Detailed Syllabus

Semester I

Differential Calculus

Course Code	Differential Calculus	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	I	**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)		
Prerequisite	• Calculus of intermediate level		

Course Objectives

- The main emphasis of this course is to equip the student with necessary analytic and technical skills.
- main target of this course is to explore the different tools for higher order derivatives, to plot the various curves and to solve the problems associated with differentiation
- 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:

- Use Leibnitz's rule to evaluate derivatives of higher order.
- able to study the geometry of various types of functions
- Trace the curve

Course Contents

Unit I **(weightage 25%)**

Successive differentiation, Leibnitz's theorem, Partial differentiation, Euler's theorem on homogeneous functions. Tangents and normals.

Unit II **(weightage 25%)**

Curvature, Asymptotes, Singular points, Concavity and point of inflexion, Envelopes,

Unit III **(weightage 25%)**

Taylor's theorem with Lagrange's and Cauchy's forms of remainder, Taylor's series, Maclaurin's series of $\sin x$, $cos\ x, e^x$, $\log(1+x)$, $(1+x)^m$, Maxima and Minima, Indeterminate forms.

Unit IV **(weightage 25%)**

Tracing of curves, Parametric representation of curves and tracing of parametric curves, Polar coordinates and tracing of curves in polar coordinates

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-10	Successive differentiation, Leibnitz's theorem, Partial differentiation, Euler's theorem on homogeneous functions. Tangents and normal.
11-20	Curvature, Asymptotes, Singular points, Concavity and point of inflexion, Envelopes,
21-35	Taylor's theorem with Lagrange's and Cauchy's forms of remainder, Taylor's series, Maclaurin's series of $\sin x$, $cos\ x, e^x$, $\log l + x)$, $(1+x)^m$, Maxima and Minima, Indeterminate forms.
36-45	Tracing of curves. Parametric representation of curves and tracing of parametric curves, Polar coordinates and tracing of curves in polar coordinates

Texts/ References Books Recommended

1. H. Anton, I. Birens and S. Davis, *Calculus*, John Wiley and Sons, Inc.. 2002.

2. G.B. Thomas and R.L. Finney, *Calculus*, Pearson Education,.2007.

3. Shanti Narayan, P. K. Mittal, *Differential Calculus*, S. Chand. 2014

Semester II

Analytical Geometry and Tensor

Course Code	**Analytical Geometry and Tensor**	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	II	**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)		
Prerequisite	• Calculus of intermediate level		

Course Objectives

- The main emphasis of this course is to introduce basics of 3D analytical geometry
- To introduce definitions of various tensors
- To orient the students with the applications and examples of geometry and tensor

Learning Outcomes

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

- The students will be familiar with the concept and examples based on 3D geometry
- They will be able to know concepts of tensor

Course Contents

Unit I **(weightage 25%)**

. Angle between two planes; Perpendicular distance of a point from a plane; Bisectors of two planes; Equations of straight lines in space; Coplanarity of two straight lines; Perpendicular distance of a point from a straight line; Shortest distance between two straight lines in space.

Unit II **(weightage 25%)**

Plane section and its equation; Sphere through a given circle; Tangent plane; Pole and polar plane; Intersection of two spheres; Radical plane; Equation of a cone with a conic as a guiding curve; Enveloping cone; Mutually perpendicular generators; Tangent planes; Reciprocal cone; Right circular cone; Equation of a cylinder with a conic as a guiding curve; Right circular cylinder.

Unit III **(weightage 25%)**

Introduction to tensor, Contravariant tensor, Covariant tensor, Tensors of second order, Symmetric and skew symmetric tensor, Quotient law of tensor, Riemannian metric, Associated tensors.

Unit IV **(weightage 25%)**

Christoffel symbols of first kind, Christoffel symbols of second kind, laws of transformation, Covariant Differentiation of covariant tensors, Covariant Differentiation of contravariant tensors, Divergence of a contravariant vector, Divergence of a covariant vector,

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-15	. Angle between two planes; Perpendicular distance of a point from a plane; Bisectors of two planes; Equations of straight lines in space; Coplanarity of two straight lines; Perpendicular distance of a point from a straight line; Shortest distance between two straight lines in space.
15--30	Plane section and its equation; Sphere through a given circle; Tangent plane; Pole and polar plane; Intersection of two spheres; Radical plane; Equation of a cone with a conic as a guiding curve; Enveloping cone; Mutually perpendicular generators; Tangent planes; Reciprocal cone; Right circular cone; Equation of a cylinder with a conic as a guiding curve; Right circular cylinder. .

31-37	Introduction to tensor, Contravariant tensor, Covariant tensor, Tensors of second order, Symmetric and skew symmetric tensor, Quotient law of tensor, Riemannian metric, Associated tensors. .
38-45	Christoffel symbols of first kind, Christoffel symbols of second kind, laws of transformation, Covariant Differentiation of covariant tensors, Covariant Differentiation of contravariant tensors, Divergence of a contravariant vector, Divergence of a covariant vector,
15	Tutorials

Texts/ References Books Recommended

1. Shanti Narayan: Analytical Solid Geometry (S. Chand & Co., New Delhi), 2003 Edition.
2. Loney, S. L.: The Elements of Coordinate Geometry, (S. Chand & Co., New Delhi).
3. Das, B.: Analytical Geometry and vector Analysis (Orient Book Co., Calcutta), 2006 Edition
4. C. E. Weatherburn: Riemannian geometry and Tensor Calculus, Cambridge University Press, 1938.
5. UC De, A A Shaikh and J Sengupta: Tensor Calculus, Narosa Publication, New Delhi, 2008.

Semester III

Real Analysis - I

Course Code	Analysis I	Credits	4
L + T + P	3 + 1 + 0	Course Duration	One Semester
Semester	III	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)		
Prerequisite	• Calculus of intermediate level		

Course Objectives

- The main emphasis of this course is to introduce the real number sequences. The relation between the convergent and Cauchy sequences has been explained
- Convergence of different type of real series
- To orient the students with the concept of Limit, Continuity, Uniform Continuity

Learning Outcomes

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

- The students will be familiar with the concept of sequences, series.
- They will be able to test the convergence and divergence of series using the ratio test, Leibnitz test.
- Learn the concept and applications of Limit, Continuity, Uniform Continuity

Course Contents

Unit I **(weightage 25%)**

Axiomatic introduction to R, Natural Numbers, Integers, Rational numbers and irrational numbers, Archimedean property, density of rational numbers and irrational numbers in R, Intervals, characterization of intervals, neighbourhoods, open sets, closed sets, limit points of a set,

Unit II **(weightage 25%)**

Real sequences, Convergence, Monotone sequences and their convergence; Sub sequences and the Bolzano-Weierstrass theorem; Limit superior and limit inferior of a bounded sequence; Cauchy sequences, Cauchy convergence criterion for sequences.

Unit III **(weightage 25%)**

Definition and a necessary condition for convergence of an infinite series, Geometric series, Cauchy convergence criterion for series; Positive term series, The integral test, Convergence of p-series, Comparison test, Limit comparison test, D'Alembert's Ratio test, Cauchy's Root test; Alternating series, Leibniz test; Absolute and conditional convergence.,

Unit IV **(weightage 25%)**

Limits and continuity, properties of continuous functions, uniform continuity,

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**<u>Unit/Topic/Sub-Topic</u>**
1-15	Axiomatic introduction to R, Natural Numbers, Integers, Rational numbers and irrational numbers, Archimedean property, density of rational numbers and irrational numbers in R, Intervals, characterization of intervals, neighbourhoods, open sets, closed sets, limit points of a set,
16-30	Real sequences, Convergence, Sum and product of convergent sequences, Order preservation and squeeze theorem; Monotone sequences and their convergence; Proof of convergence of some simple sequences, Subsequences and the Bolzano-Weierstrass theorem; Limit superior and limit inferior of a bounded sequence; Cauchy sequences, Cauchy convergence criterion for sequences
30-45	Definition and a necessary condition for convergence of an infinite series, Geometric series, Cauchy convergence criterion for series; Positive term series, The integral test, Convergence of p-series, Comparison test, Limit comparison test, D'Alembert's Ratio test, Cauchy's Root test; Alternating series, Leibniz test; Absolute and conditional convergence.
45-60	Limits and continuity, properties of continuous functions, uniform continuity .

15	Tutorials

Texts/ References Books Recommended

1. Robert G. Bartle,, & Donald R. Sherbert, *Introduction to Real Analysis (4th ed.)*, Wiley India Edition. 2015
2. Charles G. Denlinger, *Elements of analysis*. Jones & Bartlett India Pvt. Ltd. 2015.
3. Kenneth A. Ross, *Elementary Analysis: The theory of calculus (2nd ed.)*, Undergraduate Texts in Mathematics, Springer. Indian Reprint, 2013
4. Shanti Narayan, M. D. Raisinghana, *Elements of Real Analysis*, S Chand and Co Ltd. 2015

Ordinary Differential Equations

Course Details			
Course Title: Ordinary Differential Equations			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
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	Differential Calculus		

Course Objectives

● The exciting world of differential equations.

● Their applications and mathematical modeling.

Learning Outcomes

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

● Learn the basics of differential equations and compartmental models.

● Formulate differential equations for various mathematical models.

● Solve first order non-linear differential equations, linear differential equations of higher order and system of linear differential equations using various techniques.

● Apply these techniques to solve and analyze various mathematical models.

Course Contents

Unit I: (25% Weightage)

Introduction of differential equations, Order and degree of ordinary differential equations, Concept of implicit, general and singular solutions for the first order first degree ordinary differential equations; Bernoulli's equation, Exact equations, Integrating factors, Initial value problems, Applications of first order differential equations to Newton's law of cooling, exponential growth and decay problems.

Unit II: (20% Weightage)

First-order higher degree ordinary differential equations: solvable for p, solvable for y, solvable for x, Clairaut's form, application of first- higher degree ordinary differential equations.

Unit III: (35% Weightage)

Higher order Differential equation, homogeneous and non-homogeneous equation, Reduction of order, solution of Linear equation with constant coefficients, method of undetermined coefficients, Wronskian, method of variation of parameters. Cauchy- Euler's equation, Application of second order differential equation.

Unit IV: (20% Weightage)

Formulation of ODE models such as Epidemic model and Predator prey model etc.

<u>Content Interaction Plan:</u>

Lecture cum Discussion (Each session of 1 Hour)	**<u>Unit/Topic/Sub-Topic</u>**
1-11	Introduction of differential equations, Order and degree of ordinary differential equations, Concept of implicit, general and singular solutions for the first order first degree ordinary differential equations; Bernoulli's equation, Exact equations, Integrating factors, Initial value problems, Applications of first order differential equations to Newton's law of cooling, exponential growth and decay problems.
12-20	First-order higher degree ordinary differential equations: solvable for p, solvable for y, solvable for x, Clairaut's form, application of first- higher degree ordinary differential equations.
21-37	Higher order Differential equation, homogeneous and non-homogeneous equation, Reduction of order, solution of Linear equation with constant coefficients, method of undetermined coefficients, Wronskian, method of variation of parameters. Cauchy- Euler's equation, Application of second order differential equation.
38-45	Formulation of ODE models such as Epidemic model and Predator prey model etc
15 Hours	*Tutorials*

<u>Suggested References:</u>

1. Barnes, Belinda & Fulford, Glenn R. (2015). Mathematical Modeling with Case Studies, Using Maple and MATLAB (3rd ed.). CRC Press. Taylor & Francis Group.
2. Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). Differential Equations and Boundary Value Problems: Computing and Modeling (5th ed.). Pearson Education.
3. Ross, Shepley L. (2014). Differential Equations (3rd ed.). Wiley India Pvt. Ltd.

4. Simmons, George F. (2017). Differential Equations with Applications and Historical Notes (3rd ed.). CRC Press. Taylor & Francis Group.

