with major link between mathematics and its applications.
- To develop a skill to formulate (if possible) problems.

Learning Outcomes

After completion of the course the learners should be able to:

- the basic results associated to different types of Topics and its applications.
- The student has knowledge of central concepts from Simplex Method, Duality, Transportation and Assignment problem, Game theory, Queuing and Non linear Analysis .
- Be able to produce examples illustrating the mathematical concepts presented in the course.
- Understand the statements and proofs of important theorems and be able to explain the key steps in proofs.

Course Contents

UNIT I **(25% Weightage)**

Linear Programming: Convex sets, hyperplanes and half spaces, vertices of a convex set,

polyhedron and polytopes, separating and supporting hyperplanes, basic definitions and theorems for a general linear programming problems using convex sets theory, A simple LPP model and its graphical solution, standard form of a general LPP, basic feasible solutions, Simplex method and algorithm, M Technique, Two-phase Technique, Duality.

UNIT II **(25% Weightage)**

Mathematical formulation of transportation and assignment problems, balanced and unbalanced transportation problems, Initial basic feasible solutions of a T.P.using North-west corner rule, the Least Cost method and Vegel's approximation method (VAM), the optimum solution of a T.P. using u-v Method., Hungarian method for solving an assignment problem, Salesman routing problems, Problems of maximization.

UNIT III **(25% Weightage)**

Game Theory: Basic concepts, pure and mixed strategies, Two Person Zero sum matrix game, saddle point and maximin minimax principle, reduction of size of pay off matrix by dominance rules, mixed strategies for games without saddle point, 2 x 2 games, 2 x n & n x 2 games, graphical method, subgames method, Matrix method for n x n games, ($n \geq 3$), solution of a game by linear programming

method.

UNIT IV **(25% Weightage)**

Non-Linear Programming: Kuhu-Tucker conditions, Quadratic programming and its solution by Wolfe's Method and Beale's Method, Poisson distributions, Kendall's Notation for representing Queueing Models, Single-Channel Queueing Theory, Single-channel Poisson Arrivals with Exponential Service Times, Infinite- Population (M/M/1) (FCFS/ ∞) and (M/M/1) (SIRO/ ∞).

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-6	Linear Programming: Convex sets, hyperplanes and half spaces, vertices of a convex set, polyhedron and polytopes, separating and supporting hyperplanes, basic definitions and theorems for a general linear programming problems using convex sets theory,
5-8	A simple LPP model and its graphical solution, standard form of a general LPP, basic feasible solutions,
9-11	Simplex method and algorithm, M Technique, Two-phase Technique, M Technique
11-13	Tutorial

14-16	Duality.
17-20	Mathematical formulation of transportation and assignment problems, balanced and unbalanced transportation problems, Initial basic feasible solutions of a T.P.using North-west corner rule, the Least Cost method and Vegel's approximation method (VAM), the optimum solution of a T.P. using u-v Method.
21-23	Hungarian method for solving an assignment problem, Salesman routing problems, Problems of maximization.
24-28	Tutorial
29-32	Game Theory: Basic concepts, pure and mixed strategies, Two Person Zero sum matrix game, saddle point and maximin minimax principle, reduction of size of pay off matrix by dominance rules,
33-38	Mixed strategies for games without saddle point, 2 x 2 games, 2 x n & n x 2 games, graphical method, subgames method, Matrix method for n x n games, ($n \geq 3$), solution of a game by linear programming
39-42	Tutorial
43-48	Non-Linear Programming: Kuhu-Tucker conditions,
49-52	Quadratic programming and its solution by Wolfe's Method and Beale's Method,
53-54	Tutorial
55-56	Poisson distributions, Kendall's Notation for representing Queueing Models, Single-Channel Queueing Theory, Single-channel Poisson
57-59	Arrivals with Exponential Service Times, Infinite- Population (M/M/1) (FCFS/ ∞) and (M/M/1) (SIRO/ ∞).
60	**Tutorial**

Texts/ References

- Robert J. Vanderbei, Linear Programming Foundations and extensions, 3rd Edition, Springer,
- 2008.
- H. A. Taha, Operations Research An Introduction, 7th Edition, Pearson Education.
- P. K. Gupta & D. S. Hira, Operations Research, S. Chand and Co., New Delhi.
- V. K. Kapoor and S. Kapoor, Operation Research, Sultan Chand and Sons, New Delhi.
- Kanti Swarup , P. K. Gupta, Man Moha, Operation research, Sultan Chand & Sons (New Delhi)

Course Details			
Course Title: Operator Theory			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lecture, Tutorials, Group discussion; self-study, seminar, presentations by students, individual and group drills, group and individual field based assignments followed by workshops and seminar presentation.		
Assessment and Evaluation	30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 70% - End Term External Examination (University Examination)		
Prerequisite	Complex Analysis, Functional Analysis and Measure and integration.		

