Bachelor of Science (Honours) Mathematics under CBCS
PATNA UNIVERSITY, PATNA

Programme Code:

Programme Outcomes

At the completion of the programme, students will attain the ability to:

PO1:

PO2:

PO3:

PO4:

Programme Specific Outcomes

At the completion of the programme, students will attain the ability to:

PSO1:

PSO2:

PSO3:

PSO4:

Course Structure

Semester –I

Sl.No.	Name ofthe Course	Type ofCourse	L-T-P	Credit	Marks
1	Algebra	CC-1	6-1-0	6	100
2	Calculus	CC-2	6-1-0	6	100
3	EnglishCommunication/MIL	AECC-1	2-1-0	2	100
4	GenericElective- 1	GE-1	6-1-0	6	100
					Totalcredit-20

Semester–II

Sl.No.	Name ofthe Course	Type ofCourse	L-T-P	Credit	Marks
1	Real Analysis	CC-3	6-1-0	6	100
2	Ordinary Differential Equations	CC-4	6-1-0	6	100
3	Environmental Science	AECC-2	2-1-0	2	100
4	Generic Elective- 2	GE-2	6-1-0	6	100

	Totalcredit-20

Semester–III

Sl.No.	Name ofthe Course	Type of Course	L-T-P	Credit	Marks
1	Theory of Real Functions	CC-5	6-1-0	6	100
2	Group Theory	CC-6	6-1-0	6	100
3	Partial Differential Equations	CC-7	6-1-0	6	100
4	SkillEnhancementCourse-1	SEC-1	2-1-0	2	100
5	GenericElective-3	GE-3	6-1-0	6	100
					Totalcredit-26

Semester–IV

Sl.No.	Name ofthe Course	Type ofCourse	L-T-P	Credit	Marks
1	RingTheory&LinearAlgebra-I	CC-8	6-1-0	6	100
2	MultivariateCalculus	CC-9	6-1-0	6	100
3	ComplexAnalysis	CC-10	6-1-0	6	100
4	SkillEnhancementCourse-2	SEC-2	2-1-0	2	100
5	GenericElective- 4	GE-4	6-1-0	6	100
					Totalcredit-26

Semester –V

Sl.No.	Name ofthe Course	Type ofCourse	L-T-P	Credit	Marks
1	MetricSpace	CC-11	6-1-0	6	100
2	Riemann Integration & Series ofFunction	CC-12	6-1-0	6	100
3	DisciplineSpecificElective-1	DSE-1	6-1-0	6	100
4	DisciplineSpecificElective-2	DSE-2	6-1-0	6	100
					Totalcredit-24

Semester–VI

Sl.No.	Name ofthe Course	Type ofCourse	L-T-P	Credit	Marks
1	RingTheory& LinearAlgebra-II	CC-13	6-1-0	6	100
2	NumericalMethods	CC-14	6-1-0	6	100
3	DisciplineSpecificElective-3	DSE-3	6-1-0	6	100
4	DisciplineSpecificElective-4 (Project/Dissertation)	DSE-4	0-0-6	6	100
					Totalcredit-24

TotalCredits–140

***L/T/P: number of classes per week**

Discipline Specific Elective Course (DSE):

Course name	L-T-P

Generic Elective (GE):

For Mathematics Students		For Other Students	
Course name	L-T-P	Course name	L-T-P

Skill Enhancement courses (SEC):

SEMESTER – I

CC1 : Algebra

Course Outcomes

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

CO1: Employ De Moivre's theorem in a number of applications to solve numerical problems.

CO2: Apply Euclid's algorithm and backwards substitution to find greatest common divisor.

CO3: Recognize consistent and inconsistent systems of linear equations by the row echelon form of the augmented matrix, using rank.

CC1 : Algebra (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Polar representation of complex numbers, nth roots of unity, Complex argument, De-Moivre's theorem for integer and rational indices and its applications, Hyperbolic functions, Summation of series, Gregory series.	12
2	Fundamental theorem of algebra, Relation between roots and coefficients of a polynomial equation, Transformation of equation, Descartes rule of signs, Solution of Cubic equation (Cardon's method) and bi-quadratic equation (Euler's method).	12
3	Cartesian product of sets, Equivalence relations, Functions, Composition of functions, Invertible functions, Cardinality of a set, Countable and Uncountable sets, Cantor's theorem, Well-ordering principle, Division algorithm, Euclidean algorithm, Fundamental Theorem of Arithmetic, Modular arithmetic and basic properties of congruences, Principle of mathematical induction.	14
4	Fuzzy Sets and its types, Characteristics of fuzzy set, Equality, Containment, Union & Intersection of Fuzzy sets, Height, Core, Support, Normal fuzzy set, Nucleus, Convex fuzzy sets and its algebra, Product and difference.	10
5	Matrices, Operation on Matrices, Matrix algebra, Kinds of matrices, Transpose, Adjoint and Inverse of a matrix, Solution of a system of linear equations by matrix methods, Row reduction and Echelon forms using elementary row operations, Rank of a matrix	12
	TOTAL	60

Suggested Reading :

1. Andreescu, Titu&AndricaDorin. (2014). Complex Numbers from A to...Z. (2nd ed.). Birkhäuser.
2. Dickson, Leonard Eugene (1922). First Course in The Theory of Equations. John Wiley & Sons, Inc. New York.
3. Goodaire, Edgar G., & Parmenter, Michael M. (2005). Discrete Mathematics with Graph Theory (3rd ed.). Pearson Education Pvt. Ltd. Indian Reprint 2015.
4. Kolman, Bernard, & Hill, David R. (2001). Introductory Linear Algebra with Applications (7th ed.). Pearson Education, Delhi. First Indian Reprint 2003.
5. Lay, David C., Lay, Steven R., & McDonald, Judi J. (2016). Linear Algebra and its Applications (5th ed.). Pearson Education

Additional Readings:

1. Andrilli, Stephen, & Hecker, David (2016). Elementary Linear Algebra (5th ed.). Academic Press, Elsevier India Private Limited.
2. Burton, David M. (2007). Elementary Number Theory (7th ed.). Tata Mc-Graw Hill Edition, Indian Reprint.
3. K.K.Jha , Advanced Set Theory.

CC 2 : Calculus

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Apply derivatives in Optimization, Social sciences, Physics and Life sciences etc.

CO2: Compute area of surfaces of revolution and the volume of solids by integrating over cross-sectional areas.

CC 2 : Calculus (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Successive differentiation and Leibnitz's theorem, Expansion of functions, Tangent and Normal, Partial differentiation and Euler's theorem, Concavity and inflection points, Asymptotes, Curve tracing in Cartesian coordinates, Tracing in polar coordinates of standard curves, Curvature, L'Hospital's rule, Applications in business, economics and life sciences.	12
2	Evaluation of definite integrals, Reduction formulae, Volumes by Slicing, Disk and Washer methods, Volumes by cylindrical shells, parametric equations, rectification and quadrature, Volume and surface area of solids of revolution, Multiple integrals and change of order of integration, improper integrals, Beta and Gamma functions.	12
3	Transformation of rectangular axes, General equations of conic and its reduction to the normal form, Equation of the tangent and normal at a point of the Conic.	10
4	Sphere, cone, cylinder, Central conicoid, Paraboloids, Plane section of conicoid, Generating lines, Tangent plane and normal to a conicoid.	12
5	Scalar triple product and vector triple product, Product of four vectors, Introduction to vector functions, Operations with vector-valued functions, Limits and continuity of vector functions, Differentiation and integration of vector functions, Gradient of a scalar and Divergence and Curl of a vector function in Cartesian coordinate.	14
	TOTAL	60

Suggested Reading :

1. Anton, Howard, Bivens, Irl, & Davis, Stephen (2013). Calculus (10th ed.). John Wiley & Sons Singapore Pte. Ltd. Indian Reprint (2016) by Wiley India Pvt. Ltd. Delhi.
2. Osborne, George. A. (1906). Differential and Integral Calculus with Examples and Applications. Revised Edition. D. C. Health & Co. Publishers. Boston, U.S.A.
3. Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). Calculus (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011.