Semester IV

Basic Linear Algebra

Course Details			
Course Title: Linear Algebra			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	45 (L) + 15 (T) Hours
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	• Knowledge of Matrices and linear Equations		

Course Objectives

- To develop the understanding of concepts of linearity 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:

- perform elementary row operations and find corresponding elementary matrices.
- solve system of linear equations.
- find dimension and basis of vector spaces.
- find the matrix of linear transformation.
- determine the rank and nullity of a linear transformation or matrix.
- check whether given matrix or transformation is diagonal or not.
- determine the orthogonal basis in an inner product space.

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Course Contents

Unit I

Algebra of Matrices, Elementary row operations, Elementary Matrices, Echelon form, Reduced Echelon form, LU decomposition, Systems of linear equations, Homogeneous systems of linear equations, augmented matrix, Inverse of a matrix, Determinants, Properties of Determinant, Cramer's Rule.

Unit II

Vector Spaces and examples, Subspace, Special examples of R^{n}, Sum and intersection of subspaces, Solution space of linear equations, Linear independence of vectors, Basis and Dimension, Coordinates with respect to different basis.

Unit III

Linear Transformation between two vector spaces, representing Linear Transformation by a Matrix, Rank-Nullity Theorem, Linear Operators and square Matrices, Algebra of Linear operators, Base change and similarity of matrices. Eigen value and Eigen vector, Characteristic polynomials, Diagonalization of Matrices, Cayley Hamilton Theorem, Minimal Polynomial of a Matrix

Unit IV

Inner Product Spaces, Cauchy- Schwartz Inequality, Orthogonal basis, Grahm-Schmidt orthonormalization.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Algebra of Matrices, Elementary row operations, Elementary Matrices
3-8	Echelon form, Reduced Echelon form, LU decomposition.
9-13	Systems of linear equations, Homogeneous systems of linear equations, augmented matrix, Inverse of a matrix.
14-18	Determinants, Properties of Determinant, Cramer's Rule.
19-20	Vector Spaces and examples, Subspace, Special examples of R^n.
21-24	Sum and intersection of subspaces, Solution space of linear equations, Linear independence of vectors.
25-28	Basis and Dimension, Coordinates with respect to different basis.
29-32	Linear Transformation between two vector spaces, representing Linear Transformation by a Matrix, Rank-Nullity Theorem.
33-35	Linear Operators and square Matrices, Algebra of Linear operators, Base change and similarity of matrices.
36-39	Eigen value and Eigen vector, Characteristic polynomials, Diagonalization of Matrices.
40-41	Cayley Hamilton Theorem, Minimal Polynomial of a Matrix.
42-45	Inner Product Spaces, Cauchy- Schwartz Inequality, Orthogonal basis, Grahm-Schmidt orthonormalization.
Texts/References 1. K. Hoffman and R. A. Kunze, Linear Algebra, 3rd edition, Prentice Hall, 2002. 2. S. Lang, Introduction to Linear Algebra, 3nd Edition, Addition-Wesley, 1999. 3. Sheldon Axler, Linear Algebra Done right, Springer UTM, 1997.	

4. G. Strang, Linear Algebra and its Applications, Thomas Brooks/Cole, 2006.
5. Promode Kumar Saikia, Linear Algebra, Pearson Education, 2009.

Real Analysis II

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.		
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	• Real Analysis I		

Course Objectives

• To understand the concept of Riemann Integral and Improper integral. Able to differentiate between them.

• To understand the difference between the behaviour of sequence of functions in case of pointwise convergence and uniform convergence.

Learning Outcomes

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

- Check the differentiability of a single variable real valued function,
- determine the convergence of improper integrals,
- decide the convergence of series and sequence of functions.
- Calculate Riemann integral (if exists)

Course **Contents**

Unit I **(weightage 20%)**

Differentiability, Properties of Differentiable functions, Mean Value Theorem and its consequences.

Unit II **(25% Weightage)**

Riemann integral, Integrability of continuous and monotonic functions, Fundamental theorem of integral calculus, Mean value theorems of integral calculus, Differentiation under the sign of Integration.

Unit III **(20% Weightage)**

Improper integrals and their convergence, Comparison test, Abel's and Dirichlet's test, Beta and Gamma functions.

Unit IV **(35% Weightage)**

Point wise and uniform convergence of sequence of functions, uniform convergence and continuity, uniform convergence and differentiation, Uniform convergence and integration, **S**eries of functions, Weierstrass M-test, Abel's Test, Dirichlet's Test, Weierstrass approximation theorem (statement only).

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	Differentiability, Properties of Differentiable functions, Mean Value Theorem and its consequences,
5-11	Riemann integral: definition, properties and equivalent conditions; Integrability of continuous and monotonic functions,
12-16	Fundamental theorem of integral calculus, Mean value theorems of integral calculus, Differentiation under the sign of Integration.
17-22	Improper integrals and their convergence, Comparison test,
22-27	Abel's and Dirichlet's test, Beta and Gamma functions and their relations.
27-33	Point wise and uniform convergence of sequence of functions,
34-40	Uniform convergence and continuity, uniform convergence and differentiation, Uniform convergence and integration,
40-45	**S**eries of functions, Weierstrass M-test, Abel's Test, Dirichlet's Test, Weierstrass approximation theorem (statement only).
15 Hours	*Tutorials*

Suggested References:

- S. C. Malik, Savita Arora, *Mathematical Analysis*, Revised Edition, New Age International, New Delhi, 2018.
- Tom M. Apostol, *Mathematical Analysis*, Narosa Publications, NewDelhi, 2002.
- Walter Rudin, *Principles of Mathematical Analysis*, McGraw-Hill International Editions, 1976.
- S. K. Mappa, *Introduction to Real Analysis*, Levant Books, 2019.

Probability and Probability Distributions

Course Details			
Probability and Probability Distributions			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	45 (L) + 15 (T) Hours
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	• Sets, functions and basics of probability		

Course Objectives

- Explain simple unconditional probabilities and conditional probabilities, Bayes' theorem
- Define the probability mass function of a discrete random variable and the distribution
- Define the probability density function of a continuous random variable
- Define the expectation of a function of a random variable and properties in one dimension and two dimensions.
- Define probability distributions
- Define correlation and simple linear regression

Learning Outcomes

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

- calculate a simple unconditional probability and conditional probability, Application of Bayes' theorem
- calculate a probability from a probability mass function of a discrete random variable and a binomial distribution, Poisson distribution
- calculate a probability from a probability density function of a continuous random variable and a and normal distribution
- calculate correlation and a linear regression for a given data set

Course Contents

Unit I: (20% Weightage)

Concept of Probability, Classical, Statistical and Subjective definitions of probability. Some basic theorems. Sample Space, Probability function, Axiomatic definition of probability, Probability under statistical independent and dependence, Conditional Probability, Baye's Theorem. Applications of Baye's Theorem.

Unit II: (20% Weightage)

One dimensional and two dimensional Random Variables: discrete and continuous random variables, Discrete and continuous probability distribution functions, Probability mass function, Probability density function.

Unit II: (30% Weightage)

Expectation (operations on one dimension and two dimensions): Moments, Independent Random Variables, Marginal, Joint and Conditional distributions, Conditional Expectation, Covariance, Moment generating functions, Probability generating functions, Symmetrical and asymmetric distributions, Skewness and kurtosis. Karl Pearson's coefficients of Skewness and kurtosis.

Unit IV: (30% Weightage)

Standard discrete and continuous probability distributions and their properties: Bernoulli, Binomial, Poisson, Normal, exponential. Correlation and Simple regression, curve fitting, fitting of straight line.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-8	Sample Space, Axioms of Probability, Conditional Probability, Independence, Bayes Theorem
9-14	Random Variables: Discrete and Continuous random variables, Probability Distribution Functions
14-16	Probability mass function, Probability density function
17-22	Expectation (operations on one dimension)
23-28	Expectation (operations on two dimensions)
29-37	probability distributions
38-45	Correlation and Simple linear regression
15 Hours	*Tutorials*

Suggested References:

1. V. Rohatgi, A. Saleh, *Introduction to Probability Theory and Statistics, Second Edition*, Wiley-Interscience, 2000.
2. W. Feller, *Introduction to Probability Theory and Its Applications*, Vol.1, Third Edition, Wiley, 1968.
3. G. Casella, R. L. Berger, *Statistical Inference, Second Edition*, Duxbury Press, 2001.

4. J. S. Rosenthal, *A Fist look at Rigorous Probability Theory, Second Edition*, World Scientific, 2006.
5. Robert V. Hogg, Joseph W. McKean and T. Craig, *Introduction to Mathematical Statistics*, Pearson Education, Asia, 2007.
6. Miller & Freund's**,** *Probability and Statistics for Engineers* **,**Eighth Edition, Pearson, 2015

Elementary Number theory

Course Details			
Course Title: Elementary Number Theory			
Course Code	MSMTH1002C04	**Credits**	2
L + T + P	1 + 1 + 0	**Course Duration**	One Semester
Semester	IV	**Contact Hours**	15 (L) + 15 (T) Hours
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 teach fundamentals of Number Theory.
- To develop a skill to solve problems.

Learning Outcomes

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

- Understand why Euclidean algorithm gives gcd.
- Understand Fundamental theorem of Arithmetic and infinitude of prime numbers.
- To find integral solution of system of linear equations.
- State and proof Wilson theorem, Fermat Little theorem, Euler's theorem.

Unit I

Divisibility, The Division Algorithm, The greatest common divisors, The Euclidean algorithm, Linear Diophantine equations, Primes and their distribution,

Unit II

The fundamental theorem of arithmetic, Congruence, The Chinese remainder theorem, Fermat Little theorem, Wilson theorem, Euler's Phi- function,

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Divisibility
3-4	GCD and LCM
5-6	Euclidean Algorithm
7-8	Prime numbers
9-10	Fundamental theorem of Arithmetic and its consequence
11-15	Concurrences and its applications
17-18	Wilson theorem
19-20	Fermat Little theorem
21-22	Applications of Fermat Little Theorem and Wilson Theorem
23-24	Chinese remainder Theorem
25-26	Applications of Chinese remainder Theorem
27-28	Euler's phi function and Euler's theorem
29-30	Applications of Euler's theorem

- Texts/References
- Elementary Number theory by David M Burton
- Elementary Number Theory By Gareth A. Jones, J. Mary Jones (Springer)

Semester V

Introduction to Group Theory

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	V	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type			
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lectures, Tutorials, Group discussions, Self-study, Seminars, and 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 the foundation of the mathematical object groups;
- To study the different types of groups and their properties;
- To train the students in problem-solving in group theory.

Learning Outcomes

On completion of the course, a student will be able to:

- recognize the mathematical objects called groups;
- link the fundamental concepts of groups and symmetries of geometrical objects;
- explain the significance of the notions of cosets, normal subgroups, and factor groups;
- analyze the consequences of Lagrange's theorem;
- describe structure-preserving maps between groups and their consequences.

Course Contents

Unit I: (20% Weightage)

Symmetries of a square, Dihedral groups, Definition and examples of groups including permutation groups and quaternion groups (illustration through matrices), Elementary properties of groups.

Unit II: (25% Weightage)

Subgroups and examples of subgroups, Centralizer, Normalizer, Center of a group, Product of two subgroups, Generation of groups, Cyclic groups and their properties, Classification of subgroups of cyclic groups.

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

Cycle notation for permutations, Properties of permutations, Even and odd permutations, Alternating groups; Definitions and properties of cosets, Coset decomposition, Lagrange's theorem and its consequences including Fermat's Little theorem and Euler's theorem, External direct product of a finite number of groups, Normal subgroups, Factor groups, Cauchy's theorem for finite abelian groups.