Course Objectives

- To acquaint the students with the operator theory
- To orient the students with major link between opertor theory and its applications.

Learning Outcomes

After completion of the course the learners should be able to:

- The basic results associated to bounded linear opertor.
- The student has knowledge of central concepts from different theorems.
- Be able to produce examples illustrating the mathematical concepts presented in the course.
- Understand the statements and proofs of important theorem and be able to explain the key steps.

Course Contents

UNIT I **(25% Weightage)**

Linear operators in normed linear spaces: Definition and examples, Linear operators on finite dimensional linear spaces and bounded linear operators on normed linear spaces, Spectrum and resolvent sets of bounded linear operator, compact operator and its properties.

UNIT II **(25% Weightage)**

Spectral properties of operators on finite dimensional spaces and the spectral theory of operators on Banach spaces including the use of complex analysis in the theory.

UNIT III **(25% Weightage)**

Banach algebras: Definition and examples, Commutative Banach algebra and C*-algebra.

UNIT IV **(25% Weightage)**

General theory of Banach algebras including Gelfand-Naimark theorem for commutative C*-algebras. Spectral theory of bounded linear operator.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Linear operators in normed linear spaces: Definition and examples, Linear operators on finite dimensional linear spaces,
5-7	Bounded linear operators on normed linear spaces
8-10	Spectrum and resolvent sets of bounded linear operator.
11-15	Spectral properties of operators on finite dimensional spaces
16-20	The spectral theory of operators on Banach spaces

21-23	Its use in complex analysis in the theory.
24-28	Banach algebras: Definition and examples
28-33	Commutative Banach algebra
34-40	C*-algebra
41-43	General theory of Banach algebras
44-45	Gelfand-Naimark theorem for commutative C*-algebras

Texts/ References

- C. D. Aliprintis, An invitation to Operator Theory, American Mathematical Society, 2008.
- G. Bachman and L. Narici, Functional Analysis, Academic Press,1966.
- J. B. Conway, A First Course in Functional Analysis, Springer- Verlag, 2000.
- N. Dunford and J.T. Schwartz, Linear Operators, Part-I,Interscience, 1958.
- E. Kreyszig, Introductory Functional Analysis with Applications, John Wiley and sons, 1978.
- G. F. Simmons, Introduction to Topology and Modern Analysis,McGrawh-Hill, 1963.

V. S. Sunder, Functional Analysis, Hindustan Publishing House, 2001.

Course Details			
Course Title: Representation theory of finite groups			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T)

			Hours
Course Type	Discipline Based Core Elective Course		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	Value Based (Human Values /Ethics/ Constitutional Values etc.)/Indian Knowledge System/ Lok Vidya/ Skill Based/ Any other (Specify) (*More than one can apply*) (*Keep this category even if one or more than one unit or some part(s) of a unit are related to these categories*)		
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Self-study, Seminar, presentations by students.		
Assessment and Evaluation	30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 70% - End Term External Examination (University Examination)		
Prerequisite	Linear Algebra and Algebra-I		

Course Objectives

- ❖ To develop the understanding of concepts through examples, counter examples and problems.
- ❖ To orient the students with tools and techniques of Representation Theory.
- ❖ To develop a skill to solve problems.

Learning Outcomes

After completion of the course, the learners will be able to: Understand module, irreducible and reducible module. Understand character map.

Understand representation of small order groups. Understand induced representation.

Course Contents

UNIT I: **(25% Weightage)**

Irreducible and completely reducible modules, Schur's Lemma, Jacobson density Theorem, Wedderburn Structure theorem for semisimple modules and rings, Group algebra, Maschke's Theorem.

UNIT II: (25% Weightage)

Representations, Subrepresentations, Characters, Orthogonality relations, Decomposition of regular representation, Number of irreducible representations, Canonical decomposition and explicit decompositions, Subgroups, Product groups, Abelian groups.

UNIT III: (25% Weightage)

Example including cyclic groups, dihedral groups, Quaternion group of order 8, Symmetric

and alternating groups on 3 and 4 symbols. Representations of direct product of two groups, Integrality properties of characters, Burnside's p^aq^b theorem.

