UNIVERSITY OF DELHI

CNC-II/093/1(26)/2023-24/194

Dated: 14.09.2023

N O T I F I C A T I O N

Sub: Amendment to Ordinance V

[E.C Resolution No. 14/ (14-1-7/) and 27-1-2/ dated 09.06.2023 and 25.08.2023 respectively]

Following addition be made to Appendix-II-A to the Ordinance V (2-A) of the Ordinances of the University;

Add the following:

Syllabi of Semester-IV, V and VI of the following departments under Faculty of Mathematical Sciences based on Under Graduate Curriculum Framework -2022 implemented from the Academic Year 2022-23.

FACULTY OF MATHEMATICAL SCIENCES

1. Department of Mathematics
2. Department of Statistics
3. Department of Operational Research
4. Department of Computer Science

DEPARTMENT OF MATHEMATICS

Category-I

B.Sc. (Hons.) Mathematics, Semester-IV

DISCIPLINE SPECIFIC CORE COURSE – 10: SEQUENCES AND SERIES OF FUNCTIONS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Sequences and Series of Functions	4	3	1	0	Class XII pass with Mathematics	DSC-2: Real Analysis DSC-5: Calculus DSC-8: Riemann Integration

Learning Objectives: The objective of the course is to introduce:

- The sequences and series of real-valued functions as a generalization to the sequences and series of real numbers.
- The situations under which the process of convergence of a sequence and series of real-valued functions may commute with the processes of calculus while taking differentiation, or integration.
- An important class of series functions (i.e., power series), and the elementary functions-exponential, logarithmic and trigonometric.

Learning Outcomes: This course will enable the students to:

- Learn about Cauchy criterion for uniform convergence and Weierstrass *M*-test for uniform convergence of series of real-valued functions.
- Know about the constraints for the inter-changeability of differentiation, and integration with infinite sum of a series of functions.
- Handle the convergence of power series and properties of the limit function, including differentiation and integration of power series.
- Appreciate utility of polynomials in the space of continuous functions.

SYLLABUS OF DSC-10

UNIT – I: Sequences of Functions (18 hours)

Pointwise and uniform convergence of sequence of functions, The uniform norm, Cauchy criterion for uniform convergence, Continuity of the limit function of a sequence of functions, Interchange of the limit and derivative, and the interchange of the limit and integral of a sequence of functions, Bounded convergence theorem.

UNIT – II: Series of Functions (12 hours)

Pointwise and uniform convergence of series of functions, Theorems on the continuity, differentiability and integrability of the sum function of a series of functions, Cauchy criterion and the Weierstrass *M*-test for uniform convergence.

UNIT – III: Power Series **(15 hours)**

Definition of a power series, Radius of convergence, Absolute convergence (Cauchy-Hadamard theorem), Differentiation and integration of power series, Abel's theorem, Weierstrass's approximation theorem; The exponential, logarithmic and trigonometric functions: Definitions and their basic properties.

Essential Readings

1. Bartle, Robert G., & Sherbert, Donald R. (2011). Introduction to Real Analysis (4th ed.). Wiley India Edition. Indian Reprint.
2. Ross, Kenneth A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.

Suggestive Readings

- Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E. (2010). An Introduction to Analysis (2nd ed.). Jones and Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.
- Denlinger, Charles G. (2011). Elements of Real Analysis. Jones and Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

DISCIPLINE SPECIFIC CORE COURSE – 11: MULTIVARIATE CALCULUS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Multivariate Calculus	4	3	1	0	Class XII pass with Mathematics	DSC-2: Real Analysis DSC-5: Calculus DSC-8: Riemann Integration

Learning Objectives: The primary objective of this course is to introduce:

- The extension of the studies of single variable differential and integral calculus to functions of two or more independent variables.
- The geometry and visualisation of curves and surfaces in two dimensions (plane) and three dimensions (space).
- The techniques of integration to functions of two and three independent variables.
- The applications of multivariate calculus tools to physics, economics, optimization etc.

Learning Outcomes: This course will enable the students to:

- Learn the conceptual variations when advancing in calculus from one variable to multivariable discussion.
- Understand the maximization and minimization of multivariable functions subject to the given constraints on variables.
- Learn about inter-relationship amongst the line integral, double, and triple integral formulations.
- Familiarize with Green's, Stokes' and Gauss divergence theorems, and learn applications.

SYLLABUS OF DSC-11

UNIT – I: Calculus of Functions of Several Variables (18 hours)
Basic concepts, Limits and continuity, Partial derivatives, Tangent planes, Total differential, Differentiability, Chain rules, Directional derivatives and the gradient, Extrema of functions of two variables, Method of Lagrange multipliers with one constraint.

UNIT – II: Double and Triple Integrals (15 hours)
Double integration over rectangular and nonrectangular regions, Double integrals in polar co-ordinates, Triple integrals over a parallelopiped and solid regions, Volume by triple integrals, Triple integration in cylindrical and spherical coordinates, Change of variables in double and triple integrals.

UNIT – III: Green's, Stokes' and Gauss Divergence Theorem (12 hours)
Vector field, Divergence and curl, Line integrals and applications to mass and work, Fundamental theorem for line integrals, Conservative vector fields, Green's theorem, Area as a line integral, Surface integrals, Stokes' theorem, Gauss divergence theorem.

Essential Reading

1. Strauss, Monty J., Bradley, Gerald L., & Smith, Karl J. (2007). Calculus (3rd ed.). Dorling Kindersley (India) Pvt. Ltd. Pearson Education. Indian Reprint.

Suggestive Reading

- Marsden, J. E., Tromba, A., & Weinstein, A. (2004). Basic Multivariable Calculus. Springer (SIE). Indian Reprint.

DISCIPLINE SPECIFIC CORE COURSE – 12: NUMERICAL ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Numerical Analysis	4	3	0	1	Class XII pass with Mathematics	DSC-2: Real Analysis DSC-5: Calculus

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

- Various computational techniques to find approximate value for possible root(s) of algebraic and non-algebraic equations.
- Methods to solve system of linear equations and ordinary differential equations.
- The use of computer algebra system (CAS) by which the numerical problems can be solved both numerically and analytically, and to enhance the problem-solving skills.

Learning Outcomes: This course will enable the students to:

- Learn some numerical methods to find the zeroes of nonlinear functions of a single variable, up to a certain given level of precision.
- Learn Gauss−Jacobi, Gauss−Seidel methods to solve system of linear equations.
- Get aware of using interpolation techniques, for example in finding values of a tabulated function at points which are not part of the table.
- Learn finding numerical solutions of difference equations which are obtained converting differential equations using techniques from calculus.

SYLLABUS OF DSC-12

UNIT – I: Methods for Solving Algebraic and Transcendental Equations (12 hours)

Rate and order of convergence; Bisection method, Method of false position, Fixed point iteration method, Newton's method, and Secant method, their order of convergence and convergence analysis.

UNIT – II: Techniques to Solve Linear Systems and Interpolation (15 hours)

LU decomposition and its applications; Iterative methods: Gauss−Jacobi, Gauss−Seidel methods; Lagrange and Newton interpolation, Piecewise linear interpolation.

UNIT – III: Numerical Differentiation and Integration (18 hours)

First and higher order approximation for the first derivative, Approximation for the second derivative; Numerical integration by closed Newton−Cotes formulae: Trapezoidal rule, Simpson's rule and its error analysis; Euler's method to solve ODE's, Modified Euler method, Runge−Kutta Method (fourth-order).

Essential Reading

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

Suggestive Readings

- Gerald, Curtis F., & Wheatley, Patrick O. (2007). Applied Numerical Analysis (7th ed.). Pearson Education. India.
- 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.

Note: Non programmable scientific calculator may be allowed in the University examination.

Practical (30 hours)- Practical / Lab work to be performed in Computer Lab: Use of computer algebra system (CAS) software: Python/SageMath/Mathematica/MATLAB/Maple/Maxima/ Scilab etc., for developing the following numerical programs:

1. Bisection method.

2. Newton-Raphson method.
3. Secant method.
4. LU decomposition method.
5. Gauss−Jacobi method.
6. Gauss−Seidel method.
7. Lagrange interpolation.
8. Newton interpolation.
9. Trapezoidal rule.
10. Simpson's rule.
11. Euler’s method.
12. Runge−Kutta Method (fourth-order).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

B.Sc. (Hons) Mathematics, Semester-IV, DSE-Courses

DISCIPLINE SPECIFIC ELECTIVE COURSE – 2(i): BIOMATHEMATICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Biomathematics	**4**	**3**	**1**	**0**	**Class XII pass with Mathematics**	**DSC-6: Ordinary Differential Equations**

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.

SYLLABUS OF DSE-2(i)

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 and Modeling Molecular Evolution (15 hours)

Bifurcation, Bifurcation of a limit cycle, Discrete bifurcation and period-doubling, Chaos, Stability of limit cycles, Introduction of the Poincaré plane; Modeling molecular evolution: Matrix models of base substitutions for DNA sequences, Jukes-Cantor and Kimura models, Phylogenetic distances.

Essential 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.

Suggestive Readings

- 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.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 2(ii): MATHEMATICAL MODELING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mathematical Modeling	4	3	0	1	Class XII pass with Mathematics	DSC-6: Ordinary Differential Equations

Learning Objectives: Primary objective of this course is to introduce:

- Mathematical modeling as the representation of a system by a set of mathematical relations or equations.
- Mathematical epidemiological models susceptible-infectious-recovered (SIR) and its variant SEIR (S-Exposed-IR) for the spread of diseases.
- Monte Carlo simulation techniques, and simplex method for solving linear programming problems.

Learning Outcomes: This course will enable the students to:

- Understand the methodology of solving SIR models for disease spread.
- Learn significance of dieting model that provides important insights and guides to a biomedical issue that is of interest to the general public.
- Understand nonlinear systems and phenomena with stability analysis ranges from phase plane analysis to ecological and mechanical systems.

- Use Monte Carlo simulation technique to approximate area under a given curve, and volume under a given surface.

SYLLABUS OF DSE-2(ii)

UNIT – I: Mathematical Epidemiological and Dieting Models (15 hours)
Modeling concepts and examples, Scaling of variables, and approximations of functions; SIR and SEIR models for disease spread: Methodology, Standard and solvable SIR models, Basic reproduction number; Dieting model with analysis and approximate solutions.

UNIT – II: Modeling with Nonlinear Systems and Phenomena (15 hours)
Stability and the phase plane, Almost linear systems; Ecological models: Predators and competitors, Critical points, Oscillating populations, Survival of single species, Peaceful coexistence of two species, Interaction of logistic populations, Wildlife conservation preserve; Nonlinear mechanical systems: Hard and soft spring oscillations, Damped nonlinear vibrations.

UNIT – III: Simulation and Optimization Modeling (15 hours)
Monte Carlo simulating deterministic, and probabilistic behavior, Generating random numbers; Linear programming model: Geometric and algebraic solutions, Simplex method and its tableau format, Sensitivity analysis.

Essential Readings

1. Mickens, Ronald E. (2022). Mathematical Modelling with Differential Equations. CRC Press, Taylor & Francis Group.
2. Edwards, C. Henry, Penney, David E., & Calvis, David T. (2023). Differential Equations and Boundary Value Problems: Computing and Modeling (6th 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 India Pvt. Ltd.

Suggestive Readings

- Barnes, Belinda & Fulford, Glenn R. (2015). Mathematical Modeling with Case Studies, Using Maple and MATLAB (3rd ed.). CRC Press. Taylor & Francis Group.
- Ross, Shepley L. (2014). Differential Equations (3rd ed.). Wiley India Pvt. Ltd.
- Simmons, George F. (2017). Differential Equations with Applications and Historical Notes (3rd ed.). CRC Press. Taylor & Francis Group.

Practical (30 hours)- Practical work to be performed in Computer Lab: Modeling of the following problems using: R/Python/SageMath/Mathematica/MATLAB/Maxima/Scilab etc.

1. a) Simulation of SIR model and its variants using some initial parameter values, and finding basic reproduction number for analysis.
   b) Analysis of the dieting process, which includes both body-mass loss and gain.
2. Nonlinear Systems and Phenomena.
   a) Plot phase plane portraits and solutions of first-order equations.
   b) Obtain interesting and complicated phase portraits for almost linear systems.

c) Discuss large wildlife conservation preserve model and obtain (i) The period of oscillation of the rabbit and fox populations, (ii) The maximum and minimum numbers of rabbits and foxes.
d) Discuss the Rayleigh and van der Pol models.

3. (i) Random number generation and then use it for the following:
   a) Simulate area under a given curve.
   b) Simulate volume under a given surface.

   (ii) [2] Chapter 7 (Projects 7.4 and 7.5).

DISCIPLINE SPECIFIC ELECTIVE COURSE – 2(iii): MECHANICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mechanics	4	3	1	0	Class XII pass with Mathematics	DSC-5: Calculus DSC-6: Ordinary Differential Equations

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

- Starting Newtonian laws, learning various technical notions which explains various states of motion under given forces.
- Deals with the kinematics and kinetics of the rectilinear and planar motions of a particle including constrained oscillatory motions of particles, projectiles, and planetary orbits.
- Understand hydrostatic pressure and thrust on plane surfaces.

Learning Outcomes: This course will enable the students to:

- Understand necessary conditions for the equilibrium of particles acted upon by various forces and learn the principle of virtual work for a system of coplanar forces.
- Apply the concepts of center of gravity, laws of static and kinetic friction.
- Learn that a particle moving under a central force describes a plane curve and know the Kepler's laws of the planetary motions.
- Evaluate the hydrostatic pressure at any given depth in a heavy homogeneous liquid at rest under gravity.

SYLLABUS OF DSE-2(iii)

UNIT – I: Statics (15 hours)

Fundamental laws of Newtonian mechanics, Law of parallelogram of forces, Equilibrium of a particle, Lamy's theorem, Equilibrium of a system of particles, External and internal forces, Couples, Reduction of a plane force system, Work, Principle of virtual work, Potential energy and conservative field, Mass centers, Centers of gravity, Friction.

UNIT – II: Dynamics **(18 hours)**

Kinemetics of a particle, Motion of a particle, Motion of a system, Principle of linear momentum, Motion of mass center, Principle of angular momentum, Motion relative to mass center, Principle of energy, D'Alembert's principle; Moving frames of reference, Frames of reference with uniform translational velocity, Frames of reference with constant angular velocity; Applications in plane dynamics- Motion of a projectile, Harmonic oscillators, General motion under central forces, Planetary orbits.

UNIT – III: Hydrostatics **(12 hours)**

Shearing stress, Pressure, Perfect fluid, Pressure at a point in a fluid, Transmissibility of liquid pressure, Compression, Specific gravity, Pressure of heavy fluid- Pressure at all points in a horizontal plane, Surface of equal density; Thrust on plane surfaces.

Essential Readings

1. Synge, J. L., & Griffith, B. A. (2017). Principles of Mechanics (3rd ed.). McGraw-Hill Education. Indian Reprint.
2. Ramsey, A. S. (2017). Hydrostatics. Cambridge University Press. Indian Reprint.

Suggestive Readings

- Roberts, A. P. (2003). Statics and Dynamics with Background Mathematics. Cambridge University Press.
- Ramsey, A. S. (1985). Statics (2nd ed.). Cambridge University Press.

B.A. (Prog.) Semester-IV with Mathematics as Major
Category-II

DISCIPLINE SPECIFIC CORE COURSE (DSC-4): INTRODUCTION TO GRAPH THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Graph Theory	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:
- Problem-solving techniques using various concepts of graph theory.
- Various properties like planarity and chromaticity of graphs.
- Several applications of these concepts in solving practical problems.

Learning Outcomes: This course will enable the students to:
- Good familiarity with all initial notions of graph theory and related results and seeing them used for some real-life problems.
- Learning notion of trees and their enormous usefulness in various problems.
- Learning various algorithms and their applicability.
- Studying planar graphs, Euler theorem associated to such graphs and some useful applications like coloring of graphs.

SYLLABUS OF DSC-4

UNIT-I: Graphs, Types of Graphs and Basic Properties (12 hours)

Graphs and their representation, Pseudographs, Subgraphs, Degree sequence, Euler's theorem, Isomorphism of graphs, Paths and circuits, Connected graphs, Euler trails and circuits, Hamiltonian paths and cycles, Adjacency matrix, Weighted graphs, Travelling salesman problem, Dijkstra's algorithm.

UNIT-II: Directed Graphs and Applications, Trees (18 hours)

The Chinese postman problem; Digraphs, Bellman-Ford algorithm, Tournaments, Directed network, Scheduling problem; Trees and their properties, Spanning trees, Kruskal's algorithm, Prim's algorithm, Acyclic digraphs and Bellman's algorithm.

UNIT-III: Planar Graphs, Graph Coloring and Network Flows (15 hours)

Planar graphs, Euler's formula, Kuratowski theorem, Graph coloring, Applications of graph coloring, Circuit testing and facilities design, Flows and cuts, Max flow-min cut theorem, Matchings, Hall's theorem.

Essential Reading

1. Goodaire, Edgar G., & Parmenter, Michael M. (2011). Discrete Mathematics with Graph Theory (3rd ed.). Pearson Education Pvt. Ltd. Indian Reprint.

Suggestive Readings

- Bondy, J. A. & Murty, U.S.R. (2008), Graph Theory with Applications. Springer.
- Chartrand, Gary, & Zhang, P. (2012). A First Course in Graph Theory. Dover Publications.
- Diestel, R. (1997). Graph Theory (Graduate Texts in Mathematics). Springer Verlag.
- West, Douglas B. (2001). Introduction to graph theory (2nd ed.). Pearson India.

DISCIPLINE SPECIFIC CORE COURSE – 4 (Discipline A-4): ABSTRACT ALGEBRA

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Abstract Algebra	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of the course is to introduce:

- Modular arithmetic, fundamental theory of groups, rings, integral domains, and fields.
- Symmetry group of a plane figure, and basic concepts of cyclic groups.
- Cosets of a group and its properties, Lagrange's theorem, and quotient groups.

Learning Outcomes: This course will enable the students to:

- Appreciate ample types of groups present around us which explains our surrounding better, and classify them as abelian, cyclic and permutation groups.
- Explain the significance of the notion of cosets, normal subgroups and homomorphisms.
- Understand the fundamental concepts of rings, subrings, fields, ideals, and factor rings.

SYLLABUS OF DISCIPLINE A-4

UNIT-I: Introduction to Groups (12 hours)

Modular arithmetic; Definition and examples of groups, Elementary properties of groups, Order of a group and order of an element of a group; Subgroups and its examples, Subgroup tests; Center of a group and centralizer of an element of a group.

UNIT-II: Cyclic Groups, Permutation Groups and Lagrange's Theorem (18 hours)

Cyclic groups and its properties, Generators of a cyclic group; Group of symmetries; Permutation groups, Cyclic decomposition of permutations and its properties, Even and odd permutations and the alternating group; Cosets and Lagrange's theorem; Definition and examples of normal subgroups, Quotient groups; Group homomorphisms and properties.

UNIT-III: Rings, Integral Domains and Fields (15 hours)

Definition, examples and properties of rings, subrings, integral domains, fields, ideals and factor rings; Characteristic of a ring; Ring homomorphisms and properties.

Essential Reading

1. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint (2021).

Suggestive Reading

- Beachy, John A., & Blair, William D. (2006). Abstract Algebra (3rd ed.). Waveland Press.

B.Sc. (Prog.)/ BA (Prog.) Semester-IV with Mathematics as non-Major

Category-III

DISCIPLINE SPECIFIC CORE COURSE – 4 (Discipline A-4): ABSTRACT ALGEBRA

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Abstract Algebra	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of the course is to introduce:

- Modular arithmetic, fundamental theory of groups, rings, integral domains, and fields.
- Symmetry group of a plane figure, and basic concepts of cyclic groups.
- Cosets of a group and its properties, Lagrange's theorem, and quotient groups.

Learning Outcomes: This course will enable the students to:

- Appreciate ample types of groups present around us which explains our surrounding better, and classify them as abelian, cyclic and permutation groups.
- Explain the significance of the notion of cosets, normal subgroups and homomorphisms.
- Understand the fundamental concepts of rings, subrings, fields, ideals, and factor rings.

SYLLABUS OF DISCIPLINE A-4

UNIT-I: Introduction to Groups (12 hours)

Modular arithmetic; Definition and examples of groups, Elementary properties of groups, Order of a group and order of an element of a group; Subgroups and its examples, Subgroup tests; Center of a group and centralizer of an element of a group.

UNIT-II: Cyclic Groups, Permutation Groups and Lagrange's Theorem (18 hours)

Cyclic groups and its properties, Generators of a cyclic group; Group of symmetries; Permutation groups, Cyclic decomposition of permutations and its properties, Even and odd permutations and the alternating group; Cosets and Lagrange's theorem; Definition and examples of normal subgroups, Quotient groups; Group homomorphisms and properties.

UNIT-III: Rings, Integral Domains and Fields (15 hours)

Definition, examples and properties of rings, subrings, integral domains, fields, ideals and factor rings; Characteristic of a ring; Ring homomorphisms and properties.

Essential Reading

1. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint (2021).

Suggestive Reading

- Beachy, John A., & Blair, William D. (2006). Abstract Algebra (3rd ed.). Waveland Press.

B.Sc. (Physical Sciences/Mathematical Sciences) Semester-IV with Mathematics as one of the Core Discipline

Category-III

DISCIPLINE SPECIFIC CORE COURSE – 4 (Discipline A-4): ABSTRACT ALGEBRA

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Abstract Algebra	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of the course is to introduce:

- Modular arithmetic, fundamental theory of groups, rings, integral domains, and fields.
- Symmetry group of a plane figure, and basic concepts of cyclic groups.
- Cosets of a group and its properties, Lagrange's theorem, and quotient groups.

Learning Outcomes: This course will enable the students to:

- Appreciate ample types of groups present around us which explains our surrounding better, and classify them as abelian, cyclic and permutation groups.
- Explain the significance of the notion of cosets, normal subgroups and homomorphisms.
- Understand the fundamental concepts of rings, subrings, fields, ideals, and factor rings.

SYLLABUS OF DISCIPLINE A-4

UNIT-I: Introduction to Groups (12 hours)

Modular arithmetic; Definition and examples of groups, Elementary properties of groups, Order of a group and order of an element of a group; Subgroups and its examples, Subgroup tests; Center of a group and centralizer of an element of a group.

UNIT-II: Cyclic Groups, Permutation Groups and Lagrange's Theorem (18 hours)

Cyclic groups and its properties, Generators of a cyclic group; Group of symmetries; Permutation groups, Cyclic decomposition of permutations and its properties, Even and odd permutations and the alternating group; Cosets and Lagrange's theorem; Definition and examples of normal subgroups, Quotient groups; Group homomorphisms and properties.

UNIT-III: Rings, Integral Domains and Fields (15 hours)

Definition, examples and properties of rings, subrings, integral domains, fields, ideals and factor rings; Characteristic of a ring; Ring homomorphisms and properties.

Essential Reading

1. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint (2021).

Suggestive Reading

- Beachy, John A., & Blair, William D. (2006). Abstract Algebra (3rd ed.). Waveland Press.

DSE Courses of B.Sc. (Physical Sciences/Mathematical Sciences) Semester-IV
Category-III

DISCIPLINE SPECIFIC ELECTIVE COURSE – 2(i): ELEMENTS OF DISCRETE MATHEMATICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Discrete Mathematics	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: Students are introducing to:
- Order (or partial order) and related properties.
- Notion of a lattice which is also a step towards abstract algebra.
- Concept of Boolean algebra and its applications to minimizing a Boolean polynomial and switching circuits, which has further applications in computer science.

Learning Outcomes: This course will enable the students to:
- Understand the basic concepts of sets, relations, functions, and induction.
- Understand mathematical logic and logical operations to various fields.
- Understand the notion of order and maps between partially ordered sets.
- Minimize a Boolean polynomial and apply Boolean algebra techniques to decode switching circuits.

SYLLABUS OF DSE-2(i)

UNIT-I: Sets, Relations and Functions (18 hours)

Sets, Propositions and logical operations, Conditional statements, Mathematical induction, Relations and equivalence relation, Equivalence classes, Partial order relation, Partially ordered set, Hasse diagrams, Chain, Maximal and minimal elements, least and greatest elements, Least upper bound, Greatest lower bound, Zorn's lemma, Functions and bijective functions, Functions between POSETS, Order isomorphism.

UNIT-II: Lattices (12 hours)

Lattice as a POSET, Lattice as an algebra and their equivalence, Bounded lattices, Sublattices, Interval in a lattice, Products and homomorphism of lattices, Isomorphism of lattices; Distributive, Complemented, Partition and pentagonal lattices.

UNIT-III: Boolean Algebra and Switching Circuits (15 hours)

Boolean algebra, De Morgan's laws, Boolean expressions, Truth tables, Logic diagrams, Boolean functions, Disjunctive normal forms (as join of meets), Minimal forms of Boolean polynomials, Quine Mc-Cluskey method, Karnaugh maps, Switching circuits, Applications of switching circuits.

Essential Readings

1. Rudolf Lidl, & Gunter Pilz (2004). Applied Abstract Algebra (2nd ed.). Undergraduate text in Mathematics, Springer (SIE), Indian Reprint.
2. Bernard Kolman, Robert C. Busby, & Sharon Cutler Ross (2009). Discrete Mathematical Structures (6th ed.). Pearson education Inc., Indian reprint.

Suggestive Reading

- Rosen, Kenneth H. (2017). Discrete Mathematics and its applications with combinatorics and Graph Theory (7th ed.). McGraw Hill Education.

DISCIPLINE SPECIFIC ELECTIVE COURSE-2(ii): INTRODUCTION TO GRAPH THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Graph Theory	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- Problem-solving techniques using various concepts of graph theory.
- Various properties like planarity and chromaticity of graphs.
- Several applications of these concepts in solving practical problems.

Learning Outcomes: This course will enable the students to:

- Good familiarity with all initial notions of graph theory and related results and seeing them used for some real-life problems.
- Learning notion of trees and their enormous usefulness in various problems.
- Learning various algorithms and their applicability.
- Studying planar graphs, Euler theorem associated to such graphs and some useful applications like coloring of graphs.

SYLLABUS OF DSE-2(ii)

UNIT-I: Graphs, Types of Graphs and Basic Properties (12 hours)

Graphs and their representation, Pseudographs, Subgraphs, Degree sequence, Euler's theorem, Isomorphism of graphs, Paths and circuits, Connected graphs, Euler trails and circuits, Hamiltonian paths and cycles, Adjacency matrix, Weighted graphs, Travelling salesman problem, Dijkstra's algorithm.

UNIT-II: Directed Graphs and Applications, Trees (18 hours)
The Chinese postman problem; Digraphs, Bellman-Ford algorithm, Tournaments, Directed network, Scheduling problem; Trees and their properties, Spanning trees, Kruskal's algorithm, Prim's algorithm, Acyclic digraphs and Bellman's algorithm.

UNIT-III: Planar Graphs, Graph Coloring and Network Flows (15 hours)
Planar graphs, Euler's formula, Kuratowski theorem, Graph coloring, Applications of graph coloring, Circuit testing and facilities design, Flows and cuts, Max flow-min cut theorem, Matchings, Hall's theorem.

Essential Reading
1. Goodaire, Edgar G., & Parmenter, Michael M. (2011). Discrete Mathematics with Graph Theory (3rd ed.). Pearson Education Pvt. Ltd. Indian Reprint.

Suggestive Readings
- Bondy, J. A. & Murty, U.S.R. (2008), Graph Theory with Applications. Springer.
- Chartrand, Gary, & Zhang, P. (2012). A First Course in Graph Theory. Dover Publications.
- Diestel, R. (1997). Graph Theory (Graduate Texts in Mathematics). Springer Verlag.
- West, Douglas B. (2001). Introduction to graph theory (2nd ed.). Pearson India.

DISCIPLINE SPECIFIC ELECTIVE COURSE-2(iii): LINEAR PROGRAMMING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:
- The solution of linear programming problem using simplex method.
- The solution of transportation and assignment problems.
- Game theory which makes possible the analysis of the decision-making process of two interdependent subjects.

Learning Outcomes: This course will enable the students to:
- Learn about the simplex method used to find optimal solutions of linear optimization problems subject to certain constraints.
- Write the dual of a linear programming problem.

- Solve the transportation and assignment problems.
- Learn about solution of rectangular games using graphical method and dominance.
- Formulate game to a pair of associated prima-dual linear programming problems.

SYLLABUS OF DSE-2(iii)

UNIT-I: Linear Programming Problem, Simplex Method, and Duality (18 hours)

Standard form of the LPP, graphical method of solution, basic feasible solutions, and convexity; Introduction to the simplex method**:** Optimality criterion and unboundedness, Simplex tableau and examples, Artificial variables; Introduction to duality, Formulation of the dual problem with examples.

UNIT-II: Transportation and Assignment Problems (15 hours)

Definition of transportation problem, finding initial basic feasible solution using Northwest-corner method, Least-cost method, and Vogel approximation method; Algorithm for solving transportation problem; Hungarian method of solving assignment problem.

UNIT-III: Two-Person Zero-Sum Games (12 hours)

Introduction to game theory, rectangular games, Mixed strategies, Dominance principle; Formulation of game to primal and dual linear programming problems.

Essential Readings

1. Thie, Paul R., & Keough, G. E. (2014). An Introduction to Linear Programming and Game Theory. (3rd ed.). Wiley India Pvt. Ltd.
2. Taha, Hamdy A. (2017). Operations Research: An Introduction (10th ed.). Pearson.

Suggestive Readings

- Hadley, G. (1997). Linear Programming. Narosa Publishing House. New Delhi.
- Hillier, F. S., & Lieberman, G. J. (2021). Introduction to Operations Research (11th ed.). McGraw-Hill Education (India) Pvt. Ltd.

COMMON POOL OF GENERIC ELECTIVES (GE) Semester-IV COURSES OFFERED BY DEPARTMENT OF MATHEMATICS

Category-IV

GENERIC ELECTIVES (GE-4(i)): ELEMENTS OF REAL ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Real Analysis	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- The real line with algebraic, order and completeness properties.
- Convergence and divergence of sequences and series of real numbers with applications.

Learning Outcomes: This course will enable the students to:

- Understand the basic properties of the set of real numbers, including completeness and Archimedean with some consequences.
- Recognize bounded, convergent, monotonic and Cauchy sequences
- Learn to apply various tests such as limit comparison, ratio, root, and alternating series tests for convergence and absolute convergence of infinite series of real numbers.

SYLLABUS OF GE-4(i)

UNIT-I: Basic Properties of the Set of Real Numbers (12 hours)

Field and order properties of $\mathbb{R}$, basic properties and inequalities of the absolute value of a real number, bounded above and bounded below sets, Suprema and infima, The completeness axiom and the Archimedean property of $\mathbb{R}$.

UNIT-II: Real Sequences (18 hours)

Convergence of a real sequence, Algebra of limits, The squeeze principle and applications, Monotone sequences, Monotone convergence theorem and applications, Cauchy sequences, Cauchy criterion for convergence and applications.

UNIT-III: Infinite Series of Real Numbers (15 hours)

Convergence and divergence of infinite series of real numbers, Necessary condition for convergence, Cauchy criterion for convergence of series, Tests for convergence of positive term series, Applications of the integral test, Comparison tests, D'Alembert's ratio test, Cauchy's nth root test, Raabe's test; Alternating series, Leibniz alternating series test, Absolute and conditional convergence.

Essential Reading

1. Denlinger, Charles G. (2011). Elements of Real Analysis. Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

Suggestive Readings

- Bartle, Robert G., & Sherbert, Donald R. (2011). Introduction to Real Analysis (4th ed.). John Wiley & Sons. Wiley India Edition 2015.
- Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E. (2010). An Introduction to Analysis (2nd ed.). Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

GENERIC ELECTIVES (GE-4(ii)): LINEAR PROGRAMMING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- The solution of linear programming problem using simplex method.
- The solution of transportation and assignment problems.
- Game theory which makes possible the analysis of the decision-making process of two interdependent subjects.

Learning Outcomes: This course will enable the students to:

- Learn about the simplex method used to find optimal solutions of linear optimization problems subject to certain constraints.
- Write the dual of a linear programming problem.
- Solve the transportation and assignment problems.
- Learn about solution of rectangular games using graphical method and dominance.
- Formulate game to a pair of associated prima-dual linear programming problems.

SYLLABUS OF GE-4(ii)

UNIT-I: Linear Programming Problem, Simplex Method, and Duality (18 hours)

Standard form of the LPP, graphical method of solution, basic feasible solutions, and convexity; Introduction to the simplex method: Optimality criterion and unboundedness, Simplex tableau and examples, Artificial variables; Introduction to duality, Formulation of the dual problem with examples.

UNIT-II: Transportation and Assignment Problems (15 hours)

Definition of transportation problem, finding initial basic feasible solution using Northwest-corner method, Least-cost method, and Vogel approximation method; Algorithm for solving transportation problem; Hungarian method of solving assignment problem.

UNIT-III: Two-Person Zero-Sum Games (12 hours)

Introduction to game theory, rectangular games, Mixed strategies, Dominance principle; Formulation of game to primal and dual linear programming problems.

Essential Readings

1. Thie, Paul R., & Keough, G. E. (2014). An Introduction to Linear Programming and Game Theory. (3rd ed.). Wiley India Pvt. Ltd.
2. Taha, Hamdy A. (2017). Operations Research: An Introduction (10th ed.). Pearson.

Suggestive Readings

- Hadley, G. (1997). Linear Programming. Narosa Publishing House. New Delhi.
- Hillier, F. S., & Lieberman, G. J. (2021). Introduction to Operations Research (11th ed.). McGraw-Hill Education (India) Pvt. Ltd.

DEPARTMENT OF MATHEMATICS

Category-I

B.Sc. (Hons.) Mathematics Semester-V

DISCIPLINE SPECIFIC CORE COURSE – 13: METRIC SPACES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Metric Spaces	4	3	1	0	Class XII pass with Mathematics	DSC-2: Real Analysis DSC-5: Calculus

Learning Objectives: The objective of the course is to introduce:

- The usual idea of distance into an abstract form on any set of objects, maintaining its inherent characteristics, and the resulting consequences.
- The two important topological properties, namely connectedness, and compactness of metric spaces with their characterizations.

Learning Outcomes: This course will enable the students to:

- Learn various natural and abstract formulations of distance on the sets of usual or unusual entities. Become aware one such formulations leading to metric spaces.
- Analyse how a theory advances from a particular frame to a general frame.
- Appreciate the mathematical understanding of various geometrical concepts, viz. balls or connected sets etc. in an abstract setting.
- Know about Banach fixed point theorem, whose far-reaching consequences have resulted into an independent branch of study in analysis, known as fixed point theory.

SYLLABUS OF DSC-13

UNIT – I: Topology of Metric Spaces (18 hours)

Definition, examples, sequences and Cauchy sequences, Complete metric space; Open and closed balls, Neighborhood, Open set, Interior of a set, Limit point of a set, Derived set, Closed set, Closure of a set, Diameter of a set, Cantor's theorem, Subspaces.

UNIT – II: Continuity and Uniform Continuity in Metric Spaces (15 hours)

Continuous mappings, Sequential criterion and other characterizations of continuity, Uniform continuity; Homeomorphism, Isometry and equivalent metrics, Contraction mapping, Banach fixed point theorem.

UNIT – III: Connectedness and Compactness (12 hours)

Connectedness, Connected subsets of $\mathbb{R}$, Connectedness and continuous mappings, Compactness and boundedness, Characterizations of compactness, Continuous functions on compact spaces.

Essential Reading

3. Shirali, Satish & Vasudeva, H. L. (2009). Metric Spaces. Springer. Indian Reprint 2019.

Suggestive Readings

- Kumaresan, S. (2014). Topology of Metric Spaces (2nd ed.). Narosa Publishing House. New Delhi.
- Rudin, Walter. Principles of mathematical Analysis (3rd ed.).
- Simmons, George F. (2004). Introduction to Topology and Modern Analysis. McGraw-Hill Education. New Delhi.

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

DISCIPLINE SPECIFIC CORE COURSE – 14: RING THEORY

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Ring Theory	4	3	1	0	Class XII pass with Mathematics	DSC-7: Group Theory

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

- Introduce the fundamental theory of rings, and their homomorphisms.
- Develop the basic concepts of polynomial rings and irreducibility tests for polynomials over the ring of integers, and rational numbers.
- Introduce polynomial analog of a prime number.
- Describe polynomial rings, principal ideal domains, Euclidean domains and unique factorization domains, and their relationships.

Learning Outcomes: This course will enable the students to:

- Learn about the fundamental concept of rings, integral domains, and fields.
- Know about ring homomorphisms and isomorphisms theorems of rings, and construct quotient fields for integral domains.
- Appreciate the significance of unique factorization in rings and integral domains.
- Apply several criteria for determining when polynomials with integer coefficients have rational roots or are irreducible over the field of rational numbers.