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

Group homomorphisms and their properties, Group Isomorphisms and automorphisms, Cayley's theorem, Properties of group Isomorphisms, First, Second, and Third Isomorphism theorems for groups.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-3	Symmetries of a square, Dihedral groups.
4-8	Definition and examples of groups including permutation groups and quaternion groups (illustration through matrices).
9-12	Elementary properties of groups.
13-15	Subgroups and examples of subgroups.
16-17	Centralizer, Normalizer, Center of a group.
18-19	Product of two subgroups, Generation of groups.
20-23	Cyclic groups and their properties, Classification of subgroups of cyclic groups.
24-27	Cycle notation for permutations, Properties of permutations, Even and odd permutations, Alternating groups.
28-32	Definitions and properties of cosets, Coset decomposition, Lagrange's theorem and its consequences including Fermat's Little theorem and Euler's theorem.
33-36	External direct product of a finite number of groups, Normal subgroups, Factor groups, Cauchy's theorem for finite abelian groups.
37-39	Group homomorphisms and their properties.
40-42	Group Isomorphisms and automorphisms, Cayley's theorem, Properties of group Isomorphisms.
43-45	First, Second, and Third Isomorphism theorems for groups.
15 Hours	*Tutorials*

Suggested References:

1. J. A. Gallian, *Contemporary Abstract Algebra, 8th Ed.*, Cengage Learning India Private Limited, 2013.
2. I. N. Herstein, *Topics in Algebra, 4th Ed.*, Wiley Eastern Limited, 2003.
3. D. S. Dummit and R. M. Foote, *Abstract Algebra*, John Wiley & Sons, 2003.
4. M. Artin, *Algebra*, Prentice Hall of India, 1994.
5. J. J. Rotman, *An Introduction to The Theory of Groups*, 4th ed., Springer-Verlag, 1995.
6. J. B. Fraleigh, *A First Course in Abstract Algebra*, 7th Ed., Pearson, 2002.

Multivariable calculus

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	V	**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.		
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 the concept of functions of several variables and multiple integral.

• To understand the difference between total derivative, partial derivative and directional derivative of a function of several variables.

Learning Outcomes

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

- determine the Jacobian,
- check the continuity of a function
- determine extreme values of function
- determine multiple integral
- do change of variables in multiple integral.

Course Contents

Unit I **(25% Weightage)**

Introduction to function of several variables, neighbourhood of a point in R^n, Limit of function of several variables, continuity of function of several variables, partial derivatives, Gradient, Directional derivatives.

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

Differentiability of function of n variables, Jacobian, Extreme values of functions of several variables, Necessary and Sufficient conditions for extreme values. Lagrange's multiplier.

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

Integration and its application to length, area, volume and surface area of revolution, centroids and quadrature rules.

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

Multiple integrals, Existence and Properties of integrals, iterated integrals, change of variables, Parametric equations, Parametric surfaces and their areas, surface integrals, volume integrals.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-7	Introduction to function of several variables, neighbourhood of a point in R^n, Limit of function of several variables
8-11	continuity of function of several variables, partial derivatives, Gradient, Directional derivatives
12-16	Differentiability of function of n variables, Jacobian,
17-22	Extreme values of functions of several variables, Necessary and Sufficient conditions for extreme values. Lagrange's Multiplier
22-27	Integration and its application to length, area, volume
27-33	surface area of revolution, centroids and quadrature rules.

34-40	Multiple integrals, Existence and Properties of integrals, iterated integrals, change of variables,
40-45	Parametric equations, Parametric surfaces and their areas, surface integrals, volume integrals.
15 Hours	*Tutorials*

Texts/References

1. J. Stewart, *Calculus with Early Transcendental Functions*, Cengage Learning.
2. M. J. Strauss, G. L. Bradley and K. J. Smith, *Calculus* (3rd Edition), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2007.
3. T.M. Apostol, *Mathematical Analysis*, 5th edition, Addison-Wesley; Publishing Company, 2001.
4. T. M. Apostol, *Calculus-II*, 2nd edition, John Wiley & Sons, 2003.
5. W. Rudin, *Principles of Mathematical Analysis*, 5th edition, McGraw Hill Kogakusha Ltd., 2004.
6. R. G. Bartle, *The elements of Real Analysis*, 2nd edition, John Wiley & Sons, Inc., New York, 1976.
7. Sudhir R. Ghorpade, Balmohan V. Limaye, *A Course in Multivariable Calculus and Analysis*, Springer International Edition, 2010.
8. Sean Dineen, *Multivariate Calculus and Geometry*, SUMS, 2001.

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Statics

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	V	**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.
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 theory and application forces and their equilibrium
- To orient the students with tools and techniques of finding friction due to forces on rough objects
- To enable the students with knowledge of evaluating center of mass and gravity

Learning Outcomes

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

- To find center of mass and gravity
- Evaluate shape of catenary
- To find condition of equilibrium of forces

Course Contents

Unit I **(25% Weightage)**

Forces. Couples. Co-planar forces**.** Concurrent coplanar forces-composition and resolution of forces-resultant of forces. Equilibrium equations – methods of projections – methods of moments. basic principles of statics-Parallelogram law.

Unit II **(25% Weightage)**

A static equilibrium, stable and unstable equilibrium. General conditions of equilibrium.

Unit III **(25% Weightage)**

Centre of Mass, Radius of gyration, Centre of gravity of a plane area, arc and sector of a curve. Centre of mass and gravity of different bodies.

Unit IV **(25% Weightage)**

Friction. laws of friction, limiting friction. Equilibrium of a particle on a rough curve. Virtual work. Catenary. Forces in three dimensions. Reduction of a system of forces in space. Invariance of the system.

Content Interaction Plan:

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

1-5	Forces. Couples. Co-planar forces with examples
6-8	Concurrent coplanar forces-composition and resolution of forces-resultant of forces
9-14	Equilibrium equations – methods of projections – methods of moments. basic principles of statics-Parallelogram law.
15-18	Astatic equilibrium, stable and unstable equilibrium. General conditions of equilibrium
19-25	Centre of Mass, Radius of gyration, Centre of gravity of a plane area, arc and sector of a curve
26-28	Center of mass and gravity of different bodies.
29-34	Friction. laws of friction, limiting friction
34-37	Equilibrium of a particle on a rough curve with examples
38-40	Virtual work. Catenary
41-45	Forces in three dimensions. Reduction of a system of forces in space. Invariance of the system.
15 Hours	*Tutorials*

- <u>Suggested References:</u>
- S. L.Loney,, *Elements of Statics and Dynamics I and II*, 2004..
- I.H. Shames and G. Krishna Mohan Rao, *Engineering Mechanics: Statics and Dynamics, 2006*. Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), Delhi, 2009.
- A.S. Ramsay, *Statics*, CBS Publishers & Distributors.

Metric spaces

Course Details			
Course Title: Metric Spaces			
Course Code		**Credits**	2
L + T + P	1 + 1 + 0	**Course Duration**	One Semester
Semester	V	**Contact Hours**	30 (L) + 15 (T) Hours
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 introduce concept of distance on a set.
- To develop a skill to solve problems.

Learning Outcomes

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

- Understand distance function.
- Understand sequence in metric space
- Check the continuity and uniform continuity of a function.
- Understand Contraction mapping.
- Understand completeness.

Unit I

Metric spaces: Definition and examples of metric spaces, isometries, diameter, isolated points, accumulation (limit point) and boundary points, closure and interior, open and closed sets, Cantor's intersection theorem, open and closed balls,

Unit II

Sequence in metric space, convergence, Cauchy sequence and boundedness, Continuity and uniform continuity, completeness, contraction mapping theorem.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Definition and examples of metric spaces,
6-10	open and closed balls, isometries, diameter, isolated points, accumulation (limit point) and boundary points,
11-15	closure and interior, open and closed sets, Cantor's intersection theorem
16-20	Sequence in metric space, convergence, Cauchy sequence and boundedness,
21-25	Continuity and uniform continuity, completeness,
26-30	contraction mapping theorem.
• Texts/References • S. C. Malik, Savita Arora, *Principles of Real Analysis*, Revised Edition, New Age International, New Delhi, 2000. • S. Kumarsan, *Topology of Metric Spaces* 2nd Edition, Narosa Publications, New Delhi, • N.L. Carothers, Real Analysis, Cambridge University Press, UK, 2000.	

Semester VI

Numerical Methods

Course Code		**Credits**	4
Numerical Methods			
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester		**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)		
Prerequisite	• Differentiation, Integration, Ordinary differential equations of first order and first degree		

\Course Objectives

- To understand the error analysis

- To orient the students with tools and techniques of solving algebraic and transcendental equations
- To understand interpolation theory to estimate missing data by using interpolation
- To learn interpolation
- To learn numerical differentiation and inverse interpolation
- To acquaint the students with application of Numerical analysis and its application engineering and applied sciences

Learning Outcomes

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

To solve algebraic and transcendental equations approximately

- Interpolate missing value of a statistical data
- To find interpolation of equal and unequal data
- To find numerical differentiation of equal and unequal data
- To find inverse interpolation

Course Contents

Unit I **(weightage 25%)**

General Theory of Approximations and Errors, Scientific notation for representing decimal numbers, Floating point arithmetic, Valid significant digits, Absolute and Relative errors and error bounds, Errors of sum, difference, product, quotient, power and root, General formula for Errors. Calculus of operators Δ,δ,μ,E, D etc. Interpolation, Gregory-Newton forward and backward interpolation formulas Central difference: Gauss (forward and backward), Stirling formulae. Lagrangian and Divided difference interpolation formulas.

Lab work.

Unit II **(weightage 25%)**

Numerical Differentiation with equal interval: Derivatives of forward and backward interpolation formulas Central difference: Stirling formulae. Numerical Differentiation with unequal interval: Lagrange's, Newton's divided difference formula. Inverse interpolation.

Numerical Integration: Numerical Integration, Newton-Cotes Formulas, numerical schemes: Trapezoidal, Simpson's 1/3 and 3/8, Weddle, Euler-Maclaurin with error estimates.

Lab work.

Unit III **(weightage 25%)**

Solutions of algebraic and transcendental equations: Methods of Bisection, Fixed point iteration, Regula- falsi, and Newton-Raphson together with their convergence.

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.

Lab work.

Unit IV (weightage 25%)

Numerical solution of Ordinary differential equations of first order, 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.

Lab work.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-4	General Theory of Approximations and Errors.

5-8	Absolute and Relative errors and error bounds, Errors of sum, difference, product, quotient, power and root, General formula for Errors.
9-12	Interpolation, Gregory-Newton forward and backward interpolation formulas Central difference: Gauss (forward and backward), Stirling formulae. Lagrangian and Divided difference interpolation formulas.
13-18	Numerical Differentiation with equal interval: Derivatives of forward and backward interpolation formulas Central difference: Stirling formulae. Numerical Differentiation with unequal interval: Lagrange's, Newton's divided difference formula. Inverse interpolation.
19-24	Numerical Integration: Numerical Integration, Newton-Cotes Formulas, numerical schemes: Trapezoidal, Simpson's 1/3 and 3/8, Weddle, Euler-Maclaurin with error estimates. Lab work.
23-26	Solutions of algebraic and transcendental equations: Methods of Bisection, Fixed point iteration, Regula- falsi, and Newton-Raphson together with their convergence.
27-35	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.
36-45	Numerical solution of Ordinary differential equations of first order, 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.
15 Hours	*Tutorials*

- Suggested References:

1. D. Prasad, *Introduction to Numerical Analysis*. Narosa Publishing House.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, *Numerical Methods for Scientific and Engineering Computation*, New Age.
3. K. Sankar Rao, *Numerical Methods for Scientists and Engineers*, Prentice Hall of India.
4. S. D. Conte & C.de Boor, *Elementary Numerical Analysis*, an Algorithmic Approach. Tata McGraw-Hill.
5. F. B. Hildebrandt, *Introduction to Numerical Analysis*, Dover.
6. H. M. Antia, *Numerical Methods for Scientists and Engineers*, Hindustan Book Agency

Introduction to Rings and Fields

Course Details			
Course Title: Introduction to Rings and Fields			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	VI	**Contact Hours**	45 (L) + 15 (T) Hours
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	• Introduction to group theory		

Course Objectives

- To introduce basic theory of rings and fields.