UNIT IV: (25% Weightage)

Induced representations, The character of induced representation, Frobenius Reciprocity Theorem, Mackey's irreducibility criterion, Examples of induced representations, Statement of Brauer and Artin's Theorems.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-2	Irreducible and completely reducible modules
3-4	Schur's Lemma
5-6	Jacobson density Theorem,
7-8	Wedderburn Structure theorem for semisimple modules and rings
9-10	group algebra,
11-12	Maschke's Theorem.
13-14	Representations, Subrepresentations, Characters
15-16	Orthogonality relations
17-18	Decomposition of regular representation
19-20	Number of irreducible representations
21-22	canonical decomposition and explicit decompositions
23-24	Subgroups, Product groups, Abelian groups
25-26	Example including cyclic groups
27-28	dihedral groups, quaternion group of order 8

29-30	symmetric and alternating groups on 3 and 4 symbols
31-32	Representations of direct product of two groups
33-34	Integrality properties of characters
35-36	Burnside's p^aq^b theorem
37-38	Induced representations
39-40	The character of induced representation
41-42	Frobenius Reciprocity Theorem
43-45	Mackey's irreducibility criterion, Examples of induced representations, Statement of Brauer and Artin's Theorems
15 Hours	*Tutorials*

Texts/References

1. M. Burrow, Representation Theory of Finite Groups, Academic Press, 1965.
2. L. Dornhoff, Group Representation Theory-I, Marcel Dekker, New York, 1971.
3. N. Jacobson, Basic Algebra II, Hindustan Publishing Corproation, 1983.
4. S. Lang, Algebra, 3rd Ed. Springer, 2004.
5. J. P. Serre, Linear Representation of Groups, Springer-Verlag, 1977.

Semigroup Theory

Course Code	………….	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective Course		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	Value Based (Human Values /Ethics/ Constitutional Values etc.)/Indian Knowledge System/ Lok Vidya/ Skill Based/ Any other (Specify) (*More than one can apply*) (*Keep this category even if one or more than one unit or some part(s) of a unit are related to these categories*)		
Methods of Content Interaction	*Lecture, Tutorials, Group discussion, seminar, presentations by students*		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		
Prerequisite	NIL		

Course Objectives:

- ❖ This course aims to expose the students to more liberal and powerful tools of Algebra that are applicable in the present-day life.

Course Learning Outcomes:

After completion of the course the students will be able to:

- ❖ Learn and feel that learning further advance tools of this discipline will equip them to apply these tools to the huge world of Automata, Languages and Machines.

- ❖ Able to develop an analytical skill to analyze these theories.
- ❖ Critically analyze recent empirical trends in the major branch of Political Science.

Course Contents:

UNIT I: Introductory Ideas **(30 % Weightage)**

Basic definitions and examples, Subsemigroups and Subgroups, Idempotents, Semigroup with zero, Rectangular bands, Generators, Monogenic semigroups, Periodic semigroups, Partially ordered sets, Semilattices and lattices, Homomorphisms and Isomorphisms, Cayley's Theorem for Semigroups.

UNIT II: Equivalences and Congruences **(20 % Weightage)**

Binary relations, Partial and full transformations, Equivalence relations, Kernels, Congruences and Quotients, First Isomorphism Theorem, Ideals and Rees congruences, Lattices of equivalences and congruences, Free semigroups and the Universal property.

UNIT III: Green's Relations **(20% Weightage)**

Green's relations, Structure of D-classes, Green's lemma and its corollaries, Green's theorem, Regular elements and regular D-classes.

UNIT IV: Regular and Inverse Semigroups **(30% Weightage)**

Simple and 0-Simple semigroups, Completely 0-Simple semigroups, Completely simple semigroups, Completely regular semigroups, Left and right groups, Inverse semigroups and equivalent characterizations.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-8	**UNIT I: Introductory Ideas**
1-2	Basic definitions and examples.
3-4	Subsemigroups and Subgroups, Idempotents, Semigroup with zero, Rectangular bands.
5-6	Generators, Monogenic semigroups, Periodic semigroups.
7-8	Partially ordered sets, Semilattices and lattices.
9-12	Homomorphisms and Isomorphisms, Cayley's Theorem for Semigroups.
13-21	**UNIT II: Equivalences and Congruences**
13	Binary relations, Partial and full transformations
14-15	Equivalence relations, Kernels, Congruences and Quotients, First Isomorphism Theorem
16-17	Ideals and Rees congruences
18-19	Lattices of equivalences and congruences