SYLLABUS OF DSC-14

UNIT – I: Introduction to Rings and Ideals (18 hours)

Definition and examples of rings, Properties of rings, Subrings, Integral domains and fields, Characteristic of a ring; Ideals, operations on ideals, ideal generated by a set and properties, Factor rings, Prime ideals and maximal ideals, Principal ideal domains.

UNIT – II: Ring Homomorphisms and Polynomial Rings (15 hours)

Definition, examples and properties of ring homomorphisms; First, second and third isomorphism theorems for rings; The field of quotients; Polynomial rings over commutative rings, Division algorithm and consequences.

UNIT–III: Unique Factorization Domain and Divisibility in Integral Domains (12 hours)
Factorization of polynomials, Reducibility tests, Mod p Irreducibility test, Eisenstein's criterion, Unique factorization in $\mathbb{Z}[x]$; Divisibility in integral domains, Irreducibles, Primes, Unique factorization domains, Euclidean domains.

Essential Readings

1. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint 2021.
2. Dummit, David S. & Foote, Richard M. (2016). Abstract Algebra (3rd ed.). Student Edition. Wiley India.

Suggestive Readings

- Herstein, I. N. (2006). Topics in Algebra (2nd ed.). Wiley Student Edition. India.
- Hungerford, Thomas W. (2012). Abstract Algebra: An Introduction (3rd ed.). Cengage Learning.

DISCIPLINE SPECIFIC CORE COURSE – 15: PARTIAL DIFFERENTIAL EQUATIONS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Partial Differential Equations	4	3	0	1	Class XII pass with Mathematics	DSC-6: Ordinary Differential Equations

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

- Basic concepts of first and second order linear/nonlinear partial differential equations.
- Modeling of wave equation, heat equation, Burgers equation, traffic flow and their solutions.

Learning Outcomes: The course will enable the students to learn:

- The method of characteristics and reduction to canonical forms to solve first and second order linear/nonlinear partial differential equations.
- The macroscopic modeling of the traffic flow, where the focus will be on modeling the density of cars and their flow, rather than modeling individual cars and their velocity.
- The Cauchy problem and solutions of wave equations with initial boundary-value problems, and non-homogeneous boundary conditions.

SYLLABUS OF DSC-15

UNIT – I: First Order Partial Differential Equations (15 hours)
Basic concepts, classification, construction, and geometrical interpretation; Method of characteristics and general solutions, Cauchy problem for a first-order PDE, Canonical

forms of first-order linear equations; Method of separation of variables; Charpit's method for solving non-linear PDEs.

UNIT – II: Classification and Solutions of Second-Order Linear PDEs (12 hours)
Classification (hyperbolic, parabolic, and elliptic), reduction to canonical forms, and general solutions of second-order linear PDEs; Higher order linear partial differential equations with constant coefficients.

UNIT – III: Applications of Partial Differential Equations (18 hours)
Mathematical models: The vibrating string, vibrating membrane, conduction of heat in solids, the gravitational potential, conservation laws and the Burgers equation, Traffic flow; Cauchy problem and wave equations: Solutions of homogeneous wave equations with initial boundary-value problems, and non-homogeneous boundary conditions, Cauchy problem for non-homogeneous wave equations.

Essential Readings

1 Myint-U, Tyn & Debnath, Lokenath. (2007). Linear Partial Differential Equations for Scientists and Engineers (4th ed.). Birkhäuser. Indian Reprint.
2 Sneddon, Ian N. (2006). Elements of Partial Differential Equations, Dover Publications. Indian Reprint.

Suggestive Readings

- Abell, Martha & Braselton, J.P. (2004) Differential Equations with Mathematica, Elsevier, Academic Press, Third Edition.
- Stavroulakis, Ioannis P & Tersian, Stepan A. (2004). Partial Differential Equations: An Introduction with Mathematica and MAPLE (2nd ed.). World Scientific.

Practical (30 hours)- Practical / Lab work to be performed in a Computer Lab:
Modeling of the following similar problems using SageMath/Python/Mathematica/ MATLAB/Maple/Maxima/Scilab:

1. General solution of first and second order partial differential equations.
2. Solution and plotting of Cauchy problem for first order PDEs.
3. Plotting the characteristics for the first order partial differential equations.
4. Solution of vibrating string problem using D'Alembert formula with initial conditions.
5. Solution of heat equation $u_t = k\, u_{xx}$ with initial conditions.
6. Solution of one-dimensional wave equation with initial conditions:
   i. $u(x,0) = f(x),\ u_t(x,0) = g(x),\ x \in \mathbb{R}, t > 0$
   ii. $u(x,0) = f(x),\ u_t(x,0) = g(x),\ u(0,t) = 0,\ x \in \mathbb{R}, t > 0$
   iii. $u(x,0) = f(x),\ u_t(x,0) = g(x),\ u_x(0,t) = 0,\ x \in \mathbb{R}, t > 0$
7. Solution of traffic flow problem with given initial conditions, and plotting of the characteristic base curves and the traffic density function.

B.Sc. (Hons) Mathematics, Semester-V, DSE-Courses

DISCIPLINE SPECIFIC ELECTIVE COURSE – 3(i): MATHEMATICAL DATA SCIENCE

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title &	Credits	Credit distribution of the course	Eligibility	Pre-requisite of

Code		Lecture	Tutorial	Practical/ Practice	criteria	the course (if any)
Mathematical Data Science	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of R/Python DSC-3: Probability & Statistics

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

- Introduce various types of data and their sources, along with steps involved in data science case-study, including problems with data and their rectification and creation methods.
- Cover dimensionality reduction techniques, clustering algorithms and classification methods.

Learning Outcomes: The course will enable the students to:

- Gain a comprehensive understanding of data science, its mathematical foundations including practical applications of regression, principal component analysis, singular value decomposition, clustering, support vector machines, and *k*-NN classifiers.
- Demonstrate data analysis and exploration, linear regression techniques such as simple, multiple explanatory variables, cross-validation and regularization using R/Python.
- Use real-world datasets to practice dimensionality reduction techniques such as PCA, SVD, and multidimensional scaling using R/Python.

SYLLABUS OF DSE-3(i)

UNIT-I: Principles of Data Science (12 hours)

Types of Data: nominal, ordinal, interval, and ratio; Steps involved in data science case-study: question, procurement, exploration, modeling, and presentation; Structured and unstructured data: streams, frames, series, survey results, scale and source of data – fixed, variable, high velocity, exact and implied/inferred; Overview of problems with data – dirty and missing data in tabular formats – CSV, data frames in R/Pandas, anomaly detection, assessing data quality, rectification and creation methods, data hygiene, meta-data for inline data-description-markups such as XML and JSON; Overview of other data-source formats – SQL, pdf, Yaml, HDF5, and Vaex.

Unit-II: Mathematical Foundations (15 hours)

Model driven data in R^n, Log-likelihoods and MLE, Chebyshev, and Chernoff-Hoeffding inequalities with examples, Importance sampling; Norms in Vector Spaces– Euclidean, and metric choices; Types of distances: Manhattan, Hamming, Mahalanobis, Cosine and angular distances, KL divergence; Distances applied to sets– Jaccard, and edit distances; Modeling text with distances; Linear Regression: Simple, multiple explanatory variables, polynomial, cross-validation, regularized, Lasso, and matching pursuit; Gradient descent.

Unit-III: Dimensionality Reduction, Clustering and Classification (18 hours)

Problem of dimensionality, Principal component analysis, Singular value decomposition (SVD), Best *k*-rank approximation of a matrix, Eigenvector and eigenvalues relation to SVD, Multidimensional scaling, Linear discriminant analysis; Clustering: Voronoi diagrams, Delaunay triangulation, Gonzalez's algorithm for *k*-center clustering, Lloyd's algorithm for *k*-means clustering, Mixture of Gaussians, Hierarchical clustering, Density-based clustering and outliers, Mean shift clustering; Classification: Linear classifiers, Perceptron algorithm, Kernels, Support vector machines, and *k*-nearest neighbors (*k*-NN) classifiers.

Essential Readings

1. Mertz, David. (2021). Cleaning Data for Effective Data Science, Packt Publishing.
2. Ozdemir, Sinan. (2016). Principles of Data Science, Packt Publishing.
3. Phillips, Jeff M. (2021). Mathematical Foundations for Data Analysis, Springer. (https://mathfordata.github.io/).

Suggestive Readings

- Frank Emmert-Streib, et al. (2022). Mathematical Foundations of Data Science Using R. (2nd ed.). De Gruyter Oldenbourg.
- Wes McKinney. (2022). Python for Data Analysis (3rd ed.). O'Reilly.
- Wickham, Hadley, et al. (2023). R for Data Science (2nd ed.). O'Reilly.

Practical (30 hours)- Practical work to be performed in Computer Lab using R/Python:

1. To explore different types data (nominal, ordinal, interval, ratio) and identify their properties.
2. To deal with dirty and missing data, such as imputation, deletion, and data normalization.
3. Use the real-world datasets (https://data.gov.in/) to demonstrate the following:
   a) Data analysis and exploration, linear regression techniques such as simple, multiple explanatory variables, cross-validation, and regularization.
   b) Dimensionality reduction techniques such as principal component analysis, singular value decomposition (SVD), and multidimensional scaling.
   c) Clustering algorithms such as *k*-means, hierarchical, and density-based clustering and evaluate the quality of the clustering results.
   d) Classification methods such as linear classifiers, support vector machines (SVM), and *k*-nearest neighbors (*k*-NN).

DISCIPLINE SPECIFIC ELECTIVE COURSE – 3(ii): LINEAR PROGRAMMING AND APPLICATIONS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming and Applications	4	3	1	0	Class XII pass with Mathematics	DSC-4: Linear Algebra

Learning Objectives: Primary objective of this course is to introduce:

- Simplex Method for linear programming problems.
- Dual linear programming problems.
- The applications of linear Programming to transportation, assignment, and game theory.

Learning Outcomes: The course will enable the students to:

- Learn about the basic feasible solutions of linear programming problems.
- Understand the theory of the simplex method to solve linear programming problems.
- Learn about the relationships between the primal and dual problems.
- Solve transportation and assignment problems.
- Understand two-person zero sum game, games with mixed strategies and formulation of game to primal and dual linear programing problems to solve using duality.

SYLLABUS OF DSE-3(ii)

UNIT– I: Introduction to Linear Programming (12 hours)

Linear programming problem: Standard, Canonical and matrix forms, Geometric solution; Convex and polyhedral sets, Hyperplanes, Extreme points; Basic solutions, Basic feasible solutions, Correspondence between basic feasible solutions and extreme points.

UNIT– II: Optimality and Duality Theory of Linear Programming Problem (18 hours)

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. Duality Theory: Motivation and formulation of dual problem, Primal-Dual relationships, Fundamental theorem of duality; Complementary slackness.

UNIT – III: Applications (15 hours)

Transportation Problem: Definition and formulation, Northwest-corner, Least- cost, and Vogel's approximation methods of finding initial basic feasible solutions; Algorithm for solving transportation problem.

Assignment Problem: Mathematical formulation and Hungarian method of solving.

Game Theory: Two-person zero sum game, Games with mixed strategies, Formulation of game to primal and dual linear programming problems, Solution of games using duality.

Essential Readings

1. Bazaraa, Mokhtar S., Jarvis, John J., & Sherali, Hanif D. (2010). Linear Programming and Network Flows (4th ed.). John Wiley and Sons. Indian Reprint.
2. Hillier, Frederick S. & Lieberman, Gerald J. (2021). Introduction to Operations Research (11th ed.). McGraw-Hill Education (India) Pvt. Ltd.
3. Taha, Hamdy A. (2017). Operations Research: An Introduction (10th ed.). Pearson.

Suggestive Readings

- Hadley, G. (1997). Linear Programming. Narosa Publishing House. New Delhi.
- Thie, Paul R., & Keough, G. E. (2008). An Introduction to Linear Programming and Game Theory. (3rd ed.). Wiley India Pvt. Ltd. Indian Reprint 2014.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 3(iii): MATHEMATICAL STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/		

				Practice		
Mathematical Statistics	**4**	**3**	**1**	**0**	**Class XII pass with Mathematics**	**DSC-3: Probability & Statistics DSC-11: Multivariate Calculus**

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

- The joint behavior of several random variables theoretically and through illustrative practical examples.
- The theory underlying modern statistics to give the student a solid grounding in (mathematical) statistics and the principles of statistical inference.
- The application of the theory to the statistical modeling of data from real applications, including model identification, estimation, and interpretation.
- The idea of Fisher information to find the minimum possible variance for an unbiased estimator, and to show that the MLE is asymptotically unbiased and normal.

Learning Outcomes: The course will enable the students to:

- Understand joint distributions of random variables including the bivariate normal distribution.
- Estimate model parameters from the statistical inference based on point estimation and hypothesis testing.
- Apply Rao-Blackwell theorem for improving an estimator, and Cramér-Rao inequality to find lower bound on the variance of unbiased estimators of a parameter.
- Understand the theory of linear regression models and contingency tables.

SYLLABUS OF DSE - 3(iii)

UNIT–I: Joint Probability Distributions (15 hours)

Joint probability mass function for two discrete random variables, Marginal probability mass function, Joint probability density function for two continuous random variables, Marginal probability density function, Independent random variables; Expected values, covariance, and correlation; Linear combination of random variables and their moment generating functions; Conditional distributions and conditional expectation, Laws of total expectation and variance; Bivariate normal distribution.

UNIT-II: Sampling Distributions and Point Estimation (15 hours)

Distribution of important statistics such as the sample totals, sample means, and sample proportions, Central limit theorem, Law of large numbers; Chi-squared, *t*, and *F* distributions; Distributions based on normal random samples; Concepts and criteria for point estimation, The methods of moments and maximum likelihood estimation (MLE); Assessing estimators: Accuracy and precision, Unbiased estimation, Consistency and sufficiency, The Neyman factorization theorem, Rao-Blackwell theorem, Fisher Information, The Cramér-Rao inequality, Efficiency,

UNIT-III: Confidence Intervals, Tests of Hypotheses and Linear Regression Analysis (15 hours)

Interval estimation and basic properties of confidence intervals, One-sample t confidence interval, Confidence intervals for a population proportion and population variance.
Statistical hypotheses and test procedures, One-sample tests about a population mean and a population proportion, P-values for tests; The simple linear regression model and its estimating parameters; Chi-squared goodness-of-fit tests, Two-way contingency tables.

Essential Reading

1. Devore, Jay L., Berk, Kenneth N. & Carlton Matthew A. (2021). Modern Mathematical Statistics with Applications. (3rd ed.). Springer.

Suggestive Readings

- Devore, Jay L. (2016). Probability and Statistics for Engineering and the Sciences. Ninth edition, Cengage Learning India Private Limited, Delhi. Fourth impression 2022.
- Hogg, Robert V., McKean, Joseph W., & Craig, Allen T. (2019). Introduction to Mathematical Statistics. Eighth edition, Pearson. Indian Reprint 2020.
- Mood, A.M., Graybill, F.A., & Boes, D.C. (1974). Introduction the Theory of Statistics (3rd ed.). Tata McGraw Hill Pub. Co. Ltd. Reprinted 2017.
- Wackerly, Dennis D., Mendenhall III, William & Scheaffer, Richard L. (2008). Mathematical Statistics with Applications. 7th edition, Cengage Learning.

B.A. (Prog.) Semester-V with Mathematics as Major

Category-II

DISCIPLINE SPECIFIC CORE COURSE (DSC-5): LINEAR PROGRAMMING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Linear Programming	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:
- The solution of linear programming problem using simplex method.
- The solution of transportation and assignment problems.
- Game theory which makes possible the analysis of the decision-making process of two interdependent subjects.

Learning Outcomes: This course will enable the students to:
- Learn about the simplex method used to find optimal solutions of linear optimization problems subject to certain constraints.
- Write the dual of a linear programming problem.
- Solve the transportation and assignment problems.
- Learn about solution of rectangular games using graphical method and dominance.
- Formulate game to a pair of associated prima-dual linear programming problems.

SYLLABUS OF DSC-5

UNIT-I: Linear Programming Problem, Simplex Method, and Duality (18 hours)
Standard form of the LPP, graphical method of solution, basic feasible solutions, and convexity; Introduction to the simplex method: Optimality criterion and unboundedness, Simplex tableau and examples, Artificial variables; Introduction to duality, Formulation of the dual problem with examples.

UNIT-II: Transportation and Assignment Problems (15 hours)
Definition of transportation problem, finding initial basic feasible solution using Northwest-corner method, Least-cost method, and Vogel approximation method; Algorithm for solving transportation problem; Hungarian method of solving assignment problem.

UNIT-III: Two-Person Zero-Sum Games (12 hours)
Introduction to game theory, rectangular games, Mixed strategies, Dominance principle; Formulation of game to primal and dual linear programming problems.

Essential Readings

3. Thie, Paul R., & Keough, G. E. (2014). An Introduction to Linear Programming and Game Theory. (3rd ed.). Wiley India Pvt. Ltd.
4. Taha, Hamdy A. (2017). Operations Research: An Introduction (10th ed.). Pearson.

Suggestive Readings

- Hadley, G. (1997). Linear Programming. Narosa Publishing House. New Delhi.
- Hillier, F. S., & Lieberman, G. J. (2021). Introduction to Operations Research (11th ed.).McGraw-Hill Education (India) Pvt. Ltd.

DISCIPLINE SPECIFIC CORE COURSE – 5 (Discipline A-5): ELEMENTS OF REAL ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Real Analysis	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:
- The real line with algebraic, order and completeness properties.
- Convergence and divergence of sequences and series of real numbers with applications.

Learning Outcomes: This course will enable the students to:
- Understand the basic properties of the set of real numbers, including completeness and Archimedean with some consequences.
- Recognize bounded, convergent, monotonic and Cauchy sequences
- Learn to apply various tests such as limit comparison, ratio, root, and alternating series tests for convergence and absolute convergence of infinite series of real numbers.

SYLLABUS OF DISCIPLINE A-5

UNIT-I: Basic Properties of the Set of Real Numbers (12 hours)

Field and order properties of $\mathbb{R}$, basic properties and inequalities of the absolute value of a real number, bounded above and bounded below sets, Suprema and infima, The completeness axiom and the Archimedean property of $\mathbb{R}$.

UNIT-II: Real Sequences (18 hours)

Convergence of a real sequence, Algebra of limits, The squeeze principle and applications, Monotone sequences, Monotone convergence theorem and applications, Cauchy sequences, Cauchy criterion for convergence and applications.

UNIT-III: Infinite Series of Real Numbers (15 hours)

Convergence and divergence of infinite series of real numbers, Necessary condition for convergence, Cauchy criterion for convergence of series, Tests for convergence of positive term series, Applications of the integral test, Comparison tests, D'Alembert's ratio test, Cauchy's *n*th root test, Raabe's test; Alternating series, Leibniz alternating series test, Absolute and conditional convergence.

Essential Reading

1. Denlinger, Charles G. (2011). Elements of Real Analysis. Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

Suggestive Readings

- Bartle, Robert G., & Sherbert, Donald R. (2011). Introduction to Real Analysis (4th ed.). John Wiley & Sons. Wiley India Edition 2015.
- Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E. (2010). An Introduction to Analysis (2nd ed.). Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

DSE Courses of B.A. (Prog.) Semester-V

Category-II

DISCIPLINE SPECIFIC ELECTIVE COURSE – 1(i): COMBINATORICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Combinatorics	4	3	1	0	Class XII pass with Mathematics	NIL

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

- Introduce various techniques of permutations, combinations, and inclusion-exclusion.
- Learn basic models of generating functions and recurrence relations in their application to the theory of integer partitions.

Learning Outcomes: After completing the course, student will:

- Enhance the mathematical logical skills by learning different enumeration techniques.
- Be able to apply these techniques in solving problems in other areas of mathematics.
- Be trained to provide reasoning and arguments to justify conclusions.

SYLLABUS OF DSE-1(i)

UNIT – I: Basics of Combinatorics (15 hours)

Basic counting principles, Permutations and Combinations (with and without repetitions), Binomial coefficients, Multinomial coefficients, Counting subsets of size *k*; Set-partitions, The inclusion-exclusion principle and applications.

UNIT – II: Generating Functions and Recurrence Relations (18 hours)

Generating functions: Generating function models, Calculating coefficients of generating functions, Polynomial expansions, Binomial identity, Exponential generating functions. Recurrence relations: Recurrence relation models, Divide-and-conquer relations, Solution of linear recurrence relations, Solutions by generating functions.

UNIT – III: Partition (12 hours)

Partition theory of integers: Ordered partition, Unordered partition, Ferrers diagram, Conjugate of partition, Self-conjugate partition, Durfee square, Euler's pentagonal theorem.

Essential Readings

1. Sane, Sharad S. (2013). Combinatorial Techniques. Hindustan Book Agency (India).
2. Tucker, Alan (2012). Applied Combinatorics (6th ed.). John Wiley & Sons, Inc.

Suggestive Readings

- Brualdi, Richard A. (2009). Introductory Combinatorics (5th ed.). Pearson Education.
- Cameron, Peter J. (1994). Combinatorics: Topics, Techniques, Algorithms. Cambridge University Press.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 1(ii): ELEMENTS OF NUMBER THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Number Theory	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:
- The Euclidean algorithm and linear Diophantine equations, the Fundamental theorem of arithmetic and some of the open problems of number theory viz. the Goldbach conjecture.
- The modular arithmetic, linear congruence equations, system of linear congruence equations, arithmetic functions, and multiplicative functions, e.g., Euler's Phi-function.
- Introduction of the simple encryption and decryption techniques, and the numbers of specific forms viz. Mersenne numbers, Fermat numbers etc.

Learning Outcomes: This course will enable the students to:
- Get familiar with the basic number-theoretic techniques.
- Comprehend some of the open problems in number theory.
- Learn the properties and use of number-theoretic functions and special types of numbers.
- Acquire knowledge about public-key cryptosystems, particularly RSA.

SYLLABUS OF DSE-1(ii)

UNIT – I: Divisibility and Prime Numbers (12 hours)

Revisiting: The division algorithm, divisibility and the greatest common divisor. Euclid's lemma; The Euclidean algorithm, Linear Diophantine equations; The Fundamental theorem of Arithmetic, The sieve of Eratosthenes, Euclid theorem and the Goldbach conjecture; The Fibonacci sequence and its nature.

UNIT – II: Theory of Congruences and Number-Theoretic Functions (21 hours)

Congruence relation and its basic properties, Linear congruences and the Chinese remainder theorem, System of linear congruences in two variables; Fermat's little theorem and its generalization, Wilson's theorem and its converse; Number-theoretic functions for sum and the number of divisors of a positive integer, Multiplicative functions, The greatest integer function; Euler's Phi-function and its properties.

UNIT – III: Public Key Encryption and Numbers of Special Form (12 hours)

Basics of cryptography, Hill's cipher, Public-key cryptosystems and RSA encryption and decryption technique; Introduction to perfect numbers, Mersenne numbers and Fermat numbers.

Essential Reading

1. Burton, David M. (2011). Elementary Number Theory (7th ed.). McGraw-Hill Education Pvt. Ltd. Indian Reprint 2017.

Suggestive Readings

- Jones, G. A., & Jones, J. Mary. (2005). Elementary Number Theory. Springer Undergraduate Mathematics Series (SUMS). Indian Reprint.
- Robbins, Neville (2007). Beginning Number Theory (2nd ed.). Narosa Publishing House Pvt. Ltd. Delhi.
- Rosen, Kenneth H. (2011). Elementary Number Theory and its Applications (6th ed.). Pearson Education. Indian Reprint 2015.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 1(iii): MATHEMATICAL PYTHON

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mathematical Python	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of Python

Learning Objectives: The Learning Objectives of this course are as follows:

- To be able to model and solve mathematical problems using Python Programs.
- To experience utility of open-source resources for numerical and symbolic mathematical software systems.

Learning Outcomes: This course will enable the students to use Python:

- For numerical and symbolic computation in mathematical problems from calculus, algebra, and geometry.
- To tabulate and plot diverse graphs of functions and understand tracing of shapes, geometries, and fractals.
- To prepare smart documents with LaTeX interface.

SYLLABUS OF DSE - 1(iii)

Theory

UNIT – I: Drawing Shapes, Graphing and Visualization (15 hours)

Drawing diverse shapes using code and Turtle; Using matplotlib and NumPy for data organization, Structuring and plotting lines, bars, markers, contours and fields, managing subplots and axes; Pyplot and subplots, Animations of decay, Bayes update, Random walk.

UNIT – II: Numerical and Symbolic Solutions of Mathematical Problems (18 hours)

NumPy for scalars and linear algebra on *n*-dimensional arrays; Computing eigenspace, Solving dynamical systems on coupled ordinary differential equations, Functional programming fundamentals using NumPy; Symbolic computation and SymPy: Differentiation and integration of functions, Limits, Solution of ordinary differential equations, Computation of eigenvalues, Solution of expressions at multiple points (lambdify), Simplification of expressions, Factorization, Collecting and canceling terms, Partial fraction decomposition, Trigonometric simplification, Exponential and logarithms, Series expansion and finite differences, Solvers, Recursive equations.

UNIT – III: Document Generation with Python and LaTeX (12 hours)

Pretty printing using SymPy; Pandas API for IO tools: interfacing Python with text/csv, HTML, LaTeX, XML, MSExcel, OpenDocument, and other such formats; Pylatex and writing document files from Python with auto-computed values, Plots and visualizations.

Practical (30 hours): Software labs using IDE such as Spyder and Python Libraries.

- Installation, update, and maintenance of code, troubleshooting.
- Implementation of all methods learned in theory.
- Explore and explain API level integration and working of two problems with standard Python code.

Essential Readings

1. Farrell, Peter (2019). Math Adventures with Python. No Starch Press. ISBN Number: 978-1-59327-867-0.
2. Farrell, Peter and et al. (2020). The Statistics and Calculus with Python Workshop. Packet Publishing Ltd. ISBN: 978-1-80020-976-3.
3. Saha, Amit (2015). Doing Math with Python. No Starch Press. ISBN: 978-1-59327-640-9

Suggestive Readings

- Morley, Sam (2022). Applying Math with Python (2nd ed.). Packet Publishing Ltd. ISBN: 978-1-80461-837-0
- Online resources and documentation on the libraries, such as:
  - https://matplotlib.org
  - https://sympy.org
  - https://pandas.pydata.org
  - https://numpy.org
  - https://pypi.org
  - https://patrickwalls.github.io/mathematicalpython/

Note: **Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.**

B.Sc. (Prog.)/ BA (Prog.) Semester-V with Mathematics as non-Major

Category-III

DISCIPLINE SPECIFIC CORE COURSE – 5 (Discipline A-5): ELEMENTS OF REAL ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Real Analysis	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- The real line with algebraic, order and completeness properties.
- Convergence and divergence of sequences and series of real numbers with applications.

Learning Outcomes: This course will enable the students to:

- Understand the basic properties of the set of real numbers, including completeness and Archimedean with some consequences.
- Recognize bounded, convergent, monotonic and Cauchy sequences
- Learn to apply various tests such as limit comparison, ratio, root, and alternating series tests for convergence and absolute convergence of infinite series of real numbers.

SYLLABUS OF DISCIPLINE A-5

UNIT-I: Basic Properties of the Set of Real Numbers (12 hours)

Field and order properties of $\mathbb{R}$, basic properties and inequalities of the absolute value of a real number, bounded above and bounded below sets, Suprema and infima, The completeness axiom and the Archimedean property of $\mathbb{R}$.

UNIT-II: Real Sequences (18 hours)

Convergence of a real sequence, Algebra of limits, The squeeze principle and applications, Monotone sequences, Monotone convergence theorem and applications, Cauchy sequences, Cauchy criterion for convergence and applications.

UNIT-III: Infinite Series of Real Numbers (15 hours)

Convergence and divergence of infinite series of real numbers, Necessary condition for convergence, Cauchy criterion for convergence of series, Tests for convergence of positive term series, Applications of the integral test, Comparison tests, D’Alembert’s ratio test, Cauchy’s *n*th root test, Raabe’s test; Alternating series, Leibniz alternating series test, Absolute and conditional convergence.

Essential Reading

1. Denlinger, Charles G. (2011). Elements of Real Analysis. Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

Suggestive Readings

- Bartle, Robert G., & Sherbert, Donald R. (2011). Introduction to Real Analysis (4th ed.). John Wiley & Sons. Wiley India Edition 2015.
- Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E. (2010). An Introduction to Analysis (2nd ed.). Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

B.Sc. (Physical Sciences/Mathematical Sciences) Sem-V with Mathematics as one of the Core Discipline

Category-III

DISCIPLINE SPECIFIC CORE COURSE – 5 (Discipline A-5): ELEMENTS OF REAL ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Real Analysis	4	3	1	0	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- The real line with algebraic, order and completeness properties.
- Convergence and divergence of sequences and series of real numbers with applications.

Learning Outcomes: This course will enable the students to:

- Understand the basic properties of the set of real numbers, including completeness and Archimedean with some consequences.
- Recognize bounded, convergent, monotonic and Cauchy sequences
- Learn to apply various tests such as limit comparison, ratio, root, and alternating series tests for convergence and absolute convergence of infinite series of real numbers.

SYLLABUS OF DISCIPLINE A-5

UNIT-I: Basic Properties of the Set of Real Numbers (12 hours)

Field and order properties of $\mathbb{R}$, basic properties and inequalities of the absolute value of a real number, bounded above and bounded below sets, Suprema and infima, The completeness axiom and the Archimedean property of $\mathbb{R}$.

UNIT-II: Real Sequences (18 hours)

Convergence of a real sequence, Algebra of limits, The squeeze principle and applications, Monotone sequences, Monotone convergence theorem and applications, Cauchy sequences, Cauchy criterion for convergence and applications.

UNIT-III: Infinite Series of Real Numbers (15 hours)

Convergence and divergence of infinite series of real numbers, Necessary condition for convergence, Cauchy criterion for convergence of series, Tests for convergence of positive term series, Applications of the integral test, Comparison tests, D'Alembert's ratio test, Cauchy's nth root test, Raabe's test; Alternating series, Leibniz alternating series test, Absolute and conditional convergence.

Essential Reading

1. Denlinger, Charles G. (2011). Elements of Real Analysis. Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

Suggestive Readings

- Bartle, Robert G., & Sherbert, Donald R. (2011). Introduction to Real Analysis (4th ed.). John Wiley & Sons. Wiley India Edition 2015.
- Bilodeau, Gerald G., Thie, Paul R., & Keough, G. E. (2010). An Introduction to Analysis (2nd ed.). Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

DSE Courses of B.Sc. (Physical Sciences/Mathematical Sciences) Semester-V

Category-III

DISCIPLINE SPECIFIC ELECTIVE COURSE – 3(i): BIOMATHEMATICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Biomathematics	4	3	1	0	Class XII pass with Mathematics	Discipline A-3: Differential Equations

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: The course will enable the students to:

- Get a better comprehension of mathematical models, utilised in biology.
- To identify and explain the findings from models of population studies, species' communication, adaptation, and dynamics of disorder.
- Create a basic model of molecular evolution by making use of probability and matrices.

SYLLABUS OF DSE-3(i)

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 and Modeling Molecular Evolution (15 hours)
Bifurcation, Bifurcation of a limit cycle, Discrete bifurcation and period-doubling, Chaos, Stability of limit cycles, Introduction of the Poincaré plane; Modeling molecular evolution: Matrix models of base substitutions for DNA sequences, Jukes-Cantor and Kimura models, Phylogenetic distances.

Essential Readings

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

Suggestive Readings

- 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.

DISCIPLINE SPECIFIC ELECTIVE COURSE-3(ii): MATHEMATICAL PYTHON

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mathematical Python	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of Python

Learning Objectives: The Learning Objectives of this course are as follows:

- To be able to model and solve mathematical problems using Python Programs.
- To experience utility of open-source resources for numerical and symbolic mathematical software systems.

Learning Outcomes: This course will enable the students to use Python:

- For numerical and symbolic computation in mathematical problems from calculus, algebra, and geometry.
- To tabulate and plot diverse graphs of functions and understand tracing of shapes, geometries, and fractals.
- To prepare smart documents with LaTeX interface.

SYLLABUS OF DSE - 3(ii)

Theory

UNIT – I: Drawing Shapes, Graphing and Visualization (15 hours)

Drawing diverse shapes using code and Turtle; Using matplotlib and NumPy for data organization, Structuring and plotting lines, bars, markers, contours and fields, managing subplots and axes; Pyplot and subplots, Animations of decay, Bayes update, Random walk.

UNIT – II: Numerical and Symbolic Solutions of Mathematical Problems (18 hours)

NumPy for scalars and linear algebra on *n*-dimensional arrays; Computing eigenspace, Solving dynamical systems on coupled ordinary differential equations, Functional programming fundamentals using NumPy; Symbolic computation and SymPy: Differentiation and integration of functions, Limits, Solution of ordinary differential equations, Computation of eigenvalues, Solution of expressions at multiple points (lambdify), Simplification of expressions, Factorization, Collecting and canceling terms, Partial fraction decomposition, Trigonometric simplification, Exponential and logarithms, Series expansion and finite differences, Solvers, Recursive equations.

UNIT – III: Document Generation with Python and LaTeX (12 hours)

Pretty printing using SymPy; Pandas API for IO tools: interfacing Python with text/csv, HTML, LaTeX, XML, MSExcel, OpenDocument, and other such formats; Pylatex and writing document files from Python with auto-computed values, Plots and visualizations.

Practical (30 hours): Software labs using IDE such as Spyder and Python Libraries.

- Installation, update, and maintenance of code, troubleshooting.
- Implementation of all methods learned in theory.
- Explore and explain API level integration and working of two problems with standard Python code.

Essential Readings

1. Farrell, Peter (2019). Math Adventures with Python. No Starch Press. ISBN Number: 978-1-59327-867-0.
2. Farrell, Peter and et al. (2020). The Statistics and Calculus with Python Workshop. Packet Publishing Ltd. ISBN: 978-1-80020-976-3.
3. Saha, Amit (2015). Doing Math with Python. No Starch Press. ISBN: 978-1-59327-640-9

Suggestive Readings

- Morley, Sam (2022). Applying Math with Python (2nd ed.). Packet Publishing Ltd. ISBN: 978-1-80461-837-0
- Online resources and documentation on the libraries, such as:
  - https://matplotlib.org
  - https://sympy.org
  - https://pandas.pydata.org
  - https://numpy.org
  - https://pypi.org
  - https://patrickwalls.github.io/mathematicalpython/

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE-3(iii): MECHANICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mechanics	4	3	1	0	Class XII pass with Mathematics	Discipline A-1: Topics in Calculus Discipline A-3: Differential Equations

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

- Starting Newtonian laws, learning various technical notions which explains various states of motion under given forces.
- Deals with the kinematics and kinetics of the rectilinear and planar motions of a particle including constrained oscillatory motions of particles, projectiles, and planetary orbits.
- Understand hydrostatic pressure and thrust on plane surfaces.

Learning Outcomes: This course will enable the students to:

- Understand necessary conditions for the equilibrium of particles acted upon by various forces and learn the principle of virtual work for a system of coplanar forces.
- Apply the concepts of center of gravity, laws of static and kinetic friction.
- Learn that a particle moving under a central force describes a plane curve and know the Kepler's laws of the planetary motions.
- Evaluate the hydrostatic pressure at any given depth in a heavy homogeneous liquid at rest under gravity.

SYLLABUS OF DSE-3(iii)

UNIT – I: Statics **(15 hours)**

Fundamental laws of Newtonian mechanics, Law of parallelogram of forces, Equilibrium of a particle, Lamy's theorem, Equilibrium of a system of particles, External and internal forces, Couples, Reduction of a plane force system, Work, Principle of virtual work, Potential energy and conservative field, Mass centers, Centers of gravity, Friction.

UNIT – II: Dynamics **(18 hours)**

Kinemetics of a particle, Motion of a particle, Motion of a system, Principle of linear momentum, Motion of mass center, Principle of angular momentum, Motion relative to mass center, Principle of energy, D'Alembert's principle; Moving frames of reference, Frames of reference with uniform translational velocity, Frames of reference with constant angular velocity; Applications in plane dynamics- Motion of a projectile, Harmonic oscillators, General motion under central forces, Planetary orbits.

UNIT – III: Hydrostatics **(12 hours)**

Shearing stress, Pressure, Perfect fluid, Pressure at a point in a fluid, Transmissibility of liquid pressure, Compression, Specific gravity, Pressure of heavy fluid- Pressure at all points in a horizontal plane, Surface of equal density; Thrust on plane surfaces.