Learning Outcomes

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

- understand ideal, factor rings, maximal ideal, prime ideal and isomorphisms of rings.
- Understand UFD, PID, Polynomial rings, irreducible polynomials.
- Understand field extensions, degree of an extension, finite fields.

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Course Contents

Unit I

Definition and examples of rings, properties of rings, subrings, integral domains, characteristic of rings, ideals, ideal generated by subsets in a commutative ring with unity, factor rings, prime ideals, maximal ideals,

Unit II

Homomorphisms and isomorphisms of rings. Integral domain, Unique factorization domains, principal ideal domains,

Unit III

Polynomial rings over commutative rings, the division algorithm and consequences, factorization of polynomials, reducibility tests, irreducibility tests, Eisenstein criterion, unique factorization in Z[X], an application of unique factorization to weird dice.

Unit IV

Definition of fields, examples, Field extensions, degree of field extensions; Adjoining roots, Kronecker's Theorem; Finite fields.

<u>Content Interaction Plan:</u>

<u>Lecture cum Discussion</u>	

(Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-5	Definition and examples of rings, properties of rings, subrings, integral domains, characteristic of rings.
6-10	Ideals, ideal generated by subsets in a commutative ring with unity, factor rings.
11-15	Prime ideals, maximal ideals.
16-20	Homomorphisms and isomorphisms of rings.
21-24	Unique factorization domains, principal ideal domains.
25-28	Polynomial rings over commutative rings, the division algorithm and consequences.
29-32	Factorization of polynomials, reducibility tests, irreducibility tests, Eisenstein criterion.
33-35	Unique factorization in Z[X], an application of unique factorization to weird dice.
36-39	Definition of fields, examples, Field extensions, degree of field extensions;
40-42	Adjoining roots, Kronecker's Theorem.
43-45	Finite fields.

Texts/References

1. J. A. Gallian, *Contemporary Abstract Algebra*, 7th Edition, Cengage Learning, 2010.
2. D.S. Dummit and R.M. Foote, *Abstract Algebra*, John Wiley & Sons, 2003.
3. M. Artin, *Algebra*, Prentice Hall of India, 1994.
4. I. N. Herstein, *Topics in Algebra*, 4th Edition, Wiley Eastern Limited, New Delhi, 2003.

Dynamics

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	VI	**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)		
Prerequisite	• Calculus of intermediate level		

Course Objectives

- The main emphasis of this course is to equip the student with necessary analytic part of particle dynamics
- Familiar with concept of force

- Motion of a particle

Learning Outcomes

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

- velocity and acceleration in rectangular Cartesian and polar co-ordinates for a particle moving in a plane.
- Study of motion of a particle in a straight line under
- Motion in two dimensions

Course Contents

Unit I **(weightage 25%)**

Velocity and Acceleration of a particle. Expressions for velocity and acceleration in rectangular Cartesian and polar co-ordinates for a particle moving in a plane. Tangential and normal components of velocity and acceleration of a particle moving along a plane curve.

Unit II **(weightage 25%)**

Concept of Force : Statement and explanation of Newton's laws of motion. Work, power and energy. Principles of conservation of energy and momentum. Motion under impulsive forces. Equations of motion of a particle (i) moving in a straight line, (ii) moving in a plane.

Unit III **(weightage 25%)**

Study of motion of a particle in a straight line under (i) constant forces, (ii) variable forces (S.H.M., Inverse square law, Damped oscillation, Forced and Damped oscillation, Motion in an elastic string). Equation of Energy. Conservative forces.

Unit IV **(weightage 25%)**

Motion in two dimensions : Projectiles in vacuum and in a medium with resistance varying linearly as velocity. Motion under forces varying as distance from a fixed point. Central orbit. Kepler's laws of motion. Motion under inverse square law.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-12	Velocity and Acceleration of a particle. Expressions for velocity and acceleration in rectangular Cartesian and polar co-ordinates for a particle moving in a plane. Tangential and normal components of velocity and acceleration of a particle moving along a plane curve.
13-24	Concept of Force : Statement and explanation of Newton's laws of motion. Work, power and energy. Principles of conservation of energy and momentum. Motion under impulsive forces. Equations of motion of a particle (i) moving in a straight line, (ii) moving in a plane

25-37	Study of motion of a particle in a straight line under (i) constant forces, (ii) variable forces (S.H.M., Inverse square law, Damped oscillation, Forced and Damped oscillation, Motion in an elastic string). Equation of Energy. Conservative forces.
38-50	Motion in two dimensions : Projectiles in vacuum and in a medium with resistance varying linearly as velocity. Motion under forces varying as distance from a fixed point. Central orbit. Kepler's laws of motion. Motion under inverse square law.
Texts/ References Books Recommended 1. S. L. Loney, *An Elementary Treatise on the Dynamics of particle and of Rigid Bodies*, Loney Press. 2. A.S. Ramsey, *Dynamics*, Part-II; ELBS.	

Complex Analysis and Partial Differential Equations

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	VI	**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.		
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 concepts of complex functions and applications
- To acquaint the students with knowledge of theory and applications analytic functions and complex line integral

Learning Outcomes

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

- To solve linear and non linear PDE
- To apply Fourier series in solving PDE
- Solve Heat and wave equations
- To construct analytic functions
- To evaluate complex integration

Course Contents

UNIT I: (25% 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, Total differential equation, Lagrange's or Quasi- linear equations.

Unit II (25% Weightage)

Integral surfaces through a given curve, Surfaces orthogonal to a given system of surfaces, Linear PDE with constant coefficients. Fourier Series, Pfaffian differential equations

Unit III (25% Weightage)

Complex Numbers, Stereographic Projection, Elementary Functions, Limits, Continuity of complex functions, Differentiable functions, Analytic and Harmonic Functions, The Cauchy-Riemann Equations, Singular points.

Unit IV (25% Weightage)

Conformal Mapping and Möbius transformation.

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	Total differential equation,
7-8	Lagrange's or Quasi- linear equations,
9-10	Integral surfaces through a given curve, Surfaces orthogonal to a given system of surfaces
15-17	Pfaffian differential equations, and some exercise

18-20	Linear equations with constant coefficients, Separation of variables, Fourier Series
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	Complex numbers and complex valued functions with some properties and examples
31-33	Stereographic Projection, Elementary Functions, Limits, Continuity of complex functions
34-35	Differentiable functions, Analytic and Harmonic Functions with examples
36	The Cauchy-Riemann Equations
37-39	Complex line Integration with examples
40-42	Cauchy;s theorem using Green's Theorem with some applications
43-45	Cauchy's Integral formula with applications, Residue and Contour integration with examples.
15 Hours	*Tutorials*

- Suggested References:

1. N. Sneddon, *Elements of Partial Differential Equations*, McGraw Hill Publications.
2. T. Amaranath, *Partial Differential Equations*, Narosa Publ.
3. P. Prasad and R. Ravindran, *Partial Differential Equations*, Wiley Eastern Ltd, New Delhi, 1991.
4. C. R. Chester, *Techniques in Partial Differential Equations*, McGraw-Hill, New York, 1971.
5. John H. Mathews, Russel W. Howel, *Complex Analysis for Mathematics and Engineering*, Jones and Bartlett Publishers.
6. W. Gamelin Theodore, *Complex Analysis*, Springer, UTM, 2001.
7. Lars V. Ahlfors , *An Introduction to the Theory of Analytic. Functions of One Complex Variable*. Third Edition,.

Semester VII

Linear Algebra

Course Details			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	VII	**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)
Prerequisite	• Basic Course in Linear Algebra

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:

- 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 25%)**

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

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Unit II **(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 III **(weightage 30%)**

Inner product space: Definition and Examples, Norm of a Vector, orthogonally, Orthonormal set, Gram Schmidt orthogonalization, Best approximation, Orthogonal complement, Bessel's Inequality, adjoint of a linear transformation. Self-adjoint operator, Unitary operator, Orthogonal, Unitary, Hermitian, skew-Hermitian, symmetric and skew-symmetric matrices.

Unit IV **(weightage 20%)**

Normal operator, Orthogonal reduction of symmetric matrices, Unitary reduction of Hermitian matrices. Polar and Singular value decomposition.

Content Interaction Plan:

Lecture cum Discussion	**Unit/Topic/Sub-Topic**

(Each session of 1 Hour)	
1-2	Invariant subspaces, Eigen values, Eigen vectors, Characteristic polynomials of a linear transformation,
3-4	Diagonalization of a matrix with distinct Eigen values,
5-6	Cayley Hamilton Theorem.
7-8	Jordan Canonical forms.
9-10	Bilinear forms on a vector space and examples, Matrix of a Bilinear from,
11-12	Symmetric and Skew-symmetric bilinear forms,
13-14	Definition of a Quadratic form, matrix of a quadratic form,
15-16	Reduction to normal form,
17-18	Orthogonal and congruent reduction.,
19-20	Sylvester's Law of Inertia.
21-22	positive definiteness.
23-24	Inner product space: Definition and Examples,
25-26	Norm of a Vector,
27-28	orthogonally, Orthonormal set,
29-30	Best approximation
31-32	Bessel's Inequality,
33-34	Gram Schmidt orthogonalization, Orthogonal complement
35-36	adjoint of a linear transformation. Self-adjoint operator,
37-38	Unitary operator, Orthogonal, Unitary, Hermitian, skew-Hermitian, symmetric and skew-symmetric matrices.
39-40	Orthogonal reduction of symmetric matrices, Unitary reduction of Hermitian matrices.
41-45	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.

Real Analysis

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

Discrete Mathematics

Course Details			
Course Code		**Credits**	4

L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	VII	**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)**

The Euclidean algorithm, Congruence, Chinese remainder theorem,Wilson theorem, Number theoretic functions, Euler's Phi- function and Euler's Theorem, Mobius function and Mobius inversion formula Primitive roots, Quadratic residues and Quadratic reciprocity law.

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	The Euclidean algorithm, Congruences
13-14	Chinese remainder theorem,Wilson theorem
15-16	Number theoretic functions
16-17	Euler's Phi- function, Mobius function and Mobius inversion formula.
18-20	Primitive roots, Quadratic residues and Quadratic reciprocity law.
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.

Ordinary Differential Equations and Laplace Transform

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

Semester VIII

Topology

Course Details			
Course Code	MSMTH2003C04	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester

Semester	VIII	**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	**Unit/Topic/Sub-Topic**

<u>(Each session of 1 Hour)</u>	
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*

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

- 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 Title: Advance Numerical Analysis

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

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, 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. Solutions of Ordinary and partial differential equations.

Content Interaction Plan:

Lecture cum Discussion (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.
	Tutorial
53----	Finite element method: Linear, triangular elements and rectangular elements. Solutions of Ordinary and partial differential equations.
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 Details			
Course Title: Operation Research and Statistics			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	VIII	**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)		
Prerequisite	• Linear Algebra, Statistics, Matrix		

Course Objectives

- 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.
- Demonstrate ability to understand a Central Limit Theorem and hypothesis testing
- Demonstrate ability to test hypothesis for large and small samples.
- Demonstrate ability to apply Chi - Square test for goodness of fit
- Demonstrate ability to apply Neyman-Pearson lemma and likelihood ratio test
- Demonstrate ability to learn single channel queue models.

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, 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)**

Transportation and Assignment problems, Non-Linear Programming: Kuhu-Tucker conditions, Quadratic programming and its solution by Wolfe's Method and Beale's Method.