Additional Reading:

1. Thomas, Jr. George B., Weir, Maurice D., & Hass, Joel (2014). *Thomas*' *Calculus* (13th ed.). Pearson Education, Delhi. Indian Reprint 2017

SEMESTER- II

CC3 : Real Analysis

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Understand many properties of the real line and learn to define sequence in terms of functions from to a subset of R.

CO2: Recognize bounded, convergent, divergent, Cauchy and monotonic sequences and to calculate their limit superior, limit inferior, and the limit of a bounded sequence.

CO3: Apply the ratio, root, Alternating series and limit comparison tests for convergence and absolute convergence of an infinite series of real numbers

CC3 : Real Analysis (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Dedekind theory of real numbers, Algebraic and order properties of R, Archimedean Property, Density Theorem, Completeness property of R, Bounded sets, Theorems on Suprema and Infima	10

2	Definition and types of intervals, Nested intervals property, Neighborhood of a point in R, Open and closed sets, Limit points and isolated points of a set, Bolzano-Weierstrass theorem for a set.	12
3	Sequence and its convergence, Bounded sequence, Limit of a sequence. Limit Theorem, Monotone sequences, Subsequences, Bolzano-Weierstrass theorem for sequences, Limit superior and limit inferior for bounded sequence, Cauchy sequence, Cauchy's general principle of convergence.	14
4	Infinite series and their convergence, Cauchy Criterion, Tests for convergence: Comparison test, Ratio Test, Logarithmic ratio test, Cauchy's root test, Alternating series, Leibniz test, Absolute and Conditional convergence.	12
5	Integral test for series of arbitrary terms, Euler's constant, Dirichlet's and Abel's test for series of arbitrary terms, Riemann and Pringsheim's method for rearrangement of terms of conditionally convergent series, Cauchy's Theorem, Infinite product and its convergence.	12
	TOTAL	60

Suggested Reading :

1. Bartle, Robert G., &Sherbert, Donald R. (2015). Introduction to Real Analysis (4^{th}ed.). Wiley India Edition. New Delhi.
2. Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E. (2010). An Introduction to Analysis (2^{nd}ed.). Jones and Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.
3. Denlinger, Charles G. (2011). Elements of Real Analysis. Jones and Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

Additional Readings:

1. Ross, Kenneth A. (2013). Elementary Analysis: The theory of calculus (2^{nd} ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.
2. Thomson, Brian S., Bruckner, Andrew. M., & Bruckner, Judith B. (2001). Elementary Real Analysis. Prentice Hall.
3. K.K.Jha , Advanced Real Analysis.

CC4 : Ordinary Differential Equations

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Formulate Differential Equations for various Mathematical models.

CO2: Solve first order non-linear differential equation and linear differential equations of higher order using various techniques

CO3: Apply these techniques to solve and analyze various mathematical models.

CC4 : Ordinary Differential Equations (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Differential equations and mathematical models, general, particular, explicit, implicit and singular solutions of a differential equation, Exact differential equations and integrating factors, special integrating factors and transformations, separable equations and equations reducible to this form, linear equation and Bernoulli equations.	14
2	Differential equations of the first order but not of the first degree. Singular solutions, Clairaut's form, Orthogonal Trajectories of family of curves, Total differential equation in three variables, Simultaneous differential equations.	10
3	General solution of homogeneous equation of second order, Principle of super position for homogeneous equation, Wronskian: its properties and applications, Linear homogeneous and non-homogeneous equations of higher order with constant coefficients, Euler's equation, Method of undetermined coefficients, Method of variation of parameters.	12
4	Definition and Linearity of Laplace transform, Existence Theorem, Laplace transform of derivatives and integrals, shifting theorems and inverse Laplace transform, Solution of ordinary differential equation using Laplace transform.	14

5	Fourier series for odd and even functions, Half range series, other forms of Fourier series.	10
	TOTAL	60

Suggested Reading :

1. Edwards, C. Henry, Penney, David E., &Calvis, David T. (2015). Differential Equation and Boundary Value Problems: Computing and Modeling (5th ed.). Pearson Education.
2. Ross, Shepley L. (2004). Differential Equations (3rd ed.). John Wiley & Sons. India
3. M.D. Raisinghaniya, Ordinary Differential Equations, S. Chand Publication.

SEMESTER – III

CC5 : Theory of Real Functions

Course Outcomes

After the completion of the course, the student will be able to:

CO1: To have a rigorous understanding of the concept of limit of a function.

CO2: The geometrical properties of continuous functions on closed and bounded intervals.

CO3: The applications of mean value theorem and Taylor's theorem.

CC5 : Theory of Real Functions (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Limit of functions, Sequential criterion for limits, Divergence criteria, Limit theorems, One-sided limits, Infinite limits and limits at infinity.	12
2	Continuous functions, Sequential criterion for continuity and discontinuity, Algebra of continuous functions, Properties of continuous functions on closed and bounded intervals.	12
3	Uniform continuity, Non-uniform continuity criteria, Uniform continuity theorem.	08
4	Differentiability of a function, Algebra of differentiable functions, Carathéodory's theorem and chain rule; Relative extrema, Interior extremum theorem, Rolle's theorem, Mean- value theorem and its applications, Intermediate value property of derivatives - Darboux's theorem.	14
5	Taylor polynomial, Taylor's theorem with Lagrange form of remainder, Application of Taylor's theorem in error estimation; Relative extrema, and to establish a criterion for convexity; Taylor's series expansions of e^x, sin(x), and cos(x).	14
	TOTAL	60

Suggested Reading :

1. Bartle, Robert G., &Sherbert, Donald R. (2015). Introduction to Real Analysis (4th ed.). Wiley India Edition. New Delhi.

Additional Readings:

1. Ghorpade, Sudhir R. & Limaye, B. V. (2006). A Course in Calculus and Real Analysis. Undergraduate Texts in Mathematics, Springer (SIE). First Indian reprint.
2. Mattuck, Arthur. (1999). Introduction to Analysis, Prentice Hall.
3. Ross, Kenneth A. (2013). Elementary Analysis: The theory of calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.

CC6 : Group Theory

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc.

CO2: Link the fundamental concepts of Groups and symmetrical figures.

CO3: Analyze the subgroups of cyclic groups.

CO4: Explain the significance of the notion of cosets, normal subgroups, and factor groups.

CC6 : Group Theory (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Definition and examples of groups, Elementary properties of groups, Subgroups and examples of subgroups, Centralizer, Normalizer, Center of a group, Product of two subgroups; Properties of cyclic groups, Classification of subgroups of cyclic groups.	14
2	Permutations Groups, Properties of permutations, Even and odd permutations, Properties of Cosets, Lagrange's theorem and consequences including Fermat's Little theorem; Normal subgroups, Quotient groups, Cauchy's theorem for finite abelian groups	12
3	Group homomorphisms, Properties of homomorphisms, Group isomorphisms, Cayley's theorem, Properties of isomorphisms, First, Second and Third isomorphism theorems for groups.	10
4	Automorphism, Inner automorphism, Automorphism groups, Automorphism groups of finite and infinite cyclic groups.	12
5	Conjugacy classes, The class equation, p-groups, The Sylow theorems and consequences, Applications of Sylow theorems.	12
	TOTAL	60

Reading List :

1. Gallian, Joseph. A. (2013). Contemporary Abstract Algebra (8^{th} ed.). Cengage Learning India Private Limited, Delhi. Fourth impression, 2015.
2. N. Herstein, Topics in Algebra.

Additional Reading:

1. K K Jha, Advanced Abstract Algebra
2. Khanna and Bhamri, Abstract Algebra

CC7 : Partial Differential Equations

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Formulate, classify and transform partial differential equations into canonical form.

CO2: Solve linear and non-linear partial differential equations using various methods; and apply these methods in solving some physical problems.