Essential Readings

3. Synge, J. L., & Griffith, B. A. (2017). Principles of Mechanics (3rd ed.). McGraw-Hill Education. Indian Reprint.
4. Ramsey, A. S. (2017). Hydrostatics. Cambridge University Press. Indian Reprint.

Suggestive Readings

- Roberts, A. P. (2003). Statics and Dynamics with Background Mathematics. Cambridge University Press.
- Ramsey, A. S. (1985). Statics (2nd ed.). Cambridge University Press.

COMMON POOL OF GENERIC ELECTIVES (GE) Semester-V COURSES OFFERED BY DEPARTMENT OF MATHEMATICS

Category-IV

GENERIC ELECTIVES (GE-5(i)): NUMERICAL METHODS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Numerical Methods	4	3	0	1	Class XII pass with Mathematics	NIL

Learning Objectives: The core purpose of the course is to:

- Acquaint students with various topics in numerical solutions of nonlinear equations in one variable, interpolation and approximation, numerical differentiation and integration, direct methods for solving linear systems, numerical solution of ordinary differential equations using Computer Algebra System (CAS).

Learning Outcomes: The course will enable the students to:

- Find the consequences of finite precision and the inherent limits of numerical methods.
- Appropriate numerical methods to solve algebraic and transcendental equations.
- Solve first order initial value problems of ODE's numerically using Euler methods.

SYLLABUS OF GE-5(i)

UNIT-I: Errors and Roots of Transcendental and Polynomial Equations (12 hours)

Errors: Roundoff error, Local truncation error, Global truncation error; Order of a method, Convergence, and terminal conditions; Bisection method, Secant method, Regula−Falsi method, Newton−Raphson method.

UNIT-II: Algebraic Linear Systems and Interpolation (18 hours)

Gaussian elimination method (with row pivoting); Iterative methods: Jacobi method, Gauss−Seidel method; Interpolation: Lagrange form, Newton form, Finite difference operators.

UNIT-III: Numerical Differentiation, Integration and ODE (15 hours)

First and second order numerical derivatives; Trapezoidal rule, Simpson's rule for numerical integration; Ordinary differential equation: Euler's, and Runge-Kutta method.

Essential Readings

1. Chapra, Steven C. (2018). Applied Numerical Methods with MATLAB for Engineers and Scientists (4th ed.). McGraw-Hill Education.
2. Fausett, Laurene V. (2009). Applied Numerical Analysis Using MATLAB. Pearson. India.
3. Jain, M. K., Iyengar, S. R. K., & Jain R. K. (2012). Numerical Methods for Scientific and Engineering Computation (6th ed.). New Age International Publishers. Delhi.

Suggestive Reading

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

Note: Non programmable scientific calculator may be allowed in the University examination.

Practical (30 hours): Practical/Lab work to be performed in Computer Lab: Use of computer algebra software (CAS), for example Python/SageMath/Mathematica/MATLAB/ Maple/ Maxima/Scilab etc., for developing the following numerical programs:

1. Bisection method
2. Secant method and Regula−Falsi method
3. Newton-Raphson method
4. Gauss−Jacobi method and Gauss−Seidel method
5. Lagrange interpolation and Newton interpolation
6. Trapezoidal rule and Simpson's rule
7. Euler's, and Runge-Kutta methods for solving first order initial-value problems of ordinary differential equations.

GENERIC ELECTIVES (GE-5(ii)): MATHEMATICAL PYTHON

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Mathematical Python	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of python

Learning Objectives: The Learning Objectives of this course are as follows:

- To be able to model and solve mathematical problems using Python Programs.
- To experience utility of open-source resources for numerical and symbolic mathematical software systems.

Learning Outcomes: This course will enable the students to use Python:

- For numerical and symbolic computation in mathematical problems from calculus, algebra, and geometry.
- To tabulate and plot diverse graphs of functions and understand tracing of shapes, geometries, and fractals.
- To prepare smart documents with LaTeX interface.

SYLLABUS OF GE-5(ii)

Theory

UNIT – I: Drawing Shapes, Graphing and Visualization (15 hours)

Drawing diverse shapes using code and Turtle; Using matplotlib and NumPy for data organization, Structuring and plotting lines, bars, markers, contours and fields, managing subplots and axes; Pyplot and subplots, Animations of decay, Bayes update, Random walk.

UNIT – II: Numerical and Symbolic Solutions of Mathematical Problems (18 hours)

NumPy for scalars and linear algebra on *n*-dimensional arrays; Computing eigenspace, Solving dynamical systems on coupled ordinary differential equations, Functional programming fundamentals using NumPy; Symbolic computation and SymPy: Differentiation and integration of functions, Limits, Solution of ordinary differential equations, Computation of eigenvalues, Solution of expressions at multiple points (lambdify), Simplification of expressions, Factorization, Collecting and canceling terms, Partial fraction decomposition, Trigonometric simplification, Exponential and logarithms, Series expansion and finite differences, Solvers, Recursive equations.

UNIT – III: Document Generation with Python and LaTeX (12 hours)

Pretty printing using SymPy; Pandas API for IO tools: interfacing Python with text/csv, HTML, LaTeX, XML, MSExcel, OpenDocument, and other such formats; Pylatex and writing document files from Python with auto-computed values, Plots and visualizations.

Practical (30 hours): Software labs using IDE such as Spyder and Python Libraries.

- Installation, update, and maintenance of code, troubleshooting.
- Implementation of all methods learned in theory.
- Explore and explain API level integration and working of two problems with standard Python code.

Essential Readings

1. Farrell, Peter (2019). Math Adventures with Python. No Starch Press. ISBN Number: 978-1-59327-867-0.
2. Farrell, Peter and et al. (2020). The Statistics and Calculus with Python Workshop. Packet Publishing Ltd. ISBN: 978-1-80020-976-3.
3. Saha, Amit (2015). Doing Math with Python. No Starch Press. ISBN: 978-1-59327-640-9

Suggestive Readings

- Morley, Sam (2022). Applying Math with Python (2nd ed.). Packet Publishing Ltd. ISBN: 978-1-80461-837-0
- Online resources and documentation on the libraries, such as:
  - https://matplotlib.org
  - https://sympy.org
  - https://pandas.pydata.org
  - https://numpy.org
  - https://pypi.org
  - https://patrickwalls.github.io/mathematicalpython/

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DEPARTMENT OF MATHEMATICS

Category-I

B.Sc. (Hons.) Mathematics, Semester-VI

DISCIPLINE SPECIFIC CORE COURSE – 16: ADVANCED GROUP THEORY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Group Theory	4	3	1	0	Class XII pass with Mathematics	DSC-7: Group Theory

Learning Objectives: The objective of the course is to introduce:
- The concept of group actions.
- Sylow's Theorem and its applications to groups of various orders.
- Composition series and Jordan-Hölder theorem.

Learning Outcomes: This course will enable the students to:
- Understand the concept of group actions and their applications.
- Understand finite groups using Sylow's theorem.
- Use Sylow's theorem to determine whether a group is simple or not.
- Understand and determine if a group is solvable or not.

SYLLABUS OF DSC-16

UNIT – I: Group Actions (18 hours)

Definition and examples of group actions, Permutation representations; Centralizers and Normalizers, Stabilizers and kernels of group actions; Groups acting on themselves by left multiplication and conjugation with consequences; Cayley's theorem, Conjugacy classes, Class equation, Conjugacy in S_n, Simplicity of A_5.

UNIT – II: Sylow Theorems and Applications (15 hours)

p-groups, Sylow p-subgroups, Sylow's theorem, Applications of Sylow's theorem, Groups of order pq and p^2q (p and q both prime); Finite simple groups, Nonsimplicity tests.

UNIT – III: Solvable Groups and Composition Series (12 hours)

Solvable groups and their properties, Commutator subgroups, Nilpotent groups, Composition series, Jordan-Hölder theorem.

Essential Readings

1. Dummit, David S., & Foote, Richard M. (2004). Abstract Algebra (3rd ed.). John Wiley & Sons. Student Edition, Wiley India 2016.
2. Gallian, Joseph. A. (2017). Contemporary Abstract Algebra (9th ed.). Cengage Learning India Private Limited, Delhi. Indian Reprint 2021.
3. Beachy, John A., & Blair, William D. (2019). Abstract Algebra (4th ed.). Waveland Press.

Suggestive Readings

- Fraleigh, John B., & Brand Neal E. (2021). A First Course in Abstract Algebra (8th ed.). Pearson.
- Herstein, I. N. (1975). Topics in Algebra (2nd ed.). Wiley India. Reprint 2022.
- Rotman, Joseph J. (1995). An Introduction to the Theory of Groups (4th ed.). Springer.

DISCIPLINE SPECIFIC CORE COURSE – 17: ADVANCED LINEAR ALGEBRA

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advanced Linear Algebra	4	3	1	0	Class XII pass with Mathematics	DSC-4: Linear Algebra

Learning Objectives: The objective of the course is to introduce:

- Linear functionals, dual basis and the dual (or transpose) of a linear transformation.
- Diagonalization problem and Jordan canonical form for linear operators or matrices using eigenvalues.
- Inner product, norm, Cauchy-Schwarz inequality, and orthogonality on real or complex vector spaces.
- The adjoint of a linear operator with application to least squares approximation and minimal solutions to linear system.
- Characterization of self-adjoint (or normal) operators on real (or complex) spaces in terms of orthonormal bases of eigenvectors and their corresponding eigenvalues.

Learning Outcomes: This course will enable the students to:

- Understand the notion of an inner product space in a general setting and how the notion of inner products can be used to define orthogonal vectors, including to the Gram-Schmidt process to generate an orthonormal set of vectors.
- Use eigenvectors and eigenspaces to determine the diagonalizability of a linear operator.
- Find the Jordan canonical form of matrices when they are not diagonalizable.

- Learn about normal, self-adjoint, and unitary operators and their properties, including the spectral decomposition of a linear operator.
- Find the singular value decomposition of a matrix.

SYLLABUS OF DSC-17

UNIT-I: Dual Spaces, Diagonalizable Operators and Canonical Forms (18 hours)
The change of coordinate matrix; Dual spaces, Double dual, Dual basis, Transpose of a linear transformation and its matrix in the dual basis, Annihilators; Eigenvalues, eigenvectors, eigenspaces and the characteristic polynomial of a linear operator; Diagonalizability, Direct sum of subspaces, Invariant subspaces and the Cayley-Hamilton theorem; The Jordan canonical form and the minimal polynomial of a linear operator.

UNIT-II: Inner Product Spaces and the Adjoint of a Linear Operator (12 hours)
Inner products and norms, Orthonormal basis, Gram-Schmidt orthogonalization process, Orthogonal complements, Bessel's inequality; Adjoint of a linear operator with applications to least squares approximation and minimal solutions to systems of linear equations.

UNIT-III: Class of Operators and Their Properties (15 hours)
Normal, self-adjoint, unitary and orthogonal operators and their properties; Orthogonal projections and the spectral theorem; Singular value decomposition for matrices.

Essential Reading

1. Friedberg, Stephen H., Insel, Arnold J., & Spence, Lawrence E. (2019). Linear Algebra (5th ed.). Pearson Education India Reprint.

Suggestive Readings

- Hoffman, Kenneth, & Kunze, Ray Alden (1978). Linear Algebra (2nd ed.). Prentice Hall of India Pvt. Limited. Delhi. Pearson Education India Reprint, 2015.
- Lang, Serge (1987). Linear Algebra (3rd ed.). Springer.

DISCIPLINE SPECIFIC CORE COURSE – 18: COMPLEX ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Complex Analysis	4	3	0	1	Class XII pass with Mathematics	DSC-2 & 11: Real Analysis, Multivariate Calculus

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

- Acquaint with the basic ideas of complex analysis.
- Learn complex-valued functions with visualization through relevant practicals.

- Emphasize on Cauchy's theorems, series expansions and calculation of residues.

Learning Outcomes: The accomplishment of the course will enable the students to:

- Grasp the significance of differentiability of complex-valued functions leading to the understanding of Cauchy-Riemann equations.
- Study some elementary functions and evaluate the contour integrals.
- Learn the role of Cauchy-Goursat theorem and the Cauchy integral formula.
- 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.

SYLLABUS OF DSC-18

UNIT – I: Analytic and Elementary Functions (15 hours)

Functions of a complex variable and mappings, Limits, Theorems on limits, Limits involving the point at infinity, Continuity and differentiation, Cauchy-Riemann equations and examples, Sufficient conditions for differentiability, Analytic functions and their examples; Exponential, logarithmic, and trigonometric functions.

UNIT – II: Complex Integration (15 hours)

Derivatives of functions, Definite integrals of functions; Contours, Contour integrals and examples, Upper bounds for moduli of contour integrals; Antiderivatives; Cauchy-Goursat theorem; Cauchy integral formula and its extension with consequences; Liouville's theorem and the fundamental theorem of algebra.

UNIT – III: Series and Residues (15 hours)

Taylor and Laurent series with examples; Absolute and uniform convergence of power series, Integration, differentiation and uniqueness of power series; Isolated singular points, Residues, Cauchy's residue theorem, Residue at infinity; Types of isolated singular points, Residues at poles and its examples, An application to evaluate definite integrals involving sines and cosines.

Essential Reading

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

Suggestive Readings

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

Practical (30 hours)- Practical / Lab work to be performed in Computer Lab:

Modeling of the following similar problems using SageMath/Python/Mathematica/Maple/ MATLAB/Maxima/ Scilab etc.

1. Make a geometric plot to show that the *n*th roots of unity are equally spaced points that lie on the unit circle $C_1(0) = \{z : |z| = 1\}$ and form the vertices of a regular polygon with *n* sides, for *n* = 4, 5, 6, 7, 8.
2. Find all the solutions of the equation $z^3 = 8i$ and represent these geometrically.
3. Write parametric equations and make a parametric plot for an ellipse centered at the origin with horizontal major axis of 4 units and vertical minor axis of 2 units.
   Show the effect of rotation of this ellipse by an angle of $\frac{\pi}{6}$ radians and shifting of the centre from (0,0) to (2,1), by making a parametric plot.
4. Show that the image of the open disk $D_1(-1-i) = \{z : |z+1+i| < 1\}$ under the linear transformation $w = f(z) = (3-4i)z + 6 + 2i$ is the open disk:
   $$D_5(-1+3i) = \{w : |w+1-3i| < 5\}.$$
5. Show that the image of the right half-plane Re $z = x > 1$ under the linear transformation $w = (-1+i)z - 2 + 3i$ is the half-plane $v > u + 7$, where $u = \mathrm{Re}(w)$, etc. Plot the map.
6. Show that the image of the right half-plane A = $\{z\text{: Re } z \geq \frac{1}{2}\}$ under the mapping
   $w = f(z) = \frac{1}{z}$ is the closed disk $\overline{D_1(1)} = \{w : |w-1| \leq 1\}$ in the *w*- plane.
7. Make a plot of the vertical lines $x = a$, for $a = -1, -\frac{1}{2}, \frac{1}{2}, 1$ and the horizontal lines $y = b$, for $b = -1, -\frac{1}{2}, \frac{1}{2}, 1$. Find the plot of this grid under the mapping $f(z) = \frac{1}{z}$.
8. Find a parametrization of the polygonal path $C = C_1 + C_2 + C_3$ from $-1+i$ to $3-i$, where C_1 is the line from: $-1+i$ to -1, C_2 is the line from: -1 to $1+i$ and C_3 is the line from $1+i$ to $3-i$. Make a plot of this path.
9. Plot the line segment '*L*' joining the point $A = 0$ to $B = 2 + \frac{\pi}{4}i$ and give an exact calculation of $\int_L e^z dz$.
10. Evaluate $\int_C \frac{1}{z-2} dz$, where *C* is the upper semicircle with radius 1 centered at $z = 2$ oriented in a positive direction.
11. Show that $\int_{C_1} z dz = \int_{C_2} z dz = 4 + 2i$, where C_1 is the line segment from $-1-i$ to $3+i$ and C_2 is the portion of the parabola $x = y^2 + 2y$ joining $-1-i$ to $3+i$.
    Make plots of two contours C_1 and C_2 joining $-1-i$ to $3+i$.
12. Use the ML inequality to show that $\left|\int_C \frac{1}{z^2+1} dz\right| \leq \frac{1}{2\sqrt{5}}$, where *C* is the straight-line segment from 2 to $2+i$. While solving, represent the distance from the point *z* to the points *i* and $-i$, respectively, i.e., $|z-i|$ and $|z+i|$ on the complex plane $\mathbb{C}$.
13. Find and plot three different Laurent series representations for the function:
    $$f(z) = \frac{3}{2+z-z^2},$$ involving powers of *z*.
14. Locate the poles of $f(z) = \frac{1}{5z^4+26z^2+5}$ and specify their order.
15. Locate the zeros and poles of $g(z) = \frac{\pi\cot(\pi z)}{z^2}$ and determine their order. Also justify that Res $(g, 0) = -\pi^2/3$.

16. Evaluate $\int_{C_1^+(0)} \exp\left(\frac{2}{z}\right) dz$, where $C_1^+(0)$ denotes the circle $\{z: |z| = 1\}$ with positive orientation. Similarly evaluate $\int_{C_1^+(0)} \frac{1}{z^4+z^3-2z^2} dz$.

B.Sc. (Hons) Mathematics, Semester-VI, DSE-Courses

DISCIPLINE SPECIFIC ELECTIVE COURSE – 4(i): MATHEMATICAL FINANCE

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Mathematical Finance	4	3	0	1	Class XII pass with Mathematics	DSC-3, 11, & 15: Probability and Statistics, Multivariate Calculus, & PDE's

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

- Introduce the application of mathematics in the financial world.
- Understand some computational and quantitative techniques required for working in the financial markets and actuarial sciences.

Learning Outcomes: The course will enable the students to:

- Know the basics of financial markets and derivatives including options and futures.
- Learn about pricing and hedging of options.
- Learn the Itô's formula and the Black–Scholes model.
- Understand the concepts of trading strategies.

SYLLABUS OF DSE-4(i)

Unit - I: Interest Rates, Bonds and Derivatives (15 hours)

Interest rates, Types of rates, Measuring interest rates, Zero rates, Bond pricing, Forward rates, Duration, Convexity, Exchange-traded markets and Over-the-counter markets, Derivatives, Forward contracts, Futures contracts, Options, Types of traders, Hedging, Speculation, Arbitrage, No Arbitrage principle, Short selling, Forward price for an investment asset.

Unit - II: Properties of Options and the Binomial Model (15 hours)

Types of options, Option positions, Underlying assets, Factors affecting option prices, Bounds for option prices, Put-call parity (in case of non-dividend paying stock only), Early exercise, Trading strategies involving options (except box spreads, calendar spreads and diagonal spreads), Binomial option pricing model, Risk-neutral valuation (for European and American options on assets following binomial tree model).

Unit - III: The Black-Scholes Model and Hedging Parameters (15 hours)
Brownian motion (Wiener Process), Geometric Brownian Motion (GBM), The process for a stock price, Itô's lemma, Lognormal property of stock prices, Distribution of the rate of return, Expected return, Volatility, Estimating volatility from historical data, Derivation of the Black-Scholes-Merton differential equation, Extension of risk-neutral valuation to assets following GBM (without proof), Black−Scholes formulae for European options, Hedging parameters - The Greek letters: Delta, Gamma, Theta, Rho and Vega; Delta hedging, Gamma hedging.

Essential Readings

1. Hull, John C., & Basu, S. (2022). Options, Futures and Other Derivatives (11th ed.). Pearson Education, India.
2. Benninga, S. & Mofkadi, T. (2021). Financial Modeling, (5th ed.). MIT Press, Cambridge, Massachusetts, London, England.

Suggestive Readings

- Luenberger, David G. (2013). Investment Science (2nd ed.). Oxford University Press.
- Ross, Sheldon M. (2011). An elementary Introduction to Mathematical Finance (3rd ed.). Cambridge University Press.
- Day, A.L. (2015). Mastering Financial Mathematics in Microsoft Excel: A Practical Guide for Business Calculations (3rd ed.). Pearson Education Ltd.

Note: Use of non-programmable scientific calculator is allowed in theory examination.

Practical (30 hours)- Practical/Lab work using Excel/R/Python/MATLAB/MATHEMATICA

1. Computing simple, nominal, and effective rates. Conversion and comparison.
2. Computing price and yield of a bond.
3. Comparing spot and forward rates.
4. Computing bond duration and convexity.
5. Trading strategies involving options.
6. Simulating a binomial price path.
7. Computing price of European call and put options when the underlying follows binomial model (using Monte Carlo simulation).
8. Estimating volatility from historical data of stock prices.
9. Simulating lognormal price path.
10. Computing price of European call and put options when the underlying follows lognormal model (using Monte Carlo simulation).

11. Implementing the Black-Scholes formulae.
12. Computing Greeks for European call and put options.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 4(ii): INTEGRAL TRANSFORMS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Integral Transforms	4	3	1	0	Class XII pass with Mathematics	DSC-6,15: ODE's, PDE's DSC-8, 10: Riemann Integration, Sequences & Series of Functions

Learning Objectives: Primary objective of this course is to introduce:

- The basic idea of integral transforms of functions and their applications through an introduction to Fourier series expansion of a periodic function.
- Fourier transform and Laplace transform of functions of a real variable with applications to solve ODE's and PDE's.

Learning Outcomes: The course will enable the students to:

- Understand the Fourier series associated with a periodic function, its convergence, and the Gibbs phenomenon.
- Compute Fourier and Laplace transforms of classes of functions.
- Apply techniques of Fourier and Laplace transforms to solve ordinary and partial differential equations and initial and boundary value problems.

SYLLABUS OF DSE-4(ii)

UNIT-I: Fourier Series and Integrals (18 hours)

Piecewise continuous functions and periodic functions, Systems of orthogonal functions, Fourier series: Convergence, examples and applications of Fourier series, Fourier cosine series and Fourier sine series, The Gibbs phenomenon, Complex Fourier series, Fourier series on an arbitrary interval, The Riemann-Lebesgue lemma, Pointwise convergence, uniform convergence, differentiation, and integration of Fourier series; Fourier integrals.

UNIT-II: Integral Transform Methods (15 hours)

Fourier transforms, Properties of Fourier transforms, Convolution theorem of the Fourier transform, Fourier transforms of step and impulse functions, Fourier sine and cosine transforms, Convolution properties of Fourier transform; Laplace transforms, Properties of Laplace transforms, Convolution theorem and properties of the Laplace transform, Laplace transforms of the heaviside and Dirac delta functions.

UNIT-III: Applications of Integral Transforms (12 hours)

Finite Fourier transforms and applications, Applications of Fourier transform to ordinary and partial differential equations; Applications of Laplace transform to ordinary differential equations, partial differential equations, initial and boundary value problems.

Essential Readings

1. Tyn Myint-U & Lokenath Debnath (2007). Linear Partial Differential Equations for Scientists and Engineers (4th ed.). Birkhauser. Indian Reprint.
2. Lokenath Debnath & Dambaru Bhatta (2015). Integral Transforms and Their Applications (3rd ed.). CRC Press Taylor & Francis Group.

Suggestive Readings

- Baidyanath Patra (2018). An Introduction to Integral Transforms. CRC Press.
- Joel L. Schiff (1999). The Laplace Transform-Theory and Applications. Springer.
- Rajendra Bhatia (2003). Fourier Series (2nd ed.). Texts and Readings in Mathematics, Hindustan Book Agency, Delhi.
- Yitzhak Katznelson (2004). An Introduction to Harmonic Analysis (3rd ed.). Cambridge University Press.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 4(iii): RESEARCH METHODOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	NIL

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

- Prepare the students with skills needed for successful research in mathematics.
- Develop a basic understanding of how to pursue research in mathematics.
- Prepare students for professions other than teaching, that requires independent mathematical research, critical analysis, and advanced mathematical knowledge.
- Introduce some open source softwares to carry out mathematical research.
- Impart the knowledge of journals, their rankings and the disadvantages of rankings.

Learning Outcomes: The course will enable the students to:

- Develop researchable questions and to make them inquisitive enough to search and verify new mathematical facts.
- Understand the methods in research and carry out independent study in areas of mathematics.
- Write a basic mathematical article and a research project.
- Gain knowledge about publication of research articles in good journals.
- Communicate mathematical ideas both in oral and written forms effectively.

SYLLABUS OF DSE - 4(iii)

UNIT– I: How to Learn, Write, and Research Mathematics (17 hours)

How to learn mathematics, How to write mathematics: Goals of mathematical writing, general principles of mathematical writing, avoiding errors, writing mathematical solutions and proofs, the revision process, What is mathematical research, finding a research topic, Literature survey, Research Criteria, Format of a research article (including examples of mathematical articles) and a research project (report), publishing research.

UNIT- II: Mathematical Typesetting and Presentation using LaTeX (16 hours)

How to present mathematics: Preparing a mathematical talk, Oral presentation, Use of technology which includes LaTeX, PSTricks and Beamer; Poster presentation.

UNIT- III: Mathematical Web Resources and Research Ethics (12 hours)

Web resources- MAA, AMS, SIAM, arXiv, ResearchGate; Journal metrics: Impact factor of journal as per JCR, MCQ, SNIP, SJR, Google Scholar metric; Challenges of journal metrics; Reviews/Databases: MathSciNet, zbMath, Web of Science, Scopus; Ethics with respect to science and research, Plagiarism check using software like URKUND/Ouriginal by Turnitin.

Essential Readings

1. Bindner, Donald, & Erickson Martin (2011). A Student's Guide to the Study, Practice, and Tools of Modern Mathematics. CRC Press, Taylor & Francis Group.
2. Committee on Publication Ethics- COPE (https://publicationethics.org/)
3. Declaration on Research Assessment. https://en.wikipedia.org/wiki/San_Francisco_Declaration_on_Research_Assessment
4. Evaluating Journals using journal metrics; (https://academicguides.waldenu.edu/library/journalmetrics#s-lg-box-13497874)
5. Gallian, Joseph A. (2006). Advice on Giving a Good PowerPoint Presentation (https://www.d.umn.edu/~jgallian/goodPPtalk.pdf). MATH HORIZONS.
6. Lamport, Leslie (2008). LaTeX, a Document Preparation System, Pearson.
7. Locharoenrat, Kitsakorn (2017). Research Methodologies for Beginners, Pan Stanford Publishing Pte. Ltd., Singapore.
8. Nicholas J. Higham. Handbook for writing for the Mathematical Sciences, SIAM, 1998.
9. Steenrod, Norman E., Halmos, Paul R., Schiffer, M. M., & Dieudonné, Jean A. (1973). How to Write Mathematics, American Mathematical Society.

10. Tantau, Till,Wright, Joseph, & Miletić, Vedran (2023). The BEAMER class, Use Guide for Version 3.69. TeX User Group. (https://tug.ctan.org/macros/latex/contrib/beamer/doc/beameruserguide.pdf)
11. University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations 2018 (The Gazette of India: Extraordinary, Part-iii-Sec.4)

Practical (30 hours): Practical work to be performed in the computer lab of the following using any TeX distribution software:

1. Starting LaTeX, Preparing an input file, Sequences and paragraphs, Quotation marks, Dashes, Space after a period, Special symbols, Simple text- generating commands, Emphasizing text, Preventing line breaks, Footnotes, ignorable input.
2. The document, The document class, The title page, Sectioning, Displayed material, Quotations, Lists, Displayed formulas, Declarations.
3. Running LaTeX, Changing the type style, Accents, Symbols, Subscripts and superscripts, Fractions, Roots, Ellipsis.
4. Mathematical Symbols, Greek letters, Calligraphic letters, Log-like functions, Arrays, The array environment, Vertical alignment, Delimiters, Multiline formulas.
5. Putting one thing above another, Over and underlining, Accents, Stacking symbols, Spacing in math mode, Changing style in math mode, Type style, Math style.
6. Defining commands, Defining environments, Theorems.
7. Figure and tables, Marginal notes, The tabbing environment, The tabular environment.
8. The Table and contents, Cross-references, Bibliography and citation.
9. Beamer: Templates, Frames, Title page frame, Blocks, Simple overlays, Themes.
10. PSTricks
11. Demonstration of web resources.

B.A. (Prog.) Semester-VI with Mathematics as Major
Category-II

DISCIPLINE SPECIFIC CORE COURSE (DSC-6): ELEMENTARY MATHEMATICAL ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elementary Mathematical Analysis	4	3	1	0	Class XII pass with Mathematics	Discipline A-5: Elements of Real Analysis

Learning Objectives: The primary objective of this course is to introduce:
- Sequential criterion for limits and continuity of real-valued functions.
- Riemann integral of real-valued function f on $[a, b]$ using Darboux sums.
- Pointwise and uniform convergence of sequences and series of functions.

Learning Outcomes: This course will enable the students to:
- Apply sequential continuity criterion for the proof of intermediate value theorem.
- Understand the basic tool used to calculate integrals.
- Apply uniform convergence for term-by-term integration in power series expansion.

SYLLABUS OF DSC-6

UNIT-I: Continuous Functions (12 hours)
Sequential criterion for limits and continuity of functions, Continuity on intervals, Intermediate value theorem and applications; Uniform continuity.

UNIT-II: The Riemann Integral (15 hours)
Riemann integration, criterion for integrability and examples; Integrability of continuous and monotone functions, Algebraic properties of the Riemann integral, Fundamental theorem of calculus (first form).

UNIT-III: Uniform Convergence (18 hours)
Sequences and series of functions: Pointwise and uniform convergence, Uniform Cauchy criterion, Weierstrass M-test, Implications of uniform convergence in calculus; Power series, Radius and interval of convergence, Applications of Abel's theorem for power series.

Essential Reading

1. Denlinger, Charles G. (2011). Elements of Real Analysis. Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

Suggestive Readings

- Bartle, Robert G., & Sherbert, Donald R. (2011). Introduction to Real Analysis (4th ed.). John Wiley & Sons. Wiley India Edition 2015.
- Ross, Kenneth A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.

DISCIPLINE SPECIFIC CORE COURSE – 6 (Discipline A-6): PROBABILITY AND STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Probability and Statistics	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	**NIL**

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

- Make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness.
- Render the students to several examples and exercises that blend their everyday experiences with their scientific interests to form the basis of data science.

Learning Outcomes: This course will enable the students to:

- Understand some basic concepts and terminology-population, sample, descriptive and inferential statistics including stem-and-leaf plots, dotplots, histograms and boxplots.
- Learn about probability density functions and various univariate distributions such as binomial, hypergeometric, negative binomial, Poisson, normal, exponential, and lognormal.
- Understand the remarkable fact that the empirical frequencies of so many natural populations, exhibit bell-shaped (i.e., normal) curves, using the Central Limit Theorem.
- Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.

SYLLABUS OF DISCIPLINE A-6

UNIT-I: Descriptive Statistics, Probability, and Discrete Probability Distributions (15 hours)

Descriptive statistics: Populations, Samples, Stem-and-leaf displays, Dotplots, Histograms, Qualitative data, Measures of location, Measures of variability, Boxplots; Sample spaces and events, Probability axioms and properties, Conditional probability, Bayes' theorem, and independent events; Discrete random variables & probability distributions, Expected values; Probability distributions: Binomial, geometric, hypergeometric, negative binomial, Poisson, and Poisson distribution as a limit.

UNIT-II: Continuous Probability Distributions **(15 hours)**
Continuous random variables, Probability density functions, Uniform distribution, Cumulative distribution functions and expected values, The normal, exponential, and lognormal distributions.

UNIT-III: Central Limit Theorem and Regression Analysis **(15 hours)**
Sampling distribution and standard error of the sample mean, Central Limit Theorem, and applications; Scatterplot of bivariate data, Regression line using principle of least squares, Estimation using the regression lines; Sample correlation coefficient and properties.

Practical (30 hours): Software labs using Microsoft Excel or any other spreadsheet.

1) Presentation and analysis of data (univariate and bivariate) by frequency tables, descriptive statistics, stem-and-leaf plots, dotplots, histograms, boxplots, comparative boxplots, and probability plots ([1] Section 4.6).
2) Fitting of binomial, Poisson, and normal distributions.
3) Illustrating the Central Limit Theorem through Excel.
4) Fitting of regression line using the principle of least squares.
5) Computation of sample correlation coefficient.

Essential Reading

1. Devore, Jay L. (2016). Probability and Statistics for Engineering and the Sciences (9th ed.). Cengage Learning India Private Limited. Delhi. Indian Reprint 2022.

Suggestive Reading

- Mood, A. M., Graybill, F. A., & Boes, D. C. (1974). Introduction to the Theory of Statistics (3rd ed.). Tata McGraw-Hill Pub. Co. Ltd. Reprinted 2017.

DSE Courses of B.A. (Prog.) Semester-VI
Category-II

DISCIPLINE SPECIFIC ELECTIVE COURSE – 2(i): DISCRETE DYNAMICAL SYSTEMS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		

Discrete Dynamical Systems	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	**NIL**

Learning Objectives: The primary objective of this course is to introduce:

- The fundamental concepts of discrete dynamical systems and emphasis on its study through several applications.
- The concepts of the fixed points, chaos and Lyapunov exponents for linear and nonlinear equations have been explained through examples.
- Various applications of chaos in higher dimensional models.

Learning Outcomes: This course will enable the students to:

- Understand the basic concepts of difference equation, chaos and Lyapunov exponents.
- Obtain fixed points and discuss the stability of the dynamical system.
- Find Lyapunov exponents, Bifurcation, and Period-doubling for nonlinear equations.
- Analyze the behavior of different realistic systems with chaos cascade.

SYLLABUS OF DSE-2(i)

UNIT-I: Discrete-time Models (12 hours)

Dynamical systems concepts and examples; Some linear models: Bouncing ball, investment growth, population growth, financial, economic and linear price models; Nonlinear models: Density-dependent population, contagious-disease, economic and nonlinear price models; Some linear systems models: Prey-predator, competing species, overlapping-generations, and economic systems.

UNIT-II: Linear Equations, Systems, their Solutions and Dynamics (18 hours)

Autonomous, non-autonomous linear equations and their solutions, time series graphs; Homogenous, non-homogeneous equations and their solutions with applications; Dynamics of autonomous linear equations, fixed points, stability, and oscillation; Homogeneous, non-homogeneous linear systems and their dynamics, solution space graphs, fixed points, sinks, sources and saddles.

UNIT-III: Nonlinear Equations, their Dynamics and Chaos (15 hours)

Autonomous nonlinear equations and their dynamics: Exact solutions, fixed points, stability; Cobweb graphs and dynamics: Linearization; Periodic points and cycles: 2-cycles, m-cycles, and their stability; Parameterized families; Bifurcation of fixed points and period-doubling; Characterizations and indicators of chaos.

Practical (30 hours)- Use of Excel/SageMath/MATHEMATICA/MATLAB/Scilab Software:

1. If Rs. 200 is deposited every 2 weeks into an account paying 6.5% annual interest compounded bi-weekly with an initial zero balance:
   (a) How long will it take before Rs. 10,000/- is in account?
   (b) During this time how much is deposited and how much comes from interest?

(c) Create a time series graph for the bi-weekly account balances for the first 40 weeks of saving scenario.

[1] Computer Project 2.5 pp. 68

2. (a) How much can be borrowed at an annual interest rate of 6% paid quarterly for 5 years in order to have the payments equal Rs. 1000/- every 3 months.

   (b) What is the unpaid balance on this loan after 4 years.

   (c) Create a time series graph for the unpaid balances each quarter for the loan process.

   [1] Computer Project 2.5 pp. 68

3. Four distinct types of dynamics for any autonomous linear equation:

   $x_{n+1} = a\, x_n + b$ for different values of a and b.

   [1] Dynamics of autonomous linear equation, pp. 74

4. Find all fixed points and determine their stability by generating at least the first 100 iterates for various choices of initial values and observing the dynamics
   a. $I_{n+1} = I_n - r\, I_n + s\, I_n\,(1 - I_n\, 10^{-6})$
      for: (i) $r = 0.5, s = 0.25$, (ii) $r = 0.5, s = 1.75$, (iii) $r = 0.5, s = 2.0$.
   b. $P_{n+1} = \frac{1}{P_n} + 0.75\, P_n + c$
      for: $(i)\ c = 0$; $(ii)\ c = -1$; $(iii)\ c = -1.25$; $(iv)\ c = -1.38$.
   c. $x_{n+1} = a\, x_n\,(1 - x_n^2)$
      for: $(i)\ a = 0.5$; $(ii)\ a = 1.5$; $(iii)\ a = 2.25$; $(iv)\ a = 2.3$.

   [1] Computer Project 3.2 pp. 110

5. Determine numerically whether a stable cycle exists for the given parameter values, and if so, its period. Perform at least 200 iterations each time and if a cycle is found (approximately), use the product of derivatives to verify its stability.
   a. $P_{n+1} = r\, P_n\,\left(1 - \frac{P_n}{5000}\right)$, for: $(i)\ r = 3.4$; $(ii)\ r = 3.5$;
      $(iii)\ r = 3.566$; $(iv)\ r = 3.569$; $(v)\ r = 3.845$.
   b. $P_{n+1} = r\, P_n\, e^{-P_n/1000}$
      for: $(i)\ r = 5$; $(ii)\ r = 10$; $(iii)\ r = 14$; $(iv)\ r = 14.5$; $(v)\ r = 14.75$.