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). Hypothesis testing: Confidence interval, Level of Significance, Type I and Type II errors; Concepts of Hypothesis Testing, Single large Sample test.

UNIT IV **(25% Weightage)**

Two large sample test; t- test (paired and unpaired), F-test, Chi-Square test and goodness of fit; Neyman- Pearson lemma. Likelihood Ratio Test. Chi- Square test and goodness of fit; Concepts of Hypothesis Testing: Neyman- Pearson lemma, Likelihood Ratio Test.

Poisson process, Kendall's Notation for representing Queuing Models, Single-Channel Queuing 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.
17-21	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
22-23	. Tutoria
24-28	Non-Linear Programming: Kuhu-Tucker conditions, Quadratic programming and its solution by Wolfe's Method and Beale's Method,
29-30	Tutorial
31-32	Introduction to the sampling distribution, Central Limit theorem, bounds on probability Weak and Strong law of large numbers
33-36	Methods of Finding Estimators: Point Estimation (Method of Maximum Likelihood, Method of Moments);
37-39	Interval Estimation (Estimation of mean, maximum error of estimate); Confidence interval, Type I and Type II errors
40-42	Hypothesis testing: single large sample test
43-45	Two large sample test
46-50	t-test (paired and unpaired), F-test
51-54	Chi-Square test and goodness of fit
55-56	Concepts of Hypothesis Testing: Neyman-Pearson lemma, Likelihood Ratio Test.
57-58	Poisson process, Kendall's Notation for representing Queuing Models, Single-Channel Queuing Theory, Single-channel Poisson Arrivals with Exponential Service Times
59-60	Infinite- Population (M/M/1) (FCFS/ ∞) and (M/M/1) (SIRO/ ∞).

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)
- Hogg, Robert V., McKean, Joseph W., & Craig, Allen T. (2013). Introduction to Mathematical Statistics (7th ed.). Pearson Education, Inc.
- Miller, Irwin & Miller, Marylees. (2014).John E. Freund's Mathematical Statistics with Applications (8th ed.). Pearson. Dorling Kindersley (India).
- Ross, Sheldon M. (2014). Introduction to Probability Models (11th ed.). Elsevier Inc.
- Anderson, Sweeney, Williams, Freemann and Shoesmith, Statistics for Business and Economics, Third Edition, Cengage Learning.
- Levin and Rubin, Statistics for Management, Pearson India.

Semester IX

Complex Analysis

Course Code	…………..	**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	IX	**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 learn complex integration
- . Demonstrate ability to learn holomorphic functions and Homotopy and its uses.
- Understand singularities of a function, know the different types of singularities, and be able to determine the points of singularities of a function.
- 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 understanding of analytic continuations and its applications.

Course Content

UNIT I: (20% Weightage)
Complex line integrals, complex Integrals, Contour and Contours Integrals, The fundamental theorem of Integration, Cauchy's Theorem, Independence of path, Cauchy's integral formula. Morera's theorem, Liouville's theorem, Fundamental theorem of algebra.

UNIT II: (30% Weightage)
Holomorphic functions and their basic properties, zeros of holomorphic functions, Bi holomorphic maps, Homotopy and simply connected domains, counting zeros, conformal equivalence. Homotopic version of Cauchy's theorem. Open mapping theorem, Maximum modulus theorem, Goursat's theorem.

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: (20%Weightage)
Meromorphic function, Argument Principle, Rouche's Theorem, Hurwitz's theorem, Critical Points, Winding Numbers, Analytic continuation.

Content Interaction Plan:

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

1	Introduction to the line integration, simply and multiply connected domains, Introduction to the contour integration,
2-3	Cauchy's Integral Theorem (with proof) and its deduction for multiply connected domain, Independence of path
4-5	Cauchy's integral formula and its derivative form
6-9	The fundamental theorem of Integration, Morera's theorem Liouville's theorem
10-14	Holomorphic functions and their basic properties, zeros of holomorphic functions, Bi holomorphic maps,
15-19	Homotopy and simply connected domains, counting zeros, conformal equivalence. Homotopic version of Cauchy's theorem.
20-23	Open mapping theorem, Maximum modulus theorem, Goursat's theorem.
24-25	Infinite series, sequence and series of functions
26-27	Power series, Convergence of power series
28-31	Taylor's and Laurent series, The zeroes of an analytic function Singularities
32-34	Maximum Modulus Principle. Cauchy's residues Theorem (with proof)
35-38	Evaluation of contour integral and integral over the real line using residue theorem.
39-40	Meromorphic function, Argument Principle, Critical Points, Winding Numbers
41-42	Rouche's Theorem (with proof), Hurwitz's theorem (with proof)
43-45	Analytic continuation.

Suggested References:

- 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 Title: Algebra I

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

the course (if applicable)	
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.

Unit III **(25% Weightage)**

Basic definition and examples of Modules, Z-Modules, F[x]-Modules; Quotient Modules and Module Homomorphisms; Generation of Modules, Finitely generated Modules, Direct sums, and Free Modules.

Unit IV **(25% Weightage)**

Principal Ideal Domains (PID.s), Modules over PIDs, Structure theorem for finitely generated modules over a PID; The fundamental theorem of finitely generated abelian groups; The Jordan Canonical form.

Content Interaction **Plan:**

Lecture cum Discussion (Each	**Unit/Topic/Sub-Topic**

session of 1 Hour)	
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 definition and examples of Modules, Z-Modules, F[x]-Modules
33-35	Quotient Modules and Module Homomorphisms,
36-38	Generation of Modules, Finitely generated Modules
37-38	Direct sums, and Free Modules.
39-40	Principal Ideal Domains (PID.s), Modules over PIDs
41-42	Structure theorem for finitely generated modules over a PID;
43-45	The fundamental theorem of finitely generated abelian groups; The Jordan Canonical form.

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

Measures and Integration

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

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.

Partial Differential Equation and Fourier Analysis

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

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 and brief introduction to algebraic geometry and commutative algebra. 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.
- To learn fundamentals of algebraic geometry.

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)**

The K -Spectrum of a K -algebra and Affine algebraic sets; Identity theorem for polynomial functions; Basic property of K algebraic sets, Examples of K-algebraic sets, K Zariski topology, Noetherian rings, Hilbert's Basis Theorem and Consequences, Radicals and affine Varieties.

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	The K -Spectrum of a K -algebra and Affine algebraic sets; Identity theorem for polynomial functions;,
38-40	Basic property of K algebraic sets, Examples of K-algebraic sets and K Zariski topology
41-45	Noetherian rings; Hilbert's Basis Theorem and Consequences, Radicals and affine Varieties.
15 Hours	*Tutorials*
Suggested Texts/References: • 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.

Semester X

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

Syllabus of Multidisciplinary courses

Trigonometry and theory of Equations

Course Details			
Course Code	…………..	**Credits**	4
L + T + P	3 + 0+0	**Course Duration**	One Semester
Semester		**Contact Hours**	45 (L) + 15 (T) Hours
Course Type			
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 relationship between roots and coefficients
- To orient the students with the concept of hyperbolic functions.
- Knowledge of the logarithm of complex quantities and summation of trigonometric series

Learning Outcomes

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

- know the relationship between roots and coefficients
- identify the nature of the roots of the given equation
- expand powers of sines and cosines of θ in terms of functions of multiples of θ

- know the concept of hyperbolic functions
- know the logarithm of complex quantities
- find the summation of trigonometric series..

Course Contents

Unit I **(weightage 30%)** De Moivre's Theorem. Statement. Proof of De Moivre's theorem for integral indices. Alternative method. Proof for rational indices. All possible values of (cos x + i sinx) p/q. Application of De Moivre's theorem for integral and fractional indices.

Unit II **(weightage 40%)**

Expansion of sin nx, cos nx, in series of sinx, cosx. Expansion of sinn x, cosn x in terms of sin and cosine of multiple angles. Series expansion of sinx, cos x and tan x. Exponential, sine, cosine and logarithms of a complex number. Definitions. Logarithmic, exponential and hyperbolic functions. Inverse functions - trigonometric and hyperbolic functions. Laws of logarithm. Summation of series.,

Unit III **(weightage 30%)**

Theory of Equations Division algorithm. Remainder theorem. Factor theorem. Fundamental theorem of algebra. Nature of the roots of an equation. Complex roots. Surd roots. Relation between roots and coefficients.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	De Moivre's Theorem. Statement. Proof of De Moivre's theorem for integral indices. Alternative method. Proof for rational indices
6-10	All possible values of (cos x + i sinx) p/q. Application of De Moivre's theorem for integral and fractional indices.
11-16	Expansion of sin nx, cos nx, in series of sinx, cosx. Expansion of sinn x, cosn x in terms of sin and cosine of multiple angles. Series expansion of sinx, cos x and tan x
17-20	**Tutorial**
21-26	Definitions. Logarithmic, exponential and hyperbolic functions. Inverse functions
27-32	Theory of Equations Division algorithm. Remainder theorem. Factor theorem
33-38	Fundamental theorem of algebra. Nature of the roots of an equation.
39-40	Complex roots. Surd roots. Relation between roots
40-45	**Tutorial**

Texts/ References

- M L Khanna , Theory of Equations, Jai Prakash Nath and co. 1956
- Mazumdar & Dasgupta, Trigonometry -.

- B.S.Grewal. (2002) Higher Engineering Mathematics. Khanna Publishers. New Delhi.
- S.L.Loney. (1982) Plane Trigonometry, Part II, Cambridge University Press, London.
- P.Kandasamy, K.Thilagavathy (2004), Mathematics for B.Sc. Vol-I, II, III & IV, S.Chand& Company Ltd., New Delhi-55.

Matrix Theory

Course Code		**Credits**	4
L + T + P	2+ 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 Matrices.
- To develop a skill to solve problems.

Learning Outcomes

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

- Introduction of Matrices
- Operations on Matrices
- Finding Rank, Inversion of matices
- Applications of Matrices.

Course Contents

UNIT I

Introduction to matrices, different types of matrices, operations on matrices, Elementary operations on matrices and types of matrices, Symmetric and skew-symmetric matrices, Hermitian and skew-Hermitian matrices, orthogonal matrices, unitary matrices, normal matrices.

Unit II

Elementary Matrices. Linear dependence and independence of row and column matrices, Row rank, column rank and rank of a matrix, Row Reduced Echelon (RRE) form of a matrix and matrix inversion using it.

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Unit III
Eigen values, Eigen vectors and the characteristic equation of a matrix. Cayley Hamilton (CH) theorem and its use in finding inverse of a matrix, Application of matrices in solving a system of simultaneous linear equations

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-5	Introduction to matrices, different types of matrices, operations on matrices
6-10	Elementary operations on matrices and types of matrices, Symmetric and skew-symmetric matrices
11-15	Hermitian and skew-Hermitian matrices, orthogonal matrices, unitary matrices, normal matrices
16-20	Elementary Matrices. Linear dependence and independence of row and column matrices
21-25	Row rank, column rank and rank of a matrix
26-30	Row Reduced Echelon (RRE) form of a matrix and matrix inversion using it.
31-35	Eigen values, Eigen vectors and the characteristic equation of a matrix
36-40	CayleyHamilton (CH) theorem and its use in finding inverse of a matrix
41-45	Application of matrices in solving a system of simultaneous linear equations

Texts/References

- Shanti Narayan, A text book of Matrices, S. Chand Publication, 2010.
- Fumio Hiai, Dénes Petz , Introduction to Matrix Analysis and Applications, Springer International Publishing, 2014.

Sets, Relations, and Functions

Course Code		**Credits**	3
L + T + P	2 + 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	30 (L) + 15 (T) Hours
Course Type			
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)	NA		
Methods of Content Interaction	Lectures, Tutorials, Group discussions, Self-study, Seminars, and 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 understand the fundamental concepts of sets, relations, and functions;

- To train the students in problem-solving in sets, relations, and functions.