CC7 : Partial Differential Equations (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Partial differential equations – Basic concepts and definitions. Formation of PDE, Mathematical problems. First order equations: classification, construction and geometrical interpretation, Lagrange's and Charpit's method for solving PDE.	14
2	Method of characteristics for obtaining general solution of quasi linear equations, Canonical forms of first-order linear equations, Method of separation of variables for solving first order partial differential equations.	12
3	Partial differential equation of second and higher order, Homogeneous and non-homogeneous equation with constant coefficients, Cauchy problem for second order PDE.	12
4	Partial differential equations reducible to equations with constant coefficients, Monge's Methods	10
5	Classification of second order linear equations as hyperbolic, parabolic or elliptic, Reduction of second order linear equations to canonical forms, Concept of the wave equation and heat equation.	12
	TOTAL	60

Suggested Reading :

1. Myint-U, Tyn& Debnath, Lokenath. (2007). Linear Partial Differential Equation for Scientists and Engineers (4th ed.). Springer, Third Indian Reprint, 2013.

Additional Readings:

1. Sneddon, I. N. (2006). Elements of Partial Differential Equations, Dover Publications. Indian Reprint.
2. Stavroulakis, Ioannis P &Tersian, Stepan A. (2004). Partial Differential Equations: An Introduction with Mathematica and MAPLE (2nd ed.). World Scientific.
3. M. D. Raisinghania, Ordinary and Partial Differential Equations, S. Chand Publication.

SEMESTER – IV

CC8 : Ring Theory and Linear Algebra-I

Course Outcomes

After the completion of the course, the student will be able to:

CO1: The fundamental concept of Rings, Fields, subrings, integral domains and the corresponding homomorphisms.

CO2: The concept of linear independence of vectors over a field, the idea of a finite dimensional vector space, basis of a vector space and the dimension of a vector space.

CO3: Basic concepts of linear transformations, the Rank-Nullity Theorem, matrix of a linear transformation, algebra of transformations and the change of basis.

CC8 : Ring Theory and Linear Algebra-I (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Definition and examples of rings, Properties of rings, Subrings, Integral domains and fields, Characteristic of a ring, Ideal, Ideal generated by a subset of a ring, Quotient rings, Operations on ideals, Prime and maximal ideals.	14
2	Ring homomorphisms, Properties of ring homomorphisms, Isomorphism theorems.	10
3	Vector spaces, Subspaces, Algebra of subspaces, Quotient spaces, Linear combination of vectors, Linear span, Linear independence, Basis and dimension, Dimension of subspaces.	14
4	Linear transformations, Rank-Nullity theorem, Matrix representation of a linear transformation, Algebra of linear transformation, Eigen values and Eigen vector, Characteristic equation of a matrix and Cayley-Hamilton theorem.	12
5	Isomorphisms, Isomorphism theorems, Invertibility and Isomorphisms, Change of coordinate matrix.	10
	TOTAL	60

Suggested Reading :

1. Gallian, Joseph. A. (2013). Contemporary Abstract Algebra (8th ed.). Cengage Learning India Private Limited. Delhi. Fourth impression, 2015.
2. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2003). Linear Algebra (4th ed.). Prentice-Hall of India Pvt. Ltd. New Delhi.
3. Hoffman and Kunze, Linear Algebra.

CC9 : Multivariate Calculus

Course Outcomes

After the completion of the course, the student will have to:

CO1: The conceptual variations when advancing in calculus from one variable to multivariable discussions.

CO2: Inter-relationship amongst the line integral, double and triple integral formulations.

CO3: Applications of multi variable calculus tools in physics, economics, optimization, and understanding the architecture of curves and surfaces in plane and space etc.

CC9 : Multivariate Calculus (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Functions of several variables, Level curves and surfaces, Limits and continuity, Partial differentiation, Higher order partial derivative, Tangent planes, Total differential and differentiability, Chain rule, Directional derivatives, Gradient, Maximal and normal property of the gradient, Tangent planes and normal lines.	14
2	Extrema of functions of two variables, Method of Lagrange multipliers, Constrained optimization problems.	10
3	Double integration over rectangular and nonrectangular regions, Double integrals in polar co-ordinates, Triple integral over a parallelepiped and solid regions, Volume by triple integrals, triple integration in cylindrical and spherical coordinates, Change of variables in double and triple integrals.	14
4	Line integrals, Applications of line integrals: Mass and Work, Fundamental theorem for line integrals, Definition of vector field, Conservative vector fields, Divergence and curl.	12
5	Green's theorem, Area as a line integral, Surface integrals, Stokes' theorem, The Gauss divergence theorem.	10
	TOTAL	60

Suggested Reading :

1. Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). Calculus (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi. Indian Reprint 2011.
2. Marsden, J. E., Tromba, A., & Weinstein, A. (2004). Basic Multivariable Calculus. Springer (SIE). First Indian Reprint.

CC10 : Complex Analysis

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Understand the significance of differentiability of complex functions leading to the understanding of Cauchy-Riemann equations.

CO2: Evaluate the contour integrals and understand the role of Cauchy-Goursat theorem and the Cauchy integral formula.

CO3: Expand some simple functions as their Taylor and Laurent series, classify the nature of singularities, find residues and apply Cauchy Residue theorem to evaluate integrals.

CC10 : Complex Analysis (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Functions of complex variable, Mappings; Mappings by the exponential function, Limits, Theorems on limits, Limits involving the point at infinity, Continuity, Derivatives, Differentiation formulae, Cauchy-Riemann equations, Sufficient conditions for differentiability; Analytic functions and their examples.	16
2	Exponential function, Logarithmic function, Branches and derivatives of logarithms, Trigonometric function, Derivatives of functions, Definite integrals of functions, Contours, Contour integrals and its examples, Upper bounds for moduli of contour integrals.	12
3	Antiderivatives, Proof of antiderivative theorem, Cauchy-Goursat theorem, Cauchy integral formula; An extension of Cauchy integral formula, Consequences of Cauchy integral formula, Liouville's theorem and the fundamental theorem of algebra.	12

4	Convergence of sequences and series, Taylor series and its examples; Laurent series and its examples, Absolute and uniform convergence of power series, Uniqueness of series representations of power series.	10
5	Isolated singular points, Residues, Cauchy's residue theorem, Residue at infinity; Types of isolated singular points, Residues at poles and its examples.	10
	TOTAL	60

Suggested Reading :

1. Brown, James Ward, & Churchill, Ruel V. (2014). Complex Variables and Applications (9th ed.). McGraw-Hill Education. New York.
2.

Additional Readings:

1. Bak, Joseph & Newman, Donald J. (2010). Complex analysis (3rd ed.). Undergraduate Texts in Mathematics, Springer. New York.
2. Zills, Dennis G., & Shanahan, Patrick D. (2003). A First Course in Complex Analysis with Applications. Jones & Bartlett Publishers, Inc.
3. Mathews, John H., & Howell, Rusell W. (2012). Complex Analysis for Mathematics and Engineering (6th ed.). Jones & Bartlett Learning. Narosa, Delhi. Indian Edition.

SEMESTER – V

CC11: Metric Space

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Understand the basic concepts of metric spaces;

CO2: Correlate these concepts to their counter parts in real analysis;

CO3: Appreciate the abstractness of the concepts such as open balls, closed balls, compactness, connectedness etc. beyond their geometrical imaginations.

CC11: Metric Space (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Metric spaces: Definition and examples, Notion of Open and closed ball, Neighbourhood, Open set, Interior of a set, Limit point of a set, Derived set, Closed set, Closure of a set, Diameter of a set, Dense set, Subspaces.	14
2	Sequences in metric spaces, Cauchy sequences, Complete metric space, Cantor's intersection theorem, Baire's category theorem, Contraction mapping, Banach fixed point theorem.	14
3	Continuous mappings, Sequential criterion and other characterizations of continuity, Uniform continuity, Homeomorphism.	12
4	Connectedness, Connected subsets of R, Connectedness and continuous mappings.	10
5	Compactness, Compactness and boundedness, Continuous functions on compact spaces.	10
	TOTAL	60

Suggested Reading :

1. Kumaresan, S. (2014). Topology of Metric Spaces (2nd ed.). Narosa Publishing House. New Delhi.
2. Simmons, G. F. (2004). Introduction to Topology and Modern Analysis. Tata McGraw Hill. New Delhi.