   [1] Computer Project 3.5 pp. 154

6. Find through numerical experimentation the approximate intervals of stability of the (a) 2-cycle; (b) 4-cycle; (c) 8-cycle; (d) 16-cycle; (e) 32-cycle for the following
   a. $f_r(x) = r\, x\, e^{-x}$
   b. $f_r(x) = r\, x^2\,(1 - x)$
   c. $f_a(x) = x\,(a - x^2)$
   d. $f_c(x) = \frac{2}{x} + 0.75\, x - c$

   [1] Computer Project 3.6 pp. 164

7. Through numerical simulation, show that each of the following functions undergoes a period doubling cascade: (**[1] Computer Project 3.7 pp.175**)
   a. $f_r(x) = r\, x\, e^{-x}$
   b. $f_r(x) = r\, x^2\,(1 - x)$
   c. $f_r(x) = r\, x\, e^{-x^2}$
   d. $f_r(x) = \frac{r\, x}{(x^2+1)^2}$
   e. $f_a(x) = x\,(a - x^2)$

8. Discuss (a) Pick two initial points close together, i.e., that perhaps differ by 0.001 or 0.00001, and perform at least 100 iterations of $x_{n+1} = f(x_n)$. Do solutions exhibit sensitive dependence on initial conditions?
   (b) For several random choices of x_0 compute at least 1000 iterates x_n and draw a frequency distribution using at least 50 sub-intervals. Do dense orbits appear to exit?
   (c) Estimate the Lyapunov exponent L by picking several random choices of x_0 and computing $\frac{1}{N}\sum_{n=1}^{N} \ln|f'(x_n)|$ for $N = 1000, 2500, 5000, etc.$
   Does L appear to be positive? i). $f(x) = 2 - x^2$ ii). $f(x) = \frac{2}{x} + \frac{3x}{4} - 2$.
   [1] Computer Project 3.8 pp. 187
9. Show that $f(x) = r\,x\,(1 - x)$ for $r > 4$ and $f(x) = 6.75\,x^2\,(1 - x)$ have horseshoes and homoclinic orbits, and hence chaos. **[1] Computer Project 3.8 pp. 188**
10. Find the fixed point and determine whether it is a sink, source or saddle by iterating and graphing in solution space the first few iterates for several choices of initial conditions. **[1] Computer Project 4.2 pp. 207**
    a. $x_{n+1} = x_n - y_n + 30$
       $y_{n+1} = x_n + y_n - 20.$
    b. $x_{n+1} = x_n + y_n$
       $y_{n+1} = x_n - y_n.$

Essential Reading

1. Marotto, Frederick R. (2006). Introduction to Mathematical Modeling Using Discrete Dynamical Systems. Thomson, Brooks/Cole.

Suggestive Readings

- Devaney, Robert L. (2022). An Introduction to Chaotic Dynamical Systems (3rd ed.). CRC Press, Taylor & Francis Group, LLC.
- Lynch, Stephen (2017). Dynamical Systems with Applications using Mathematica® (2nd ed.). Birkhäuser.
- Martelli, Mario (1999). Introduction to Discrete Dynamical Systems and Chaos. John Wiley & Sons, Inc., New York.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 2(ii): INTRODUCTION TO MATHEMATICAL MODELING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		

Introduction to Mathematical Modeling	**4**	**3**	**0**	**1**	**Class XII pass with Mathematics**	**Discipline A-3: Differential Equations**

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

- Compartmental models and real-life case studies through differential equations, their applications and mathematical modeling.
- Choosing the most appropriate model from competing types that have been fitted.
- Fitting a selected model type or types to the data and making predictions from the collected data.

Learning Outcomes: The course will enable the students to:

- Learn basics of differential equations and compartmental models.
- Formulate differential equations for various mathematical models.
- Construct normal equation of best fit and predict the future values.

SYLLABUS OF DSE-2(ii)

UNIT-I: Compartmental Models (15 hours)

Compartmental diagram and balance law; Exponential decay, radioactive dating, and lake pollution models; Case study: Lake Burley Griffin; Drug assimilation into the blood; Case study: Dull, dizzy or dead; Exponential growth, Density-dependent growth, Equilibrium solutions and stability of logistic equation, Limited growth with harvesting.

UNIT-II: Interacting Population Models and Phase-plane Analysis (15 hours)

SIR model for influenza, Predator-prey model, Ecosystem model of competing species, and model of a battle.

UNIT-III: Analytic methods of model fitting and Simulation (15 hours)

Fitting models to data graphically; Chebyshev approximation criterion, Least-square criterion: Straight line, parabolic, power curve; Transformed least-square fit, Choosing a best model. Monte Carlo simulation modeling**:** Simulating deterministic behavior (area under a curve, volume under a surface); Generating random numbers: middle-square method, linear congruence; Simulating probabilistic behavior.

Essential Readings

1. Barnes, Belinda & Fulford, Glenn R. (2015). Mathematical Modelling with Case Studies, Using Maple and MATLAB (3rd ed.). CRC Press, Taylor & Francis Group.
2. Giordano, Frank R., Fox, William P., & Horton, Steven B. (2014). A First Course in Mathematical Modeling (5th ed.). CENGAGE Learning India.

Suggestive Readings

- Albright, Brian, & Fox, William P. (2020). Mathematical Modeling with Excel (2nd ed.). CRC Press, Taylor & Francis Group.

- Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). Differential Equations and Boundary Value Problems: Computing and Modeling (5th ed.). Pearson.

Practical (30 hours)- Practical / Lab work to be performed in Computer Lab:

Modeling of the following problems using Mathematica/MATLAB/Maple/Maxima/Scilab etc.

1. Plotting the solution and describe the physical interpretation of the Mathematical Models mentioned below:
   a. Exponential decay and growth model.
   b. Lake pollution model (with constant/seasonal flow and pollution concentration).
   c. Case of single cold pill and a course of cold pills.
   d. Limited growth of population (with and without harvesting).
   e. Predatory-prey model (basic volterra model, with density dependence, effect of DDT, two prey one predator).
   f. Epidemic model of influenza (basic epidemic model, contagious for life, disease with carriers).
   g. Ecosystem model of competing species
   h. Battle model

2. Random number generation and then use it to simulate area under a curve and volume under a surface.
3. Write a computer program that finds the least-squares estimates of the coefficients in the following models.
   a. $y = a\,x^2 + b\,x + c$
   b. $y = a\,x^n$

4. Write a computer program that uses Equations (3.4) in [3] and the appropriate transformed data to estimate the parameters of the following models.
   a. $y = b\,x^n$
   b. $y = b\,e^{a\,x}$
   c. $y = a\ln x + b$
   d. $y = a\,x^2$
   e. $y = a\,x^3$.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 2(iii): RESEARCH METHODOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/		

				Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	NIL

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

- Prepare the students with skills needed for successful research in mathematics.
- Develop a basic understanding of how to pursue research in mathematics.
- Prepare students for professions other than teaching, that requires independent mathematical research, critical analysis, and advanced mathematical knowledge.
- Introduce some open source softwares to carry out mathematical research.
- Impart the knowledge of journals, their rankings and the disadvantages of rankings.

Learning Outcomes: The course will enable the students to:

- Develop researchable questions and to make them inquisitive enough to search and verify new mathematical facts.
- Understand the methods in research and carry out independent study in areas of mathematics.
- Write a basic mathematical article and a research project.
- Gain knowledge about publication of research articles in good journals.
- Communicate mathematical ideas both in oral and written forms effectively.

SYLLABUS OF DSE - 2(iii)

UNIT– I: How to Learn, Write, and Research Mathematics (17 hours)

How to learn mathematics, How to write mathematics: Goals of mathematical writing, general principles of mathematical writing, avoiding errors, writing mathematical solutions and proofs, the revision process, What is mathematical research, finding a research topic, Literature survey, Research Criteria, Format of a research article (including examples of mathematical articles) and a research project (report), publishing research.

UNIT- II: Mathematical Typesetting and Presentation using LaTeX (16 hours)

How to present mathematics: Preparing a mathematical talk, Oral presentation, Use of technology which includes LaTeX, PSTricks and Beamer; Poster presentation.

UNIT- III: Mathematical Web Resources and Research Ethics (12 hours)

Web resources- MAA, AMS, SIAM, arXiv, ResearchGate; Journal metrics: Impact factor of journal as per JCR, MCQ, SNIP, SJR, Google Scholar metric; Challenges of journal metrics; Reviews/Databases: MathSciNet, zbMath, Web of Science, Scopus; Ethics with respect to science and research, Plagiarism check using software like URKUND/Ouriginal by Turnitin.

Essential Readings

1. Bindner, Donald, & Erickson Martin (2011). A Student's Guide to the Study, Practice, and Tools of Modern Mathematics. CRC Press, Taylor & Francis Group.
2. Committee on Publication Ethics- COPE (https://publicationethics.org/)
3. Declaration on Research Assessment. https://en.wikipedia.org/wiki/San_Francisco_Declaration_on_Research_Assessment
4. Evaluating Journals using journal metrics; (https://academicguides.waldenu.edu/library/journalmetrics#s-lg-box-13497874)
5. Gallian, Joseph A. (2006). Advice on Giving a Good PowerPoint Presentation (https://www.d.umn.edu/~jgallian/goodPPtalk.pdf). MATH HORIZONS.
6. Lamport, Leslie (2008). LaTeX, a Document Preparation System, Pearson.
7. Locharoenrat, Kitsakorn (2017). Research Methodologies for Beginners, Pan Stanford Publishing Pte. Ltd., Singapore.
8. Nicholas J. Higham. Handbook for writing for the Mathematical Sciences, SIAM, 1998.
9. Steenrod, Norman E., Halmos, Paul R., Schiffer, M. M., & Dieudonné, Jean A. (1973). How to Write Mathematics, American Mathematical Society.
10. Tantau, Till,Wright, Joseph, & Miletić, Vedran (2023). The BEAMER class, Use Guide for Version 3.69. TeX User Group. (https://tug.ctan.org/macros/latex/contrib/beamer/doc/beameruserguide.pdf)
11. University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations 2018 (The Gazette of India: Extraordinary, Part-iii-Sec.4)

Practical (30 hours): Practical work to be performed in the computer lab of the following using any TeX distribution software:

1. Starting LaTeX, Preparing an input file, Sequences and paragraphs, Quotation marks, Dashes, Space after a period, Special symbols, Simple text- generating commands, Emphasizing text, Preventing line breaks, Footnotes, ignorable input.
2. The document, The document class, The title page, Sectioning, Displayed material, Quotations, Lists, Displayed formulas, Declarations.
3. Running LaTeX, Changing the type style, Accents, Symbols, Subscripts and superscripts, Fractions, Roots, Ellipsis.
4. Mathematical Symbols, Greek letters, Calligraphic letters, Log-like functions, Arrays, The array environment, Vertical alignment, Delimiters, Multiline formulas.
5. Putting one thing above another, Over and underlining, Accents, Stacking symbols, Spacing in math mode, Changing style in math mode, Type style, Math style.
6. Defining commands, Defining environments, Theorems.
7. Figure and tables, Marginal notes, The tabbing environment, The tabular environment.
8. The Table and contents, Cross-references, Bibliography and citation.
9. Beamer: Templates, Frames, Title page frame, Blocks, Simple overlays, Themes.
10. PSTricks
11. Demonstration of web resources.

B.Sc. (Prog.)/ BA (Prog.) Semester-VI with Mathematics as non-Major

Category-III

DISCIPLINE SPECIFIC CORE COURSE–6 (Discipline A-6): PROBABILITY AND STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Probability and Statistics	4	3	0	1	Class XII pass with Mathematics	NIL

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

- Make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness.
- Render the students to several examples and exercises that blend their everyday experiences with their scientific interests to form the basis of data science.

Learning Outcomes: This course will enable the students to:

- Understand some basic concepts and terminology-population, sample, descriptive and inferential statistics including stem-and-leaf plots, dotplots, histograms and boxplots.

- Learn about probability density functions and various univariate distributions such as binomial, hypergeometric, negative binomial, Poisson, normal, exponential, and lognormal.
- Understand the remarkable fact that the empirical frequencies of so many natural populations, exhibit bell-shaped (i.e., normal) curves, using the Central Limit Theorem.
- Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.

SYLLABUS OF DISCIPLINE A-6

UNIT-I: Descriptive Statistics, Probability, and Discrete Probability Distributions (15 hours)
Descriptive statistics: Populations, Samples, Stem-and-leaf displays, Dotplots, Histograms, Qualitative data, Measures of location, Measures of variability, Boxplots; Sample spaces and events, Probability axioms and properties, Conditional probability, Bayes' theorem, and independent events; Discrete random variables & probability distributions, Expected values; Probability distributions: Binomial, geometric, hypergeometric, negative binomial, Poisson, and Poisson distribution as a limit.

UNIT-II: Continuous Probability Distributions (15 hours)
Continuous random variables, Probability density functions, Uniform distribution, Cumulative distribution functions and expected values, The normal, exponential, and lognormal distributions.

UNIT-III: Central Limit Theorem and Regression Analysis (15 hours)
Sampling distribution and standard error of the sample mean, Central Limit Theorem, and applications; Scatterplot of bivariate data, Regression line using principle of least squares, Estimation using the regression lines; Sample correlation coefficient and properties.

Practical (30 hours)

Software labs using Microsoft Excel or any other spreadsheet.

1) Presentation and analysis of data (univariate and bivariate) by frequency tables, descriptive statistics, stem-and-leaf plots, dotplots, histograms, boxplots, comparative boxplots, and probability plots ([1] Section 4.6).
2) Fitting of binomial, Poisson, and normal distributions.
3) Illustrating the Central Limit Theorem through Excel.
4) Fitting of regression line using the principle of least squares.
5) Computation of sample correlation coefficient.

Essential Reading

1. Devore, Jay L. (2016). Probability and Statistics for Engineering and the Sciences (9th ed.). Cengage Learning India Private Limited. Delhi. Indian Reprint 2022.

Suggestive Reading

- Mood, A. M., Graybill, F. A., & Boes, D. C. (1974). Introduction to the Theory of Statistics (3rd ed.). Tata McGraw-Hill Pub. Co. Ltd. Reprinted 2017.

B.Sc. (Physical Sciences/Mathematical Sciences) Semester-VI with Mathematics as one of the Core Discipline

Category-III

DISCIPLINE SPECIFIC CORE COURSE – 6 (Discipline A-6): PROBABILITY AND STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Probability and Statistics	4	3	0	1	Class XII pass with Mathematics	NIL

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

- Make the students familiar with the basic statistical concepts and tools which are needed to study situations involving uncertainty or randomness.
- Render the students to several examples and exercises that blend their everyday experiences with their scientific interests to form the basis of data science.

Learning Outcomes: This course will enable the students to:

- Understand some basic concepts and terminology-population, sample, descriptive and inferential statistics including stem-and-leaf plots, dotplots, histograms and boxplots.
- Learn about probability density functions and various univariate distributions such as binomial, hypergeometric, negative binomial, Poisson, normal, exponential, and lognormal.
- Understand the remarkable fact that the empirical frequencies of so many natural populations, exhibit bell-shaped (i.e., normal) curves, using the Central Limit Theorem.
- Measure the scale of association between two variables, and to establish a formulation helping to predict one variable in terms of the other, i.e., correlation and linear regression.

SYLLABUS OF DISCIPLINE A-6

UNIT-I: Descriptive Statistics, Probability, and Discrete Probability Distributions (15 hours)
Descriptive statistics: Populations, Samples, Stem-and-leaf displays, Dotplots, Histograms, Qualitative data, Measures of location, Measures of variability, Boxplots; Sample spaces and events, Probability axioms and properties, Conditional probability, Bayes' theorem, and independent events; Discrete random variables & probability distributions, Expected values; Probability distributions: Binomial, geometric, hypergeometric, negative binomial, Poisson, and Poisson distribution as a limit.

UNIT-II: Continuous Probability Distributions (15 hours)

Continuous random variables, Probability density functions, Uniform distribution, Cumulative distribution functions and expected values, The normal, exponential, and lognormal distributions.

UNIT-III: Central Limit Theorem and Regression Analysis (15 hours)

Sampling distribution and standard error of the sample mean, Central Limit Theorem, and applications; Scatterplot of bivariate data, Regression line using principle of least squares, Estimation using the regression lines; Sample correlation coefficient and properties.

Practical (30 hours)

Software labs using Microsoft Excel or any other spreadsheet.

1) Presentation and analysis of data (univariate and bivariate) by frequency tables, descriptive statistics, stem-and-leaf plots, dotplots, histograms, boxplots, comparative boxplots, and probability plots ([1] Section 4.6).
2) Fitting of binomial, Poisson, and normal distributions.
3) Illustrating the Central Limit Theorem through Excel.
4) Fitting of regression line using the principle of least squares.
5) Computation of sample correlation coefficient.

Essential Reading

1. Devore, Jay L. (2016). Probability and Statistics for Engineering and the Sciences (9th ed.). Cengage Learning India Private Limited. Delhi. Indian Reprint 2022.

Suggestive Reading

- Mood, A. M., Graybill, F. A., & Boes, D. C. (1974). Introduction to the Theory of Statistics (3rd ed.). Tata McGraw-Hill Pub. Co. Ltd. Reprinted 2017.

DSE Courses of B.Sc. (Physical Sciences/Mathematical Sciences) Sem-VI

Category-III

DISCIPLINE SPECIFIC ELECTIVE COURSE – 4(i): ELEMENTARY MATHEMATICAL ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elementary Mathematical Analysis	4	3	1	0	Class XII pass with Mathematics	Discipline A-5: Elements of Real Analysis

Learning Objectives: The primary objective of this course is to introduce:
- Sequential criterion for limits and continuity of real-valued functions.
- Riemann integral of real-valued function *f* on [a, b] using Darboux sums.
- Pointwise and uniform convergence of sequences and series of functions.

Learning Outcomes: This course will enable the students to:
- Apply sequential continuity criterion for the proof of intermediate value theorem.
- Understand the basic tool used to calculate integrals
- Apply uniform convergence for term-by-term integration in power series expansion.

SYLLABUS OF DSE-4(i)

UNIT-I: Continuous Functions (12 hours)

Sequential criterion for limits and continuity of functions, Continuity on intervals, Intermediate value theorem and applications; Uniform continuity.

UNIT-II: The Riemann Integral (15 hours)

Riemann integration, criterion for integrability and examples; Integrability of continuous and monotone functions, Algebraic properties of the Riemann integral, Fundamental theorem of calculus (first form).

UNIT-III: Uniform Convergence (18 hours)

Sequences and series of functions: Pointwise and uniform convergence, Uniform Cauchy criterion, Weierstrass M-test, Implications of uniform convergence in calculus; Power series, Radius and interval of convergence, Applications of Abel's theorem for power series.

Essential Reading

1. Denlinger, Charles G. (2011). Elements of Real Analysis. Jones & Bartlett India Pvt. Ltd. Student Edition. Reprinted 2015.

Suggestive Readings

- Bartle, Robert G., & Sherbert, Donald R. (2011). Introduction to Real Analysis (4th ed.). John Wiley & Sons. Wiley India Edition 2015.
- Ross, Kenneth A. (2013). Elementary Analysis: The Theory of Calculus (2nd ed.). Undergraduate Texts in Mathematics, Springer. Indian Reprint.

DISCIPLINE SPECIFIC ELECTIVE COURSE-4(ii): INTRODUCTION TO MATHEMATICAL MODELING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Mathematical Modeling	4	3	0	1	Class XII pass with Mathematics	Discipline A-3: Differential Equations

Learning Objectives: The main objective of this course is to introduce:
- Compartmental models and real-life case studies through differential equations, their applications and mathematical modeling.
- Choosing the most appropriate model from competing types that have been fitted.
- Fitting a selected model type or types to the data and making predictions from the collected data.

Learning Outcomes: The course will enable the students to:
- Learn basics of differential equations and compartmental models.
- Formulate differential equations for various mathematical models.
- Construct normal equation of best fit and predict the future values.

SYLLABUS OF DSE-4(ii)

UNIT-I: Compartmental Models (15 hours)

Compartmental diagram and balance law; Exponential decay, radioactive dating, and lake pollution models; Case study: Lake Burley Griffin; Drug assimilation into the blood; Case study: Dull, dizzy or dead; Exponential growth, Density-dependent growth, Equilibrium solutions and stability of logistic equation, Limited growth with harvesting.

UNIT-II: Interacting Population Models and Phase-plane Analysis (15 hours)

SIR model for influenza, Predator-prey model, Ecosystem model of competing species, and model of a battle.

UNIT-III: Analytic methods of model fitting and Simulation (15 hours)

Fitting models to data graphically; Chebyshev approximation criterion, Least-square criterion: Straight line, parabolic, power curve; Transformed least-square fit, Choosing a best model. Monte Carlo simulation modeling**:** Simulating deterministic behavior (area under a curve, volume under a surface); Generating random numbers: middle-square method, linear congruence; Simulating probabilistic behavior.

Essential Readings

1. Barnes, Belinda & Fulford, Glenn R. (2015). Mathematical Modelling with Case Studies, Using Maple and MATLAB (3rd ed.). CRC Press, Taylor & Francis Group.
2. Giordano, Frank R., Fox, William P., & Horton, Steven B. (2014). A First Course in Mathematical Modeling (5th ed.). CENGAGE Learning India.

Suggestive Readings

- Albright, Brian, & Fox, William P. (2020). Mathematical Modeling with Excel (2nd ed.). CRC Press, Taylor & Francis Group.
- Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). Differential Equations and Boundary Value Problems: Computing and Modeling (5th ed.). Pearson.

Practical (30 hours)- Practical / Lab work to be performed in Computer Lab:

Modeling of the following problems using Mathematica/MATLAB/Maple/Maxima/Scilab etc.

1. Plotting the solution and describe the physical interpretation of the Mathematical Models mentioned below:
   a. Exponential decay and growth model.
   b. Lake pollution model (with constant/seasonal flow and pollution concentration).
   c. Case of single cold pill and a course of cold pills.
   d. Limited growth of population (with and without harvesting).
   e. Predatory-prey model (basic volterra model, with density dependence, effect of DDT, two prey one predator).
   f. Epidemic model of influenza (basic epidemic model, contagious for life, disease with carriers).
   g. Ecosystem model of competing species
   h. Battle model

2. Random number generation and then use it to simulate area under a curve and volume under a surface.
3. Write a computer program that finds the least-squares estimates of the coefficients in the following models.
   a. $y = a\,x^2 + b\,x + c$
   b. $y = a\,x^n$

4. Write a computer program that uses Equations (3.4) in [3] and the appropriate transformed data to estimate the parameters of the following models.
   a. $y = b\,x^n$
   b. $y = b\,e^{a\,x}$
   c. $y = a\ln x + b$
   d. $y = a\,x^2$
   e. $y = a\,x^3$.

DISCIPLINE SPECIFIC ELECTIVE COURSE-4(iii): RESEARCH METHODOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	NIL

Learning Objectives: The main objective of this course is to:
- Prepare the students with skills needed for successful research in mathematics.
- Develop a basic understanding of how to pursue research in mathematics.
- Prepare students for professions other than teaching, that requires independent mathematical research, critical analysis, and advanced mathematical knowledge.
- Introduce some open source softwares to carry out mathematical research.
- Impart the knowledge of journals, their rankings and the disadvantages of rankings.

Learning Outcomes: The course will enable the students to:
- Develop researchable questions and to make them inquisitive enough to search and verify new mathematical facts.
- Understand the methods in research and carry out independent study in areas of mathematics.
- Write a basic mathematical article and a research project.
- Gain knowledge about publication of research articles in good journals.
- Communicate mathematical ideas both in oral and written forms effectively.

SYLLABUS OF DSE - 4(iii)

UNIT– I: How to Learn, Write, and Research Mathematics (17 hours)

How to learn mathematics, How to write mathematics: Goals of mathematical writing, general principles of mathematical writing, avoiding errors, writing mathematical solutions and proofs, the revision process, What is mathematical research, finding a research topic, Literature survey, Research Criteria, Format of a research article (including examples of mathematical articles) and a research project (report), publishing research.

UNIT- II: Mathematical Typesetting and Presentation using LaTeX (16 hours)

How to present mathematics: Preparing a mathematical talk, Oral presentation, Use of technology which includes LaTeX, PSTricks and Beamer; Poster presentation.

UNIT- III: Mathematical Web Resources and Research Ethics (12 hours)

Web resources- MAA, AMS, SIAM, arXiv, ResearchGate; Journal metrics: Impact factor of journal as per JCR, MCQ, SNIP, SJR, Google Scholar metric; Challenges of journal metrics; Reviews/Databases: MathSciNet, zbMath, Web of Science, Scopus; Ethics with respect to science and research, Plagiarism check using software like URKUND/Ouriginal by Turnitin.

Essential Readings

1. Bindner, Donald, & Erickson Martin (2011). A Student's Guide to the Study, Practice, and Tools of Modern Mathematics. CRC Press, Taylor & Francis Group.
2. Committee on Publication Ethics- COPE (https://publicationethics.org/)
3. Declaration on Research Assessment. https://en.wikipedia.org/wiki/San_Francisco_Declaration_on_Research_Assessment
4. Evaluating Journals using journal metrics; (https://academicguides.waldenu.edu/library/journalmetrics#s-lg-box-13497874)
5. Gallian, Joseph A. (2006). Advice on Giving a Good PowerPoint Presentation (https://www.d.umn.edu/~jgallian/goodPPtalk.pdf). MATH HORIZONS.
6. Lamport, Leslie (2008). LaTeX, a Document Preparation System, Pearson.
7. Locharoenrat, Kitsakorn (2017). Research Methodologies for Beginners, Pan Stanford Publishing Pte. Ltd., Singapore.
8. Nicholas J. Higham. Handbook for writing for the Mathematical Sciences, SIAM, 1998.
9. Steenrod, Norman E., Halmos, Paul R., Schiffer, M. M., & Dieudonné, Jean A. (1973). How to Write Mathematics, American Mathematical Society.
10. Tantau, Till,Wright, Joseph, & Miletić, Vedran (2023). The BEAMER class, Use Guide for Version 3.69. TeX User Group. (https://tug.ctan.org/macros/latex/contrib/beamer/doc/beameruserguide.pdf)
11. University Grants Commission (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations 2018 (The Gazette of India: Extraordinary, Part-iii-Sec.4)

Practical (30 hours): Practical work to be performed in the computer lab of the following using any TeX distribution software:

1. Starting LaTeX, Preparing an input file, Sequences and paragraphs, Quotation marks, Dashes, Space after a period, Special symbols, Simple text- generating commands, Emphasizing text, Preventing line breaks, Footnotes, ignorable input.

2. The document, The document class, The title page, Sectioning, Displayed material, Quotations, Lists, Displayed formulas, Declarations.
3. Running LaTeX, Changing the type style, Accents, Symbols, Subscripts and superscripts, Fractions, Roots, Ellipsis.
4. Mathematical Symbols, Greek letters, Calligraphic letters, Log-like functions, Arrays, The array environment, Vertical alignment, Delimiters, Multiline formulas.
5. Putting one thing above another, Over and underlining, Accents, Stacking symbols, Spacing in math mode, Changing style in math mode, Type style, Math style.
6. Defining commands, Defining environments, Theorems.
7. Figure and tables, Marginal notes, The tabbing environment, The tabular environment.
8. The Table and contents, Cross-references, Bibliography and citation.
9. Beamer: Templates, Frames, Title page frame, Blocks, Simple overlays, Themes.
10. PSTricks
11. Demonstration of web resources.

COMMON POOL OF GENERIC ELECTIVES (GE) Semester-VI COURSES OFFERED BY DEPARTMENT OF MATHEMATICS

Category-IV

GENERIC ELECTIVES (GE-6(i)): INTRODUCTION TO MATHEMATICAL MODELING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Introduction to Mathematical Modeling	4	3	0	1	Class XII pass with Mathematics	GE-3(i): Differential Equations

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

- Compartmental models and real-life case studies through differential equations, their applications and mathematical modeling.
- Choosing the most appropriate model from competing types that have been fitted.
- Fitting a selected model type or types to the data and making predictions from the collected data.

Learning Outcomes: The course will enable the students to:

- Learn basics of differential equations and compartmental models.
- Formulate differential equations for various mathematical models.
- Construct normal equation of best fit and predict the future values.

SYLLABUS OF GE-6(i)

UNIT-I: Compartmental Models (15 hours)

Compartmental diagram and balance law; Exponential decay, radioactive dating, and lake pollution models; Case study: Lake Burley Griffin; Drug assimilation into the blood; Case study: Dull, dizzy or dead; Exponential growth, Density-dependent growth, Equilibrium solutions and stability of logistic equation, Limited growth with harvesting.

UNIT-II: Interacting Population Models and Phase-plane Analysis (15 hours)

SIR model for influenza, Predator-prey model, Ecosystem model of competing species, and model of a battle.

UNIT-III: Analytic methods of model fitting and Simulation (15 hours)

Fitting models to data graphically; Chebyshev approximation criterion, Least-square criterion: Straight line, parabolic, power curve; Transformed least-square fit, Choosing a best model. Monte Carlo simulation modeling: Simulating deterministic behavior (area under a curve, volume under a surface); Generating random numbers: middle-square method, linear congruence; Simulating probabilistic behavior.

Essential Readings

1. Barnes, Belinda & Fulford, Glenn R. (2015). Mathematical Modelling with Case Studies, Using Maple and MATLAB (3rd ed.). CRC Press, Taylor & Francis Group.
2. Giordano, Frank R., Fox, William P., & Horton, Steven B. (2014). A First Course in Mathematical Modeling (5th ed.). CENGAGE Learning India.

Suggestive Readings

- Albright, Brian, & Fox, William P. (2020). Mathematical Modeling with Excel (2nd ed.). CRC Press, Taylor & Francis Group.
- Edwards, C. Henry, Penney, David E., & Calvis, David T. (2015). Differential Equations and Boundary Value Problems: Computing and Modeling (5th ed.). Pearson.

Practical (30 hours)- Practical / Lab work to be performed in Computer Lab: Modeling of the following problems using Mathematica/MATLAB/Maple/Maxima/Scilab etc.

1. Plotting the solution and describe the physical interpretation of the Mathematical Models mentioned below:
   a. Exponential decay and growth model.
   b. Lake pollution model (with constant/seasonal flow and pollution concentration).
   c. Case of single cold pill and a course of cold pills.
   d. Limited growth of population (with and without harvesting).
   e. Predatory-prey model (basic volterra model, with density dependence, effect of DDT, two prey one predator).
   f. Epidemic model of influenza (basic epidemic model, contagious for life, disease with carriers).
   g. Ecosystem model of competing species
   h. Battle model
2. Random number generation and then use it to simulate area under a curve and volume under a surface.
3. Write a computer program that finds the least-squares estimates of the coefficients in the following models.
   a. $y = a\,x^2 + b\,x + c$
   b. $y = a\,x^n$
4. Write a computer program that uses Equations (3.4) in [3] and the appropriate transformed data to estimate the parameters of the following models.
   a. $y = b\,x^n$
   b. $y = b\,e^{a\,x}$
   c. $y = a\ln x + b$
   d. $y = a\,x^2$
   e. $y = a\,x^3$.

GENERIC ELECTIVES (GE-6(ii)): DISCRETE DYNAMICAL SYSTEMS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Discrete Dynamical Systems	4	3	0	1	Class XII pass with Mathematics	NIL

Learning Objectives: The primary objective of this course is to introduce:

- The fundamental concepts of discrete dynamical systems and emphasis on its study through several applications.
- The concepts of the fixed points, chaos and Lyapunov exponents for linear and nonlinear equations have been explained through examples.
- Various applications of chaos in higher dimensional models.

Learning Outcomes: This course will enable the students to:

- Understand the basic concepts of difference equation, chaos and Lyapunov exponents.
- Obtain fixed points and discuss the stability of the dynamical system.
- Find Lyapunov exponents, Bifurcation, and Period-doubling for nonlinear equations.
- Analyze the behavior of different realistic systems with chaos cascade.

SYLLABUS OF GE-6(ii)

UNIT-I: Discrete-time Models (12 hours)

Discrete dynamical systems concepts and examples; Some linear models: Bouncing ball, investment growth, population growth, financial, economic and linear price models; Nonlinear models: Density-dependent population, contagious-disease, economic and nonlinear price models; Some linear systems models: Prey-predator, competing species, overlapping-generations, and economic systems.

UNIT-II: Linear Equations, Systems, their Solutions and Dynamics (18 hours)

Autonomous, non-autonomous linear equations and their solutions, time series graphs; Homogenous, non-homogeneous equations and their solutions with applications; Dynamics of autonomous linear equations, fixed points, stability, and oscillation; Homogeneous, non-homogeneous linear systems and their dynamics, solution space graphs, fixed points, sinks, sources and saddles.

UNIT-III: Nonlinear Equations, their Dynamics and Chaos (15 hours)

Autonomous nonlinear equations and their dynamics: Exact solutions, fixed points, stability; Cobweb graphs and dynamics: Linearization; Periodic points and cycles: 2-cycles, m-cycles, and their stability; Parameterized families; Bifurcation of fixed points and period-doubling; Characterizations and indicators of chaos.

Practical (30 hours)- Use of Excel/SageMath/MATHEMATICA/MATLAB/Scilab Software:

1. If Rs. 200 is deposited every 2 weeks into an account paying 6.5% annual interest compounded bi-weekly with an initial zero balance:
   (a) How long will it take before Rs. 10,000/- is in account?
   (b) During this time how much is deposited and how much comes from interest?
   (c) Create a time series graph for the bi-weekly account balances for the first 40 weeks of saving scenario.
   [1] Computer Projects 2.5 pp. 68
2. (a) How much can be borrowed at an annual interest rate of 6% paid quarterly for 5 years in order to have the payments equal Rs. 1000/- every 3 months.
   (b) What is the unpaid balance on this loan after 4 years.
   (c) Create a time series graph for the unpaid balances each quarter for the loan process.
   [1] Computer Projects 2.5 pp. 68
3. Four distinct types of dynamics for any autonomous linear equation:
   $x_{n+1} = a\, x_n + b$ for different values of a and b.
   [1] Dynamics of autonomous linear equation, pp. 74
4. Find all fixed points and determine their stability by generating at least the first 100 iterates for various choices of initial values and observing the dynamics
   a. $I_{n+1} = I_n - r\, I_n + s\, I_n\,(1 - I_n\, 10^{-6})$
      for: (i) $r = 0.5, s = 0.25$, (ii) $r = 0.5, s = 1.75$, (iii) $r = 0.5, s = 2.0$.
   b. $P_{n+1} = \frac{1}{P_n} + 0.75\, P_n + c$
      for: $(i)\ c = 0$; $(ii)\ c = -1$; $(iii)\ c = -1.25$; $(iv)\ c = -1.38$.
   c. $x_{n+1} = a\, x_n\,(1 - x_n^2)$
      for: $(i)\ a = 0.5$; $(ii)\ a = 1.5$; $(iii)\ a = 2.25$; $(iv)\ a = 2.3$.
   [1] Computer Projects 3.2 pp. 110
5. Determine numerically whether a stable cycle exists for the given parameter values, and if so, its period. Perform at least 200 iterations each time and if a cycle is found (approximately), use the product of derivatives to verify its stability.
   a. $P_{n+1} = r\, P_n\left(1 - \frac{P_n}{5000}\right)$, for: $(i)\ r = 3.4$; $(ii)\ r = 3.5$; $(iii)\ r = 3.566$; $(iv)\ r = 3.569$; $(v)\ r = 3.845$.
   b. $P_{n+1} = r\, P_n\, e^{-P_n/1000}$
      for: $(i)\ r = 5$; $(ii)\ r = 10$; $(iii)\ r = 14$; $(iv)\ r = 14.5$; $(v)\ r = 14.75$.
   [1] Computer Projects 3.5 pp. 154
6. Find through numerical experimentation the approximate intervals of stability of the (a) 2-cycle; (b) 4-cycle; (c) 8-cycle; (d) 16-cycle; (e) 32-cycle for the following
   a. $f_r(x) = r\, x\, e^{-x}$
   b. $f_r(x) = r\, x^2\,(1 - x)$
   c. $f_a(x) = x\,(a - x^2)$
   d. $f_c(x) = \frac{2}{x} + 0.75\, x - c$

[1] Computer Projects 3.6 pp. 164

7. Through numerical simulation, show that each of the following functions undergoes a period doubling cascade:
    a. $f_r(x) = r\,x\,e^{-x}$
    b. $f_r(x) = r\,x^2\,(1-x)$
    c. $f_r(x) = r\,x\,e^{-x^2}$
    d. $f_r(x) = \frac{r\,x}{(x^2+1)^2}$
    e. $f_a(x) = \ x\,(a - x^2)$

    [1] Computer Projects 3.7 pp. 175
8. Discuss (a) Pick two initial points close together, i.e., that perhaps differ by 0.001 or 0.00001, and perform at least 100 iterations of $x_{n+1} = f(x_n)$. Do solutions exhibit sensitive dependence on initial conditions?
    (b) For several random choices of x_0 compute at least 1000 iterates x_n and draw a frequency distribution using at least 50 sub-intervals. Do dense orbits appear to exit?
    (c) Estimate the Lyapunov exponent L by picking several random choices of x_0 and computing $\frac{1}{N}\sum_{n=1}^{N} \ln|f'(x_n)|$ for $N = 1000, 2500, 5000, etc.$
    Does L appear to be positive? i). $f(x) = 2 - x^2$ ii). $f(x) = \frac{2}{x} + \frac{3x}{4} - 2.$

    [1] Computer Projects 3.8 pp. 187
9. Show that $f(x) = r\,x\,(1-x)$ for $r > 4$ and $f(x) = 6.75\,x^2\,(1-x)$ have horseshoes and homoclinic orbits, and hence chaos. **[1] Computer Projects 3.8 pp. 188**
10. Find the fixed point and determine whether it is a sink, source or saddle by iterating and graphing in solution space the first few iterates for several choices of initial conditions.
    a. $x_{n+1} = x_n - y_n + 30$
    $y_{n+1} = x_n + y_n - 20.$
    b. $x_{n+1} = x_n + y_n$
    $y_{n+1} = x_n - y_n.$

[1] Computer Projects 4.2 pp. 207

Essential Reading

1. Marotto, Frederick R. (2006). Introduction to Mathematical Modeling Using Discrete Dynamical Systems. Thomson, Brooks/Cole.