On completion of the course, a student will be able to:

- recognize the importance of equivalence relations;
- Learn about various functions;
- Learn about some important results of relations and functions.

Course Contents

UNIT I: (30% Weightage)

Sets and their representations, equality of sets, subsets, proper subsets, empty set, power set, universal set, Venn diagrams, union and intersection of sets, difference of sets, symmetric differences, complement of a set and its properties, partitions of a set, finite and infinite sets.

UNIT II: (40% Weightage)

Ordered pairs, Cartesian product of sets, Number of elements in the Cartesian product of finite sets, Relations and their pictorial diagrams, domain, co-domain and range of a relation, Inverse of a relation, binary relations, equivalence relations, partitions induced by equivalence relations, Equivalence classes and quotient sets.

UNIT III: (30% Weightage)

Functions, equality of functions, composition of functions, restriction of a function, Images and Inverse images of sets, equivalence relations induced by functions, Injections, surjections, and bijections.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-2	Sets and their representations
3-4	equality of sets, subsets, proper subsets, empty set, power set, universal set
5-6	Venn diagrams, union and intersection of sets
7-8	Difference of sets, Symmetric differences, Complement of a set and its properties
9-10	Partitions of a set, Finite and Infinite sets
11-12	Ordered pairs, Cartesian product of sets, Number of elements in the Cartesian product of finite sets
13-15	Relations and their pictorial diagrams, domain, co-domain and range of a relation, Inverse of a relation
16-18	Binary relations, equivalence relations
19-20	Partitions induced by equivalence relations, Equivalence classes and quotient sets
21-22	Functions, equality of functions, composition of functions
23-24	Restriction of a function, Images, and Inverse images of sets
25-26	Equivalence relations induced by functions
27-30	Injections, surjections, and bijections
15 hours	*Tutorials*

Suggested References:

1. Ramji Lal, *Algebra 1: Groups, Rings, Fields and Arithmetic*, Springer, 2017.
2. Michael L. O'Leary, *A First Course in Mathematical Logic and Set Theory*. John Wiley & Sons, 2016.
3. Robert R. Stoll, *Set Theory and Logic*, Dover Publications, Inc., New York, 1963.
4. K. Hrbacek and T. Jech, *Introduction to Set Theory*, 3rd edition, Marcel Dekker, Inc., 1999.
5. Y. Moschovakis, *Notes on Set Theory*, 2nd edition, Springer, 2006.

Syllabus of Skill Enhancement Course

MATLAB

Course Details			
Course Code	…………..	**Credits**	4
L + T + P	2 + 1	**Course Duration**	One Semester
Semester		**Contact Hours**	30 (L) + 15 (T) Hours
Course Type	Elective		
Nature of the Course	Theory and practical		
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

Introduce the MATLAB software environment.

Fortify an organized, top-down way to define and solve big problems.

Introduce common approaches, structures, and conventions for creating and evaluating computer programs, primarily in a procedural paradigm with a introduction to object-oriented concepts and terminology.

Apply a variety of common numerical techniques to solve and visualize engineering-related computational problems. To study various toolboxes to solve real life applications learning outcomes

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

- Use MATLAB effectively to analyze and visualize data.
- Apply numerical techniques and simulations to solve engineering-related problems.
- Apply a top-down, modular, and systematic approach to design, write, test, and debug sequential MATLAB programs to achieve computational objectives.
- Have in-depth understanding and use of MATLAB fundamental data structures (classes).
- Create and control simple plot and user-interface graphics objects in MATLAB.
- Be able to understand and use MATLAB Toolboxes for solving real life problems.

Course Contents

Unit I **(weightage 40%)**

MATLAB Fundamentals: What is MATLAB? History of MATLAB, origin, growth and development, Features of MATLAB, Why to use MATLAB? , menus and the toolbar, computing with MATLAB, types of file , editor debugger, some useful MATLAB commands, MATLAB help system, creating directory and saving files, constants variables and expressions-character set, data type in MATLAB, constants, variables and expressions, operators, hierarchy of operations, built-in-function, assignment statements. vectors and matrices-scalars and vectors, entering data in matrices, line continuation, matrices subscripts, muti-dimensional matrices and arrays, matrix manipulation, special Matrices, commands related to matrices, structure arrays, cell arrays.

Unit II (weightage 40%)

Polynomials -Entering, evaluation, roots, operations input/output statements- data input, interactive inputs, reading/storing data files, output commands, low level input output functions, introduction to data import and export, other MATLAB I/O capabilities, supported file format, working with audio/video file, importing audio/video data, reading audio/video data from a file, exporting audio/video data, example, working with spreadsheets, writing to an XLS file, reading from an XLS files, working with graphics file, importing graphics data, exporting graphics data, MATLAB-GUI with GUIDE, creating a simple GUI programmatically, creating menus.

Unit III (weightage 20%)

2D/3D plotting visualization using MATLAB 2D plot , multiple plot, style options, legends, subplots, specialized 2D plotlogarithmic, polar, area, bar, barh, hist, rose, pie, stairs, stem, compass. 3D plot - plot3, bar3, bar3h, pie3, stem 3, meshgrid, mesh, surf, contour, contour3. control structures- loops- for, nested for, while, branch control structure- if, switch, break, continue, error, try-catch.

Texts/ References

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-4	What is MATLAB? , History of MATLAB, Origin, Growth and Development, Features of MATLAB, Why to use MATLAB? ,
5-9	Menus and the toolbar, computing with MATLAB, types of file , Editor Debugger, Some useful MATLAB Commands, MATLAB Help System, creating directory and saving files, Constants Variables and Expressions-Character Set, Data Type in MATLAB, Constants, Variables and Expressions,
10-14	Operators, Hierarchy of Operations, Built-in-Function, Assignment Statements. Vectors and Matrices- Scalars and Vectors, Entering data in matrices, Line continuation, Matrices Subscripts, Muti-dimensional matrices and Arrays, Matrix Manipulation, Special Matrices, Commands related to matrices, Structure Arrays, Cell Arrays.
15-19	Polynomials -Entering, Evaluation, Roots, Operations Input/Output Statements- Data Input, Interactive Inputs, Reading/Storing Data files, Output Commands, Low level Input Output Functions
20-24	Introduction to Data Import and Export, Other MATLAB I/O capabilities, Supported File Format, Working with Audio/Video File, Importing Audio/Video Data, Reading Audio/video Data From a file, Exporting Audio/Video Data, Example, Working with Spreadsheets,
24-30	Writing to an XLS File, Reading from an XLS Files, Working with Graphics File, Importing Graphics data, Exporting Graphics data, MATLAB-GUI with GUIDE, Creating a simple GUI Programmatically, Dissertations of different components in GUIDE, Creating Menus.
31-34	MATLAB Graphics- 2D/3D Plotting Visualization Using MATLAB 2D plot , Multiple Plot, Style options, legends, subplots, Specialized 2D plotlogarithmic, polar, area, bar, barh, pie, stairs, stem, compass.
35-45	3D plot - plot3, bar3, bar3h, pie3, stem 3, meshgrid, mesh, surf, contour, contour3. Control Structures- loops- for, nested for, while, Branch Control Structure - if, switch, break, continue, error, try-catch.

1. Jim Sizemore, John P.Mueller, MATLAB FOR DUMMIES", Wiley.
2. Stephen J.Chapman, Matlab Programming for Engineers, Thomson-Engineering Publisher, CENGAGE Learning.
3. Duane Hanselman, Bruce L Littlefield, Mastering MATLAB Prentice Hall.
4. Amos Gilat, MATLAB: An Introduction with Application, Wiley Publisher.
5. Jaydeep Chakravorty, Introduction to MATLAB Programming , Toolbox and Simulink, Universities Press.
6. 8. S.N. Sivanandam, S.N.Deepa, MATLAB with Control system, signal processing, Image processing toolboxes, Wiley.

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

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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 ,

Unit III

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

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References:

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

Course Details

Syllabus of Value Added Courses

History of Mathematics in India 1

Course Code	…………..	**Credits**	2
L + T + P	2+ 1 + 0	**Course Duration**	One Semester
Semester		**Contact Hours**	30 (L)
Course Type			
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 introduce the students the history of ancient Indian Mathematics.
- To make aware of the students about the Indian contributions to Mathematics.

Unit I:

Three Key Periods of mathematics, Sources, Methodology, Sanskrit and its Syllabary, Background: Culture and Language , The Indus Valley Civilisation. The Vedic Period, The Oral Tradition , Grammar, Maths from bricks:Evidence from the Harappan culture

Unit2

Vedic Geometry ,The Sulbasuutra , The Theorem of the Diagonal , Rectilinear Figures and their Transformations , Circle from Square: The Direct Construction , The Inverse Formula: Square from Circle Antecedents? Mathematics in the Indus Valley, Maths from bricks:Evidence from the Harappan culture Measures and Integer, Decimal Numbers , Numbers and Based Numbers ,The Place-value Principle and its Realisations

References:

1. Kim Plofker ; Mathematics In India ; Hndustan Book Agency
2. History of Science and Technology in ancient India: the beginnings, D. Chattopadhyaya. Firma KLM Pvt Calcutta 1986.
3. History of Hindu Mathematics, B. Datta and A.N. Singh, Bharatiya Kala Prakashan N.Delhi 2001 (reprint)
4. Studies in the History of Indian Mathematics (Culture and History of Indian Mathematics) C. S. Seshadri (Editor), Hindustan Book Agency (15 August 2010)
5. An introduction to the history of Mathematics 5th Edn, H. Eves. Saunders Philadelphia 1983.
6. A history of Mathematics, C.B. Boyer. Princeton University Press, NJ, 1985.
7. P. P. Divakaran The Mathematics of India, Concepts, Methods, Connections, Hndustan Book Agency

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	Unit/Topic/Sub-Topic
1-7	Three Key Periods of mathematics, Sources, Methodology, Sanskrit and its Syllabary, Background: Culture and Language ,,

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8-12	The Indus Valley Civilisation. The Vedic Period, The Oral Tradition , Grammar, Maths from bricks:Evidence from the Harappan culture
13-16	Vedic Geometry ,The Sulbasuutra , The Theorem of the Diagonal
17-20	Rectilinear Figures and their Transformations , Circle from Square: The Direct Construction ,
21-25	The Inverse Formula: Square from Circle Antecedents? Mathematics in the Indus Valley, Maths from bricks:Evidence from the Harappan culture Measures and Integer,
26-30	Decimal Numbers , Numbers and Based Numbers ,The Place-value Principle and its Realisations
	References: 1. Kim Plofker ; Mathematics In India ; Hndustan Book Agency 2. History of Science and Technology in ancient India: the beginnings, D. Chattopadhyaya. Firma KLM Pvt Calcutta 1986. 3. History of Hindu Mathematics, B. Datta and A.N. Singh, Bharatiya Kala Prakashan N.Delhi 2001 (reprint) 4. Studies in the History of Indian Mathematics (Culture and History of Indian Mathematics) C. S. Seshadri (Editor), Hindustan Book Agency (15 August 2010) 5. An introduction to the history of Mathematics 5th Edn, H. Eves. Saunders Philadelphia 1983. 6. A history of Mathematics, C.B. Boyer. Princeton University Press, NJ, 1985. 7. P. P. Divakaran The Mathematics of India, Concepts, Methods, Connections, Hndustan Book Agency .

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)

Brahmagupta's plane and solid geometry, Brahmagupta's number theory and algebra, Works of Baudhayana, Baudhayana-Pythagorus theorem, Pythagorean triples, History of Pell's equation, Hemachandra and Fibonacci sequence.