20-21	Free semigroups and the Universal property
22-33	**UNIT III: Green’s Relations**
22-25	Green's relations
26-28	Structure of D-classes
29-31	Green’s lemma and its corollaries, Green’s theorem
32-33	Regular elements and regular D-classes
34-45	**UNIT IV: Regular and Inverse Semigroups**
34-36	Simple and 0-Simple semigroups
37-39	Completely 0-Simple semigroups, Completely simple semigroups
40-41	Completely regular semigroups,
42	Left and right groups
43-45	Inverse semigroups and equivalent characterizations
15 Hours	*Tutorials*

Text/Reference Books:

- J. M. Howie, *Fundamentals of Semigroup Theory,* Oxford University Press, New York, 1995.
- A. H. Clifford and G. B. Preston, *The Algebraic Theory of Semigroups*, American Mathemati Society, Providence, Vol.I, 1961
- A. H. Clifford and G. B. Preston, *The Algebraic Theory of Semigroups*, American Mathemati Society, Providence, Vol.II, 1967.
- P. M. Higgins, *Technique of Semigroup Theory*, Oxford University Press, 1992.
- G. Lallembent, Semigroups and Combinatorial Applications, John Willey and Sons, 1979.

Course Details			
Course Title: Spectral Graph Theory			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		

Nature of the Course	Theory
Special Nature/ Category of the Course (*if applicable*)	Value Based (Human Values /Ethics/ Constitutional Values etc.)/Indian Knowledge System/ Lok Vidya/ Skill Based/ Any other (Specify) (*More than one can apply*) (*Keep this category even if one or more than one unit or some part(s) of a unit are related to these categories*)
Methods of Content Interaction	Lecture, Tutorials, Group discussion, Self-study, Seminar, Presentations by students.
Assessment and Evaluation	30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) 70% - End Term External Examination (University Examination)

Course Objectives

The learning objectives of this course are to:

Introduce students to the mathematical foundations of spectral graph theory. Understand and apply the fundamental concepts in graph theory.

To apply matrix theory based tools in solving practical problems.

View the adjacency (or related) matrix of a graph with a linear algebra lens.

Identify connections between spectral properties of such a matrix and structural properties of the graph such as connectivity, bipartiteness, and cut.

Learning Outcomes

After successful completion of this course, students will be able to: Understand concepts and compute spectra of graphs.

Use spectra of graphs to deduce other graph properties. Use spectral method to analyse real-world graphs.

Read research papers and present results in the class.

Apply principles and concepts of spectra of graphs in practical situations.

Course Contents

UNIT I: (25 % Weightage)

A brief review of matrices and graphs, Adjacency matrix, The spectrum of a graph, Integral graphs, Isomorphic graphs, Cospectral graphs, The spectrum of various graphs, Operations on graphs and the resulting spectra, Graph characterization using spectra.

UNIT II: (25 % Weightage)

Symmetric matrices, positive semidefinite matrices, Spectral gap, Spectral radius, The Perron-Frobenius theorem, Interlacing, Equitable partitions, Strongly regular graphs and its eigenvalues.

UNIT III: (25 % Weightage)

Laplacian matrix, The Laplacian spectrum, Laplacian integral graphs, The Laplacian spectrum of various graphs, Graph operations and the resulting Laplacian spectra, Matrix-Tree theorem, Largest Laplacian eigenvalue, Algebraic connectivity, Laplacian eigenvalues and graph structure.

UNIT IV: (25 % Weightage)

Graph partitioning, Graph expansion, Sparsest cut, Cheeger constant, Cheeger inequality, Normalized Laplacian matrix, Signless Laplacian matrix, Distance matrix, The spectrum of Cayley graphs.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	A brief review of matrices and graphs.
5-8	Adjacency matrix, The spectrum of a graph, Integral graphs, Isomorphic graphs, Cospectral graphs, The spectrum of various graphs.
9-11	Operations on graphs and the resulting spectra, Graph characterization using spectra.
12-18	Symmetric matrices, positive semidefinite matrices, Spectral gap, Spectral radius, The Perron-Frobenius theorem, Interlacing.
19-22	Equitable partitions, Strongly regular graphs and its eigenvalues.
23-28	Laplacian matrix, The Laplacian spectrum, Laplacian integral graphs, The Laplacian spectrum of various graphs, Graph operations and the resulting Laplacian spectra.
29-33	Matrix-Tree theorem, Largest Laplacian eigenvalue, Algebraic connectivity, Laplacian eigenvalues and graph structure.
34-40	Graph partitioning, Graph expansion, Sparsest cut, Cheeger constant, Cheeger inequality.
41-45	Normalized Laplacian matrix, Signless Laplacian matrix, Distance matrix, The spectrum of Cayley graphs.