Suggestive Readings

- Devaney, Robert L. (2022). An Introduction to Chaotic Dynamical Systems (3rd ed.). CRC Press Taylor & Francis Group, LLC.
- Lynch, Stephen (2017). Dynamical Systems with Applications using Mathematica® (2nd ed.). Birkhäuser.
- Martelli, Mario (1999). Introduction to Discrete Dynamical Systems and Chaos. John Wiley & Sons, Inc., New York.

Semester 4

DEPARTMENT OF STATISTICS

B. Sc. (H) Statistics

Category I

DISCIPLINE SPECIFIC CORE COURSE-10: SAMPLING DISTRIBUTIONS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the Course			Eligibility Criteria	Pre-requisite of the Course (if any)
		Lecture	Tutorial	Practical/ Practice		
Sampling Distributions	4	3	0	1	Class XII with Mathematics	Basic knowledge of probability and probability distributions

Learning Objectives:

The learning objectives of this course are as follows:

- To introduce the modes of convergence and their relation to limit laws, with a focus on the central limit theorem.
- To introduce the concept of sampling distributions and their applications in statistical inference.
- To describe the statistical ideas behind the procedure of hypothesis testing.
- To explain the assumptions and conditions under which to apply different tests of hypothesis about population parameters and draw appropriate conclusions from the analysis.

Learning Outcomes:

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

- Understand the basics of convergence theory and its importance in limit laws.
- Apply the concept of the central limit theorem and the relevance of the theorem in inferential statistics.
- Analyze data by using suitable hypothesis testing procedures in real-life applications related to large and small samples.
- Apply the knowledge of the idea of sampling distributions and appreciate their importance in the field of statistics.
- Integrate the knowledge of various sampling distributions like chi-square, t, and F distributions in hypothesis testing problems.

SYLLABUS OF DSC-10

Theory

UNIT I **(10 Hours)**

Modes of Convergence and Central Limit Theorem

Convergence in probability, convergence with probability one, convergence in the mean square, convergence in distribution – definitions and relations between the various modes.
Chebyshev's inequality, Weak Law of Large Numbers (WLLN), and Strong Law of Large Numbers (SLLN) along with examples and applications.
Basic idea and relevance of Central Limit Theorem (CLT), De-Moivre Laplace theorem, Lindeberg Levy theorem, Liapunov Theorem (only statement), and applications of CLT.

UNIT II **(4 Hours)**

Order Statistics

Basic concept and discussion on the area of applications, probability distribution and cumulative distribution function of a single order statistic, joint probability distribution of two and the general case of all order statistics, distribution of range, and distribution of sample median.

UNIT III **(9 Hours)**

Sampling Distributions and Test of Hypotheses

Concepts of parameter, statistic, sampling distribution of a statistic, standard error. Sampling distribution of sample mean, standard errors of the sample mean, sample variance, and sample proportion.
Null and alternative hypotheses, level of significance, Type I and Type II errors, their probabilities and critical region, determination of sample size, confidence intervals, and p-value.
Tests of significance and confidence intervals for - single proportion, difference of two proportions, single mean, difference of two means, and difference of two standard deviations.

UNIT IV **(10 Hours)**

Exact Sampling Distribution

Chi-Square distribution: Definition and derivation of the probability distribution of Chi-square distribution with n degrees of freedom, nature of the curve for different degrees of freedom, mean, mode, variance, moment generating function, cumulant generating function, additive property, and limiting form of the Chi-square distribution, Applications of Chi-Square distribution.

UNIT V **(12 Hours)**

Exact Sampling Distributions (continued)

Student's t-statistic and Fishers t-statistic: definition and derivation of their sampling distributions, nature and characteristics of graph of t distribution, moments, limiting form and applications of the t distribution.
F-statistic: Definition and derivation of the sampling distribution, the graph of F distribution, moments, and applications of the F distribution. Relationship between t, F, and Chi-square distributions.

PRACTICAL / LAB WORK – 30 Hours
List of Practicals:

1. Large Sample Tests:
   a) Testing of significance and confidence intervals for single proportion and difference of two proportions.
   b) Testing of significance and confidence intervals for single mean and difference of two means.
   c) Testing of significance and confidence intervals for the difference of two standard deviations.
2. Tests based on Chi-Square Distribution:
   a) Testing of significance and confidence intervals for the population variance has a specific value.
   b) Testing for the goodness of fit.
   c) Testing of significance for the independence of attributes.
   d) Testing based on a 2 x 2 contingency table without and with Yates' corrections.
3. Tests based on t- Distribution and F- Distribution:
   a) Testing of significance and confidence intervals for single mean and difference of two means and paired t-test.
   b) Testing of significance and confidence intervals of an observed sample correlation coefficient.
   c) Testing and confidence intervals of equality of two population variances.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Gupta, S. C. and Kapoor, V. K. (2020). Fundamentals of Mathematical Statistics, Twelfth Edition, S. Chand and Sons. Delhi.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2016). An Outline of Statistical Theory, Volume I, The World Press, Kolkata.
- Mukhopadhyay, P. (2016). Mathematical Statistics, Books and Allied, India.
- Hogg, R.V., Tanis, E.A. and Rao, J.M. (2009). Probability and Statistical Inference, Seventh Edition, Pearson Education, New Delhi.
- Miller, I. and Miller, M. (2006). John E. Freund's Mathematical Statistics with Applications, Eight Edition, Pearson Education, Asia.
- Johnson, R.A. and Bhattacharya, G.K. (2001). Statistics-Principles and Methods, Fourth Edition, John Wiley and Sons.

SUGGESTED READINGS

- Bhat, B.R. (2016). Modern Probability Theory- An Introductory Textbook, Fourth Edition, New Age International Publishers.
- Rohatgi, V. K and Saleh M. E. (2015). An Introduction to Probability and Statistics, Third Edition, John Wiley and Sons, Inc., New Jersey.
- Mood, A.M. Graybill, F.A. and Boes, D.C. (2007). Introduction to the Theory of Statistics, Third Edition, (Reprint), Tata McGraw-Hill Pub. Co. Ltd.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE-11: TOTAL QUALITY MANAGEMENT

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the Course			Eligibility Criteria	Pre-requisite of the Course (if any)
		Lecture	Tutorial	Practical/ Practice		
Total Quality Management	4	3	0	1	Class XII with Mathematics	Introductory statistics and familiarity probability distributions

Learning Objectives:

The learning objectives of this course are as follows:

- To introduce statistical and management techniques,
- To explain the approach of Quality control being used in industry to manufacture goods and services of high quality at low cost.
- To introduce Six-sigma, TQM which is in high demand in the market both in the manufacturing as well as the service sector

Learning Outcomes:

After completing this course, students will be able to:

- Understand the concept of quality, its historical background, and ISO standards.
- Apply the statistical process control tools and product control tools.
- Understand the idea of Six sigma- Lean manufacturing, TQM
- Comprehend the Six sigma training plans, Voice of customers (VOC), Critical to Quality (CTQ)
- Analyze the data to find the root cause of defects through DMAIC (Define-Measure-Analyze-Improve-Control).

SYLLABUS OF DSC-11

Theory

UNIT I (9 Hours)

Basics of Quality Management

Quality: Definition, dimensions of quality, its concept, application, and importance. Brief historical perspective of quality control and improvements, Quality Gurus, and Quality Hall of Fame. Quality system and standards: Introduction to ISO quality standards, Quality registration.

Introduction to Process and Product Control, Statistical Process Control - Seven tools of SPC, Chance and Assignable causes of quality variation.

UNIT II **(12 Hours)**
Statistical Control Charts
Statistical Control Charts- Construction and Statistical basis of 3-σ Control charts,. Control charts for variables: X-bar & R-chart, X-bar & s-chart. Rational Sub-grouping, Revised and Modified Control Limits. Control charts for attributes: np-chart, p-chart, c-chart and u-chart. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on a control chart, estimation of process capability.

UNIT III **(12 Hours)**
Sampling Plans
Acceptance sampling plan: Principle of acceptance sampling plans. Single and Double sampling plans, their Operating Characteristic (OC), Acceptance Quality Level (AQL), Lot Tolerance Percent Defective (LTPD), Average Outgoing Quality (AOQ), Average Outgoing Quality Limit (AOQL), Average Sample Number (ASN), and Average Total Inspection (ATI) functions with graphical interpretation, use, and interpretation of Dodge and Romig's sampling inspection plan tables.

UNIT IV **(12 Hours)**
Six-Sigma
Overview of Six Sigma, Lean Manufacturing, and Total Quality Management (TQM). Organizational Structure and Six Sigma training plans- Selection Criteria for Six Sigma roles and training plans. Voice of customers (VOC): Importance and VOC data collection. Critical to Quality (CTQ), Introduction to DMAIC (Define-Measure-Analyze-Improve-Control).

PRACTICAL / LAB WORK – 30 Hours

List of Practical:
1. Construction and interpretation of statistical control charts for
   a) $\bar{X}$ and R-chart for known parameters.
   b) $\bar{X}$ and R-chart with revised control limits for unknown parameters.
   c) $\bar{X}\ and$ s-chart
   d) np-chart
   e) p-chart with fixed sample size
   f) p-chart with variable sample size.
   g) c-chart
   h) u-chart
2. Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, and AOQL curves under a Single sample inspection plan
3. Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, and AOQL curves under a Single sample inspection plan for varying acceptance numbers.
4. Calculation of process capability and comparison of 3-sigma control limits with specification limits.

5. Plan a single sampling plan using Dodge and Romig sampling inspection tables.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Goon A M, Gupta M K and Dasgupta B (2018): Fundamentals of Statistics, Volume I & II, 9^{th} Edition and 4^{th} reprint.
- Montogomery, D. C. (2009): Introduction to Statistical Quality Control, 6th Edition, Wiley India Pvt. Ltd.
- Ehrlich, B. Harris (2002): Transactional Six Sigma and Lean Servicing, 2nd Edition, St. Lucie Press.

SUGGESTED READING:

- Gupta S.C., Kapoor V.K.(2007): Fundamentals of Applied Statistics. 4th Edition, Sultan Chand and Sons., New Delhi.
- Hoyle, David (1995): ISO Quality Systems Handbook, 2nd Edition, Butterworth Heinemann Publication.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE-12: TIME SERIES ANALYSIS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the Course			Eligibility Criteria	Pre-requisite of the Course (if any)
		Lecture	Tutorial	Practical / Practice		
Time Series Analysis	4	3	0	1	Class XII with Mathematics	Introductory probability theory and statistics, Calculus, and matrix algebra

Learning Objectives:

The learning objectives of this course are as follows:

- To introduce basic time series analysis, trend, and seasonality,
- To understand spectral analysis,
- To familiarise students with stationary processes,
- To understand various time series models,

- To use nonstationary and seasonal time series models,
- To introduce forecasting techniques and forecasting methods.

Learning Outcomes:

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

- Understand the important time series models and their applications in various fields.
- Formulate real-life problems using time series models.
- Use statistical software to estimate the models from real data, and draw conclusions and develop solutions from the estimated models.
- Use visual and numerical diagnostics to assess the soundness of their models.
- Communicate the statistical analyses of substantial data sets through explanatory text, tables, and graphs.
- Combine and adapt different statistical models to analyze larger and more complex data.
- Possess skills to understand the components and forecast values of a time series at future time points.

SYLLABUS OF DSC-12

Theory

UNIT I (6 Hours)

Time Series Data and its Components

Introduction to times series data and its applications; Components of a time series and its decomposition; Estimation of trend and the seasonal component.

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UNIT II (9 Hours)

Spectral Analysis and Stationarity

Simple sinusoidal model; Periodogram, and Harmonic Analysis; Variate-difference method; Time series, and Stochastic process; Stationarity; Autocorrelation; meaning, definition, causes, the consequence, and test for autocorrelation.

UNIT III (15 Hours)

Time Series Models

Stochastic Models: White noise Process, Random walk, Moving Average (MA), Auto-Regressive (AR), Auto-Regressive Moving Average (ARMA) models, and their properties using correlogram, ACF, and PACF, Yule walker equations; Fitting of AR(1), AR(2), MA(1), MA(2), and ARMA(1,1) processes. Non-Stationary models: Auto-Regressive Integrated Moving Average (ARIMA) and Seasonal Auto-Regressive Integrated Moving Average (SARIMA) models; Dicky Fuller test, Augmented Dickey-Fuller test. Wold's Decomposition Theorem; Non-linear time series models: Auto-Regressive Conditional Heteroskedasticity (ARCH) and Generalized Auto-Regressive Conditional Heteroskedasticity (GARCH) Process.

UNIT IV (12 Hours)

Univariate Forecasting Procedures

Principles of Forecasting; Performance Evaluation; Extrapolation of Trend Curves; Exponential smoothing; Holt-Winter's; Box- Jenkins' Methodology.

PRACTICAL / LAB WORK – 30 hours

List of Practicals:

1. Fitting and plotting of modified exponential curves by different methods.
2. Fitting and plotting of Gompertz curve by different methods.
3. Fitting and plotting of logistic curves by different methods.
4. Fitting of the trend by the Moving Average Method for a given extent and for an estimated extent.
5. Measurement of Seasonal indices: a) Fixed and b) Changing Patterns
6. Construction of Periodogram and Harmonic Analysis
7. Estimation of variance of the random component
8. Construction of Correlogram for given AR(1), AR(2), MA(1), MA(2), and ARMA(1,1) processes.
9. Fitting of AR(1), AR(2), MA(1), MA(2), and ARMA(1,1) processes for given datasets.
10. Forecasting by various exponential smoothing procedures.
11. Forecasting by Box-Jenkins methodology.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Goon A M, Gupta M K and Dasgupta B (2018): Fundamentals of Statistics, Volume II, 9th Edition and 4th reprint.
- Galit Shmueli and Kenneth C. Lichtendahl Jr (2016): Practical Time Series Forecasting with R: A Hands-On Guide, 2nd Edition, Axelrod Schnall Publishers
- James D. Hamilton (2012): Time Series Analysis, 1st Indian Edition, Princeton University Press, Levant Books Kolkata.
- Chatfield, C. (1996): The Analysis of Time Series, 5th Edition, Chapman and Hall, New York.

SUGGESTED READING:

- Shumway and Stoffer (2011): Time Series Analysis and its applications, with examples in R, 3rd Edition, Springer.
- Brockwell, Peter J., and Davis, Richard A. (2002). Introduction to Time Series and Forecasting, 2nd edition. Springer-Verlag, New York.
- Montgomery D. C. and Johnson, L A. and (1967): Introduction to Time Series Analysis And Forecasting, 2nd ed. McGraw-Hill, New York.
- Kendall M.G. (1976): Time Series, Charles Griffin.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B.Sc. (P)/B.A(P) with Statistics as Major

Category II

DISCIPLINE SPECIFIC CORE COURSE-7: ELEMENTS OF STATISTICAL INFERENCE

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the Course			Eligibility Criteria	Pre-requisite of the Course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Statistical Inference	4	3	0	1	Class XII with Mathematics	Basic probability, probability distributions and sampling distributions

Learning Objectives:

The learning objectives of this course are as follows:

- To understand the concept of estimation theory and testing of hypothesis.
- To draw inferences about the unknown population parameters based on random samples.
- To validate the estimation/ inference about the population using hypothesis testing.

Learning Outcomes:

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

- Understanding of estimation theory, Point and interval estimations.
- Characteristics of a good estimator and different methods of estimation.
- Demonstrate the use of these techniques in data analysis.
- Develop the best/most powerful statistical tests to test the hypotheses regarding unknown population parameters by using Neyman-Pearson theory.

SYLLABUS OF DSC-7

Theory

UNIT I **(15 hours)**

Estimation Theory

Parameter space, sample space, point estimation, requirement of a good estimator, consistency, unbiasedness, efficiency, sufficiency, Minimum variance unbiased estimators, Factorization theorem, Fisher- Neyman Criterion: statement and applications, Cramer- Rao inequality:

statement and application, MVB estimators and their applications, Statement of Rao-Blackwell theorem and Lehmann-Scheffe theorem..

UNIT II **(15 hours)**
Method of Estimation
Maximum likelihood, least squares and minimum variance, Properties of maximum likelihood estimators (illustration), Interval Estimation: confidence interval and confidence limits for the parameters of normal distribution, confidence intervals for large samples.

UNIT III **(15 hours)**
Test of Significance
Principles of test of significance: Null and alternative hypotheses, simple and composite, Type-I and Type-II errors, critical region, level of significance, power of the test, best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased (UMPU) critical region, Neyman- Pearson Lemma: statement and its applications to construct most powerful test.

PRACTICAL / LAB WORK – 30 hours
List of Practical
Practical Based on:
1. Unbiased estimators and consistent estimators.
2. Efficient estimators and relative efficiency of estimators.
3. Sufficient estimators and factorization theorem.
4. Cramer- Rao inequality and MVB estimators.
5. Method of maximum likelihood estimation.
6. Method of least squares and minimum variance.
7. Confidence interval and confidence limits for the parameters of normal distribution.
8. Confidence intervals in case of large samples.
9. Type I and Type II errors, power of the test.
10. Most powerful critical region (NP Lemma).

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gupta, S.C. and Kapoor, V. K. (2020): Fundamentals of Mathematical Statistics, 12th Ed., Sultan Chand and Sons.
- Miller, I. and Miller, M. (2013). John E. Freund's Mathematical Statistics, 8th Ed., Prentice Hall of India.
- Hogg, R. V., Craig, A. T., and Mckean, J. W. (2005): Introduction to Mathematical Statistics, 6th Edition, Pearson Education.
- Goon, A.K., Gupta, M. K. and Das Gupta, B. (2003): An Outline of Statistical Theory (Vol. II), 4th Edition., World Press, Kolkata.

SUGGESTED READINGS:

● Rohtagi, V. K. and Md., A. K. Saleh, E. (2009): An Introduction to Probability and Statistics, 2nd Edition, John Wiley and Sons.
● Casella, G. and Berger, R. L. (2002): Statistical Inference, 2nd Edition, Thomson Duxbury.
● Mood A.M., Graybill F.A. and Boes D.C. (1974). Introduction to the Theory of Statistics, McGraw Hill.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE-8: INTRODUCTION TO VITAL STATISTICS AND DEMOGRAPHY

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the Course			Eligibility Criteria	Pre-requisite of the Course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Vital Statistics and Demography	4	3	0	1	Class XII with Mathematics	knowledge of basic statistics

Learning Objectives:

The learning objectives of this course are as follows:

- To collect valid Demographic data using different methods.
- To learn basic measures of Mortality, Fertility, and Population Growth.
- To construct life tables.

Learning Outcomes:

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

- Distinguish between Vital Statistics and Demography.
- Understand errors in Demographic data.
- Comprehend sources of data collection on Vital Statistics and errors therein.
- Use methods for measurement of Population.
- Distinguish between Rate and Ratio.
- Understand the basic measures of Mortality.
- Describe and apply the concepts of Stable and Stationary Populations.
- Understand the concept of Life Tables and their construction.
- Understand the basic measures of Fertility.
- Apply measures of Population Growth.

SYLLABUS OF DSC-8

Theory

UNIT I **(10 Hours)**

Introduction to Vital Statistics

Introduction and sources of collecting data on vital statistics, errors in the census, and registration data. Measurement of population, rate, and the ratio of vital events.

UNIT II **(12 Hours)**

Measurements of Mortality

Crude Death Rate (CDR), Specific Death Rate (SDR), Infant Mortality Rate (IMR), and Standardized Death Rates. Stationary and Stable population, Central Mortality Rates, and Force of Mortality.

UNIT III **(10 Hours)**

Life Tables

Life(Mortality) Tables: Assumption, description, construction of Life Tables, and Uses of Life Tables.

UNIT IV **(13 Hours)**

Measurements of Fertility

Crude Birth Rate (CBR), General Fertility Rate (GFR), Specific Fertility Rate (SFR), and Total Fertility Rate (TFR). Measurement of Population Growth: Crude rates of natural increase, Pearl's Vital Index, Gross Reproduction Rate (GRR), and Net Reproduction Rate (NRR).

PRACTICAL/LAB WORK - 30 hours

List of Practicals:

1. To calculate CDR and Age Specific death rate for a given set of data.
2. To find a standardized death rate by (i) Direct method and (ii) Indirect method.
3. To construct a complete life table.
4. To fill in the missing entries in a life table.
5. To calculate CBR, GFR, SFR, TFR for a given set of data.
6. To calculate Crude rate of Natural Increase and Pearle's Vital Index for a given set of data.
7. Calculate GRR and NRR for a given set of data and compare them.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008). Fundamentals of Statistics, Vol. II, 9thEd., World Press.
- Biswas, S. (1988). Stochastic Processes in Demography & Application, Wiley Eastern Ltd.

SUGGESTED READING:

- Mukhopadhyay, P. (1999). Applied Statistics, Books and Allied (P) Ltd.

● Keyfitz, N. and Beekman,J.A. (1985). Demography through Problems. S-Verlag, New York.
● Croxton, Fredrick, E. Cowden, Dudley J. and Klein, S. (1973). Applied General Statistics, 3rd Ed., Prentice Hall of India Pvt. Ltd.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B.Sc. (P)/B.A(P) with Statistics as Non- Major
Category III

DISCIPLINE SPECIFIC CORE COURSE 4: ELEMENTS OF STATISTICAL INFERENCE

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the Course			Eligibility Criteria	Pre-requisite of the Course (if any)
		Lecture	Tutorial	Practical/ Practice		
Elements of Statistical Inference	4	3	0	1	Class XII with Mathematics	Basic probability, probability distributions and sampling distributions

Learning Objectives:

The learning objectives of this course are as follows:

- To understand the concept of estimation theory and testing of hypothesis.
- To infer about the unknown population parameters based on random samples.
- To validate the estimation/ inference about the population using hypothesis testing.

Learning Outcomes:

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

- Understand estimation theory, point and interval estimations.
- Comprehend the characteristics of a good estimator and different methods of estimation.
- Apply the techniques in data analysis.
- Develop the best/most powerful statistical tests to test the hypotheses regarding unknown population parameters by using the Neyman-Pearson theory.

SYLLABUS OF DSC-4

Theory

UNIT I: (15 hours)

Estimation Theory:

Estimation: Parameter space, sample space, point estimation, requirement of a good estimator, consistency, unbiasedness, efficiency, sufficiency, Minimum variance unbiased estimators, Factorization theorem, Fisher- Neyman Criterion: statement and applications, Cramer- Rao inequality: statement and application, MVB estimators and their applications, Statement of Rao-Blackwell theorem and Lehmann-Scheffe theorem..

UNIT II (15 hours)

Methods of estimation:

Maximum likelihood, least squares and minimum variance, Properties of maximum likelihood estimators (illustration), Interval Estimation: confidence interval and confidence limits for the parameters of normal distribution, confidence intervals for large samples.

UNIT III **(15 hours)**
Test of significance
Principles of test of significance: Null and alternative hypotheses, simple and composite, Type-I and Type-II errors, critical region, level of significance, power of the test, best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased critical region (UMPU), Neyman- Pearson Lemma: statement and its applications to construct most powerful test.

Practical / Lab Work: - 30 hours
List of Practicals: Practicals based on
1. Unbiased estimators and consistent estimators.
2. Efficient estimators and relative efficiency of estimators.
3. Sufficient estimators and factorization theorem.
4. Cramer- Rao inequality and MVB estimators.
5. Method of maximum likelihood estimation.
6. Method of least squares and minimum variance.
7. Confidence interval and confidence limits for the parameters of normal distribution.
8. Confidence intervals in case of large samples.
9. Type I and Type II errors, power of the test.
10. Most powerful critical region (NP Lemma).

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gupta, S.C. and Kapoor, V. K. (2020): Fundamentals of Mathematical Statistics, 12th Ed., Sultan Chand and Sons.
- Miller, I. and Miller, M. (2013). John E. Freund's Mathematical Statistics, 8th Ed., Prentice Hall of India.
- Hogg, R. V., Craig, A. T., and Mckean, J. W. (2005): Introduction to Mathematical Statistics, 6th Edition, Pearson Education.
- Goon, A.K., Gupta, M. K. and Das Gupta, B. (2003): An Outline of Statistical Theory (Vol. II), 4th Edition., World Press, Kolkata.

SUGGESTED READINGS:

- Rohtagi, V. K. and Md., A. K. Saleh, E. (2009): An Introduction to Probability and Statistics, 2nd Edition, John Wiley and Sons.
- Casella, G. and Berger, R. L. (2002): Statistical Inference, 2nd Edition, Thomson Duxbury.
- Mood A.M., Graybill F.A. and Boes D.C. (1974). Introduction to the Theory of Statistics, McGraw Hill.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective
Category-V

DISCIPLINE SPECIFIC ELECTIVE COURSE-2A: COMPUTER PROGRAMMING IN C

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the Course			Eligibility Criteria	Pre-requisite of the Course (if any)
		Lecture	Tutorial	Practical / Practice		
Computer Programming in C	4	3	0	1	Class XII with Mathematics	NIL

Learning Objectives:

The learning objectives of this course are as follows:

- To introduce computer programming and its roles in problem-solving.
- To describe data structures
- To develop logics that will help to create well-structured programs using C language

Learning Outcomes:

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

- Understand various data types, operators, library functions, Input/Output operations.
- Decision making and branching and looping.
- Use Arrays, Characters, and strings.
- Understand user-defined functions, and recursive functions.
- Storage class of Variables
- Apply Pointers and Structure
- Pre-processors: Macro substitution, macro with argument
- File inclusion in C, I/O operations on files.

SYLLABUS OF DSE-2A

Theory

UNIT I **(6 hours)**

Introduction to C

History and importance of C. Components, basic structure programming, character set, C tokens, Keywords and Identifiers and execution of a C program. Data types: Basic data types, Enumerated data types, derived data types. Constants and variables: declaration and assignment of variables, Symbolic Constants, overflow and underflow of data.

UNIT II **(9 hours)**

Expressions and I/O functions

Operators and Expressions: Arithmetic, relational, logical, assignment, increment/decrement and conditional operators, precedence of operators in an expression. Managing input and output from the standard devices.

UNIT III **(12 hours)**

Branching and Arrays

Decision making and branching - if…else, nesting of if…else, else if ladder, switch. Looping in C: for, while, do…while, jumps in and out of loops.

Arrays: Declaration and initialization of one-dim and two-dim arrays. Character arrays and strings: Declaring and initializing string variables, reading and writing strings from Terminal (using scanf and printf only).

UNIT IV **(9 hours)**

Functions and Storage class

User- defined functions: definition of functions, return values and their types, function prototypes and calls. Category of Functions and recursive function. Passing arrays to functions, Storage class of Variables.

UNIT V **(9 hours)**

Pointers, Macros and Files

Pointers: Declaration and initialization of pointer variables, accessing the address of a variable, accessing a variable through its pointer, pointer expressions, pointer increments/decrement and scale factor. Pointers and arrays, functions returning pointers. Introduction of structure. Pre-processors: Macro substitution, macro with argument, file inclusion in C. Defining and opening a file (only r, w and a modes), closing a file, I/O operations on files-fscanf and fprintf functions.

PRACTICAL/LAB WORK – 30 Hours

List of Practicals:

1. Roots of a quadratic equation (with imaginary roots also)
2. Sorting of an array and hence finding median
3. Mean, Median and Mode of a Grouped Frequency Data
4. Variance and coefficient of variation of a Grouped Frequency Data
5. Preparing a frequency table
6. Value of n! using recursion
7. Random number generation from exponential, normal (using CLT) and gamma distribution calculate sample mean and variance.
8. Matrix addition, subtraction, multiplication, Transpose and Trace
9. Fitting of Binomial distribution and apply Chi-square test for goodness of fit
10. Chi-square contingency table
11. t-test for difference of means
12. Paired t-test
13. F-ratio test
14. Multiple and Partial correlation.
15. Compute ranks and then calculate rank correlation(without tied ranks)

16. Fitting of lines of regression

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Balagurusamy, E. (2019): Programming in ANSI C, 8th Edition, Tata McGraw Hill.
- Gottfried, B.S. (1998): Schaum's Outlines: Programming with C, 2nd Edition, Tata McGraw Hill
- Kernighan, B.W. and Ritchie, D. (1988): C Programming Language, 2ndEdition,Prentice Hall.

SUGGESTED READING:

- Kanetkar, Y. (2020) : Let Us C, 18th Edition, BPB Publications
- Perry, G. and Miller, D. (2015) : C Programming Absolute Beginner's Guide, 3rd Edition, Pearson Publications

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE-2B: ADVANCED TECHNIQUES OF SAMPLE SURVEYS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title and code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	Tutorials	Practical/ Practice		
Advanced Techniques of Sample Surveys	4	3	0	1	Class XII with Mathematics	Knowledge of sample surveys

Learning Objectives:

The learning objectives of this course are as follows:

- To introduce advanced techniques relating to stratified and systematic sampling, ratio and regression methods of estimation.
- To introduce cluster and two-stage sampling when the population is divided into groups.
- To describe the errors due to factors other than the inductive process of inferring about the population from a sample.

Learning Outcomes:

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

- Understand Post Stratification,
- Determine the optimum number of strata and their construction
- Comprehend Circular systematic sampling

- Apply Ratio and Regression method of estimation under the Superpopulation model
- Use Cluster sampling, and Two-stage sampling
- Classify non-sampling errors

SYLLABUS OF DSE-2B

Theory

UNIT I **(15 Hours)**

Stratified and Systematic Sampling

Stratified Sampling: Post Stratification, effect of increasing the number of strata, determination of optimum number of strata, construction of strata (Neyman allocation, Proportional allocation and approximate method by Dalenius and Hodges), method of collapsed strata, allocation requiring more than 100% sampling.

Systematic Sampling: Circular systematic sampling, Yates' and Cochran method of estimation of sampling variance.

UNIT II **(15 Hours)**

Superpopulation Model and Cluster Sampling

Superpopulation model, Ratio method of estimation under superpopulation model, regression method of estimation under superpopulation model.

Cluster Sampling (equal-sized clusters): Estimation of population mean and its variance, efficiency of cluster sampling, the effect of formation of clusters randomly, efficiency of cluster sampling in terms of intra-class correlation, estimation of efficiency, optimum size of cluster.

UNIT III **(15 Hours)**

Two-Stage Sampling and Non-Sampling Errors

Two-stage sampling/sub-sampling (Equal first stage units): Estimation of population mean and its variance, Estimator of variance of the sample mean, allocation of sample to two-stages, comparison of two-stage with one-stage sampling.

Non-sampling errors: Classification of non-sampling errors, types of non-sampling errors, bias due to non-response, Hansen and Hurwitz technique, comparison of Hansen and Hurwitz technique with SRS under a cost constraint

PRACTICAL/LAB WORK – 30 Hours

List of Practicals:

Practical Work based on:

1. Dalenius and Hodges method of construction of strata
2. Determination of optimum number of strata
3. Cluster sampling
4. Circular systematic sample
5. Ratio method of estimation under superpopulation model
6. Regression method of estimation under superpopulation model
7. Two-stage sampling

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Cochran, W.G. (2011): Sampling Techniques (3rd Ed.), Wiley Eastern John Wiley and Sons..
- Sukhatme, P. V., Sukhatme, B. V., Sukhatme, S., Asok, C.(1984). Sampling Theories of Survey with Application, IOWA State University Press and Indian Society of Agricultural Statistics.
- Gupta, S.C. and Kapoor, V.K. (2007): Fundamentals of Applied Statistics, Sultan Chand and Sons.
- Singh, D. and Chaudhary, F. S. (2015): Theory and Analysis of Sample Survey Designs.

SUGGESTED READING:

- Murthy M.N. (1977): Sampling Theory & Statistical Methods, Statistical Pub. Society, Calcutta.
- Des Raj and Chandhok P. (1998): Sample Survey Theory, Narosa Publishing House.
- Goon, A. M., Gupta, M. K. and Dasgupta, B. (2001): Fundamentals of Statistics (Vol.2), World Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE-2C: DEMOGRAPHY (Not for category II)

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title and code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	Tutorials	Practical/ Practice		
Demography	4	3	0	1	Class XII with Mathematics	knowledge of basic statistics

Learning Objectives:

The learning objectives of this course are as follows:

- To introduce various demographic concepts and to explain the nature and scope of population studies.
- To explain evaluation and adjustments in age data using different indices.
- To introduce the construction of abridged life tables and the estimation and projection of population by different methods.
- To describe the Graduation of mortality rates by different methods.

Learning Outcomes:

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

- Understand the various components of Demography, sources of demographic data collection and errors therein.
- Comprehend population potential, density and concentration.
- Analyse the completeness of registration data using the Chandrasekharan-Deming formula.
- Use concepts of Stable and Stationary Populations.
- Use Balancing Equations.

- Use Myer’s and UN indices in evaluating age data.
- Apply measures of the aging of population.
- Understand the concept of Abridged life tables and their construction by Reed and Merrell method and Greville’s method.
- Synthesize population estimation and projection by different methods.
- Use Graduation of mortality rates by Makeham’s and Gompertz graduation formula.
- Fit of Logistic curve and Makeham’s formula.
- Understand the scope of population studies and its relationship with other disciplines.

SYLLABUS OF DSE-2C

Theory

UNIT I: (15 Hours)

Demographic concepts

Definition of demography and its various components, Major sources of demographic data collection and errors therein; Coverage and content errors, Rate of population change, Population density, Population potential, Population composition, Scale of urbanization and scale of population concentration, Concept of Stationary and stable populations, Nature and scope of population studies and its relationship with other disciplines. Balancing equations and its uses.

UNIT II: (15 Hours)

Adjustment of demographic data and abridged life tables

Measures of aging of population: Aged-child ratio, Old-age dependency ratio, Child dependency ratio, Age-dependency ratio, Adjustment of age data at younger age groups and adult ages. Chandrasekharan-Deming formula to check completeness of registration data. Myer’s index, United Nation’s index.

Abridged life tables: Concept and its construction by Reed-Merrell method and Greville’s method.

UNIT III (15 Hours)

Population Estimates and Projections and Graduation of Mortality Rates:

Inter-censal and post-censal estimates by mathematical and component method ; Population Projection by the mathematical method: Logistic curve and its fitting by Pearl and Reed method and Rhodes method. Graduation of mortality rates: Makeham’s and Gompertz graduation formula. Fitting of Makeham’s formula.

PRACTICAL/LAB WORK - 30 hours

List of Practicals:

1. To find the Population density of a place.
2. To find Population Potential.
3. To find Rate of population change
4. To find Age Dependency ratio.
5. To find Aged Child ratio.
6. To find Child Dependency ratio.
7. To construct Abridged Life Table by Reed and Merrell method.
8. To Construct Abridged Life Table by Greville’s method.