UNIT II: (50 % Weightage)

Indian Mathematics in the colonial period and after: Life and Works of Srinivasa Ramanujan, Komaravolu Chandrasekharan, and Harish-Chandra.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-13	**UNIT I:**
1-2	Brahmagupta’s plane and solid geometry
3-4	Brahmagupta’s number theory and algebra
6-7	Works of Baudhayana, Baudhayana-Pythagorus theorem, Pythagorean triples
8-10	History of Pell’s equation
11-13	Hemachandra and Fibonacci sequence.
14-23	**UNIT II:**
13-16	Life and Works of Srinivasa Ramanujan
17-19	Life and works of Komaravolu Chandrasekharan
20-23	Life and Works of 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.

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History of Mathematics in India-II

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)

Brahmagupta's plane and solid geometry, Brahmagupta's number theory and algebra, Works of Baudhayana, Baudhayana-Pythagorus theorem, Pythagorean triples, History of Pell's equation, Hemachandra and Fibonacci sequence.

UNIT II: (50 % Weightage)

Indian Mathematics in the colonial period and after: Life and Works of Srinivasa Ramanujan, Komaravolu Chandrasekharan, and Harish-Chandra.

Content Interaction Plan:

Lecture cum Discussion **(Each session of 1 Hour)**	**Unit/Topic/Sub-Topic**
1-13	**UNIT I:**
1-2	Brahmagupta's plane and solid geometry
3-4	Brahmagupta's number theory and algebra
6-7	Works of Baudhayana, Baudhayana-Pythagorus theorem, Pythagorean triples
8-10	History of Pell's equation
11-13	Hemachandra and Fibonacci sequence.
14-23	**UNIT II:**
13-16	Life and Works of Srinivasa Ramanujan
17-19	Life and works of Komaravolu Chandrasekharan
20-23	Life and Works of 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.

List of Electives

Algebraic Geometry

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

Algebraic Number Theory

Course Details

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	X	**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 , Algebra-II

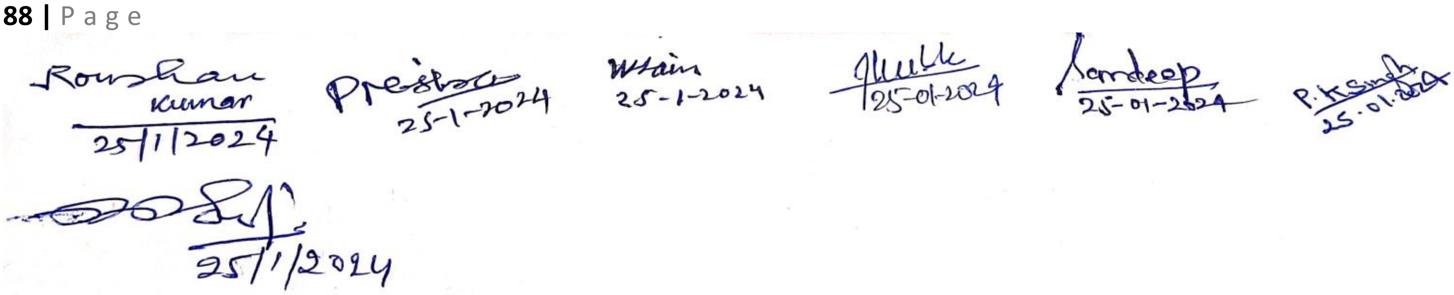
Course Contents

UNIT I **(15% Weightage)**

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

UNIT II **(25 % 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 **(25 % 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.

Course Details			
Algebraic Topology			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	X	**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		

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.

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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%)**

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	VIII	**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)		

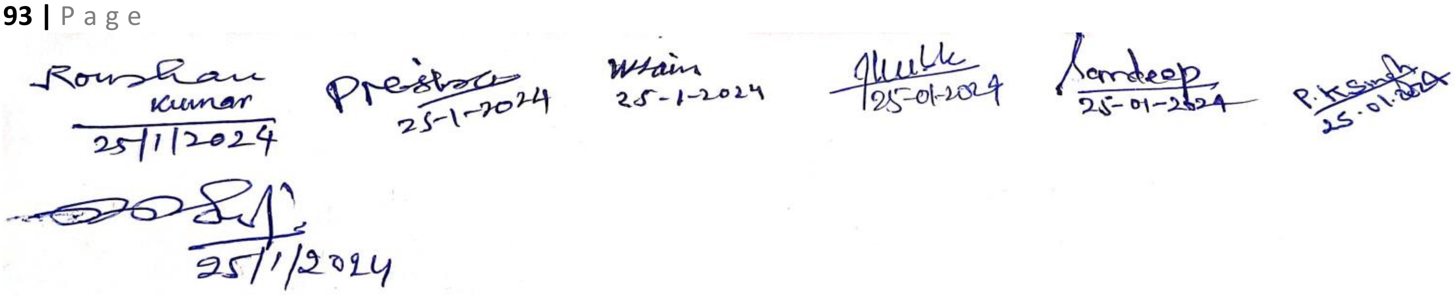
Course Objectives

- 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*

- <u>Suggested References:</u>

- 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

Commutative Algebra

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

Differential Geometry

Course Details			
Course Code		**Credits**	4

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L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	VIII	**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:

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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.

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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

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Distribution Theory

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

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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

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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	VIII	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Discipline Based Core Elective		
Nature of the Course	Theory		

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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*

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- Suggested References:

  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	VIII	**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.

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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	VIII	**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	**Unit/Topic/Sub-Topic**

(Each session of 1 Hour)	
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.

Introduction to Finite Fields and Coding theory

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

Lie Algebra

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

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

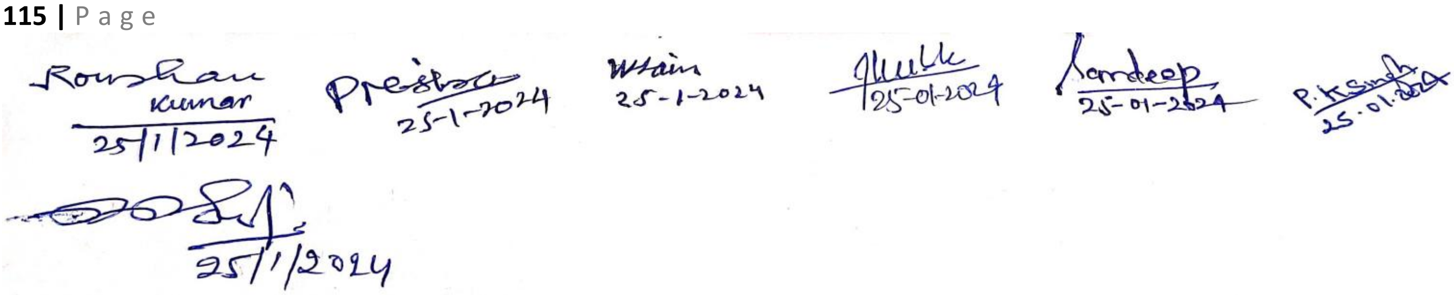
- To understand basics of number theory
- To study computational aspects of Number Theory
- To study Cryptographic applications of Number Theory.
-

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.

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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

Mechanics

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

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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

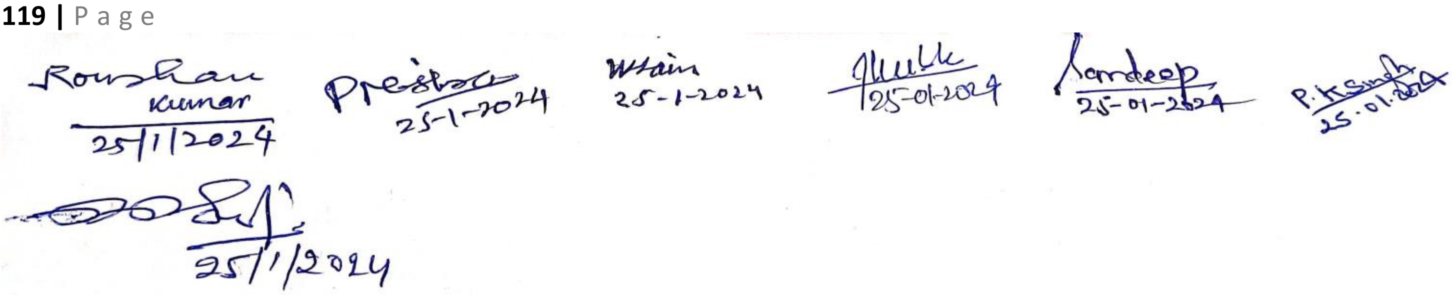
- H. Goldstein, Classical Mechanics, Narosa Publishing House, 1980.
- F. Charlton, Text book of Dynamics, 2nd edition, CBS Publishers, 1985.
- R.G. Takwale& P.S. Puranik, Introduction to Classical Mechanics, Tata McGraw Hill Publishing Co., New Delhi.
- E.T. Whittaker, A Treatise on Analytical Dynamics of Particles and Rigid Bodies, Cambridge University Press, 1993.

Number Theory

Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	VIII	**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 $\varphi(n)$, 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.
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 Details			
Operator Theory			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	X	**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)**

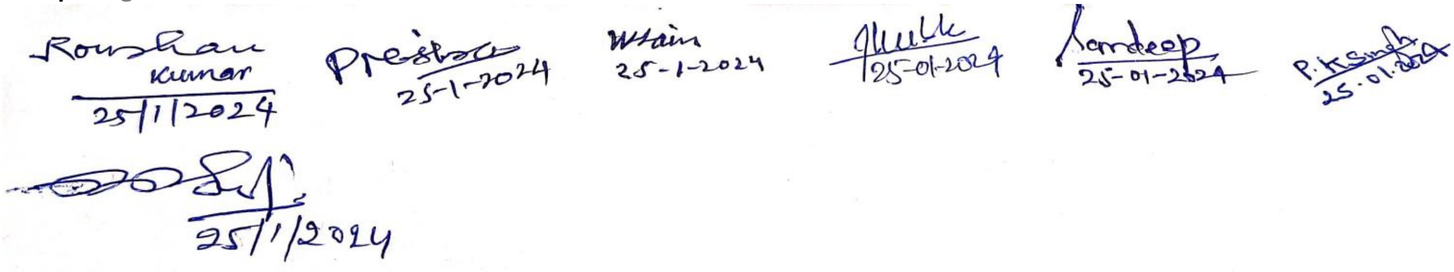
Spectral properties of operators on finite dimensional spaces and the spectral theory of operators on Banach spaces including the use of complex analysis in the theory.

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.

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Representation theory of finite groups

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

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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	X	**Contact Hours**	45 (L) + 15 (T) Hours
Course Type	Elective Course		
Nature of the Course	Theory		
Special Nature/ Category of the Course (*if applicable*)			
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:

❖ To apply these tools to the huge world of Automata, Languages and Machines.

❖ Able to develop an analytical skill to analyze these theories.

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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.

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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 Mathematical Society, Providence, Vol.I, 1961
- A. H. Clifford and G. B. Preston, *The Algebraic Theory of Semigroups,* American Mathematical 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			
Spectral Graph Theory			
Course Code		**Credits**	4
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	X	**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*)			
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)		

Roushan Kumar 25/1/2024 Pre... 25-1-2024 Wtain 25-1-2024 ... 25-01-2024 Sandeep 25-01-2024 P.K.Singh 25.01.2024
25/1/2024

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 spectral graph 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	X	**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 (Each session of 1 Hour)	Unit/Topic/Sub-Topic
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

Fractional Calculus and Fractional 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	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)

Learning Objectives: The main objective of this course is to:

- Learn fractional differentiation and fractional integration
- Learn integral transform of fractional derivatives
- Learn Fractional Differential Equations

Learning Outcomes: This course will enable the students to:

- Demonstrate ability to understand fractional differentiation and fractional integration
- Demonstrate ability to understand integral transform of fractional derivatives
- Demonstrate ability to understand Fractional Differential Equations

UNIT I (25%)

Gamma function and its properties, Beta function, Contour integral representation. Fractional derivatives: Grunwald-Letnikov, Riemann-Liouville and Caputo's fractional derivative, Leibniz rule for fractional derivatives, Geometric and physical interpretation of fractional integration and fractional differentiation.