CC12 : Riemann Integration and Series of Functions

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Some of the families and properties of Riemann integrable functions, and the applications of the fundamental theorems of integration.

CO2: Beta and Gamma functions and their properties

CO3: The valid situations for the inter-changeability of differentiability and integrability with infinite sum, and approximation of transcendental functions in terms of power series.

CC12 : Riemann Integration and Series of Functions (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Definition and existence of Riemann Integral of bounded functions, Darboux's theorem Necessary and Sufficient condition for R-Integrability, Riemann integrability of continuous functions, Monotonic function and function having finite number of discontinuities, Riemann integral as the limit of a sum, Fundamental theorem of integral calculus, Mean value theorem.	14
2	Improper integrals of Type-I, Type-II and mixed type, Convergence of Beta and Gamma functions and their properties.	10
3	Pointwise and uniform convergence of sequence of functions, Theorems on continuity, Derivability and integrability of the limit function of a sequence of functions.	10
4	Series of functions, Theorems on the continuity and derivability of the sum function of a series of functions; Cauchy criterion for uniform convergence and Weierstrass M-Test.	12
5	Limit superior and Limit inferior. Power series, radius of convergence, Cauchy Hadamard Theorem, Differentiation and integration of power series; Abel's Theorem; Weierstrass Approximation Theorem.	14
	TOTAL	60

Suggested Reading :

1. Bartle, Robert G., &Sherbert, Donald R. (2015). Introduction to Real Analysis (4th ed.). Wiley India Edition. Delhi.
2. Ghorpade, Sudhir R. & Limaye, B. V. (2006). A Course in Calculus and Real Analysis. Undergraduate Texts in Mathematics, Springer (SIE). First Indian reprint.
3. Ross, Kenneth A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer.
4. Shanti Narayan, Elements of Real Analysis, S. Chand Publication.
5. K K Jha, Advanced Real Analysis.

SEMESTER – VI

CC13: Ring Theory and Linear Algebra-II

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Appreciate the significance of unique factorization in rings and integral domains.

CO2: Compute with the characteristic polynomial, eigenvalues, eigenvectors, and eigenspaces, as well as the geometric and the algebraic multiplicities of an eigenvalue and apply the basic diagonalization result.

CO3: Compute inner products and determine orthogonality on vector spaces, including Gram-Schmidt orthogonalization to obtain orthonormal basis.

CC13 : Ring Theory and Linear Algebra-II (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Characteristics of ring, Field of quotient of an integral domain, Embedding of rings, Polynomial rings, Division algorithm, Principal ideal domains, Euclidean domains, Unique factorization domains.	14
2	Dual spaces, dual basis, Double dual, Transpose of a linear transformation and its matrix in the dual basis.	12
3	Eigen spaces of a linear operator, Diagonalizability, Invariant subspaces, The minimal polynomial for a linear operator.	10
4	Inner product spaces and norms, Orthonormal basis, Gram-Schmidt orthogonalization process, Orthogonal complements, Bessel's inequality.	10
5	The adjoint of a linear operator, Least squares approximation, Minimal solutions to systems of linear equations, Normal, Self-adjoint, Unitary and orthogonal operators and their properties.	14
	TOTAL	60

Suggested Reading :

1. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2003). Linear Algebra (4th ed.). Prentice-Hall of India Pvt. Ltd. New Delhi
2. Gallian, Joseph. A. (2013). Contemporary Abstract Algebra (8th ed.). Cengage Learning India Private Limited. Delhi. Fourth impression, 2015.

Additional Readings:

1. Herstein, I. N. (2006). Topics in Algebra (2nd ed.). Wiley Student Edition. India.
2. Hoffman, Kenneth, & Kunze, Ray Alden (1978). Linear Algebra (2nd ed.). Prentice-Hall of India Pvt. Limited. Delhi. Pearson Education India Reprint, 2015.
3. Lang, Serge (1987). Linear Algebra (3rd ed.). Springer.
4. K K Jha, Advanced Linear Algebra.

CC14: Numerical Methods

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Some numerical methods to find the zeroes of nonlinear functions of a single variable and solution of a system of linear equations, up to a certain given level of precision.

CO2: Interpolation techniques to compute the values for a tabulated function at points not in the table.

CO3: Applications of numerical differentiation and integration to convert differential equations into difference equations for numerical solutions.

CC14 : Numerical Methods (Theory: 4 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Errors: Relative, Absolute, Round off, Truncation, Finding roots of Transcendental and Polynomial equations: Bisection method, Secant method, Regula-Falsi method, Newton-Raphson method, Fixed point iteration method, Rate of convergence.	12
2	Solution of system of linear algebraic equations: Partial and scaled partial pivoting, LU decomposition and its applications, Gaussian Elimination and Gauss Jordan methods. Gauss Jacobi method, Gauss Seidel method and SOR methods and their convergence analysis.	12
3	Finite Central and divided differences, Interpolation, Inverse Interpolation, Numerical differentiation, Numerical Integration: Newton Cotes formula, Trapezoidal rule, Simpson's $1/3^{rd}$ rule, Simpsons $3/8^{th}$ rule, Gauss quadrature formula.	12
4	Solution of difference equation of the first order, General solution, Linear difference equation with constant co-efficient, Solution of ordinary differential equations one step method: Euler's modified, Picard's, Runge-Kutta methods.	12
	TOTAL	48

Suggested Reading :

1. Bradie, Brian. (2006). A Friendly Introduction to Numerical Analysis. Pearson Education, India. Dorling Kindersley (India) Pvt. Ltd. Third impression 2011.

Additional Readings:

1. Jain, M. K., Iyengar, S. R. K., & Jain, R. K. (2012). Numerical Methods for Scientific and Engineering Computation. (6th ed.). New Age International Publisher, India, 2016.
2. Gerald, C. F., & Wheatley, P. O. (2008). Applied Numerical Analysis (7th ed.). Pearson Education. India.
3. S. S. Sastry, Introductory methods of numerical analysis.

CC14 : Numerical Methods (Practical: 2 credits)
Practical List of Practicals (using any software) (i) Calculate the sum 1/1 + 1/2 + 1/3 + 1/4 + -------+ 1/ n. (ii) To find the absolute value of an integer. (iii) Enter 100 integers into an array and sort them in an ascending order. (iv) Bisection Method. (v) Newton Raphson Method. (vi) LU decomposition Method. (vii) Lagrange Interpolation or Newton Interpolation. Note: For any of the CAS (Computer aided software) Data types simple data types, floating data types, character data types, arithmetic operators and operator precedence, variables and constant declarations, expressions, input/output, relational operators, logical operators and logical expressions, control statements and loop statements, Arrays should be introduced to the students. 20

General Elective

SEMESTER – I

GE1 : Mechanics

Course Outcomes

After the completion of the course, the student will be able to:

CO1: The significance of mathematics involved in physical quantities and their uses;
CO2: To study and to learn the cause-effect related to these; and
CO3: The applications in observing and relating real situations/structures.