9. To fit Logistic curve by Pearl and Reed method.
10. To fit Logistic curve by Rhode's method.
11. To fit Makeham's formula by the method of Four Selected Points.
12. To fit Makeham's formula by the method of Partial Sums.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2008): Fundamentals of Statistics, Vol. II, 9th Edition, World Press.
- Mukhopadhyay P. (1999): Applied Statistics, Books and Allied (P) Ltd.
- Biswas, S. (1988): Stochastic Processes in Demography & Application, Wiley Eastern Ltd.
- Pathak, K. B. and F. Ram (1998), *Techniques of Demographic Analysis*, 2nd Edition, Himalaya Publishing House, Bombay.

SUGGESTED READINGS:

- Croxton, Fredrick E., Cowden, Dudley J. and Klein, S. (1973): Applied General Statistics, 3rd Edition. Prentice Hall of India Pvt. Ltd.
- Keyfitz N., Beckman John A. (1985): Demography through Problems S-Verlag New York
- Ramakumar R. (1986): Technical Demography. Wiley Eastern Limited.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY DEPARTMENT OF STATISTICS CATEGORY-VI

GENERIC ELECTIVE 4A: BASICS OF STATISTICAL INFERENCE

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the Course			Eligibility Criteria	Pre-requisite of the Course (if any)
		Lecture	Tutorial	Practical/ Practice		
Basics of Statistical Inference	4	3	0	1	Class XII with Mathematics	Basic knowledge of probability, probability distributions and sampling distributions

Learning Objectives:
The learning objectives of this course are as follows:
- To introduce the concept of estimation theory and testing of hypothesis.
- To infer about the unknown population parameters based on random samples.
- To introduce the estimation/ inference about the population using hypothesis testing.

Learning Outcomes:
After successful completion of this course, students will be able to:
- Understanding of estimation theory, Point and interval estimations.
- Characteristics of a good estimator and different methods of estimation.
- Demonstrate the use of these techniques in data analysis.
- Develop the best/most powerful statistical tests to test the hypotheses regarding unknown population parameters by using the Neyman-Pearson theory.

SYLLABUS OF GE 4A
Theory

UNIT I: **(15 Hours)**
Estimation Theory

Estimation: Parameter space, sample space, point estimation, requirement of a good estimator, consistency, unbiasedness, efficiency, sufficiency, Minimum variance unbiased estimators, Factorization theorem, Fisher- Neyman Criterion: statement and applications, Cramer- Rao inequality: statement and application, MVB estimators and their applications, Statement of Rao-Blackwell theorem and Lehmann-Scheffe theorem..

UNIT II: (15 Hours)

Methods of Estimation

Methods of estimation: maximum likelihood, least squares and minimum variance, Properties of maximum likelihood estimators (illustration), Interval Estimation: confidence interval and confidence limits for the parameters of normal distribution, confidence intervals for large samples.

UNIT III: (15 Hours)

Test of Significance

Principles of test of significance: Null and alternative hypotheses, simple and composite, Type-I and Type-II errors, critical region, level of significance, power of the test, best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased critical region (UMPU), Neyman- Pearson Lemma: statement and its applications to construct most powerful test.

PRACTICAL/LAB WORK – 30 Hours

List of Practical / Lab Work:

1. Unbiased estimators and consistent estimators.
2. Efficient estimators and relative efficiency of estimators.
3. Sufficient estimators and factorization theorem.
4. Cramer- Rao inequality and MVB estimators.
5. Method of maximum likelihood estimation.
6. Method of least squares and minimum variance.
7. Confidence interval and confidence limits for the parameters of normal distribution.
8. Confidence intervals in case of large samples.
9. Type I and Type II errors, power of the test.
10. Most powerful critical region (NP Lemma).

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Miller, I. and Miller, M. (2013). John E. Freund's Mathematical Statistics, 8th Ed., Prentice Hall of India.
- S.C. Gupta and V.K. Kapoor (2020): Fundamentals of Mathematical Statistics, 12th Ed., Sultan Chand and Sons.
- R.V. Hogg, A.T. Craig and J.W. Mckean (2005): Introduction to Mathematical Statistics, 6th Edition, Pearson Education.

- A.M. Goon, M.K. Gupta and B. Das Gupta (2003): An Outline of Statistical Theory (Vol. II), 4th Ed.,World Press, Kolkata.

SUGGESTED READING:

- G. Casella and R.L. Berger (2002): Statistical Inference, 2nd Edition, Thomson Duxbury.
- E.J. Dudewicz and S.N. Mishra (1988): Modern Mathematical Statistics, John Wiley and Sons.
- V.K. Rohtagi and A.K. Md. E. Saleh (2009): An Introduction to Probability and Statistics, 2nd Edition, John Wiley and Sons.
- Mood A.M., Graybill F.A. and Boes D.C. (1974). Introduction to the Theory of Statistics, McGraw Hill.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

GENERIC ELECTIVE 4B: STATISTICAL COMPUTING USING R

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Computation using R	**4**	**2**	0	**2**	Class XII pass with Mathematics.	Basic knowledge of computers and basics of Statistics

Learning Objectives:

The learning objectives of this course are as follows:

- Review and expand upon core topics in probability and statistics.
- Practice of graphical interpretation, probability distribution and data analysis using `R'.

Learning Outcomes:

After completing this course, students would have developed a clear understanding of:

- Various Graphical representation and interpretation of data.
- Automated reports giving detailed descriptive statistics.
- Understanding data and fitting suitable distribution.
- Testing of hypothesis, p-value and confidence interval.

- Random number generation and sampling procedures.
- Importing data, Code editing in R and flow controls if (), for (), while ()

SYLLABUS OF GE 4B

Theory

UNIT I **(07 hours)**

Overview of the R language

Installing R and R studio; working on R studio, scripts and text editors, creating and saving R workspaces, installing packages and loading libraries.

Data types in R (Numeric, Integer, Character, Logical, and Complex) Data structures in R (Vector, Matrix, Data frames, List). Mathematical operators, Relational Operators, and Logical operators and use of functions: class(), names(), head(), tail(),rbind(), cbind(), rownames(), colnames() etc. Learn how to load data, importing a data file viz. .xlsx. handling missing data in R

UNIT II **(10 hours)**

Descriptive statistics and Graphs

Generate automated reports giving detailed descriptive statistics mean, median, mode, variance, skewness, five-point summary , frequency table. Statistical/mathematical functions, scan(), summary(),str(), table(), cut(),cumsum(), cumprod()etc.

Graphical representation of data: bar-plot, pie-chart, boxplot, frequency polygon, ogives , scatter plot, Fitting of curve lm(): linear, quadratic, exponential functions, correlation, and linear and multiple regression with the interpretation of results.

UNIT III **(10 hours)**

Decision-making and distributions

Introduction to flow control: if, if-else, while, and for loops, simple coding. Distribution functions(r,d,p,q) for Binomial, Poisson, Exponential, and Normal . Data distribution: qqplot(), qqnorm()

UNIT IV **(08 hours)**

Testing of Hypothesis and Time series

Basics of statistical inference in order to understand hypothesis testing, and compute p-values and confidence intervals. Applications on t-test, F-test, and Chi-square test with the interpretation of results. Time series analysis, components of a time series data, time series model, ts(), decomposition(), and smoothing with the interpretation of results.

PRACTICAL/LAB WORK – 30 Hours

List of Practical / Lab Work:

1. Graphical representation of data with bar-plot, pie-chart, and boxplot.
2. Histogram with equal and unequal class intervals, frequency polygon
3. Less than and more than Ogives.
4. Fitting of curve linear, quadratic, exponential functions,
5. Scatter plots, correlation
6. Linear and multiple regression

7. Drawing sample using SRSWR, SRSWOR
8. Drawing sample using stratified under proportion allocation and systematic sampling,
9. functions(r,d,p,q) for discrete distributions viz. Binomial, Poisson.
10. functions(r,d,p,q) for continuous distribution viz. Uniform,Exponential, and Normal .
11. Test the goodness of fit for Binomial, Poisson distribution.
12. Chi- Square test for independence of attributes.
13. Single, paired and independent samples t-test.
14. Components of a time series data.
15. decomposition(), and smoothing() under time series data

ESSENTIAL READINGS:

- Braun, W. J., and Murdoch, D. J. (2007). A First Course in Statistical Programming with R. Cambridge University Press. New York.
- Gardener, M. (2012). Beginning R: The Statistical Programming Language, Wiley Publications.

SUGGESTIVE READING:

- Crawley, M. J. (2012). The R Book. 2nd Ed., John Wiley & Sons.
- Dalgaard, P. (2008). Introductory Statistics with R. 2nd Ed., Springer.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Semester 5

DEPARTMENT OF STATISTICS

B. Sc. (H) Statistics

Category I

DISCIPLINE SPECIFIC CORE COURSE – 13: THEORY OF ESTIMATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Theory of Estimation	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of probability, probability distributions and sampling distributions

Learning Objectives

The learning objectives include:

- Characterisation of the population based on sample information
- Understanding process of learning and determining the population characteristics based the available data.
- Strength and weakness of various methods for obtaining point and interval estimators with respect to optimal/desirable properties.

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- List desirable properties of point estimators based on an unknown parameter of a distribution viz. Unbiasedness, Consistency, Efficiency and Sufficiency.
- Derive the UMVUE of a parameter or function of a parameter (Using Cramer- Rao inequality, Rao-Blackwell theorem, and Lehmann- Scheffé Theorem).
- Understand and apply different techniques of finding optimal point estimators such as Maximum Likelihood Estimation, Method of Least Squares, Method of moments and the method of minimum chi-Squares

- Construct interval estimators, pivot method (Confidence Intervals) for unknown population parameters.

SYLLABUS OF DSC-13

Theory

UNIT I **(18 hours)**

Estimation

Estimation: Concepts of estimation, unbiasedness, sufficiency, consistency and efficiency. Fisher-Neyman Criterion (statement and applications), Factorization theorem. Complete statistic, Minimum variance unbiased estimator (MVUE), Rao-Blackwell and Lehmann-Scheffe theorems and their applications. Cramer-Rao inequality, Minimum Variance Bound estimators (MVBE) and their applications.

UNIT II **(10 hours)**

Methods of Estimations

Methods of Estimation: Method of moments, method of maximum likelihood estimation and method of minimum Chi-square.

UNIT III **(12 hours)**

Interval estimation

Interval estimation - Confidence intervals for parameters of various distributions, confidence interval for Binomial proportion, confidence interval for population correlation coefficient for Bivariate Normal distribution, pivotal quantity method of constructing confidence intervals, shortest length confidence intervals, large sample confidence intervals.

UNIT IV **(5 hours)**

Censored Data

Failure censored samples, time censored sample, estimation of expected lifetime in failure censored samples for one parameter exponential lifetime distribution

PRACTICAL/LABWORK (30 hours):

List of Practical

1. Unbiased estimators (including unbiased but absurd estimators)
2. Consistent estimators, efficient estimators and relative efficiency of estimators.
3. Cramer-Rao inequality and MVB estimators
4. Sufficient Estimators – Factorization Theorem, Complete Sufficient estimators, Rao-Blackwell theorem.
5. Lehman-Scheffe theorem and UMVUE
6. Maximum Likelihood Estimation
7. Asymptotic distribution of maximum likelihood estimators
8. Estimation by the method of moments,
9. Estimation by method of minimum Chi-square
10. Confidence interval based on large sample test
11. Confidence interval based on exact sample test

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Goon, A.M.; Gupta, M.K.; Dasgupta, B. (2013).: An Out Line of Statistical Theory, Volume 2, The World Press, Kolkata.
- Gupta, S.C. and Kapoor, V.K.(2020): Fundamental of Mathematical Statistics, 12th Edn. Sultan Chand and Sons.
- Sinha, S.K. (1986):Reliability and Life testing; Wiley Eastern.

SUGGESTIVE READINGS:

- Hogg, R.V. and Craig, A.T (2018): Introduction to Mathematical Statistics, 8th Edn. Pearson Education.
- Casella, G. and Berger, R.L. (2002): Statistical Inference. 2nd Edition, Duxbury Press, Pacific Grove.
- Hogg, R.V. and Tanis, E.A. (1988): Probability and statistical Inference, 6th Edn. Pearson Education
- Rohatgi V.K, (2013): Statistical Inference- Dover Publication, New York.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE-14: LINEAR MODELS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	tutorials	practical		
Linear Models	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of matrix theory, probability distributions and sampling distributions

Learning Objectives:

learning objectives include:

- Developing a clear understanding of the fundamental concepts of linear models.
- Developing associated skills allowing the students to work effectively with them.

Learning Outcomes:

After completion of this course, students will develop a clear understanding of:

- Theory and estimation of Linear Models.
- Gauss-Markov Theorem and its use.
- Distribution of quadratic forms.
- Simple and Multiple linear regression models and their applications.

- Fitting of these models to real or synthetic data, derivation of confidence and prediction intervals, and a sound scientific interpretation of the results.
- Techniques of Analysis of Variance and Covariance under fixed effects model.
- Assessment of the quality of the fit using classical diagnostics, awareness of potential problems (outliers, etc.) and application of remedies to deal with them.

SYLLABUS OF DSC-14

THEORY

UNIT I **(10 Hours)**

Estimation theory and Distribution of Quadratic forms

Gauss-Markov setup, Theory of linear estimation, Estimability of linear parametric functions, Method of least squares, Gauss-Markov theorem, Estimation of error variance. Cochran's theorem and distribution of quadratic forms.

UNIT II **(10 Hours)**

Analysis of Variance

Definition of fixed, random, and mixed effect models, Technique of ANOVA, assumptions for its validity, analysis of variance in one-way classified data and in two-way classified data with an equal number of observations per cell for fixed effect models.

UNIT III **(14 Hours)**

Regression analysis:

Estimation and hypothesis testing in case of simple and multiple linear regression analysis, Confidence intervals, and Prediction intervals, Concept of model matrix and its use in estimation. Effect of orthogonal columns in the X matrix, Partial F-test and Sequential F-test, Bias in regression estimates.

UNIT IV **(4 Hours)**

Analysis of Covariance:

Technique of ANOCOVA, assumptions for its validity, use, and analysis of covariance in one-way classified data with a single concomitant variable.

UNIT V **(7 Hours)**

Model checking and Model Building

Prediction from a fitted model, Residuals and Outliers, Lack of fit and pure error, Violation of usual assumptions concerning normality, Homoscedasticity, and collinearity, Diagnostics using quantile-quantile plots. Techniques for Variable selection. Polynomial Regression models: Orthogonal Polynomials.

PRACTICAL/LABWORK -30 Hours

List of Practicals

1. Estimability when X is a full rank matrix.
2. Estimability when X is not a full rank matrix.
3. Distribution of Quadratic forms.
4. Simple Linear Regression.
5. Multiple Regression.
6. Tests for Linear Hypothesis.
7. Bias in regression estimates.
8. Lack of fit.
9. Stepwise regression procedure.

10. Analysis of Variance of a one-way classified data.
11. Analysis of Variance of two-way classified data with one observation per cell.
12. Analysis of Variance of two-way classified data with m (> 1) observations per cell.
13. Analysis of Covariance of a one-way classified data.
14. Residual Analysis.
15. Orthogonal Polynomials.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012): Introduction to Linear Regression Analysis, 5th Ed., John Wiley and Sons.
- Rencher, A. C. and Schaalje, G. B. (2008): Linear Models in Statistics, 2nd Ed., John Wiley and Sons.
- Draper, N. R. and Smith, H. (1998): Applied Regression Analysis, 3rd Ed., John Wiley and Sons.

SUGGESTIVE READINGS:

- Weisberg, S. (2005): Applied Linear Regression, 3rd Ed., John Wiley and Sons.
- Rawlings, John O. Pantula Sastry G. Dickey, David A. (1998) Applied Regression Analysis: A Research Tool, Second Edition
- Bapat, R.B.(1993): Linear Algebra and Linear Models, Hindustan Book Agency.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE 15 –: STOCHASTIC PROCESSES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Stochastic Processes	4	3	0	1	Class XII pass with Mathematics.	Knowledge of probability, probability distributions, and sampling distributions

Learning Objectives:

- To define, design and model

- To analyze transitions through Markov chains
- To identify the real life applications of stochastic processes

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- The fundamental concepts of stochastic processes.
- Tools needed to analyze stochastic processes.
- Markov processes and Markov chains.
- Markov chain applications.
- Poisson process and its variations.
- Random walk and ruin theory

SYLLABUS OF DSC-15

Theory

UNIT I (13 hours)

Introduction of Stochastic Process

Probability Distributions: Generating functions, Bivariate probability generating functions, and their application.

Stochastic Process: Introduction, Covariance stationary, and Stationary Process.

UNIT II (15 hours)

Markov Chains

Markov Chains: Definition of Markov Chain, transition probability matrix, order of Markov chain, Markov chain as graphs, higher transition probabilities.

Classification of states and chains, stationary process, and stability of Markov system. Generalization of independent Bernoulli trials,

UNIT III (12 hours)

Poisson Process

Poisson Process: postulates of Poisson process, and properties of Poisson process and applications.

Gambler's Ruin Problem: Classical ruin problem, expected duration of the game.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Applications of Partial Fraction Theorem.
2. Problems based on (covariance) stationary processes.
3. Simulation of Markov chains.
4. Calculation of transition probability matrices.
5. To check whether the given chain is irreducible or not.
6. Classification of states.
7. Computation of probabilities in case of generalizations of independent Bernoulli trials.
8. Simulation and applications of Poisson processes.
9. Transition Markov chain in case of gambler's ruin problem .
10. Calculation of probabilities for ruin problems.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Feller, W. (1968). Introduction to probability Theory and Its Applications, Vol I, 3rd Ed., Wiley International.
- Medhi, J. (2019). Stochastic Processes,4th Ed., Reprint, New Age International Publishers.

SUGGESTIVE READINGS:

- Sheldon M. Ross (2007) : Introduction to Probability Models, 9th edition, Academic Press publications
- Karlin & Taylor (1975) : A first course in stochastic processes, 2nd edition, Academic Press publications
- Basu, A.K. (2005). Introduction to Stochastic Processes, Narosa Publishing.
- P. G. Hoel, S. C. Port and C. J. Stone: Introduction to Stochastic Processes.
- J. G. Kemeny, J. L. Snell and A. W. Knapp: Finite Markov Chains.
- Geoffrey R, Grimmett & David R. Stirzaker : Probability and Random Processes
- Bhat,B.R. (2000). Stochastic Models: Analysis and Applications, New Age International Publishers.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B.Sc. (P)/B.A(P) with Statistics as Major

Category II

DISCIPLINE SPECIFIC CORE COURSE - 9: INTRODUCTION TO DESIGN OF EXPERIMENTS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Design of Experiments	4	3	0	1	Class XII pass with Mathematics	knowledge of inferential statistics, and ANOVA

Learning Objectives:
The learning objectives include
- To design and conduct experiments.
- To analyze and interpret data.

Learning Outcomes:
After completing this course, students will developed a clear understanding of
- The fundamental concepts of Design of Experiments.
- Introduction to planning valid and economical experiments.
- Completely randomized design.
- Randomized block design.
- Latin square design.
- Balanced incomplete block design.
- Full and confounded factorial designs with two levels.
- Fractional factorial designs with two levels.

SYLLABUS OF DSC-9

Theory

UNIT I **(15 hours)**
Experimental designs
Experimental designs: Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks. Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) - layout, model and statistical analysis, relative efficiency.

UNIT II **(09 hours)**

Balanced Incomplete Block Designs

Balanced Incomplete Block Design (BIBD)- parameters, relationships among its parameters, incidence matrix and its properties, Symmetric BIBD, Resolvable BIBD, Affine Resolvable BIBD.

UNIT III **(15 hours)**

Factorial experiments

Factorial experiments**:** Concepts, notations and advantages, 2^2, $2^3 \ldots 2^n$ factorial experiments, design and analysis, Total and Partial confounding for 2^n ($n \leq 5$). Factorial experiments in a single replicate.

UNIT IV **(06 hours)**

Fractional factorial experiments

Fractional factorial experiments**:** Construction of one-half and one-quarter fractions of 2^n ($n \leq 5$) factorial experiments, Alias structure, Resolution of a design.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Analysis of CRD, RBD & LSD.
2. Analysis of 2^2 and 2^3 factorial experiments in CRD and RBD.
3. Analysis of a completely confounded two level factorial designs in 2 and 4 blocks.
4. Analysis of a partially confounded two level factorial design.
5. Analysis of a single replicate of a 2^n design.
6. Analysis of one-half and one-quarter fractions of 2^n factorial design.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics, Vol. II, 8thEd. World Press, Kolkata.
- Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.
- Das., M.N. and Giri, N.C. (1986): Design and Analysis of Experiments, Wiley Eastern.
- Mukhopadhyay, P (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied (P) Ltd.

SUGGESTIVE READINGS

- Cochran, W.G. and Cox, G.M. (1959): Experimental Design, Asia Publishing House.
- Kempthorne, O. (1965): The Design and Analysis of Experiments, John Wiley.
- Joshi, D.D. (1987): Linear Estimation and Design of Experiments, John Wiley & Sons.
- Dey, Aloke (1986): Theory of Block Designs, Wiley Eastern Ltd.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE– 10: STATISTICAL SIMULATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Simulation	4	3	0	1	Class XII pass with Mathematics	knowledge of basic statistics

Learning Objectives

The learning objectives include:

- Concept of simulation and simulation modelling.
- Generation of Pseudo random number generators as well as from standard statistical distributions. Monte-Carlo simulation technique.
- Application of simulation techniques.

Learning Outcomes

After completing this course, students will possess skills concerning:

- How simulation may be used to understand the behavior of real world systems by utilizing mathematical models with an emphasis on simulation.
- How to generate random numbers by the different methods.
- Hands-on experience in using simulation software packages/structured programming languages.

SYLLABUS OF DSC- 10

Theory

UNIT I **(12 Hours)**

Introduction to simulation:

Introduction, Definitions of simulation, Need for simulation, general principles, types of simulation, Simulation models, Phases in simulation models, Event type simulation, Monte Carlo simulation technique.

UNIT II **(18 Hours)**

Random numbers generation:

Methods for the generation of Random numbers, Pseudo random number generators, Mid square method for the generation of random number and its limitations, the inverse transform method; Generating the Discrete and Continuous random variables.

UNIT III **(15 Hours)**

Applications of simulation:

Applications of simulation in different fields of study, simulation of Inventory problems and simulation of Queueing problems. Advantages and disadvantages of simulation, Simulation languages, Scope of simulation techniques.

Practical/Lab Work – (30 hours)

List of Practical:

1. Pseudo random number generators;
2. Generation of U(0,1).
3. Generation using the inverse transform method applied to:
   (a) Discrete distribution and
   (b) Continuous distribution.
4. Monte Carlo simulation method and applications.
5. Problems based on Queueing systems.
6. Problems based on Inventory Controls, etc.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READING:

- Sheldon M. Ross (2022) Simulation, Sixth Edition, Elsevier Academic press publication.
- Taha, H. A. (2010). Operations Research. An Introduction, 9th Ed, Pearson.
- Swarup, K. Gupta, P.K. and Mohan, M. (2019). Operations Research, 15th Ed, Sultan Chand & Sons.

SUGGESTED READINGS:

- Voss, J. (2013). An introduction to statistical computing: A simulation-based approach, 1st Ed., Wiley series in computational statistics.
- Sharma, J. K. (2017). Operations Research: Theory and applications, 6th Edition, Trinity Press.
- Payer T.A. (1982). Introduction to simulation, McGraw Hill.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B.Sc. (P)/B.A(P) with Statistics as Non- Major

Category III

DISCIPLINE SPECIFIC CORE COURSE - 5: INTRODUCTION TO DESIGN OF EXPERIMENTS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Design of Experiments	4	3	0	1	Class XII pass with Mathematics	knowledge of inferential statistics, and ANOVA

Learning Objectives:
The learning objectives include
- To design and conduct experiments.
- To analyze and interpret data.

Learning Outcomes:
After completing this course, students will develop a clear understanding of
- The fundamental concepts of Design of Experiments.
- Introduction to planning valid and economical experiments.
- Completely randomized design.
- Randomized block design.
- Latin square design.
- Balanced incomplete block design.
- Full and confounded factorial designs with two levels.
- Fractional factorial designs with two levels.

SYLLABUS OF DSC-5
Theory

UNIT I **(15 hours)**
Experimental designs
Experimental designs: Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks. Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) - layout, model and statistical analysis, relative efficiency.

UNIT II **(09 hours)**
Balanced Incomplete Block Designs
Balanced Incomplete Block Design (BIBD)- parameters, relationships among its parameters, incidence matrix and its properties, Symmetric BIBD, Resolvable BIBD, Affine Resolvable BIBD.

UNIT III **(15 hours)**
Factorial experiments
Factorial experiments**:** Concepts, notations and advantages, 2^2, $2^3 \ldots 2^n$ factorial experiments, design and analysis, Total and Partial confounding for 2^n ($n \leq 5$). Factorial experiments in a single replicate.

UNIT IV **(06 hours)**
Fractional factorial experiments
Fractional factorial experiments**:** Construction of one-half and one-quarter fractions of 2^n ($n \leq 5$) factorial experiments, Alias structure, Resolution of a design.

PRACTICAL/LAB WORK – (30 hours)
List of Practical:

1. Analysis of CRD, RBD & LSD.
2. Analysis of 2^2 and 2^3 factorial experiments in CRD and RBD.
3. Analysis of a completely confounded two level factorial designs in 2 and 4 blocks.
4. Analysis of a partially confounded two level factorial design.
5. Analysis of a single replicate of a 2^n design.
6. Analysis of one-half and one-quarter fractions of 2^n factorial design.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics, Vol. II, 8thEd. World Press, Kolkata.
- Montgomery, D. C. (2008): Design and Analysis of Experiments, John Wiley.
- Das., M.N. and Giri, N.C. (1986): Design and Analysis of Experiments, Wiley Eastern.
- Mukhopadhyay, P (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied (P) Ltd.

SUGGESTIVE READINGS

- Cochran, W.G. and Cox, G.M. (1959): Experimental Design, Asia Publishing House.
- Kempthorne, O. (1965): The Design and Analysis of Experiments, John Wiley.
- Joshi, D.D. (1987): Linear Estimation and Design of Experiments, John Wiley & Sons.
- Dey, Aloke (1986): Theory of Block Designs, Wiley Eastern Ltd.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective
Category-V

DISCIPLINE SPECIFIC ELECTIVE COURSE – 3A: ACTUARIAL STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Actuarial Statistics	4	**3**	0	1	Class XII pass with Mathematics	**NIL**

Learning Objectives

The learning objectives include:

- To learn basics of Actuarial Science.
- To learn advanced techniques in Actuarial Science with practical applications in daily life.

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- Basics of Actuarial Science.
- Tools for applying actuarial methods in phenomena for financial research and insurance.
- computation of premiums and settlement of claims

SYLLABUS OF DSE-3A

Theory

UNIT I **(9 Hours)**

Introductory Statistics and Insurance Applications

Introductory Statistics and Insurance Applications: Discrete, continuous and mixed probability distributions. Insurance applications, sum of random variables. Utility theory: Utility functions, expected utility criterion, types of utility function, insurance and utility theory.

UNIT II **(12 Hours)**

Principles of Premium Calculation

Principles of Premium Calculation**:** Properties of premium principles, examples of premium principles. Individual risk models: models for individual claims, the sum of independent claims, approximations and their applications.

UNIT III **(6 Hours)**

Survival Distribution and Life Tables:

Survival Distribution and Life Tables: Uncertainty of age at death, survival function, time-until-death for a person, curate future lifetime, force of mortality, life tables with examples, deterministic survivorship group, life table characteristics

UNIT IV **(15 Hours)**

Life Insurance
Life Insurance: Models for insurance payable at the moment of death, insurance payable at the end of the year of death and their relationships. Life annuities: continuous life annuities, discrete life annuities. Premiums: continuous and discrete premiums.

PRACTICAL/LAB WORK – (30 hours)
List of Practical:
1. Risk computation for different utility models.
2. Discrete and continuous risk calculations.
3. Calculation of aggregate claims for collective risks.
4. Calculation of aggregate claim for individual risks.
5. Computing Ruin probabilities and aggregate losses.
6. Annuity and present value of contract.
7. Computing premium for different insurance schemes.
8. Practical based on life models and tables.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Dickson, C. M. D. (2005): Insurance Risk And Ruin (International Series On Actuarial Science), Cambridge University Press. Bowers, N. L., Gerber, H. U., Hickman,
- Atkinson, M.E. and Dickson, D.C.M. (2011): An Introduction to Actuarial Studies, Elgar Publishing.

SUGGESTIVE READINGS

- J. C., Jones, D. A. And Nesbitt, C. J. (1997): .Actuarial Mathematics, Society Of Actuaries, Itasca, Illinois, U.S.A.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE– 3B: SIMULATION TECHNIQUES IN STATISTICS (Not for category II)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Simulation Techniques in Statistics	4	3	0	1	Class XII pass with Mathematics	knowledge of basic statistics

Learning Objectives

The learning objectives include:

- The objective of this course is to introduce the nuances of techniques involved in simulation studies as applicable to modeling of systems.
- The programming implementations will be completed using C/MATLAB/R/Python.

Learning Outcomes

After completing this course, students will possess skills concerning:

- Use of simulation to understand the behavior of real world systems.
- Ability to generate Pseudo-random numbers by the different methods.
- Random variable generation from theoretical distributions.
- Use of Monte Carlo methods and regenerative simulation.
- Ability to develop programs for the purpose of simulation.

SYLLABUS OF DSE- 6d

Theory

UNIT I **(12 Hours)**

Introduction to simulation

Introduction, Systems, Simulation models, Classification of simulation models; Simulation and Monte Carlo Methods, Pseudo-random number generators; Statistical tests of Pseudo-random numbers.

UNIT II **(18 Hours)**

Generation of random numbers

Random number generation. Random variable generation- Inverse transform method, Composition method, Acceptance-Rejection method. Generating from common statistical distributions- Discrete and Continuous. Simulation of random vectors, Generating Poisson processes and Markov chain.

UNIT III **(15 Hours)**

Applications of simulation

Discrete event simulation; Monte Carlo integration; Variance reduction techniques; Applications to statistical inference; Point Estimators, Confidence Intervals and hypothesis tests.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

PRACTICAL/ LAB WORK – (30 hours)

List of Practical:

1. Pseudo random number generators.
2. Generation of U (0, 1).
3. Problems based on statistical tests.
4. Application to standard statistical distributions (discrete and continuous):
   (a) The inverse transforms method.

(b) Acceptance-Rejection method.
5. Problems based on Composition Method.
6. Problems based on Monte Carlo integration.
7. Problems based on Regenerative methods.

ESSENTIAL READINGS:

- Rubinstein, R.Y. (2017). Simulation and the Monte Carlo Methods, Wiley.
- Voss, J. (2014). An introduction to statistical computing: a simulation-based approach, Wiley series in computational statistics.
- Sheldon M. Ross (2022) Simulation, Sixth Edition, Elsevier Academic press publication.
- Averill M. Law and W. David Kelton (1991). Simulation modeling and analysis: McGraw-Hill, Inc., New York.

SUGGESTED READINGS:

- Reitman, J. (1971). Computer simulation Applications, John Wiley & Sons.
- Swarup, K. Gupta, P.K. and Mohan, M. (2014). Operations Research, 15^{th} Ed, Sultan Chand & Sons.
- Fishman, G.S. (1996). Monte Carlo-Concepts, Algorithms and Applications, Springer.
- Sheskin, D. J. (2011). Handbook of parametric and nonparametric statistical procedures, CRC Press. Boca Raton, FL.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE-SPECIFIC ELECTIVE COURSE–3C: ENVIRONMENTAL STATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Environmental Statistics	4	3	0	1	Class XII pass with Mathematics	knowledge of sampling distributions and linear models

Learning Objectives

The learning objectives include:

· To study the role of Statistics in Environmental Science.

- To study different Statistical distributions, sampling procedures, linear models and analysis of variance.
- To study environmental monitoring.
- To study time-series analysis and Spatial-data analysis.
- To learn about censored data and risk assessment.

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- The role of Statistics in Environmental Science.
- Uses and applications of different Statistical distributions, sampling procedures, linear models and analysis of variance.
- Environmental monitoring.
- Time-series analysis and Spatial-data analysis.
- Censored data and risk assessment.
- They will be able to do risk analysis using spreadsheet.

SYLLABUS OF DSE – 3C

Theory

UNIT I: (9 hours)

Introduction

The Role of Statistics in Environmental Science: Introduction, Examples, Base-line, Targeted, Regular monitoring, Role of Statistics in Environmental Science. Environmental Sampling: Introduction, Sampling Procedures, Sampling in the wild.

UNIT II: (9 hours)

Models for Data and Environmental Monitoring

Models for Data: Statistical models, Discrete statistical distribution, Continuous statistical distributions, Linear Models, ANOVA. Environmental Monitoring: Detection of changes by ANOVA, Detection of changes using control chart, Chi squared tests for a change in a distribution.

UNIT III: (9 hours)

Time Series and Spatial-Data Analysis

Introduction to Time Series Analysis, Components of Time Series, Serial correlation. Introduction to Spatial-Data Analysis, Types of spatial data, Spatial Patterns in quadrat counts, and Correlation between quadrat counts.

UNIT IV: (9 hours)

Censored Data and Risk Assessment:

Introduction to Censored Data, Single sample estimation, Types of censoring. Introduction to Risk Assessment, Principles for Monte Carlo Risk Assessment, Risk Analysis using spreadsheet.

PRACTICAL/LAB WORK - (30 HOURS)

List of Practical:

1. Collection of environmental data.

2. Fitting different discrete distributions. Case: Estimate the survival rates of salmon in rivers and continuous distributions,
3. Fitting regression model (simple and multiple), Case: Chlorophyll-a in lakes/rivers as an indicator of lake/river water quality, Soil, and Vegetation data.
4. Change detection in the environment using ANOVA, Control Charts, Hypotheses testing- Case: pH values, SO_4 concentrations etc in lakes/rivers, Annual ring widths in trees,
5. Time series analysis- Case: World Temperature data, Annual sunspot data, Rainfall data, or on any environmental issues.
6. Serial correlation- Case: Northern and Southern Hemisphere temperatures
7. Single sample estimation,
8. Correlation between quadrats counts- Case: Correlation between counts for two different species in a water body.
9. Analysis of censored environmental data,
10. Risk analysis- Case: Contaminant uptake in Tap-water

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Bryan F. J. Manly (2009): Statistics for Environmental Science and Management, 2nd Edition, Chapman and Hall.
- Barnett, Vic (2006): Environmental Statistics: Methods and Applications, Reprinted 2004, Wiley.

SUGGESTED READINGS:

- Milalrd, Steben P. and Neeranchal, Nagaraj K (2000): Environmental Statistics with S-plus, CRC Press.
- Gelfand Alan E. (2019): Handbook of Environmental and Ecological Statistics, Chapman and Hall, CRC Press.
- David Valerie (2019): Statistics in Environmental Sciences, Wiley.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 3d: REGRESSION ANALYSIS (Not for category I)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Regression Analysis	4	3	0	1	Class XII pass with Mathematics	knowledge of sampling distributions and matrix theory

Learning Objectives

The learning objectives include:

- Be able to carry out and interpret Correlation Analysis
- Be able to carry out and interpret inference procedures for simple linear regression.
- Know the simple and multiple linear regression models, and be able to state and explain the standard methods of estimation for these models.

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- Basic concept of matrix, its types and operations,
- correlation and regression techniques, the two very powerful tools in statistics,
- Linear and Multiple Linear regression,
- regression diagnostics, multicollinearity, residual plots and estimation and tests for regression coefficients.
- concept of coefficient of determination and inference on partial and multiple correlation coefficients.

SYLLABUS OF DSE-3d

Theory

UNIT I **(15 hours)**

Introduction

Correlation, Types of correlation, Methods of studying simple correlation - Scatter diagram, Covariance between two variables: Definition, computation, effect of change of origin and scale, Karl Pearson's coefficient of correlation, Spearman's Rank correlation coefficient.

UNIT II **(15 hours)**

Linear Regression

Linear Regression: Meaning of regression, difference between correlation and regression, simple linear regression model, Estimation of regression parameters by least squares method (fitting of regression model), Interpretation of parameters. Test of significance of regression and confidence interval, Concept of residual, Residual plots, comparison of two models on the basis of residual sum of squares.

UNIT III **(15 hours)**

Multiple Linear Regression

Multiple linear regression: Estimation of regression parameters by least square method and their properties, Interpretation of parameters. Concept of coefficient of determination R^2 and adj R^2. Testing of hypothesis and bias in regression estimates.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Computation of covariance, coefficient of correlation, checking for independence and uncorrelatedness of two variables.
2. Lines of regression, angle between lines and estimation of parameters.
3. Lines of regression and regression coefficients.
4. Spearman rank correlation with/without ties.
5. Fitting of simple linear regression model
6. Testing of hypothesis in SLRM
7. Fitting of multiple linear regression model
8. Testing of hypothesis in MLRM
9. Bias in regression parameters

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Draper, N. R. and Smith, H. (1998). Applied Regression Analysis. 3rdEdition. John Wiley.
- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2013). Introduction to Linear Regression Analysis. 5th Edition. Wiley.