Suggested References:

- Fan R. K. Chung, Spectral graph theory, American Mathematical Society, Volume 92, 1997.
- D. M. Cvetkovic, M. Doob, and H. Sachs, Spectra of graphs, Theory and Applications.

A. E. Brouwer and W. H. Haemers, Spectra of graphs, Electrical Book.

- C. Godsil and G. Royle, Algebraic graph theory, Springer, 2009.

N. Biggs, Algebraic graph theory, Cambridge Mathematical Library, 2nd edition.

Dan Spielman, Lecture notes of spectralgraph theory in http://cs-www.cs.yale.edu/homes/spielman/.

Wavelets Analysis

Course Code	………….	Credits	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective/Open Elective		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	N/A		
Methods of Content Interaction	*Lectures, Tutorial*		
Assessment and Evaluation	• 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) • 70% - End Term External Examination (University Examination)		

Course Objectives

- Learn Discrete time and continuous Fourier series and Fourier transform
- Learn Haar basis Wavelet system
- Learn multiresolution analysis
- Learn construction of orthogonal wavelet bases
- Learn scaling function from scaling sequences
- Learn smooth compactly supported wavelets
- Learn Debauchees' wavelets
- Learn image analysis with smooth wavelets

Learning Outcomes

After completion of the course the learners will be able to:

- understand Discrete time and continuous Fourier series and Fourier transform
- Demonstrate ability to understand Haar basis Wavelet system
- Demonstrate ability to understand multiresolution analysis

- Demonstrate ability to construct orthogonal wavelet bases
- Demonstrate ability to know scaling function from scaling sequences
- Demonstrate ability to understand smooth compactly supported wavelets
- Demonstrate ability to know Debauchees' wavelets
- Demonstrate ability to understand image analysis with smooth wavelets

Course Contents

UNIT I: (20% Weightage)

Discrete time Fourier series, discrete time Fourier transforms, Continuous time Fourier series and Continuous time Fourier transform. Poisson's summation formula.

UNIT II: (15% Weightage)

Introduction to Wavelets, The Haar basis wavelet system

UNIT III: (30 % Weightage)

Orthogonal wavelet bases: Orthogonal systems and translates, multiresolution analysis, Examples of multiresolution analysis, construction of orthogonal wavelet bases and examples, General spline wavelets.

UNIT IV: (35%Weightage)

Discrete wavelet transforms: scaling function from scaling sequences, smooth compactly supported wavelets, Debauchies wavelets, image analysis with smooth wavelets.

Content Interaction Plan:

Lecture cum Discussion	Unit/Topic/Sub-Topic

(Each session of 1 Hour)	
1-2	Fourier transform and Discrete time Fourier series
3-4	Discrete time Fourier transforms
5-6	Continuous time Fourier series
7-9	Continuous time Fourier transform
10-11	Introduction to Wavelets
12-16	Haar basis wavelet system
17-19	Orthogonal systems and translates
20-22	Multiresolution analysis
23-24	Examples of multiresolution analysis
25-27	construction of orthogonal wavelet bases and examples
28-30	General spline wavelets
31-34	Discrete wavelet transforms: scaling function from scaling sequences
35-38	smooth compactly supported wavelets
39-42	debauchees' wavelets
43-45	image analysis with smooth wavelets

Suggested References:

1. David Walnut , An introduction to wavelet analysis.
2. Stephan Mallat, A wavelet tour of signal processing, Academic press, 1998.
3. R.S. Pathak, The wavelet Transforms, 2009.
4. C. K. Chui, A first course in Wavelets, Academic Press NY 1996.
5. I. Daubechies, Ten lectures in Wavelets, Society for Industrial and Applied Maths, 1992

Mandatory Elective Non-Credit Courses

COURSE TITLE: Introduction to LaTeX

Course Code	………….	**Credits**	2
L + T + P	1 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	30
Course Type	Mandatory Elective Non-Credit Courses		
Nature of the Course	Theory/Practical		
Special Nature/ Category of the Course (*if applicable*)	Skill		
Methods of Content Interaction	*Lecture, Tutorials, Group discussion, seminar, presentations by students*		
Assessment and Evaluation	● 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) ● 70% - End Term External Examination (University Examination)		

Course Objectives:

❖ To know the LaTeX typesetting language for mathematics, with a particular emphasis on document preparation for instructional materials, articles, books, presentations, and master's thesis.