GE1 : Mechanics (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Reduction of a system of Co-planar forces, equation of the line of action of the resultant, Virtual work, Principle of virtual work for a system of particles, Forces in three dimensions.	12
2	General conditions of equilibrium, Stable and unstable equilibrium, Common catenary, Centre of gravity for different bodies.	10
3	Rectilinear motion in a non-resisting and a resisting medium, Harmonic oscillator, damped and free vibrations, elastic strings and springs, vertical and horizontal motion of a particle attached to an elastic string.Motion in a plane, velocities and accelerations in Cartesian, polar and intrinsic Co-ordinates, motion of a projectile in non-resisting and resisting medium, constrained motion in a smooth horizontal and vertical circle, simple pendulum.	14
4	Motion of a particle under a central force, differential equation of a central orbit in rectilinear, polar and pedal coordinates, Central orbits, Kepler's laws of motion deduced from Newton's law of Gravitation and vice-versa.	12

5	Degrees of freedom, Moments and products of inertia, Principal axes, D'Alembert's Principle. Motion about a fixed axis, Compound pendulum, Motion of a rigid body in two dimensions under finite and impulsive forces, Conservation of momentum and energy.	12
	TOTAL	60

Suggested Reading :

1. Hibbeler, R. C. (2016). *Engineering Mechanics*: *Statics & Dynamics* (14th ed.). Pearson Prentice Hall (Pearson Education), New Jersey.
2. Shames, Irving H., & Rao, G. Krishna Mohan (2009). *Engineering Mechanics*: *Statics and Dynamics* (4th ed.). Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). Delhi.

SEMESTER – II

GE2 : Mathematical Modelling and Graph Theory

Course Outcomes

After the completion of the course, the student will be able to:

CO1: The use of mathematics software to observe the implementations of the above-mentioned methods efficiently, and to enhance the problem-solving skills.

CO2: To solve physical problems using differential equations.

GE2 : Mathematical Modelling and Graph Theory (Theory: 4 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Power series solution of a differential equation about an ordinary point, Solution about a regular singular point, The method of Frobenius. Legendre's and Bessel's equation.	12
2	Fourier series for odd and even functions, Half range series, other forms of Fourier series, Laplace transform and inverse transform, application to initial value problem up to second order.	12
3	Monte Carlo Simulation Modeling: Simulating deterministic behavior (area under a curve, volume under a surface); Generating Random Numbers: Middle square method, Linear congruence; Queuing Models: Harbor system, Morning rush hour. Overview of optimization modeling; Linear Programming Model: Geometric solution, Algebraic solution, Simplex method, Sensitivity analysis.	12
4	Graphs, Diagraphs, Networks and subgraphs, Vertex degree, Paths and cycles, Regular and bipartite graphs, Four cube problem, Social networks, Exploring and traveling, Eulerian and Hamiltonian graphs, Applications to dominoes, Diagram tracing puzzles, Knight's tour problem, Gray codes.	12
	TOTAL	48

Suggested Reading :

1. Aldous, Joan M., & Wilson, Robin J. (2007). Graphs and Applications: An Introductory Approach. Springer. Indian Reprint.
2. Edwards, C. Henry, Penney, David E., &Calvis, David T. (2015). Differential Equation and Boundary Value Problems: Computing and Modeling (5th ed.). Pearson.
3. Giordano, Frank R., Fox, William P., & Horton, Steven B. (2014). A First Course in Mathematical Modeling (5th ed.). Brooks/Cole, Cengage Learning.

GE2 : Mathematical Modelling and Graph Theory (Practical: 2 credits)
Practical : Modeling of the following problems using Mathematica/MATLAB/Maple /Maxima/Scilab etc. (i). Plotting of Legendre polynomial for n = 1 to 5 in the interval [0, 1]. Verifying graphically that all the roots of Pn (x) lie in the interval [0, 1]. (ii). Automatic computation of coefficients in the series solution near ordinary points. (iii). Plotting of the Bessel's function of first kind of order 0 to 3. (iv). Automating the Frobenius Series Method. (v). Random number generation and then use it for one of the following:

a) Simulate area under a curve.
b) Simulate volume under a surface.
(vi). Programming of either one of the queuing model:
a) Single server queue (e.g. Harbor system).
b) Multiple server queue (e.g. Rush hour).
(vii). Programming of the Simplex method for 2 / 3 variables.

SEMESTER – III
GE3 : Advanced Group Theory

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Automorphisms for constructing new groups from the given group.
CO2: External direct product applies to data security and electric circuits.
CO3: Group actions, nonsimplicity and their applications.

GE3 : Advanced Group Theory (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Applications of factor groups to automorphism groups, Characteristic subgroups, Commutator subgroup and its properties.	12
2	External direct products of groups and its properties, The group of units modulo n as an externaldirect product, Applications to data security and electric circuits;	12
3	Internal direct products, Classification of groups of order p^2 where p is a prime; Fundamental theorem of finite Abelian groups and its isomorphism classes.	12
4	Group actions and permutation representations; Stabilizers and kernels of group actions; Groups acting on themselves by left multiplication and consequences; Conjugacy in S_n.	12
5	Finite simple groups, Nonsimplicity tests; Generalized Cayley's theorem, Index theorem, Embedding theorem and applications. Simplicity of A_5.	12
	TOTAL	60

Suggested Reading :

1. Dummit, David S., & Foote, Richard M. (2016). Abstract Algebra (3rd ed.). Student
2. Edition. Wiley India.
3. Gallian, Joseph. A. (2013). Contemporary Abstract Algebra (8th ed.). Cengage
4. Learning India Private Limited. Delhi. Fourth impression, 2015.
5. K K Jha, Advanced Abstract Algebra

SEMESTER – IV

GE4 : C++ Programming for Mathematics

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Understand and apply the programming concepts of C++ which is important to mathematical investigation and problem solving.

CO2: Use mathematical libraries for computational objectives.

CO3: Represent the outputs of programs visually in terms of well formatted text and plots.

GE4 : C++ Programming for Mathematics (Theory: 4 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Fundamentals of programming, Organization of logic flow in stored program model of computation, C++ as a general-purpose programming language, Structure of a C++ program, Common compilers and IDE's, Basic data-types, Variables and literals in C++, Operators, Expressions, Evaluation precedence, and Type compatibility. Outline of program development in C++, Debugging and testing. Applications: Greatest common divisor, and Random number generation.	14
2	Structured data-types in C++, Arrays and manipulating data in arrays with applications in factorization of an integer and finding Euler's totient; Objects and classes: Information hiding, Modularity, Constructors and Destructors, Methods and Polymorphism. Applications: Cartesian geometry using points (2 & 3-dimensional), and Pythagorean triples.	12
3	Containers and Template Libraries: Sets, Iterators, Multisets, Vectors, Maps, Lists, Stacks and Queues. Applications: Basic set algebra, Modulo arithmetic, Permutations, and Polynomials.	10
4	Arbitrary precision arithmetic using the GMP package; Linear algebra: Two-dimensional arrays in C++ with applications in finding Eigenvalues, Eigenvectors, Rank, Nullity, and Solving system of linear equations in matrices. Features of C++ for input/output and visualization: Strings, Streams, Formatting methods, Processing files in a batch, Command-line arguments, Visualization packages and their use in plots.	12
	TOTAL	48

Suggested Reading :

1. Scheinerman, Edward (2006). C++ for Mathematicians: An Introduction for Students and Professionals. Chapman & Hall/CRC. Taylor & Francis Group, LLC.

Additional Readings:

1. Dale, Nell & Weems, Chip (2013). Programming and Problem Solving with C++ (6th ed.). Comprehensive Edition. Jones & Bartlett Learning.
2. Gottschling, Peter (2016). Discovering Modern C++: An Intensive Course for
3. Scientists, Engineers, and Programmers. Addison-Wesley. Pearson Education, Inc.
4. Josuttis, Nicolai M. (2012). The C++ Standard Library: A Tutorial and Reference (2nd ed.). Addison-Wesley. Pearson Education, Inc.
5. Lippman, Stanley B. (2000). Essential C++. Addison-Wesley.
6. Stroustrup, Bjarne (2013). The C++ Programming Language (4th ed.). Addison-Wesley.

GE4 : C++ Programming for Mathematics (Practical: 2 credits)
Practical A: Preparatory 1. Setting up of C++ programming environment on Linux/Windows/Mac OS; gcc/g++/mingw/cc, Program-development methodology and use IDE's or other tools. 2. Demonstration of sample programs for a. "Hello World" b. Sum of an arithmetic progression. c. Value of sin x using series expansion. 3. Finding/demonstrating:

a. Machine epsilon.
b. Integer and float overflow/underflow.
c. Iteration and selection based logic.
(provide a list of 8-10 problems suitable to learners needs)

B: Evaluative:

Set-I:

1. Greatest common divisor (including Euclid's Method).
2. Random number generation (including a Monte Carlo Program).

Set-II:

1. Factorization of an integer, and Euler's totient.
2. Cartesian geometry using points (2 & 3-dimensional).
3. Pythagorean triples.