SUGGESTIVE READINGS:

- Hosmer, D. W., Lemeshow, S. and Sturdivant R.X. (2013). Applied Logistic Regression, Wiley Blackwell.
- Neter, J., Kutner, M. H., Nachtsheim, C.J. and Wasserman, W. (1996). Applied Linear Statistical Models, 4th Edition, Irwin USA.
- Gun, A.M., Gupta, M.K. and Dasgupta, B. (2005). An Outline of Statistical Theory, Volume II, World Press.
- Arora, S. and Bansi, L. (1968). New Mathematical Statistics, 1st Ed., Vanita Printers.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES
OFFERED BY DEPARTMENT OF STATISTICS
CATEGORY-VI

GENERIC ELECTIVE -5A: INTRODUCTION TO STATISTICAL LINEAR MODELS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lectures	tutorials	practical		
Introduction to Statistical Linear Models	**4**	**3**	**0**	**1**	Class XII pass with Mathematics	knowledge of sampling distributions and matrix theory

Learning Objectives:
learning objectives include:
- Developing a clear understanding of the fundamental concepts of linear models.
- Developing associated skills allowing the students to work effectively with them.

Learning Outcomes:
After completion of this course, students will have developed a clear understanding of:
- Theory and estimation of Linear Models.
- Gauss-Markov Theorem and its use.
- Distribution of quadratic forms.
- Simple and Multiple linear regression models and their applications.
- Fitting of these models to real or synthetic data, derivation of confidence and prediction intervals, and a sound scientific interpretation of the results.
- Techniques of Analysis of Variance under fixed effects model.
- Assessment of the quality of the fit using classical diagnostics,

SYLLABUS OF GE-5A
THEORY

UNIT I: **(12 hours)**
Introduction:
Statistical linear models and their classification, Estimability of linear parametric functions, Gauss-Markov set-up, Normal equations, and Gauss-Markov theorem: full rank case and non-full rank case (without proof).

UNIT II: **(8 hours)**
Distribution of Quadratic Forms:
Cochran's theorem (without proof), Necessary and sufficient conditions for the mutual independence of quadratic forms and for the mutual independence of a linear function and a quadratic form.

UNIT III: **(13 hours)**
Regression Analysis:
Simple and Multiple linear regression: Estimation and testing of hypothesis, confidence interval, bias in regression estimates, Lack of fit and pure error, Residuals, and their plot. Techniques for Variable selection. Polynomial Regression models: Orthogonal Polynomials.

UNIT IV: **(12 hours)**
Analysis of Variance (ANOVA):
The technique of ANOVA for one-way and two-way classifications with an equal number of observations per cell under a fixed effects model.

PRACTICAL/LABWORK -30 Hours
List of Practicals
1. Estimability when X is a full rank matrix
2. Estimability when X is not a full rank matrix
3. Distribution of Quadratic forms
4. Simple Linear Regression
5. Multiple Regression
6. Tests for Linear Hypothesis
7. Bias in regression estimates
8. Lack of fit
9. Orthogonal Polynomials
10. Analysis of Variance of a one-way classified data.
11. Analysis of Variance of a two-way classified data with one observation per cell.
12. Analysis of Variance of two-way classified data with m (> 1) observations per cell.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Montgomery, D. C., Peck, E. A. and Vining, G. G. (2012): Introduction to Linear Regression Analysis, 5th Ed., John Wiley and Sons.
- Rencher, A. C. and Schaalje, G. B. (2008): Linear Models in Statistics, 2nd Ed., John Wiley and Sons.
- Draper, N. R. and Smith, H. (1998): Applied Regression Analysis, 3rd Ed., John Wiley and Sons.

SUGGESTIVE READINGS:

- Weisberg, S. (2005): Applied Linear Regression, 3rd Ed., John Wiley and Sons.
- Rawlings, John O. Pantula Sastry G. Dickey, David A. (1998) Applied Regression Analysis: A Research Tool, Second Edition
- Bapat, R.B.(1993): Linear Algebra and Linear Models, Hindustan Book Agency.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

GENERIC ELECTIVE – 5b: STATSTICAL TECHNIQUES FOR QUALITY CONTROL

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Techniques for Quality Control	4	3	0	1	Class XII pass with Mathematics	knowledge of basic statistics

Learning Objectives

The learning objectives include:

- This course will help students to learn techniques and approach of SQC being used in industry to manufacture goods and services of high quality at low cost.
- This course will also give exposure to Sampling Inspection Plan.

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- Quality, Historical background, ISO standards.
- Statistical process control tools- Control charts for variables, attributes.
- Statistical product control tools- Sampling inspection plans, Dodge and Romig plans.

SYLLABUS OF GE-5b

Theory

UNIT I **(10 hours)**

Introduction, historical perspective and ISO Quality Standards

Quality: Definition, dimensions of quality, its concept, application and importance. Brief historical perspective of quality control and improvements. Quality system and standards: Introduction to ISO quality standards. Introduction to Process and Product Control, Statistical Process Control, Chance and Assignable causes of variation.

UNIT II **(20 hours)**

Statistical Control Charts

Construction and Statistical basis of 3-σ Control charts. Control charts for variables: X-bar & R-chart, X-bar & s-chart. Rational Sub-grouping, Revised and Modified Control Limits. Control charts for attributes: np-chart, p-chart, c-chart and u-chart. Comparison between control charts for variables and control charts for attributes. Analysis of patterns on control chart, estimation of process capability.

UNIT III **(15 hours)**

Acceptance sampling plan

Principle of acceptance sampling plans. Single sampling plans their OC, AQL, LTPD, AOQ, AOQL, ASN, ATI functions with graphical interpretation, use and interpretation of Dodge and Romig's sampling inspection plan tables.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Construction and interpretation of statistical control charts $\bar{X}$& R-chart for known parameters.
2. Construction and interpretation of statistical control charts $\bar{X}$ & R-chart with revised control limits for unknown parameters.
3. Construction and interpretation of statistical control charts $\bar{X}$ & s-chart with revised control limits for unknown parameters.
4. Construction and interpretation of statistical control charts np chart.
5. Construction and interpretation of statistical control charts p-chart with fixed sample size.
6. Construction and interpretation of statistical control charts p-chart with variable sample size.
7. Construction and interpretation of statistical control charts c-chart.
8. Construction and interpretation of statistical control charts u-chart.
9. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves.
10. Single sample inspection plan: Construction and interpretation of OC, AQL, LTPD, ASN, ATI, AOQ, AOQL curves for varying acceptance number.
11. Calculation of process capability and comparison of 3-sigma control limits with specification limits.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Montogomery, D. C. (2013). Introduction to Statistical Quality Control, 7th Edition, Wiley India Pvt. Ltd.

SUGGESTIVE READINGS:

- Goon A.M., Gupta M.K. and Dasgupta B. (2002): Fundamentals of Statistics, Vol. I & II, 8th Edn. The World Press, Kolkata.
- Gupta S.C., Kapoor V.K.(2007): Fundamentals of Applied Statistics. 4th Edition, Sultan Chand and Sons., New Delhi.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Semester 6

DEPARTMENT OF STATISTICS

B. Sc. (H) Statistics

Category I

DISCIPLINE SPECIFIC CORE COURSE – 16: TESTING OF HYPOTHESIS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Testing of Hypothesis	4	3	0	1	Class XII pass with Mathematics	Basic knowledge of sampling distributions

Learning Objectives

The learning objectives of this course are to introduce:

- Hypothesis testing as a statistical procedure for testing whether chance is a plausible explanation of a random experiment
- The logic of hypothesis testing with focus on theory and implementation of hypothesis testing with knowledge about types of error type, power and the correct computation and interpretation of p-values
- Use of nonparametric test as an alternative when assumptions of parameterization of distribution or the family itself is violated.
- Sequential Probability Ratio test with its entities like OC Curve, ASN etc.

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- The notion of statistical hypothesis test, error and its nature and the idea of acceptance and rejection region.
- Identify simple and composite hypothesis. Find critical region, size and power of the test.
- Apply Neymann-Pearson lemma to find most powerful test. Find UMP and UMPU test. Make use of likelihood ratio principle for testing of hypothesis
- Make distinction between parametric and nonparametric test. Identify suitable nonparametric test for both location and scale (Kolmogorov- Smirnov one sample and two sample tests, sign test, Wilcoxon signed rank test, run test. Median test, Kruskal-Wallis one-way analysis of variance by ranks, Friedman two way analysis of variance by ranks).
- Derive SPRT for test the parameters of normal distribution, binomial and Poisson distributions also find OC function, Average sample Number etc. of a SPRT.

SYLLABUS OF DSC-16

Theory

UNIT I **(15 hours)**
Principles of test of significance
Principles of test of significance: Null and alternative hypotheses (simple and composite), Type-I and Type-II errors, critical region, level of significance, size and power, best critical region, most powerful test, uniformly most powerful test, uniformly most powerful unbiased critical region (UMPU). Neyman Pearson Lemma and its application to construct most powerful tests.

Unit II **(10 hours)**
Likelihood ratio test
Likelihood ratio test and its application, properties of likelihood ratio tests (without proof).

UNIT III **(10 hours)**
Sequential Probability Ratio Test
Sequential Probability Ratio Test. Determination of stopping bounds A and B, OC and ASN functions of SPRT.

UNIT IV **(10 hours)**
Non-Parametric tests
Non-Parametric tests. Empirical distribution function, one sample and two-sample sign test. Wald-Wolfowitz run test. Run test for randomness, Median test, Wilcoxon-Mann-Whitney U-test. Kolmogorov-Smirnov one-sample test, Kruskal-Walli's test.

PRACTICAL/LAB. WORK(30 hours):
List of Practical

1. Type I and Type II errors
2. Most powerful critical region (NP Lemma)
3. Uniformly most powerful critical region
4. Unbiased critical region
5. Power curves of hypothesis tests.
6. Likelihood ratio test
7. Non Parametric test based on quantile and Empirical distribution
8. Test for location and scale both one and two samples
9. Test of Association for bivariate samples
10. SPRT for binomial, Poisson and Normal distribution
11. OC Curve and ASN function

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

● Goon, A.M., Gupta, M.K., and Dasgupta, B. (2005).: An Out Line of Statistical Theory, Volume 2, Third Edition.

● Gupta, S.C. and Kapoor, V.K.(2020): Fundamental of Mathematical Statistics, 12th Edn. Sultan Chand and Sons.

SUGGESTIVE READINGS:

- Hogg, R.V, McKean, J. and Craig, A.T. (2012): Introduction to Mathematical Statistics, 7th Edn. Pearson Education.
- Casella, G. and Berger, R.L. (2002): Statistical Inference. 2nd Edition, Duxbury Press, Pacific Grove.
- Siegel, S. (1956). Nonparametric statistics for the behavioral sciences. McGraw-Hill.
- Lehmann, E. and Romano. J. (2005): Testing statistical hypotheses,3rd Edn. Springer, New York.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE –17: DESIGN OF EXPERIMENTS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Design of Experiments	4	3	0	1	Class XII pass with Mathematics	knowledge of sampling distributions and linear models

Learning Objectives

The learning objectives include:

- To design and conduct experiments.
- To analyze and interpret data.

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- The fundamental concepts of design of experiments.
- Introduction to planning valid and economical experiments within given resources.
- Completely randomized design.
- Randomized block design.
- Latin square design.
- Balanced incomplete block design.
- Full and confounded factorial designs with two levels.
- Introduction to factorial designs at three levels.
- Fractional factorial designs with two levels

SYLLABUS OF DSC-17

Theory

UNIT I **(13 hours)**

Experimental designs
Role, historical perspective, terminology, experimental error, basic principles, uniformity trials, fertility contour maps, choice of size and shape of plots and blocks. Basic designs: Completely Randomized Design (CRD), Randomized Block Design (RBD), Latin Square Design (LSD) – layout, model and statistical analysis, relative efficiency, analysis with one missing observation in case of RBD.

UNIT II **(10 hours)**
Incomplete Block Designs
Balanced Incomplete Block Design (BIBD) – parameters, relationships among its parameters, incidence matrix and its properties, Symmetric BIBD, Resolvable BIBD, Affine Resolvable BIBD, Complimentary BIBD, Residual BIBD, Dual BIBD, Derived BIBD.

UNIT III **(12 hours)**
Factorial experiments
advantages, notations and concepts, 2^2, 2^3,…, 2^n, 3^2 factorial experiments, design and analysis, Total and Partial confounding for 2^n ($n\leq 6$), Factorial experiments in a single replicate.

UNIT IV **(10 hours)**
Fractional factorial experiments: Construction of one-half and one-quarter fractions of 2^n ($n\leq 6$) factorial experiments, Alias structure, Resolution of a design.

PRACTICAL/LAB WORK – (30 hours)
List of Practical:
1. Analysis of a CRD with equal and unequal replicates.
2. Analysis of RBD.
3. Analysis of LSD.
4. Analysis of RBD with one missing observation.
5. Analysis of 2^2 and 2^3 factorial in CRD, RBD and LSD.
6. Analysis of 3^2 factorial in CRD, RBD.
7. Analysis of a completely confounded two level factorial design in 2 blocks.
8. Analysis of a completely confounded two level factorial design in 4 blocks.
9. Analysis of a partially confounded two level factorial design.
10. Analysis of a single replicate of a 2^n design.
11. Analysis of one half fraction of 2^n factorial design.
12. Analysis of one quarter fraction of 2^n factorial design.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS
- Das., M.N. and Giri, N.C. (1986): Design and Analysis of Experiments. Wiley Eastern.
- Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005): Fundamentals of Statistics. Vol. II, 8th Edition. World Press, Kolkata.
- Montgomery, D. C. (2008): Design and Analysis of Experiments. John Wiley.
- Mukhopadhyay, P (2011): Applied Statistics, 2nd edition revised reprint, Books and Allied(P) Ltd.

SUGGESTIVE READINGS:
- Cochran, W.G. and Cox, G.M. (1959): Experimental Design. Asia Publishing House.
- Kempthorne, O. (1965): The Design and Analysis of Experiments. John Wiley.
- Federer, W. T. (1955): Experimental Design, Macmillan, N. Y.
- Anderson, V. L. and McLean, R. A. (1974): Design of Experiments, Marcel Dekker, Inc., N. Y.

- Dean, A. and Voss, D. (1999). Design and Analysis of Experiments, Springer. First Indian Reprint 2006

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE –18: ECONOMETRICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Econometrics	4	3	0	1	Class XII pass with Mathematics	knowledge of sampling distributions and linear models

Learning Objectives

A broad knowledge of regression analysis relevant for analyzing economic data.

- Interpretation and critical evaluation of the outcomes of empirical analysis.
- Distinguish the results of violating the assumptions of a classical regression model.
- To judge the validity of the economic theories and carry out their evaluation in numerical terms.
- To extract useful information about important economic policy issues from the available data.
- The course is designed to provide the students with the basic quantitative techniques needed to undertake applied research projects.
- The students learn to quantify and examine economic relationships employing statistical methods based on observed data.

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- Students will be trained to write a good quality undergraduate research paper in applied statistics using the econometric methods taught in this class.
- The fundamental concepts of econometrics.
- Specification of the model.
- Multiple Linear Regression.
- Multicollinearity.
- Heteroscedasticity.
- Autocorrelation.
- Autoregressive and Lag models

SYLLABUS OF DSC-18

Theory

UNIT I **(15 hours)**
Introduction
Objective behind building econometric models, Nature and scope of econometrics, model building, role of econometrics. General linear model (GLM). Estimation under linear restrictions.

UNIT II **(10 hours)**
Multicollinearity
Introduction and concepts, detection of multicollinearity, consequences, remedies Multicollinearity, tests and solutions of multicollinearity.

UNIT III **(10 hours)**
Generalized least squares and Autocorrelation
Generalized least squares estimation, Aitken estimators. Autocorrelation: concept, consequences of autocorrelated disturbances, detection and solution of autocorrelation.

UNIT IV **(10 hours)**
Heteroscedastic disturbances
Heteroscedastic disturbances: Concepts and efficiency of Aitken estimator with OLS estimator under heteroscedasticity. Consequences of heteroscedasticity. Tests and solutions of heteroscedasticity. Qualitative Forecasting Methods.

PRACTICAL/LAB WORK – (30 hours)
List of Practical:

1. Problems based on estimation of General linear model.
2. Testing of parameters of General linear model.
3. Forecasting of General linear model.
4. Problems related to consequences of Multicollinearity.
5. Diagnostics of Multicollinearity.
6. Problems related to consequences of Autocorrelation (AR(I)).
7. Diagnostics of Autocorrelation.
8. Estimation of General linear model under Autocorrelation.
9. Problems related to consequences Heteroscedasticity.
10. Diagnostics of Heteroscedasticity.
11. Estimation of problems of General linear model under Heteroscedastic disturbance terms.
12. Problems concerning specification errors as a reason for induction of Autocorrelation, Heteroscedasticity and Multicollinearity.
13. Problems related to General linear model under (Aitken Estimation).
14. Forecasting methods.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Gujarati, D. and Guneshker, S. (2007). Basic Econometrics, 4th Ed., McGraw Hill Companies.
- Johnston, J. (1972). Econometric Methods, 2nd Ed., McGraw Hill International.

SUGGESTED READINGS:

- Koutsoyiannis, A. (2004). Theory of Econometrics, 2 Ed., Palgrave Macmillan Limited.
- Maddala, G.S. and Lahiri, K. (2009). Introduction to Econometrics, 4 Ed., John Wiley & Sons.
- Greene, W. H. (2002) Econometric Analysis.5th Edition, Prentice Hall.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B.Sc. (P)/B.A(P) with Statistics as Major

Category II

DISCIPLINE SPECIFIC ELECTIVE COURSE –: 11 SURVEY SAMPLING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Survey Sampling	4	3	0	1	Class XII pass with Mathematics	knowledge of basic statistics

Learning Objectives:

The learning objectives of this course are to introduce:

- Tools and techniques for selecting a representative sample from a target population keeping in mind the objectives to be fulfilled.
- Obtain an estimator of the population parameter on the basis of the selected sample and study its properties.

Learning Outcomes:

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

- Understand the fundamental concepts of population and sample and the principles of sample survey
- Describe the value and methodologies for sample surveys versus other approaches to collecting information from populations.
- Determine the appropriate sample size and its allocation for nationwide sample surveys or for surveys to be conducted in a program area.
- Identify a proper sampling frame and select primary sample points.
- Apply steps involved in selecting a sample using Simple Random Sampling with or without replacement, Stratified Sampling, Systematic Sampling and Ratio and Regression Methods of Estimation

SYLLABUS OF DSC-11

Theory

Unit I **(15 Hours)**

Basic Concepts and Simple Random Sampling

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling basic principles of sample survey, Steps involved in survey sampling.

Simple random sampling (SRS)with and without replacement, their properties, procedures of selecting a simple random sample, estimation of population mean, and total sampling for proportions, determination of sample size.

Unit 2 **(10 Hours)**

Stratified random sampling:

Estimation of population mean and its variance. Allocation of samples in different strata using equal, proportional, and Neyman allocation. Comparison of Stratified sampling under proportional and Neyman allocation with SRSWOR. Practical difficulties in adopting Neyman allocation.

Unit 3 **(10 Hours)**

Systematic sampling:

Estimation of population mean, and total. Comparison of systematic sampling with simple random sampling and stratified sampling in the presence of linear trend. Definition and concept of circular systematic sampling.

Unit 4 **(10 Hours)**

Introduction to Indian Official Statistics:

Present official Statistical System in India, Methods of collection official statistics, their reliability and limitations. Role of Ministry of Statistics and Programme Implementation (MOSPI), Central Statistical Office CSO, NSSO.

PRACTICAL/LAB.. WORK: (30 Hours)

List of Practicals:

1. To select SRS with and without replacement.
2. For a population of size 5, estimate population mean, population mean square, and population variance. Enumerate all possible samples of size 2 by WR and WOR.
3. Estimate mean standard error and the sample size for SRSWOR.
4. Allocation of sample to strata by proportional method.
5. Allocation of sample to strata by Neyman methods.
6. Compare the efficiencies of proportional and Neyman allocation relative to SRS.
7. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Readings:

- Cochran WG (2011) Sampling techniques (3rd edition) Wiley Eastern John Wiley and sons.
- Goon AM Gupta MK and Dasgupta B. (2001) Fundamentals of statistics, volume 2, World Press Gupta SC and Kapoor VK (2007) Fundamentals of Applied Statistics, Sultan Chand and sons.
- Murthy MN (1977) Sampling theory and sampling methods, Statistical Pub. Society, Calcutta.
- Singh D and Chaudhary FS (2015): Theory and Analysis of Sample Survey Designs.

- Sukhatme PV Sukhatme BV, Sukhatme S, Asok C (1984) Sampling Theories of Survey with Application, Iowa State University press and Indian Society of agricultural statistics.
- Guide to current official statistics CSO, GOI, New Delhi

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE –: 12 STATISTICAL METHODS FOR PSYCHOLOGY AND EDUCATION

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Methods in Psychology and Education	4	3	0	1	Class XII pass with Mathematics	knowledge of basic statistics

Learning Objectives:

The learning objectives include:
- To measure psychological traits and mental abilities
- To learn basic methods of test construction, item writing and item analysis
- To check the reliability and validity of test scores.

Learning Outcomes:

After successful completion of this course, students should be able to:
- Distinguish between Psychological measurement and physical measurement.
- Understand the meaning of Tests in Psychology and Education.
- Appreciate the uses and limitations of Psychological tests.
- Learn the meaning and purpose of Item writing and analysis.
- Understand concepts of reliability and validity of test scores and their differences.
- Convert raw scores into different transformed scores.
- Apply Scaling rankings and ratings in terms of the Normal Probability Curve.

SYLLABUS OF DSC-12

Theory

Unit 1: **(15 Hours)**

Importance of statistics in psychology and education.

Importance of statistics in psychology and education. Levels of measurement: nominal ordinal interval and ratio scales. Distinction between psychological and physical measurements. General problems and sources of errors in measurements.
Meaning and types of tests in psychology and education. History of psychological measurement and testing. Uses and limitations of tests. Varieties of tests. Characteristics of a good test. General steps of test construction. Test administration and scoring.
Item writing and item analysis: Meaning and types of test items, Purpose and methods for evaluating test items.

Unit 2: (15 Hours)
Reliability and Validity:
Reliability: definition Methods of determining reliability: Test-retest, Alternate or parallel forms, Split half technique, Rational equivalence. Effect upon reliability of lengthening or repeating or test. Reliability coefficient as a measure of true variance. Estimating true scores by way of regression equation and reliability coefficient. Index of reliability.
Validity: meaning; Estimation of validity; Types of validity: validity and test length; comparison between reliability and validity.

Unit 3: (15 Hours)
Test Scores:
Meaning and differences between norm referencing and criterion referencing.
Raw score transformations- percentile scores, standard score, normalised standard scores, T- scores and Stanine scores.
Intelligence: definition. Types of intelligence test scores. Psychological scaling methods- scaling of individual test items in terms of difficulty, scaling of rankings and ratings in terms of the normal probability curve.

PRACTICAL LAB WORK (30 hours)
List of Practical:
1. Computation of reliability by Rulon and Kuder Richardson formulas.
2. Computing reliability of a test whose length is increased/decreased.
3. Computing index of reliability standard error of measurement.
4. Computing validity oblique maximum validity then test length is increased.
5. Computing relative difficulty of questions difference in difficulty between different tests.
6. Problem based on Z scores.
7. Problem based on t scores.
8. Problem based on Stanine scales.
9. Problem based on percentile scores.
10. Computing numerical scores corresponding to grades or ratings.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Anastasia, A. and Urbina, S. (1997) Psychological testing (7th edition), Prentice Hall
- Garrett H.E. (2021), Statistics in Psychology and Education. Nation press.
- Gregory RJ (2016), Psychological testing: History, Principles and Applications. (updated 7th edition) Pearson
- Singh, A.K. (2006)Test, Measurements and Research in Behavioural Sciences Bharati bhavan
- Mangal S.K. (2016) Statistics in Psychology and Education. PHI learning Pvt ltd.

SUGGESTED READINGS:

- Gupta S.C. and Kapoor V.K. (2019) Fundamentals of Applied statistics, Sultan Chand and sons.
- Goon A.M., Gupta M.K. and Dasgupta, B. (2001) Fundamental of Statistics, Volume 2, World Press Pvt ltd.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

B.Sc. (P)/B.A(P) with Statistics as Non- Major

Category III

DISCIPLINE SPECIFIC CORE COURSE –: 6 SURVEY SAMPLING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Survey Sampling	4	3	0	1	Class XII pass with Mathematics	knowledge of basic statistics

Learning Objectives:

The learning objectives of this course are to introduce:

- Tools and techniques for selecting a representative sample from a target population keeping in mind the objectives to be fulfilled.
- Obtain an estimator of the population parameter on the basis of the selected sample and study its properties.

Learning Outcomes:

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

- Understand the fundamental concepts of population and sample and the principles of sample survey
- Describe the value and methodologies for sample surveys versus other approaches to collecting information from populations.
- Determine the appropriate sample size and its allocation for nationwide sample surveys or for surveys to be conducted in a program area.
- Identify a proper sampling frame and select primary sample points.

- Apply steps involved in selecting a sample using Simple Random Sampling with or without replacement, Stratified Sampling, Systematic Sampling and Ratio and Regression Methods of Estimation

SYLLABUS OF DSC-6

Theory

Unit I **(15 Hours)**

Basic Concepts and Simple Random Sampling

Concept of population and sample, complete enumeration versus sampling, sampling and non-sampling errors. Types of sampling: non-probability and probability sampling basic principles of sample survey, Steps involved in survey sampling.

Simple random sampling (SRS)with and without replacement, their properties, procedures of selecting a simple random sample, estimation of population mean, and total sampling for proportions, determination of sample size

Unit 2 **(10 Hours)**

Stratified random sampling:

Estimation of population mean and its variance. Allocation of samples in different strata using equal, proportional, and Neyman allocation. Comparison of Stratified sampling under proportional and Neyman allocation with SRSWOR. Practical difficulties in adopting Neyman allocation.

Unit 3 **(10 Hours)**

Systematic sampling:

Estimation of population mean, and total. Comparison of systematic sampling with simple random sampling and stratified sampling in the presence of linear trend. Definition and concept of circular systematic sampling.

Unit 4 **(10 Hours)**

Introduction to Indian Official Statistics:

Present official Statistical System in India, Methods of collection official statistics, their reliability and limitations. Role of Ministry of Statistics and Programme Implementation (MOSPI), Central Statistical Office CSO, NSSO.

PRACTICAL/ LAB WORK (30 HOURS)

List of Practicals:

1. To select SRS with and without replacement.
2. For a population of size 5, estimate population mean, population mean square, and population variance. Enumerate all possible samples of size 2 by WR and WOR.
3. Estimate mean standard error and the sample size for SRSWOR.
4. Allocation of sample to strata by proportional method.
5. Allocation of sample to strata by Neyman methods.
6. Compare the efficiencies of proportional and Neyman allocation relative to SRS.
7. Comparison of systematic sampling with stratified sampling and SRS in the presence of a linear trend.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Cochran WG (2011) Sampling techniques (3rd edition) Wiley Eastern John Wiley and sons.

- Goon AM Gupta MK and Dasgupta B. (2001) Fundamentals of statistics, volume 2, World Press Gupta SC and Kapoor VK (2007) Fundamentals of Applied Statistics, Sultan Chand and sons.
- Murthy MN (1977) Sampling theory and sampling methods, Statistical Pub. Society, Calcutta.
- Singh D and Chaudhary FS (2015): Theory and Analysis of Sample Survey Designs.
- Sukhatme PV Sukhatme BV, Sukhatme S, Asok C (1984) Sampling Theories of Survey with Application, Iowa State University press and Indian Society of agricultural statistics.
- Guide to current official statistics CSO, GOI, New Delhi

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

Discipline Specific Elective
Category V

DISCIPLINE SPECIFIC ELECTIVE COURSE –4A: BIOSTATISTICS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Biostatistics	**4**	**3**	0	**1**	Class XII pass with Mathematics .	knowledge of Statistical Inference and stochastic processes

Learning objectives:
- Parametric Models for Survival data.
- Different types of censoring and its application in public health.
- Estimation of death probabilities by using the theory of competing risks.
- Non-parametric methods for incomplete survival data.
- Computation of the probability of gametes in different generations under random mating.

Learning Outcomes:
After completing this course, students will develop a clear understanding of:
- The fundamental concepts of survival functions and their interrelationship.
- Survival models and their applications.
- Handling censored data and estimating mean survival time of the patients.
- Actuarial and Kaplan-Meier methods.
- Competing Risk Theory.
- Basic concept of Statistical genetics.

SYLLABUS OF DSE-4A
Theory

UNIT I (11 Hours)
Survival Analysis
Survival Analysis: Functions of survival times, survival distributions and their applications exponential, gamma, Weibull, Rayleigh, lognormal, death density function for a distribution having bath-tub shaped hazard function.

UNIT II (13 Hours)
Censoring Schemes
Censoring Schemes: Type I, Type II and progressive or random censoring with biological examples. Estimation of mean survival time and variance of the estimator for Type I and Type II censored data with numerical examples. Non-parametric methods: Actuarial and Kaplan-Meier methods for estimating survival function and variance of the Estimator.

UNIT III **(10 Hours)**

Competing Risk Theory:

Indices for measurement of the probability of death under competing risks and their inter-relations. Estimation of probabilities of death using maximum likelihood method and modified chi squire method.

UNIT IV **(11 Hours)**

Statistical Genetics:

Statistical Genetics: Introduction, concepts-Genotype, Phenotype, Dominance, Recessiveness, Linkage and Recombination, Coupling, and Repulsion. Mendelian laws of Heredity, Random mating, Gametic array, Genotypic array, Relation between genotypic array and gametic array under random mating. Distribution of genotypes under random mating. Hardy-Weinberg law. Concept of gene frequencies.

PRACTICAL/ LAB. WORK (30 HOURS)

List of Practical:

1. Estimation of survival function, death density function and hazard function.
2. Estimation of mean survival time using various parametric survival models.
3. To Identify and analyse type-I censored data.
4. To Identify and analyse type-II censored data.
5. To Identify and analyse progressively type I censored data.
6. Estimation of mean survival time and variance of the estimator for type I censored data.
7. Estimation of mean survival time and variance of the estimator for type II censored data.
8. Estimation of mean survival time and variance of the estimator for progressively type I censored data.
9. To estimate the survival function and variance of the estimator using Actuarial methods.
10. To estimate the survival function and variance of the estimator using Kaplan-Meier method.
11. To estimate Crude probability of death.
12. To estimate Net-type I probability of death.
13. To estimate Net-type II probability of death.
14. To estimate partially crude probability of death.
15. To estimate gene frequencies.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS:

- Biswas, S. (2007). Applied Stochastic Processes: A Biostatistical and Population Oriented Approach, Reprinted 2nd Ed., New Central Book Agency.
- Lee, E.T. and Wang, J.W. (2003). Statistical Methods for Survival data Analysis, 3rd Ed., John Wiley & Sons.
- Indrayan, A. (2008). Medical Biostatistics, 2nd Ed., Chapman and Hall/CRC.

SUGGESTIVE READINGS:

- Narayan P. (1999). Statistical Genetics, New Age International Pvt. Ltd.
- Miller, R. G. (2011). Survival Analysis. John Wiley & Sons.
- Elandt-Johnson R.C (1971).Probability models and Statistical Methods in Genetics, John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 4b: ORDER STATISTICS AND ITS APPLICATIONS

CREDIT DISTRIBUTION, ELIGIBILITY, AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Order Statistics and its Applications	4	3	0	1	Class XII pass with Mathematics	knowledge of statistical distributions and stochastic processes

Learning Objectives

The learning objective of this course is to make the students aware of the properties and applications of order statistics.

Learning Outcomes:

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

- Find joint, marginal distributions and conditional distributions of order statistics in the continuous and discrete case.
- Find the distribution of sample range and other systematic statistics in case of sampling from an arbitrary continuous population and from some specific continuous distributions such as uniform and exponential.
- Understand the Markov Chain property of order statistics in the continuous case.
- Learn how to obtain distribution-free confidence intervals for population quantile for population distributions based on order statistics.
- Understand the distribution-free bounds for moments of order statistics and of the range.
- Derive the recurrence relations and identities for moments of order statistics drawn from an arbitrary population (discrete or continuous), as well as from some specific distributions.
- Understand the concept of L-moments and L-moments estimation of parameters.
- Derive the Linear estimation of location and scale parameters based on the moments of order statistics.

SYLLABUS OF DSE-4b

Theory

UNIT I **(15 hours)**
Introduction to Order Statistics

Definition and applications of order statistics. Basic distribution theory. Joint and marginal distributions of order statistics in the continuous case. Distribution of the median, range and other systematic statistics. Order statistics for a discrete parent. Examples based on discrete and continuous distributions.

UNIT II (10 hours)

Conditional distribution of order statistics

Conditional distribution of order statistics. Order statistics as a Markov Chain. Distribution-free confidence intervals for population quantiles. Distribution-free bounds for moments of order statistics and of the range.

UNIT III (10 hours)

Moments of order statistics

Moments of order statistics. Recurrence relations and identities for moments of order statistics from an arbitrary distribution. Recurrence relations for moments of order statistics from some specific distributions.

UNIT IV (10 hours)

Order statistics in statistical inference

Order statistics in statistical inference. L-moments and L-moments estimation. Linear estimation based on order statistics. Examples based on some specific continuous distributions.

PRACTICAL/LAB WORK – (30 hours)

List of Practical:

1. Problem-solving using joint, marginal, and conditional distributions of order statistics for some specific continuous distributions.
2. Distribution-free confidence intervals for population quantiles for various distributions.
3. Calculating Means, variances, and covariances by using exact expressions for the moment of order statistics for some specific continuous distribution.
4. Calculating Means, variances, and covariances by using recurrence relations for some specific continuous distributions.
5. Calculation of L-moments for some specific continuous distributions.
6. L-moments estimation of parameters for some specific continuous distributions.
7. Calculation of linear unbiased estimation for location and scale parameters for some specific continuous distributions.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- David, H. A. and Nagaraja, H. N. (2003). Order Statistics, 3rd ed., John Wiley & Sons.

SUGGESTIVE READINGS:

- Arnold, B. C., Balakrishnan, N. and Nagaraja H. N. (2008). A First Course in Order Statistics, SIAM Publishers.
- Arnold, B.C. and Balakrishnan, N. (1989). Relations, Bounds and Approximations for Order Statistics, Vol. 53, Springer-Verlag.
- Ahsanullah, M., Nevzorav, V.B. and Shakil, M. (2013). An Introduction to Order Statistics, Atlantis Studies in Probability and Statistics, Vol. III. Atlantis Press.
- Gibbons, J.D. and Chakraborti, S. (1992). Nonparametric Statistical Inference, 3rd ed., Marcel Dekker.

- Shahbaz, M. Q., Ahsanullah, M., Shahbaz, S. H. and Al-Zahrani, B. M. (2016). Ordered Random variables: Theory and Applications. Springer.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 4c: STATISTICAL COMPUTING AND BASIC DATA MINING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Computing and Basic Data Mining	4	3	0	1	Class XII pass with Mathematics	Knowledge of MATLAB / OCTAVE / R / Python / C

Learning Objectives

learning objectives include:

- Understand the theoretical foundations and practical aspects of statistical computing and data mining.
- Develop skills in the use of statistical computing and data mining software to solve problems and analyze data. The programming implementations will be completed using MATLAB/OCTAVE/R/Python/C.

Learning Outcomes:

After completion of this course, students will develop a clear understanding of:

- Apply knowledge of statistical computing and data mining techniques to solve problems and analyze data.
- Communicate effectively about statistical computing and data mining concepts and techniques both orally and in writing.
- Develop ability for programming implementation using MATLAB/OCTAVE/R/Python/C.

SYLLABUS OF DSE-4C

Theory

UNIT I **(15 hours)**

Simulation techniques
Random number generation: Review; Simulating multivariate distributions; Simulating stochastic processes. Variance reduction methods.

UNIT II **(12 hours)**
Markov Chain Monte Carlo methods
Markov Chain Monte Carlo methods: The Metropolis–Hastings Algorithm; Gibbs sampling.

UNIT III **(18 hours)**
Data Mining and its applications
Introduction to Data Mining and its Applications. Data Pre-processing Techniques: Data Cleaning, Data Integration, Data Transformation, and Data Reduction. Exploratory Data Analysis. Classification Techniques: Decision Trees, Naive Bayes, k-Nearest Neighbors (k-NN). Clustering Techniques: K-Means, Hierarchical Clustering. Association rule mining. Evaluation of Data Mining Models.