Course Learning Outcomes:

After completion of the course the students will be able to:

❖ Typeset common math symbols and operators

❖ Use arrays to align displayed equations (e.g., systems of equations, multiline displays, piecewise functions)

❖ Create simple TikZ pictures

❖ Create slides (frame) for a beamer presentation

Course Contents:

UNIT I: Introduction to LaTeX (30 % Weightage)

Installation of LaTeX . Understanding Latex compilation, Basic Syntax, Writing equations, Matrix, Tables, Page Layout – Titles, Abstract, Chapters, Sections, References, Equation references, Citation.

List making environments, Table of contents, Generating new commands. Figure handling , numbering. List of figures, List of tables, Generating index.

UNIT II: Drawing Pictures and Beamer Presentation (20% Weightage)

Simple pictures with PSTricks, Simple pictures with TikZ , Beamer presentation.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-12	**UNIT I: Introduction to LaTeX**
1-3	Installation of LaTeX . Understanding Latex compilation, Basic Syntax
4-5	Writing equations, Matrix, Tables
6-8	Page Layout – Titles, Abstract, Chapters, Sections, References, Equation references, Citation. List making environments, Table of contents
9-12	Generating new commands. Figure handling , numbering. List of figures, List of tables, Generating index
13-30	**UNIT II: Drawing Pictures and Beamer Presentation**
13-15	Simple pictures with PSTricks
16-18	Simple pictures with TikZ
19-30	Beamer presentation

References:

- Leslie Lamport, LaTeX: A Document Preparation System.
- George Gatzer, More Math into LaTeX.
- Tobias Octiker, The Not So Short Introduction to LaTeX.

COURSE TITLE: Introduction to Matlab

Course Code	………….	**Credits**	2
L + T + P	1 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours

Course Type	Mandatory Elective Non-Credit Courses
Nature of the Course	Theory/Practical
Special Nature/ Category of the Course (*if applicable*)	Skill
Methods of Content Interaction	*Lecture, Tutorials, Group discussion, seminar, presentations by students*
Assessment and Evaluation	● 30% - Continuous Internal Assessment (Formative in nature but also contributing to the final grades) ● 70% - End Term External Examination (University Examination)

Course Objectives:

❖ To learn features of MATLAB as a programming tool.

❖ To understand MATLAB as a computation.

Course Learning Outcomes:

After completion of the course the students will be able to:

❖ Understand the working of Matlab

❖ Plotting through Matlab.

❖ Make small programmes in Matlab.

Course Contents:

UNIT I: MATLAB and MATLAB Functions (25 % Weightage)

The MATLAB environment, MATLAB basics: variables, Numbers, Operators, Expressions, Input and output, Vectors, Arrays-Matrices, Built-in functions, User defined functions.

UNIT II: Programming and Computing with MATLAB (25 % Weightage)

Conditional statements, Loops, MATLAB programs – Programming and Debugging, Applications of MATLAB programming, Algebraic equations, Basic symbolic calculus and differential equations, Numerical techniques.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-8	**UNIT II: MATLAB and MATLAB Functions**
1-3	The MATLAB environment, MATLAB basics: variables, Numbers, Operators, Expressions
4-5	Input and output, Vectors, Arrays-Matrices
6-8	Built-in functions, User defined functions
9-22	**UNIT II: Programming and Computing with MATLAB**
13-22	Conditional statements, Loops
13-15	MATLAB programs – Programming and Debugging
16-18	Applications of MATLAB programming, Algebraic equations, Basic symbolic calculus and differential equations, Numerical techniques
19-22	*Tutorials*

References:

- Brain R. Hunt, Ronald L. Lipsman, Jonathan M. Rosenberg. A Guide to MATLAB- for Beginners and Experienced Users, Cambridge University Press, 2006.
- Stephen J. Chapman, Essentials of MATLAB Programming, 2nd Ed., Cengage Learning, 2009.
- Holly Moore, MATLAB For Engineers, 3rd Ed., Pearson Education, Inc., 2012.
- David M. Smith, Engineering Computation with MATLAB, 2nd Ed., Pearson Education, Inc., 2010.

Remark:

The above list of elective courses is open ended and any new course at any point of time can be proposed by any faculty members as an elective/open elective which can be approved by the external members of the BoS of the Dept of Mathematics through email.