Set-III:

1. Basic set algebra.
2. Modulo arithmetic.
3. Permutations.
4. Polynomials.

Set-IV:

1. Arbitrary precision arithmetic using the GMP package.
2. Finding Eigenvalues, Eigenvectors, Rank, Nullity, and Solving system of linear equations in matrices.
3. Plots (using the GNU plot package).

SEMESTER – V
DSE1 : Mathematical Finance

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Financial markets and derivatives including options and futures.
CO2: Pricing and hedging of options, interest rate swaps and no-Arbitrage pricing concept.
CO3: Stochastic analysis (Ito formula and Ito integration) and the Black-Scholes model.

DSE1 : Mathematical Finance (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Interest rates, Types of rates, Measuring interest rates, Zero rates, Bond pricing, Forward rate, Duration, Convexity, Exchange traded markets and OTC markets, Derivatives--Forward contracts, Futures contract, Options, Types of traders, Hedging, Speculation, Arbitrage.	12
2	No Arbitrage principle, Short selling, Forward price for an investment asset, Types of Options, Option positions, Underlying assets, Factors affecting option prices, Bounds on option prices, Put-call parity, Early exercise, Effect of dividends.	12
3	Binomial option pricing model, Risk neutral valuation (for European and American options on assets following binomial tree model), Lognormal property of stock prices, Distribution of rate of return, expected return,	12
4	Volatility, estimating volatility from historical data, Extension of risk neutral valuation to assets following GBM, Black-Scholes formula for European options.	10
5	Hedging parameters (the Greeks: Delta, Gamma, Theta, Rho and Vega), Trading strategies involving options, Swaps, Mechanics of interest rate swaps, Comparative advantage argument, Valuation of interest rate swaps, Currency swaps, Valuation of currency swaps.	14
	TOTAL	60

Suggested Reading :

1. Hull, J. C., &Basu, S. (2010). Options, Futures and Other Derivatives (7th ed.). Pearson Education. New Delhi.
2. Luenberger, David G. (1998). Investment Science, Oxford University Press. Delhi.
3. Ross, Sheldon M. (2011). An elementary Introduction to Mathematical Finance (3rd ed.). Cambridge University Press. USA.

DSE2 : Number Theory

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Some of the open problems related to prime numbers.

CO2: About number theoretic functions and modular arithmetic.

DSE2 : Number Theory (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Division algorithm, Euclidean algorithm and Greatest common Divisor (GCD or HCF), Prime and Composite numbers, Fundamental theorem of arithmetic, Co-primes, Divisor of composite numbers.	12
2	Linear Diophantine equation, Prime counting function, Prime numbertheorem, Fermat theorem	12
3	The order of an integer modulo n, Primitive roots for primes, Composite numbers having primitive roots; Definition of quadratic residue of an odd prime, and Euler's criterion.	12
4	Congruence relation and its properties, Linear congruence and Chinese remainder theorem, Fermat's little theorem, Wilson's theorem.	12
5	Number theoretic functions for sum and number of divisors, Multiplicative function, The Mobius inversion formula, The greatest integer function. Euler's phi-function and properties, Euler's theorem.	12
	TOTAL	60

Suggested Reading :

1. Burton, David M. (2007). *Elementary Number Theory* (7th ed.). Tata Mc-Graw Hill Edition, Indian Reprint.
2. Jones, G. A., &Jones, J. Mary. (2005). *Elementary Number Theo*ry. Undergraduate Mathematics Series (SUMS). First Indian Print.

Additional Reading:

1. Neville Robinns. (2007). *Beginning Number Theory* (2nd ed.). Narosa Publishing House Pvt. Limited, Delhi.

SEMESTER – VI

DSE3 : Boolean Algebra and Automata Theory

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Lattices and their types;

CO2: Boolean algebra, switching circuits and their applications;

DSE3 : Boolean Algebra and Automata Theory (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of Lectures**
1	Definition, examples and basic properties of ordered sets, maps between ordered sets, duality principle, lattices as ordered sets, lattices as algebraic structures, sublattices, products and homomorphisms.	12
2	Definition, examples and properties of modular and distributive lattices, Boolean algebras, Boolean polynomials, minimal and maximal forms of Boolean polynomials, Quinn-McCluskey method, Karnaugh diagrams, Logic gates, switching circuits and applications of switching circuits.	12
3	Introduction: Alphabets, strings, and languages. Finite automata and regular languages: deterministic and non-deterministic finite automata, regular expressions, regular languages and their relationship with finite automata, pumping lemma and closure properties of regular languages.	12

4	Context free grammars and pushdown automata: Context free grammars (CFG), parse trees, ambiguities in grammars and languages, pushdown automaton (PDA) and the language accepted by PDA, deterministic PDA, Non- deterministic PDA, properties of context free languages; normal forms, pumping lemma, closure properties, decision properties.	12
5	Turing Machines: Turing machine as a model of computation, programming with a Turing machine, variants of Turing machine and their equivalence.	12
	TOTAL	60

Suggested Reading :

1. B A. Davey and H. A. Priestley, Introduction to Lattices and Order, Cambridge University Press, Cambridge, 1990.
2. Edgar G. Goodaire and Michael M. Parmenter, Discrete Mathematics with Graph Theory,(2nd Ed.), Pearson Education (Singapore) P. Ltd., Indian Reprint 2003.
3. Rudolf Lidl and Günter Pilz, Applied Abstract Algebra, 2nd Ed., Undergraduate Texts in
4. Mathematics, Springer (SIE), Indian reprint, 2004.
5. J. E. Hopcroft, R. Motwani and J. D. Ullman, Introduction to Automata Theory, Languages, and Computation, 2nd Ed., Addison-Wesley, 2001.
6. H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, Elements of the Theory of Computation, 2nd Ed., Prentice-Hall, NJ, 1997.
7. J.A. Anderson, Automata Theory with Modern Applications, Cambridge University Press, 2006.

SEMESTER – VI
DSE4 : Differential Geometry

Course Outcomes

After the completion of the course, the student will be able to:

- **CO1:** Understand the theory of surfaces and curves in three dimensions.
- **CO2:** Acquire knowledge about method of the moving frame and overdetermined systems in Surface theory.
- **CO3:** Provide examples of Manifolds and investigate their properties.
- **CO4:** Understand the different concepts related to Tensors.

DSE4 : Differential Geometry (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of hours**
1	Theory of Space Curves: Space curves, Parametrized Curves and Arc Length, Planer curves, Curvature, torsion and Serret-Frenet formulae. Osculating plane, normal plane, rectifying plane and osculating circles and spheres.	12
2	Fundamental Theorem of the Local Theory of Curves. Evolutes and involutes of curves, Helix and Bertrand curves.	10
3	Theory of Surfaces: Regular Surfaces and Inverse Image of Regular Values, Parametric curves on surfaces, Change of Parameters and Differential Functions on Surfaces, The Tangent Plane, The Differential of a map, first Fundamental form, angle between two curves on a surface, area under parametric curves, second Fundamental form, Developable surfaces, Minimal surfaces.	14
4	Tensors: Summation convention and indicial notation, Coordinate transformation and Jacobian,Contra-variant and Covariant vectors, Tensors of different type, Algebra of tensors and contraction, Metric tensor and 3-index Christoffel symbols, Parallel propagation of vectors,	14
5	Covariant and intrinsic derivatives, Curvature tensor and its properties, Curl, Divergence and Laplacian operators in tensor form, Physical components.	10
	TOTAL	60

Suggested Reading :

1. T.J. Willmore, An Introduction to Differential Geometry, Dover Publications, 2012.
2. B. O'Neill, Elementary Differential Geometry, 2nd Ed., Academic Press, 2006.