UNIT II (25%)

Sequential fractional derivatives. Left and right fractional derivatives. Properties of fractional derivatives. Laplace transforms of fractional derivatives. Fourier transforms and Mellin transforms of fractional derivatives.

UNIT III (25%)

Linear Fractional Differential Equations: Fractional differential equation of a general form. Existence and uniqueness theorem as a method of solution. Dependence of a solution on initial conditions. The Laplace transform method. Standard fractional differential equations. Sequential fractional differential equations.

UNIT IV (25%)

Fractional Differential Equations: Introduction, Linearly independent solutions, Solutions of the homogeneous and non-homogeneous fractional differential equations, Reduction of fractional partial differential equations to ordinary differential equations.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-12	Gamma function and its properties, Beta function, Contour integral representation. Fractional derivatives: Grunwald-Letnikov, Riemann-Liouville and Caputo's fractional derivative, Leibniz rule for fractional derivatives, Geometric and physical interpretation of fractional integration and fractional differentiation.
13-24	Sequential fractional derivatives. Left and right fractional derivatives. Properties of fractional derivatives. Laplace transforms of fractional derivatives. Fourier transforms and Mellin transforms of fractional derivatives.
25-33	Linear Fractional Differential Equations: Fractional differential equation of a general form. Existence and uniqueness theorem as a method of solution. Dependence of a solution on initial conditions. The Laplace transform method. Standard fractional differential equations. Sequential fractional differential equations.
34-45	Fractional Differential Equations: Introduction, Linearly independent solutions, Solutions of the homogeneous and non-homogeneous fractional differential equations, Reduction of fractional partial differential equations to ordinary differential equations.

Suggested Readings:

1. Oldham K. B. & Spanier J., The Fractional Calculus: Theory and Applications of Differentiation and Integration to Arbitrary Order, Dover Publications Inc, 2006.
2. Miller K. S. & Ross. B., An Introduction to the Fractional Calculus and Fractional Differential Equations Hardcover, Wiley Blackwell, 1993.
3. Podlubny I., Fractional Differential Equations, Academic Press, 1998.

Approximation Theory

Course Code	…………..	**Credits**	4

Approximation Theory			
L + T + P	3 + 1 + 0	**Course Duration**	One Semester
Semester	VIII	**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)		

Learning Objectives:

The main objective of this course is to:

- Learn best approximation
- Learn Integral modulus of continuity and their properties
- Learn Approximation by means of Fourier series.
- Learn Approximation of analytic functions

Learning Outcomes:

This course will enable the students to:

- Demonstrate ability to understand best approximation
- Demonstrate ability to understand Integral modulus of continuity and their properties
- Demonstrate ability to understand Approximation by means of Fourier series.
- Demonstrate ability to understand Approximation of analytic functions

UNIT-I (25%)

Concept of best approximation in a normed linear space, Existence of the best approximation, Uniqueness problem, Convexity-uniform convexity, strict convexity and their relations, Continuity of the best approximation operator.

UNIT-II (25%)

The Weierstrass theorem, Bernstein polynomials, Korovkin theorem, Algebraic and trigonometric polynomials of the best approximation, Lipschitz class, Modulus of continuity, Integral modulus of continuity and their properties.

UNIT-III (25%)

Bernstein's inequality, Jackson's theorems and their converse theorems, Approximation by means of Fourier series.

UNIT-IV (25%)

Positive linear operators, Monotone operators, Simultaneous approximation, L^p -approximation, Approximation of analytic functions.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-11	Concept of best approximation in a normed linear space, Existence of the best approximation, Uniqueness problem, Convexity-uniform convexity, strict convexity and their relations, Continuity of the best approximation operator.
12-23	The Weierstrass theorem, Bernstein polynomials, Korovkin theorem, Algebraic and trigonometric polynomials of the best approximation, Lipschitz class, Modulus of continuity, Integral modulus of continuity and their properties.
24-33	Bernstein's inequality, Jackson's theorems and their converse theorems, Approximation by means of Fourier series.
34-45	Positive linear operators, Monotone operators, Simultaneous approximation, L^p -approximation, Approximation of analytic functions.

Suggested Books:

1. Cheney, E. W., "Introduction to Approximation Theory", AMS Chelsea Publishing Co. 1981.
2. Lorentz, G. G., "Bernstein Polynomials", Chelsea Publishing Co. 1986
3. Natanson, I. P., "Constructive Function Theory Volume-I", Fredrick Ungar Publishing Co 1964.
4. Mhaskar, H. M. and Pai, D. V., "Fundamentals of Approximation Theory" Narosa Publishing House 2000
5. Timan, A. F., "Theory of Approximation of Functions of a Real Variable," Dover Publication Inc 1994.
6. Gupta V. and Agarwal, R. P., Convergence Estimates in Approximation Theory, Springer, 2014.

Distribution Theory and Sobolev Spaces

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	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 snd 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**
1-2	Normed linear spaces, Quotient norm
3-4	Banach spaces and examples
5-6	spaces as Banach spaces
6-9	Bounded linear transformations on normed linear spaces, B(X,Y) as a normed linear spaces,
10-11	Open mapping
12-13	closed graph theorems
14-15	Uniform boundedness principle
16-17	Hahn-Banach theorem and its applications
18-20	Dual space, Separability, Reflexivity
21-23	Finite dimensional norm linear space, Reisz lemma,
24-26	Weak and weak* convergence of operators,
27-29	Inner product spaces
30-32	, Hilbert spaces
33-35	Orthogonal sets, Bessel's inequality, Complete orthonormal sets and Parseval's identity, Structure of Hilbert spaces
36-37	Projection theorem, Riesz representation theorem, Riesz-Fischer theorem
38-39	Adjoint of an operator on a Hilbert space, Reflexivity of Hilbert spaces,
40-41	Self-adjoint operators, Positive, projection
42-45	normal and unitary operators and their basic properties.

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.

BIOMATHEMATICS

Course Code	…………..	**Credits**	4
BIOMATHEMATICS			
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)		

Learning Objectives: The main objective of this course is to:

- Develop and analyse the models of the biological phenomenon with emphasis on population growth and predator-prey models.
- Interpret first-order autonomous systems of nonlinear differential equations using the Poincaré phase plane.
- Apply the basic concepts of probability to understand molecular evolution and genetics.

Learning Outcomes: This course will enable the students to:

- To learn and appreciate study of long-term behavior arising naturally in study of mathematical models and their impact on society at large.
- To understand spread of epidemic technically through various models and impact of recurrence phenomena.
- Learn what properties like Chaos and bifurcation means through various

examples and their impact in Bio-Sciences.

UNIT – I: Mathematical Modeling for Biological Processes (15 hours)

Formulation a model through data, A continuous population growth model, Long-term behavior and equilibrium states, The Verhulst model for discrete population growth, Administration of drugs, Differential equation of chemical process and predator-prey model (Function response: Types I, II and III).

UNIT – II: Epidemic Model: Formulation and Analysis (15 hours) Introduction to infectious disease, The SIS, SIR and SEIR models of the spread of an epidemic, Analyzing equilibrium states, Phase plane analysis, Stability of equilibrium points, Classifying the equilibrium state; Local stability, Limit cycles, Poincaré-Bendixson theorem.

UNIT – III: Bifurcation, Chaos (8 hours)

Bifurcation, Bifurcation of a limit cycle, Discrete bifurcation and period-doubling, Chaos, Stability of limit cycles.

UNIT – IV: Modeling Molecular Evolution (7 hours)

Introduction of the Poincaré plane; Modeling molecular evolution: Matrix models of base substitutions for DNA sequences, Jukes-Cantor and Kimura models, Phylogenetic distances.

Content Interaction Plan:

Lecture cum Discussion (Each session of 1 Hour)	**Unit/Topic/Sub-Topic**
1-15	Formulation a model through data, A continuous population growth model, Long-term behavior and equilibrium states, The Verhulst model for discrete population growth, Administration of drugs, Differential equation of chemical process and predator-prey model (Function response: Types I, II and III).
16-30	Introduction to infectious disease, The SIS, SIR and SEIR models of the spread of an epidemic, Analyzing equilibrium states, Phase plane analysis, Stability of equilibrium points, Classifying the equilibrium state; Local stability, Limit cycles, Poincaré-Bendixson theorem.
31-38	Bifurcation, Bifurcation of a limit cycle, Discrete bifurcation and period-doubling, Chaos, Stability of limit cycles.
39-45	Introduction of the Poincaré plane; Modeling molecular evolution: Matrix models of base substitutions for DNA sequences, Jukes-Cantor and Kimura models, Phylogenetic distances.

Suggestive Readings

1. Robeva, Raina S., et al. (2008). An Invitation to Biomathematics. Academic press.
2. Jones, D. S., Plank, M. J., & Sleeman, B. D. (2009). Differential Equations and Mathematical Biology (2nd ed.). CRC Press, Taylor & Francis Group.
3. Allman, Elizabeth S., & Rhodes, John A. (2004). Mathematical Models in Biology: An Introduction. Cambridge University Press.

- Linda J. S. Allen (2007). An Introduction to Mathematical Biology. Pearson Education.
- Murray, J. D. (2002). Mathematical Biology: An Introduction (3rd ed.). Springer.
- Shonkwiler, Ronald W., & Herod, James. (2009). Mathematical Biology: An Introduction with Maple and MATLAB (2nd ed.). Springer.

Project

There are two projects.

(i) In the 8th semester. This project will be of 12 credits and will be allotted to those students who have CGPA more than 7.5 in the 7th semester (if student comes from the lateral entry on 7th semester) or CGPA more than 7.5 in all previous semesters studied in CUSB. The project report is called UG Dissertation for those who have completed semester 1 to 7 from CUSB. The project report is called PG Diploma Dissertation for those taken admission in 7th semester.

(ii) This is project for all students of 10th semester. This project is of 8 credits and allotted at the beginning of 9th semester but registered and evaluated in 10th semester. The project report of this project is called PG Dissertation.

There will be a supervisor allotted for each project. Project will be evaluated in 100 marks. Out of which 70 marks will be evaluated by supervisor and 30 marks will be evaluated by a departmental committee by taking presentation from the candidate. The formation of committee will be done before evaluation by the DC.

The format of final dissertation is attached as an appendix.

Internship

There are three internships mentioned in the syllabus.

Summer Internship A/Summer Internship B (4 credits)

One of the above internship is necessary only for the students who want to exit from the programme. Both the internship is of 4 credits. There will not be any grading in this intership. This internship can be done by students in the following way

(i) A student can join as an intern in a industry/NGO/school for developing his mathematical skills after informing to the department. This should be of at least 15 days and a report after completing the internship should be submitted to the department.

(ii) A student can join a mathematical workshop of 15 days/two workshops of 7 days. And the certificate need to be submitted to the department.

(iii) A student can take a 4 credit Swayam course during his/her programme of study after approval with the department.

(iv) A student can join/visit a faculty (called supervisor) of any Indian universities in summer for at least 15 days after informing to the department. And prepare a report of his work duly forwarded by the supervisor. This report needs to be submitted to the department.

Internship in Semester V

This is a two credits internship during the semester. There will be grading for this intership. This can be done in the following way

(i) A student can join a project under any faculty of the university to develop his/her knowledge during the Semester V after informing to the department. That faculty is called supervisor. One report need to be submitted by the student duly forwarded by the supervisor at the end of semester teaching. In that report it will be clearly mentioned the kind of work done by the student. Also supervisor will give 30 marks and 70 marks will be allotted to the student by a departmental committee by taking presentation from the candidate. The formation of committee will be done before evaluation by Departmental committee.

(ii) Student can do a Swayam course of 2 credits with proper approval from the department.