3. C.E. Weatherburn, Differential Geometry of Three Dimensions, Cambridge University Press
4. 2003.
5. D.J. Struik, Lectures on Classical Differential Geometry, Dover Publications, 1988.
6. S. Lang, Fundamentals of Differential Geometry, Springer, 1999.
7. E. Kreyszig, Differential Geometry, Dover Publications, New York, 1991.

SEMESTER – VI
DSE5 : Cryptography and Network Security

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Understand the fundamentals of Cryptography and Network Security, including data and advanced encryption standard (DES & AES), RSA and elliptic curve cryptography.

CO2: Encrypt and decrypt messages using block ciphers, sign and verify messages using well known signature generation and verification algorithms.

CO3: Acquire knowledge of standard algorithms that can be used to provide confidentiality, integrity and authentication of data.

DSE5 : Cryptography and Network Security (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of hours**
1	Review of basic concepts in Number theory and Finite Fields: Divisibility, Polynomial and modular arithmetic, Fermat's and Euler's theorems, The Chinese remainder theorem, Discrete logarithm., Finite fields of the form GF(p) and GF(2n).	12
2	Overview of Cryptography, Computer security concepts, Security attacks, Symmetric cipher model, Cryptanalysis and brute-force attack, Substitution techniques, Caesar cipher, Monoalphabetic ciphers, Playfair cipher, Hill cipher, Polyalphabetic ciphers, One-time pad, Transposition techniques, Binary and ASCII,	14
3	Pseudo-random bit generation, Stream ciphers and Block ciphers, The Feistal cipher, The data encryption standard (DES), DES example, Advanced encryption standard (AES), AES transformation functions, AES key expansion, AES example.	12
4	Principles of public-key cryptosystems, The RSA algorithm and security of RSA, Elliptic curve arithmetic, Elliptic curve cryptography, Cryptographic Hash functions, Secure Hash algorithm.	10
5	Digital signatures, Elgamal and Schnorr digital signature schemes, Digital signature algorithm. Wireless network and mobile device security, Email architecture, formats, threats and security, Secure/Multipurpose Internet Mail Extension (S/MIME) and Pretty Good Privacy (PGP).	12
	TOTAL	60

Suggested Reading :

1. Stallings, William (2017). Cryptography and Network Security, Principles and Practice (7th ed.). Pearson Education Limited. England.
2. Trappe, Wade & Washington, Lawrence C. (2006). Introduction to Cryptography with Coding Theory (2nd ed.). Pearson Education International.

Additional Reading:

1. Stinson, Douglas R. (2005). Cryptography Theory and Practice (3rd ed.). CRC Press.

SEMESTER – VI
DSE6 : Point Set Topology

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Work basic problems (proofs, construction of examples, counter-examples, or argue that a claim is false) in the Topology of R, Topology of Metric Spaces, etc.

CO2: Become familiar with separability, completeness, connectedness, compactness, density, and basis.

DSE6 : Point Set Topology (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of hours**
1	Countable and Uncountable Sets, Schroeder-Bernstein Theorem, Cantor's Theorem. Cardinal numbers and cardinal arithmetic. Continuum Hypothesis, Zorns Lemma, Axiom of Choice. Well-ordered sets, Hausdorff's maximal principle. Ordinal numbers.	14
2	Topological spaces, basis and sub-basis for a topology, subspace topology, interior points, Limit points, derived set, boundary of a set, closed sets, closure and interior of a set.	12
3	Continuous functions, open maps, closed maps and homeomorphisms. Product topology, quotient topology, metric topology, Baire category theorem.	12
4	Connected and path connected spaces, connected sets in R, components and path components, local connectedness, Compact spaces, compact sets in R. Compactness in metric spaces.	12
5	Totally bounded spaces, Ascoli-Arzela theorem, the Lebesgue number lemma. Local compactness.	10
	TOTAL	60

Suggested Reading :

1. Munkres, J.R., Topology, A First Course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
2. Dugundji, J., Topology, Allyn and Bacon, 1966.
3. Simmons, G.F., Introduction to Topology and Modern Analysis, McGraw Hill, 1963.
4. Kelley, J.L., General Topology, Van Nostrand Reinhold Co., New York,1995.
5. Hocking, J., Young, G., Topology, Addison-Wesley Reading, 1961.
6. Steen, L., Seebach, J., Counter Examples in Topology, Holt, Reinhart and Winston, New York, 1970.
7. Abhijit Dasgupta, Set Theory, Birkhäuser.
8. K K Jha, Advanced Set Theory.
9. K K Jha, Advanced Topology.

SEMESTER – VI
DSE7 : Linear Programming and Applications

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Analyze and solve linear programming models of real-life situations.

CO2: The graphical solution of LPP with only two variables, and illustrate the concept of convex set and extreme points. The theory of the simplex method is developed.

CO3: The relationships between the primal and dual problems and their solutions with applications to transportation and assignment.

DSE7 : Linear Programming and Applications (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of hours**
1	The Linear Programming Problem: Standard, Canonical and matrix forms, Graphical solution. Hyperplanes, Extreme points, Convex and polyhedral sets. Basic solutions; Basic Feasible Solutions; Reduction of any feasible solution to a basic feasible solution; Correspondence between basic feasible solutions and extreme points.	14
2	Simplex Method: Optimal solution, Termination criteria for optimal solution of the Linear Programming Problem, Unique and alternate optimal solutions, Unboundedness; Simplex Algorithm and its Tableau Format; Artificial variables, Two-phase method, Big-M method.	12
3	Motivation and Formulation of Dual problem; Primal-Dual relationships; Fundamental Theorem of Duality; Complimentary Slackness.	10
4	Assignment Problem: Mathematical formulation and Hungarian method of solving.	10
5	Transportation Problem: Definition and formulation; Methods of finding initial basic feasible solutions; North West corner rule. Least cost method; Vogel's Approximation method; Algorithm for solving Transportation Problem	14
	TOTAL	60

Suggested Reading :

1. Bazaraa, Mokhtar S., Jarvis, John J., &Sherali, Hanif D. (2010). Linear Programming and Network Flows (4th ed.). John Wiley and Sons.
2. Hadley, G. (1997). Linear Programming. Narosa Publishing House. New Delhi.
3. Taha, Hamdy A. (2010). Operations Research: An Introduction (9th ed.). Pearson.

Additional Readings:

1. Hillier, F. S. & Lieberman, G. J. (2010). Introduction to Operations Research- Concepts and Cases (9th ed.). Tata McGraw Hill.
2. Thie, Paul R., & Keough, G. E. (2014). An Introduction to Linear Programming and Game Theory. (3rd ed.). Wiley India Pvt. Ltd.

SEMESTER – VI
DSE8 : Attraction, Potential and Hydrostatics

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Learn the concept of attraction and potential of rods, rectangles, etc.
CO2: Learn the basic concept of hydrostatic pressure in various situations.
CO3: Analyze the centre of pressure for different types of bodies.

DSE8 : Attraction, Potential and Hydrostatics (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of hours**
1	Attraction and Potential of rods, rectangles and circular discs, spherical shell, sphere, Laplace's and Poisson's equations, theorems on equipotential surfaces.	12
2	Perfect fluid. Pressure at a point. Pressure of heavy fluid. Pressure at any point of a fluid at rest is the same in every direction. Conditions of equilibrium for homogeneous, heterogeneous, and elastic fluid.	12
3	Lines of force. Surfaces of equal pressure and density. Pressure gradient, pressure function and equation of equilibrium. Homogeneous fluid at rest under gravity.	12
4	Definition of centre of pressure. Formula for the depth of the centre of pressure of a plane area. Position of centre of pressure.	12
5	Thrusts on plane and curved surfaces. Rotating fluid. Pressure at any point and surfaces of equi-pressure when a mass of homogeneous fluid contained in a vessel revolves uniformly about a vertical axis. Floating bodies. Stability of equilibrium of floating bodies.	12
	TOTAL	60

Suggested Reading :

1. Batchelor, George K. (1967). An Introduction to Fluid Dynamics. Cambridge University Press. ISBN 0-521-66396-2.
2. Falkovich, Gregory (2011). Fluid Mechanics (A short course for physicists). Cambridge University Press. ISBN 978-1-107-00575-4.
3. Kundu, Pijush K.; Cohen, Ira M. (2008). Fluid Mechanics (4th rev. ed.). Academic Press. ISBN 978-0-12-373735-9.
4. Currie, I. G. (1974). Fundamental Mechanics of Fluids. McGraw-Hill. ISBN 0-07-015000-1.
5. Massey, B.; Ward-Smith, J. (2005). Mechanics of Fluids (8th ed.). Taylor & Francis. ISBN 978-0-415-36206-1.
6. White, Frank M. (2003). Fluid Mechanics. McGraw–Hill. ISBN 0-07-240217-2.
7. F. Chorlton, Textbook of Fluid Dynamics.

SEMESTER – VI
DSE9 : Probability Theory and Statistics

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Distributions to study the joint behavior of two random variables.

CO2: To establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression

CO3: Central limit theorem, which helps to understand the remarkable fact that**:** the empirical frequencies of so many natural populations, exhibit a bell-shaped curve.

DSE9 : Probability Theory and Statistics (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of hours**
1	Sample space, Probability set function, Real random variables - Discrete and continuous, Cumulative distribution function, Probability mass/density functions, Transformations, Mathematical expectation, Moments, Moment generating function, Characteristic function.	14
2	Discrete distributions: Uniform, Bernoulli, Binomial, Negative binomial, Geometric and Poisson; Continuous distributions: Uniform, Gamma, Exponential, Chi-square, Beta and normal; Normal approximation to the binomial distribution.	12
3	Joint cumulative distribution function and its properties, Joint probability density function, Marginal distributions, Expectation of function of two random variables, Joint moment generating function, Conditional distributions and expectations.	12
4	The Correlation coefficient, Covariance, Calculation of covariance from joint moment generating function, Independent random variables, Linear regression for two variables, The method of least squares,	12
5	Bivariate normal distribution, Chebyshev's theorem, Strong law of large numbers, Central limit theorem and weak law of large numbers.	10
	TOTAL	60

Suggested Reading :

1. Miller, Irwin & Miller, Marylees. (2014). John E. Freund's Mathematical Statistics with
2. Applications (8th ed.). Pearson. Dorling Kindersley (India).
3. Ross, Sheldon M. (2014). Introduction to Probability Models (11th ed.). Elsevier Inc. AP.
4. Gupta and Kapoor, Fundamentals of Mathematical Statistics, S. Chand Publication.

SEMESTER – VI
DSE10 : Computational Fluid Dynamics

Course Outcomes

After the completion of the course, the student will be able to:

CO1: Understand physical properties of a fluid

CO2: Know the classification of the basic equations of fluid dynamics

CO3: Recognize the type of fluid flow occurring in a particular physical system and to use the appropriate model equations to investigate the flow

CO4: Learn the dimensional analysis

CO5: Understand CFD technique

CO6: Demonstrate the ability to analyze a flow field to determine various quantities of interest, such as flow rates, heat fluxes, pressure drops, losses, etc., using flow visualization and analysis tools

DSE10 : Computational Fluid Dynamics (Theory: 4 credits)		
Unit	**Topics to be covered**	**No. of hours**
1	Introduction to Computational Fluid Dynamics (CFD): Advantages and applications of computational field.	08
2	CFD Techniques: Discretization of governing equations, Finite-difference method, finite-volume method, converting governing equation to algebraic equation system, numerical solutions to algebraic equations-Direct method, iterative methods, pressure velocity coupling.	14
3	Basic Concepts of Fluid Dynamics: Real fluids and ideal fluids, stream lines, steak lines and path lines, steady and unsteady flows, Lagrangian and Eulerian description.	12
4	Governing Equations of Fluid Dynamics: The continuity equation, momentum equation, energy equation, conservation of linear momentum, Navier-Stokes equation, conservation of energy, Reynolds transport theorem.	14
	TOTAL	48

Suggested Reading :

1. J. Tu, G. Heng Yeoh and C. Liu Computational Fluid Dynamics: A practical Approach, Butterworth-Heinemann, 2018.
2. S.V. Parankar, Numerical Heat Transfer and Fluid Flow, McGraw-Hill. 1980.
3. T. J. Chung, Computational Fluid Dynamics, Cambridge University Press, 2010.
4. J. H. Ferziger and M. Peric, Computational Methods for Fluid Dynamics, Springer, 2002.
5. G. D. Smith, Numerical Solution of Partial Differential Equations: Finite Difference Methods, Clarendon Press, 1985.
6. H. K. Versteeg and W. Malalasekera, An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Pearson, 2010.
7. J. C. Tannehill, D. A. Anderson and R. H. Pletcher, Computational Fluid Mechanics and Heat Transfer, McGraw Hill, 2002.

DSE10 : Computational Fluid Dynamics (Practical: 2 credits)
Practical : 1. Simulate simple CFD models and analyze its results 2. Some solvable fully developed viscous flow: (i) steady flow between parallel plates, (ii) steady flow in a pipe, (iii) steady flows between concentric cylinders. Dimensional Analysis Reynolds law of similarity, physical signification of some nondimensional parameters.

SEMESTER – VI

DSE11 : Bio-Mathematics

Course Outcomes

After the completion of the course, the student will be able to:

- **CO1:** Learn the development, analysis and interpretation of bio mathematical models.
- **CO2:** Reinforce the skills in mathematical modeling.
- **CO3:** Appreciate the theory of bifurcation and chaos.
- **CO4:** Learn to apply the basic concepts of probability to molecular evolution and genetics.

DSE11 : Bio-Mathematics (Theory: 6 credits)		
Unit	**Topics to be covered**	**No. of hours**
1	Population growth, Administration of drugs, Cell division, Systems of linear ordinary differential equations, Heartbeat, Nerve impulse transmission, Chemical reactions, Predator-prey models.	12
2	Stability and oscillations: Epidemics, The phase plane and the Jacobian matrix, Local stability, Stability, Limit cycles, Forced oscillations;	10

3	Mathematics of Heart Physiology: The local model, The Threshold effect, The phase plane analysis and the heartbeat model, A model of the cardiac pacemaker, Mathematics of Nerve Impulse Transmission: Excitability and repetitive firing, Travelling waves.	14
4	Bifurcation, Bifurcation of a limit cycle, Discrete bifurcation and period-doubling, Chaos, Stability of limit cycles, The Poincaré plane.	10
5	Modelling Molecular Evolution: Matrix models of base substitutions for DNA sequences, The Jukes-Cantor model, The Kimura models, Phylogenetic distances; Constructing Phylogenetic Trees: Phylogenetic trees, Unweighted pair-group method with arithmetic means (UPGMA), Neighbor joining method; Genetics: Mendelian genetics, Probability distributions in genetics.	14
	TOTAL	60

Suggested Reading :

1. Allman, Elizabeth S., & Rhodes, John A. (2004). Mathematical Models in Biology: An Introduction. Cambridge University Press.
2. Jones, D. S., Plank, M. J., &Sleeman, B. D. (2009). Differential Equations and Mathematical Biology (2nd ed.). CRC Press, Taylor & Francis Group, LLC.

Additional Readings:

1. Murray, J. D. (2002). An Introduction to Mathematical Biology (3rd ed.). Springer.
2. Myint-U, Tyn (1977). Ordinary Differential Equation. Elsevier North-Holland, Inc.
3. Simmons, George F., & Krantz, Steven G. (2015). Differential Equations. McGraw-Hill Education. Indian Reprint.
4. Strogatz, Steven H. (2009). Nonlinear Dynamics and Chaos (2nd ed.). Perseus Book Publishing. LLC. Sarat Publication, Kolkata, India.