PRACTICAL/LAB WORK – (30 hours)
List of Practical:

1. Practical based on random number generation: univariate and multivariate distributions.
2. Practical on simulating stochastic processes; variance reduction.
3. Simple practical problems on MCMC.
4. Practical based on Data pre-processing, transformation, reduction.
5. Practical based on classification and clustering.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

ESSENTIAL READINGS

- Rubinstein, R.Y. (2017). Simulation and the Monte Carlo Methods, Wiley.
- Voss, J. (2014). An introduction to statistical computing: a simulation-based approach,Wiley series in computational statistics.
- Tan, P. N., Steinbach, M., & Kumar, V. (2016). Introduction to data mining. Pearson Education India.
- Han, J., Kamber, M., & Pei, J. (2012). Data mining concepts and techniques third edition. University of Illinois at Urbana-Champaign Micheline Kamber Jian Pei Simon Fraser University.
- Witten, I. H., Frank, E., Hall, M. A., & Pal, C. J. (2017). Data Mining: Practical machine learning tools and techniques, Elsevier Inc.

SUGGESTIVE READINGS:

- Vetterling, William T., Saul A. Teukolsky, William H. Press, and Brian P. Flannery. Numerical recipes in C: the art of scientific computing. Cambridge university press, 1999.
- Christian, P. R., & George, C. (1999). Monte Carlo statistical methods. Springer Texts in Statistics.
- Hancock, M. F. (2012). Practical data mining. CRC Press.
- Shmueli, G., Bruce, P. C., Yahav, I., Patel, N. R., & Lichtendahl Jr, K. C. (2017). Data mining for business analytics: concepts, techniques, and applications in R. John Wiley & Sons.
- Shmueli, G., Bruce, P. C., Gedeck, P., & Patel, N. R. (2019). Data mining for business analytics: concepts, techniques and applications in Python. John Wiley & Sons.
- Hastie, T., Tibshirani, R., Friedman, J. (2008). The Elements of Statistical Learning: Data Mining, Inference and Prediction, 2nd ed., Springer.
- Murphy, K. P. (2012). Machine Learning: A Probabilistic Perspective. United States: MIT Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 4d : RESEARCH METHODOLOGY

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives:

The learning objectives include

- To provide scientific approaches to develop the domain of human knowledge through empirical studies.
- To enable the student researchers to understand basic concepts and aspects related to research, data collection, analyses, interpretation and report writing.

Learning Outcomes:

After completion of this course, students will develop a clear understanding of

- Research Methods.

- Research Problems.
- Research Designs.
- Comparative study of different methods of data collection.
- Guidelines for construction of questionnaires.
- Processing and Analysis of data.
- Interpretation and Report writing.

SYLLABUS OF DSE – 4D

Theory

UNIT I **(09 hours)**
Introduction to Research:
Importance and need for research ethics, Objectives of research, Types of research, Research approaches, Review of literature, Mode of literature survey: Books and Monographs, Journals, Conference proceedings, Abstracting and Indexing Journals, E-Journals/Books, Formulation of a research problem, Identifying variables, Constructing hypothesis, Conceptualization of a research design.

UNIT II **(09 hours)**
Methods & Techniques of Data Collection:
Survey methodology and Data collection, Source of data collection-Use of secondary data, Methods of collecting primary data, Develop a questionnaire, Questions and answers in surveys, Non-response, Errors in surveys, Sample size, sampling frames and coverage error.

UNIT III **(15 hours)**
Data Processing & Analysis:
Data processing, Exploratory data analysis, Review of various techniques (Parametric and Nonparametric tests, Correlation and Regression analysis, ANOVA, Multivariate Techniques) for data analysis covered in core statistics papers, Techniques of interpretation, Precaution in interpretation.

Report writing:
Discussions, Conclusions, Referencing and various formats for reference writing, Bibliography, Thesis writing, Formats of publications in research journals including subject classification, Impact factor, Citation index.

UNIT IV **(12 hours)**
Computer Application:
Data Communication and networks, Website, Webpage, Search Engines, Scientific search engines. Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.

PRACTICAL/LAB WORK – (30 hours)
PROJECT WORK (using a spreadsheet, Scientific Word Processing with LaTeX and MS-Word, MS Equation editor, Slides making-Power Point Features, Slide preparation, SPSS, Statistical Programming with R, Simulation.)

ESSENTIAL READINGS

- Kothari, C.R., Garg, Gaurav (2015): Research Methodology: Methods and Techniques, 3rd Edition (Reprint), New Age International Publishers.
- Kumar, R. (2011): Research Methodology: A Step-by-Step Guide for Beginners, SAGE publications.

- Anderson, J., Durston, B.H., Pooole, M. (1970): Thesis and Assignment Writing, Wiley Eastern. Ltd., New Delhi.
- Braun, J., Duncan, W. and Murdock, J. (2008): A First Course in Statistical Programming with R, Cambridge University Press, London.
- Lamport, L. (1999): LATEX: A Document Preparation System, Addison, Wesley, 2nd Edition, New York.
- Cunningham, B.J. (2012): Using SPSS: An Interactive Hands-On Approach, SAGE South Asia Edition.
- Voss, J. (2014): An Introduction to Statistical Computing: A Simulation-based Approach, Wiley series in computational statistics.

SUGGESTIVE READINGS

- Pannerselvan, R. (2006): Research Methodology, Prentice-Hall of India Pvt., New Delhi.
- Landau, Sabine and Everitt, Brian S. (2004): A Handbook of Statistical Analyses using SPSS, Chapman & Hall/CRC.
- Dalgaard, P. (2008): Introductory Statistics with R, Springer Science, New York.
- Gardener, M. (2012): Beginning R: The Statistical Programming Language, Wiley Publications.
- Robert, C.P. and Casella, G. (2004): Monte Carlo Statistical Methods, Springer Science, New York.
- Rubinstein, R.Y. (1981): Simulation and the Monte Carlo Methods, Wiley.
- Venkataraman, M.K. (1998): Numerical Methods in Science and Engineering, The National Publishing Company, Chennai.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES

OFFERED BY DEPARTMENT OF STATISTICS

Category VI

GENERIC ELECTIVE COURSE – 6a: SURVEY SAMPLING AND DESIGN OF EXPERIMENTS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Survey Sampling and Design of Experiments	4	3	0	1	Class XII pass with Mathematics	knowledge of basics statistics

Learning Objectives

The learning objectives include:

- To learn about sample surveys, its need and objectives.
- To learn to draw appropriate sample and interpret the result.
- To learn to design and conduct experiments.
- To analyse and interpret the data.

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- The basic concept of sample survey and its need.
- Simple random sampling.
- Stratified random sampling
- One-way and two-way analysis of variance.
- Basic concepts of design of experiments.
- Completely randomized design.
- Randomized design.
- Latin square design.
- Factorial experiments.

SYLLABUS OF GE-6a

Theory

UNIT I **(11 hours)**

Sample Surveys

Basic concepts of sample survey, concept of sampling, need for sampling, complete enumeration v/s sampling, principles of sampling theory, principal steps in a sample surveys, planning and organization of a sample survey, sampling and non-sampling errors.
Simple random sampling (SRSWR and SRSWOR): Definition and procedures of selecting a sample, properties of simple random sample, estimation of mean and sampling variance of sample mean.

UNIT II (12 Hours)
Stratified random sampling
Introduction, estimation of population mean and its variance, choice of sample sizes in different strata, comparison of stratified sampling under proportional and Neyman allocation with SRSWOR in terms of precision.

Unit III (12 Hours)
Analysis of variance and Design of experiments
One-way and two-way classified data with one observation per cell only. Design of experiments: Principles of Design of experiments, uniformity trails, completely randomized, Randomized block and Latin square designs.

Unit IV (10 Hours)
Factorial Experiments and Designs
Factorial experiments: 2^2 and 2^3, Factorial Design: construction and analysis.

PRACTICAL/LAB WORK – (30 hours)
List of Practical:

1. Select a SRS with and without replacement.
2. For a population of size 5, estimate population means, the population mean square and population variance. Enumerate all possible samples of size 2 by WR and WOR and establish all properties relative to SRS.
3. For SRSWOR, estimate mean, standard error, the sample size.
4. Stratified Sampling: allocation of sample to strata by proportional and Neyman's methods Compare the efficiencies of the above two methods relative to SRS.
5. Estimation of gain in precision in stratified sampling.
6. Analysis of Variance of one-way classified data
7. Analysis Variance of two-way classified data
8. Analysis of CRD
9. Analysis of RBD.
10. Analysis of LSD.
11. Analysis of 2^2 and 2^3 factorial in CRD and RBD.

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Readings:

●Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005). Fundamentals of Statistics, Vol. II, 8th Ed., World Press, Kolkata.
●Goon, A.M., Gupta, M.K. and Dasgupta, B. (2005). An Outline of Statistical Theory, Vol. II, 3rd Ed., World Press, Kolkata.
●Gupta, S.C. and Kapoor, V.K. (2008). Fundamentals of Applied Statistics, 4th Ed., Sultan Chand and Sons.

Suggested Readings:

- Sukhatme, P.V., Sukhatme, B.V., Sukhatme, S. and Ashok, C. (1984). Sampling Theory of Surveys with Applications, Iowa State University Press, Iowa, USA.
- Mukhopadhyay, P. (1998). Theory and Methods of Surveys Sampling, Prentice Hall of India.
- Montgomery, D.C. (2001). Designs and Analysis of Experiments, John Wiley and Sons, New York.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

GENERIC ELECTIVE COURSE – 6B: Statistics in Actuaries

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistics in Actuaries	4	3	0	1	Class XII pass with Mathematics	Nil

Learning Objectives

The learning objectives include:

- To learn about Utility theory
- To learn the principles of premium calculations
- To understand the survival distribution and life tables
- To learn Life Insurance models and life annuities

Learning Outcomes:

After completing this course, students will develop a clear understanding of:

- Statistics and Insurance applications
- Utility theory
- Principles of premium calculations
- Survival distribution and life tables
- Life insurance models and Life annuities.

SYLLABUS OF GE-6B

Theory

UNIT I **(11 hours)**

Introductory Statistics and Insurance applications

Introductory Statistics and Insurance applications: discrete, continuous, and mixed probability distributions. Insurance applications, sum of random variables. Utility theory: Utility functions expected utility criterion, types of utility function, insurance and utility theory.

UNIT II **(12 Hours)**

Principles of premium calculation
Principles of premium calculation: Properties of premium principles, examples of premium principles

Unit III **(12 Hours)**
Survival distribution and life tables
Survival distribution and life tables: Uncertainty of age and death, survival function, time-until-death for a person, curate future lifetime, the force of mortality, life tables with examples

Unit IV **(10 Hours)**
Life Insurance and annuities
Life insurance: Models for insurance payable at the moment of death, insurance payable at the end of the year of death, and their relationships. Life annuities: continuous life annuities, discrete life annuities.

PRACTICAL/LAB WORK – (30 hours)
List of Practical:
1. Risk computation for different utility models
2. Discrete and continuous risk calculations
3. Calculation of aggregate claims for collective risks
4. Calculation of aggregate claim for individual risks
5. Computing ruin probabilities and aggregate losses
6. Annuity and present value of contract
7. Computing premium for different insurance schemes
8. Practical based on life models and tables

Practical work to be conducted using electronic spreadsheet / EXCEL/ Statistical Software Package/ SPSS/ calculators.

Essential Readings:
- Dixon C. M. D. (2005) Insurance Risk and Ruin (International Series on Actuarial Science), Cambridge University Press.
- Atkinson M.E. and Dickson, D.C.M. (2011): An Introduction to Actuarial Studies, Elgar Publishing.

Suggested Readings:
- Bowers N.L., Gerber H.U., Hickman J.C., Jones D.A., and Nesbitt C.J. (1997): Actuarial Mathematics, Society of Actuaries, Itasca, Illinois USA.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch University of Delhi, from time to time.

SEMESTER-IV

(B.Sc. Honours in Operational Research)

DISCIPLINE SPECIFIC CORE COURSE – 10: SCHEDULING TECHNIQUES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Scheduling Techniques (DSC-10)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The objective of this course is to acquaint students with various scheduling problems and their real-life applications.

Learning outcomes

After completion of the course, students will possess knowledge and skills required to

- Gain an understanding of network analysis and related mathematical models.
- Use standard methodologies for solving network flow problems.
- Manage projects with deterministic and probabilistic activity times.
- Carry out time-cost trade-off analysis in a project.
- Understand the utility of some sequencing problems.

SYLLABUS OF DSC-10

Unit I: Introduction to Network Analysis (12 hours)
Meaning and application of a network diagram, Construction of a network diagram, time estimates in network analysis, float and slack analysis, critical path analysis, Critical path method (CPM) for project management.

Unit II: Project Scheduling (12 hours)
Program Evaluation and Review Technique (PERT) for project management, three time estimates in PERT, Expected completion time and standard deviation of completion time in PERT, probability of project completion within scheduled time.

Unit III: Project Crashing (12 hours)
Project time crashing (time-cost trade off analysis): meaning and significance for project management, direct and indirect costs, finding optimal completion time of project by doing time-cost trade off analysis.

Unit IV: Theory of sequencing **(9 hours)**

Basic concepts: sequencing of jobs through machines; total elapsed time; idle time on a machine; Gantt chart, Flow shop problem, Johnsons' optimality rule, parallel processing.

Practical component (if any) [30 Hours] -

Practical/Lab to be performed on a computer using OR/Statistical packages

- Construct the network of a project with deterministic activity times.
- Finding different types of floats involved in a project network.
- Conduct time-cost trade off analysis in the context of a project network.
- Construct the network of a project with probabilistic activity times.
- Finding expected completion time and variance of completion time in PERT.
- Finding probability of completing the project within scheduled time in PERT.
- Flow shop problem: processing of n Jobs through 2 machines.
- Flow shop problem: processing of n Jobs through 3 machines.
- Flow shop problem: parallel processing.

Essential/recommended readings

- Elmaghraby, S. E. (1977). Activity networks: project planning and control by network models. John Wiley & Sons.
- Ford Jr, L. R., & Fulkerson, D. R. (2015). Flows in networks. Princeton University Press.
- Levy, F. K., & Wiest, J. D. (2016). Management guide to PERT/CPM; with GERT/PDM/DCPM and other networks. Prentice-Hall of India.
- Swarup, K., & Gupta, P. K., & Mohan, M. (2019). Operations Research (Introduction to Management Science). Sultan Chand and Sons.

Suggestive readings **Nil**

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 11: STATISTICAL INFERENCE

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Inference (DSC-11)	4	3	0	1	class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To acquaint the students with how to infer about the population using a sample drawn from it
- To explain how different parametric tests can be used in real life.

Learning outcomes

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

- Analyze the population or phenomenon from which the sample is drawn.
- Examine inferential methods wherein the distributional form of population or phenomenon from which the sample is drawn is known (parametric) .
- Conduct parametric tests of hypotheses

SYLLABUS OF DSC-11

Unit I: Introduction (12 Hours)
Concept of Inductive inference, Population and samples, Distribution of sample, statistic and sample moments, Sampling from Normal Distributions: Chi-Square, t and F-distributions, basic concepts of order statistics.

Unit II: Parametric Point Estimation (12 Hours)
Properties of point estimators- unbiasedness, consistency, sufficiency, efficiency, method of maximum likelihood for finding estimators, properties of maximum likelihood estimators, method of moments for finding estimators.

Unit III: Tests of Hypotheses (12 Hours)
Simple and Composite Hypotheses; Likelihood Ratio Tests; Construction of Confidence Intervals.

Unit IV: Parametric and Nonparametric Tests (9 Hours)
Normal tests for proportion and mean based on single sample ; Chi-Square test for variability; t-test for single mean; t-test for difference of means; paired t-test; F test for equality of variances, Chi-Square test for goodness of fit, sign test, Wilcoxon Signed Rank Test, Median Test.

Practical component (if any) [30 Hours] –

- Practicals based on applications of t-tests
- Practicals based on applications of F-tests
- Practicals based on applications of chi-square tests
- Practicals based on sign test, Wilcoxon Signed Rank Test,
- Practicals based on Median Test.

Essential/recommended readings

- Dudewicz, E. J., & Misra S. N. (1988). Modern mathematical statistics, Wiley.
- Fruend, J. E. (2013). Mathematical statistics with applications (8th ed.). Pearson Education India.
- Levin, R. I., Masood, H. S., Rubin, S. D., & Rastogi, S. (2017). Statistics for management (8th ed.). Pearson Education.
- Mood, A. M., Grabill, F. A., & Boes, D. C. (1974). Introduction to the theory of statistics (3rd ed.). McGraw Hill.

Suggestive readings:

- Goon, A. M., Gupta, A. K., & Dasgupta, B. (1989). An outline of statistical theory (volume 1) (2nd ed.). World Press Pvt. Ltd.
- Rohatgi, V. K., & Ehsanes Saleh, A. K. Md. (2000). An introduction to probability and statistics (2nd ed.). Wiley.

DISCIPLINE SPECIFIC CORE COURSE – 12: DATABASE MANAGEMENT SYSTEM

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Database Management System (DSC-12)	4	3	0	1	class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students understand the basics of database management systems.
- To acquaint them with fundamental concepts, functions and applications of the discipline, so as to deal with different types of problems faced by database managers.

Learning Outcomes

Students completing this course will be able to:

- Gain an understanding of basic concepts of database management and differentiate between DBMS and RDBMS.
- Know the importance of ER Diagrams and their relative conversions.
- Recognize the significance of Functional Dependencies and related concepts for businesses and organizations.
- Understand the utility of structured query language (SQL) for managing databases.

SYLLABUS OF DSC-12

Unit I: Fundamentals of DBMS **(9 Hours)**

Introduction to Database Management System, Purpose and characteristics of Database approach, Data Models, Database Languages, Database Users, Database Management System Architecture, Data Independence.

Unit II: Understanding Entity Relationship (ER) Modeling **(6 Hours)**

Entity Relationship (ER) Modeling: Entity, Attribute, Relationship, Entity Relationship (ER) diagram, designing a database using ER-diagrams.

Unit III: Normalization Concepts **(15 Hours)**

Relational Model concepts, Relational Algebra, Functional Dependencies, Normalization: 1NF, 2NF and 3NF.

Unit IV: Structured Query Language (SQL) **(15 Hours)**

Introduction, purpose and application. Queries in SQL. Transaction Processing: ACID properties, concurrency control.

Practical component (if any) [30 Hours]-

Practical/Lab to be performed on a computer using MS SQL Server/MySQL package

- Using DDL commands of create table, alter table, drop table.
- Utilization of DML commands of select, insert, update, delete.
- Understanding of condition specification using Boolean and comparison operators (AND,
- OR, =, >, < etc.) .
- Utility of arithmetic operators and aggregate functions (COUNT, SUM, AVG etc.).
- Application of Join condition on different tables and same table.
- Using nested select statements for database management.
- Dealing with Null values.
- Sorting of data in ascending or descending order using ORDERBY clause.
- Grouping of similar data using GROUPBY clause and application of HAVING condition.

Essential/recommended readings

- Date, C. J. (2003). Addison-Wesley, Introduction to Database Systems 8TH Edition, Pearson Education.
- Elmasri, R., & Navathe, S. B. (2017). Fundamentals of Database Systems 7 th Edition. Pearson Education
- Silberschatz, A., Korth, H. F., & Sudarshan, S. (2002). Database system concepts (Vol. 5). New York: McGraw-Hill.

- Ramakrishnan, R., Gehrke, J., & Gehrke, J. (2003). Database management systems (Vol. 3). New York: McGraw-Hill.

Suggestive readings Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category II

Operational Research Courses for Undergraduate Programme of study with Operational Research as one of the Core Disciplines

(B.A. Programme with Operational Research as Major discipline)

DISCIPLINE SPECIFIC CORE COURSE – 7: Optimization Techniques

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Optimization Techniques (DSC-7)	4	3	1	0	Class XII with Maths	Nil

Learning Objectives:
To impart knowledge about the formulations and solution techniques of integer linear and multi-objective goal programming problems.

Learning Outcomes:
Students completing this course will be able to:
- Identify different types of optimization problems and their characteristics in real life.
- Explain the theoretical concepts related to unconstrained optimization problems and demonstrate optimality conditions and solution approaches for them.
- Develop the concepts of a multi-objective programming problem and demonstrate its solution using goal programming.
- Formulate real-life problems as integer linear programming problems and solve them using Branch and Bound method.

SYLLABUS OF DSC-7

Unit I: Unconstrained Optimization (10 Hours)

Single and multiple variable problems, First and Second order necessary and sufficient conditions for finding extrema, Solution methods: Newton, Gradient search.

Unit II: Convex Functions (10 Hours)

Local and global maxima/minima for functions of one and two variables, inflection point, positive/negative definite and semi-definite matrices, convex/concave functions, and their properties, Verifying convexity/concavity through a Hessian matrix.

Unit III: Goal Programming (12 Hours)

Goal Programming: Basics of goal programming, Weighted and pre-emptive goal programming, Formulation of a goal programming problem, Graphical solution method, Modified Simplex method.

Unit IV: Integer Linear Programming (13 Hours)

Introduction to Integer linear programming problem (ILPP), Pure ILPP, Mixed ILPP, and 0-1 ILPP, Formulation of real life ILPPs, Branch and bound solution method.

Practical component (if any) – NIL
Tutorial : [30 hours]

Essential/recommended readings

- Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
- Taha , H.(2019). Operations Research-An Introduction, 10^{th} edn., Pearson.
- Wayne, Winston, L. (2003). *Operations research: applications and algorithms,* (4th ed.). Duxbury Press.

Suggestive readings Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 8: Statistical Inference

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Statistical Inference (DSC-8)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To acquaint the students with how to infer about the population using a sample drawn from it

- To explain how different parametric tests can be used in real life.

Learning outcomes

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

- Analyze the population or phenomenon from which the sample is drawn.
- Examine inferential methods wherein the distributional form of population or phenomenon from which the sample is drawn is known (parametric) .
- Conduct parametric tests of hypotheses

SYLLABUS OF DSC-8

Unit I: Introduction (12 Hours)
Concept of Inductive inference, Population and samples, Distribution of sample, statistic and sample moments, Sampling from Normal Distributions: Chi-Square, t and F-distributions, basic concepts of order statistics.

Unit II: Parametric Point Estimation (12 Hours)
Properties of point estimators- unbiasedness, consistency, sufficiency, efficiency, method of maximum likelihood for finding estimators, properties of maximum likelihood estimators, method of moments for finding estimators.

Unit III: Tests of Hypotheses (12 Hours)
Simple and Composite Hypotheses; Likelihood Ratio Tests; Construction of Confidence Intervals.

Unit IV: Parametric and Nonparametric Tests (9 Hours)
Normal tests for proportion and mean based on single sample ; Chi-Square test for variability; t-test for single mean; t-test for difference of means; paired t-test; F test for equality of variances, Chi-Square test for goodness of fit, sign test, Wilcoxon Signed Rank Test, Median Test.

Practical component (if any) [30 Hours] –

- Practicals based on applications of t-tests
- Practicals based on applications of F-tests
- Practicals based on applications of chi-square tests
- Practicals based on sign test, Wilcoxon Signed Rank Test,
- Practicals based on Median Test.

Essential/recommended readings

- Dudewicz, E. J., & Misra S. N. (1988). Modern mathematical statistics, Wiley.
- Fruend, J. E. (2013). Mathematical statistics with applications (8th ed.). Pearson Education India.
- Levin, R. I., Masood, H. S., Rubin, S. D., & Rastogi, S. (2017). Statistics for management (8th ed.). Pearson Education.

- Mood, A. M., Grabill, F. A., & Boes, D. C. (1974). Introduction to the theory of statistics (3rd ed.). McGraw Hill.

Suggestive readings:

- Goon, A. M., Gupta, A. K., & Dasgupta, B. (1989). An outline of statistical theory (volume 1) (2nd ed.). World Press Pvt. Ltd.
- Rohatgi, V. K., & Ehsanes Saleh, A. K. Md. (2000). An introduction to probability and statistics (2nd ed.). Wiley.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category III

Operational Research Courses for Undergraduate Programme of study with Operational Research as one of the Core Disciplines

(B.A Programme with Operational Research as non-Major or Minor discipline)

DISCIPLINE SPECIFIC CORE COURSE – 4: Optimization Techniques

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Optimization Techniques (DSC-4)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives:
To impart knowledge about the formulations and solution techniques of integer linear and multi-objective goal programming problems.

Learning Outcomes:
Students completing this course will be able to:
- Identify different types of optimization problems and their characteristics in real life.
- Explain the theoretical concepts related to unconstrained optimization problems and demonstrate optimality conditions and solution approaches for them.
- Develop the concepts of a multi-objective programming problem and demonstrate its solution using goal programming.
- Formulate real-life problems as integer linear programming problems and solve them using Branch and Bound method.

SYLLABUS OF DSC-4

Unit I: Unconstrained Optimization (10 Hours)

Single and multiple variable problems, First and Second order necessary and sufficient conditions for finding extrema, Solution methods: Newton, Gradient search.

Unit II: Convex Functions (10 Hours)

Local and global maxima/minima for functions of one and two variables, inflection point, positive/negative definite and semi-definite matrices, convex/concave functions, and their properties, Verifying convexity/concavity through a Hessian matrix.

Unit III: Goal Programming (12 Hours)

Goal Programming: Basics of goal programming, Weighted and pre-emptive goal programming, Formulation of a goal programming problem, Graphical solution method, Modified Simplex method.

Unit IV: Integer Linear Programming (13 Hours)

Introduction to Integer linear programming problem (ILPP), Pure ILPP, Mixed ILPP, and 0-1 ILPP, Formulation of real life ILPPs, Branch and bound solution method.

Practical component (if any) – NIL
Tutorial: [30 Hours]

Essential/recommended readings

- Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
- Taha , H.(2019). Operations Research-An Introduction, 10^{th} edn., Pearson.
- Wayne, Winston, L. (2003). *Operations research: applications and algorithms,* (4th ed.). Duxbury Press.

Suggestive readings Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category IV

BSc. Physical Sciences/ Mathematical Sciences with Operational Research as one of the three Core Disciplines

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

DISCIPLINE SPECIFIC CORE COURSE – 4: OPTIMIZATION TECHNIQUES

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Optimization Techniques (DSC-4)	4	3	1	0	Class XII with Maths	Nil

Learning Objectives:
To impart knowledge about the formulations and solution techniques of integer linear and multi-objective goal programming problems.

Learning Outcomes:
Students completing this course will be able to:
- Identify different types of optimization problems and their characteristics in real life.
- Explain the theoretical concepts related to unconstrained optimization problems and demonstrate optimality conditions and solution approaches for them.
- Develop the concepts of a multi-objective programming problem and demonstrate its solution using goal programming.
- Formulate real-life problems as integer linear programming problems and solve them using Branch and Bound method.

SYLLABUS OF DSC-4

Unit I: Unconstrained Optimization **(10 Hours)**

Single and multiple variable problems, First and Second order necessary and sufficient conditions for finding extrema, Solution methods: Newton, Gradient search.

Unit II: **Convex Functions** **(10 Hours)**

Local and global maxima/minima for functions of one and two variables, inflection point, positive/negative definite and semi-definite matrices, convex/concave functions, and their properties, Verifying convexity/concavity through a Hessian matrix.

Unit III: Goal Programming (12 Hours)

Goal Programming: Basics of goal programming, Weighted and pre-emptive goal programming, Formulation of a goal programming problem, Graphical solution method, Modified Simplex method.

Unit IV: Integer Linear Programming (13 Hours)

Introduction to Integer linear programming problem (ILPP), Pure ILPP, Mixed ILPP, and 0-1 ILPP, Formulation of real life ILPPs, Branch and bound solution method.

Practical component (if any) – NIL
Tutorial:[30 Hours]

Essential/recommended readings

- Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
- Taha , H.(2019). Operations Research-An Introduction, 10th edn., Pearson.
- Wayne, Winston, L. (2003). *Operations research: applications and algorithms,* (4th ed.). Duxbury Press.

Suggestive readings Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

CATEGORY-V

COMMON POOL OF DISCIPLINE SPECIFIC ELECTIVES (DSE) COURSES OF

(i) B.Sc.(H) OR

(ii) B Sc (Physical Sciences/Mathematical Sciences) with OR as one of the

DISCIPLINE SPECIFIC ELECTIVE (DSE-2 (a)): Introduction to Stochastic Processes

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to Stochastic Processes (DSE-2(a))	4	3	1	0	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To acquaint students with the basic concepts of stochastic processes and its mathematical framework.
- To introduce some standard stochastic processes and their properties.
- To provide students necessary mathematical support and confidence to analyze the probabilistic evolution of randomly evolving systems.

Learning outcomes

Students completing this course will be able to:

- Elucidate the power of stochastic processes and their range of applications.
- State the defining properties of various stochastic process models.
- Demonstrate essential stochastic modeling tools.
- Identify appropriate stochastic process model(s) for a given research or applied problem.
- Formulate and solve problems which involve setting up stochastic models.

SYLLABUS OF DSE-2(a)

Unit I: Introduction to Stochastic processes **(6 hours)**

Definition, specification of stochastic processes, stationary processes, martingales.

Unit II: Markov chains **(12 hours)**
Introduction, Classification of states, Limiting behaviour, Applications to Queueing Theory.

Unit III: Markov Processes **(12 hours)**
Introduction, Structure of Markov Processes, Limit Theorems, Birth and Death Processes.

Unit IV: Counting Processes **(15 hours)**
Introduction, Types of counting processes, Poisson process: definition and examples, Markov property of Poisson process, superposition of Poisson processes, thinning of Poisson processes, basics of ordinary renewal processes and non-homogenous Poisson processes, Applications in Reliability and Maintenance Theory.

Practical component (if any) – NIL
Tutorial: [30 Hours]

Essential/recommended readings :

- Kulkarni, V. G. (2011), *Modeling and Analysis of Stochastic Systems*, (2nd edition), CRC Press.
- Ross, Sheldon, M. (1995). *Stochastic Processes* (2nd edition), John Wiley.
- Pinsky, Mark A. and Karlin, Samuel. (2011), *An Introduction to Stochastic Modeling*, Elsevier.
- Blanco, L., Arunachalam, V. and Dharmaraja S. (2016), *Introduction to Probability and Stochastic Processes with Applications,* Castaneda, Wiley, Asian Edition.

Suggestive readings:

- Medhi, J. (2009), *Stochastic Processes* (3rd edition), New Age International Publishers.
- Trivedi, K. S. (2016), *Probability & Statistics with Reliability, Queuing & Computer Science Applications* (2nd edition), New Jersey, John Wiley & Sons, Inc.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-2 (b)): Multivariate Data Analysis

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Multivariate Data Analysis & DSE 2(b)	4	3	0	**1**	Class XII with Mathematics	Knowledge of elementary descriptive and inferential Statistics

Learning Objectives

The primary objective of this course is to introduce:

- Understanding the principles and concepts of multivariate data analysis.
- Developing skills in using statistical software to analyze and interpret multivariate data.
- Familiarizing with different types of multivariate techniques.

Learning outcomes

Students completing this course will be able to:

- To examine the difference between univariate and multivariate data analysis.
- To analyse data using quantitative and qualitative response regression modelsregression models.
- To conduct factor analysis.

SYLLABUS OF DSE-2(b)

Unit I: Exploring Multivariate Data (6 Hours)

The aims of multivariate analysis, basics of matrix and vector algebra, positive definite matrices, random vectors, and matrices, mean vectors and covariance matrices, Types of Data; Organization of data- Arrays, Descriptive Statistics, Graphical Techniques- The scatterplot, The scatterplot matrix, multiple box plots, concept of distance in multivariate techniques, checking distributional assumptions using probability plots.

Unit II: Regression and the Analysis of variance (15 Hours)

Multiple Regression Models: Assumptions, Estimation, Testing of Hypotheses, ANOVA models, MANOVA(one-way classification)

Unit III: Qualitative Response Regression Models: (12 Hours)

Introduction, Binary Logistic Regression, Estimation, Goodness of fit, ROC curves, basics of multinomial logistic regression, use of logistic regression for classification, 2 x 2 contingency and three - way table.

Unit IV: Factor analysis (12 Hours)

Introduction, Exploratory factor analysis, reliability of factor scales: internal consistency of scales, Confirmatory factor analysis, Structural equation modelling.

Practical Component (if any) [30 Hours]:

- Practical based on multiple regression
- Practical based on ANOVA & MANOVA – one way classification
- Practical based on ANOVA – two way classification
- Practical based on Logistic Regression
- Practical based on Factor Analysis

Essential/recommended readings:

- Cleff, T. (2019). Applied Statistics and Multivariate Data Analysis for Business and Economics- A Modern Approach Using SPSS, Stata, and Excel, Springer Nature, Switzerland.
- Hardle, W. K. and Simar, L. (2015). Applied Multivariate Statistical Analysis, 4th Edn., Springer.
- Johnson, R. A. and Wichern, D. W. (2015). Applied Multivariate Statistical Analysis, 6th Edn., Pearson Education India.
- Joseph F. Hair Jr., Black,W.C., Babin,B.J., and Anderson, R.E. (2019). Multivariate Data Analysis, 8th edition, Cengage Learning, UK.
- Kshirsagar, A. M. (1996). Multivariate Analysis, 2nd ed., Marcel Dekker.

Suggestive Readings:Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-2 (c)): INTRODUCTION TO SOCIAL MEDIA ANALYTICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
INTRODUCTION TO SOCIAL MEDIA ANALYTICS (DSE-2(c))	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students understand the basic types of social media platform.
- To equip students with skills to collect, analyse and derive actionable insights from social media websites.
- To impart knowledge of methods of social media marketing and related analytical central concepts.

Learning Outcomes

Students completing this course will be able to:

- Understand the role of social media data and analytics in helping organizations achieve their goals.
- Identify and select key performance indicators to accurately measure the success of social media efforts.
- Analyze social media data using native analytics (e.g. YouTube, Facebook, Twitter, Instagram) and social media measurement tools.
- Draw meaningful insights and provide actionable and strategic recommendations based on social media data analysis.

SYLLABUS OF DSE 2(C)

Unit I: Introduction **(9 Hours)**

Difference between social network data, Nodes, Relations, Scales of measurement, statistics and social network data., Introduction to formal methods, efficiency, using computers, seeing patterns.

Unit II: Graphs and Sociograms (12 Hours)
Introduction to graphs, sociograms, kinds of graphs. Working with NetDraw to visualize graphs: Introduction, node attributes, relation properties, location, highlighting parts of the network.

Knowledge of Network models, degree of separation, Tools for Social Network Visualization

Unit III: Ego Networks and Centrality (12 Hours)

Fundamentals of Ego network, Introduction to Degree centrality, closeness centrality, between-ness centrality, Concept of Link Analysis.

Unit IV: Concept of Virality, broadcasting and Information Diffusion (12 Hours)
Quantification of virality of information in online Social Networks, Modeling of View Count Dynamics, life cycle of a video and viewers cataloguing, Information Diffusion: Probabilistic Models of Information Flow, Cascading Behavior: Decision Based Models of Cascades and epidemic modeling to understand the spread of information.

Practical component (if any) [30 Hours]–

- Analyze the degree distribution of any social network
- Analyze various centrality measures of any Social Network using UCINET tool
- Examine the clustering coefficient of any network
- Analyze the diameter, path length
- Analyze the ego networks and evaluate them
- Apply centrality metrics (Degree, between-ness, closeness) and related algorithms to determine the topological significance of the nodes in a network.
- Extract clusters of related nodes using efficient community detection algorithms and evaluate the effectiveness of the partitioning.

Essential/recommended readings

- Hitzler, Pascal, Markus Krotzsch, and Sebastian Rudolph. (2011). Foundations of semantic web technologies. CRC Press.
- Charu.C. Aggarwal, (2011). Social Network Data Analytics, Springer.
- Easley, David, Jon Kleinberg. (2010). Networks, Crowds, and Markets: Reasoning about a Highly Connected World. New York, NY: Cambridge University Press.
- King, Andrew B. (2008). Website optimization. "O'Reilly Media, Inc."
- Jackson, Matthew O. (2008). Social and Economic Networks. Princeton, NJ: Princeton University Press.
- Liu, Bing. (2007). Web data mining. Springer-Verlag Berlin Heidelberg.

Suggestive readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

CATEGORY-VI

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY THE DEPARTMENT

GENERIC ELECTIVES (GE-4): CONVEX AND DISCRETE OPTIMIZATION

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Convex and Discrete Optimization (GE-4)	4	3	1	0	Class XII with Maths	Nil

Learning Objectives:
To impart knowledge about the formulations and solution techniques of integer linear and multi-objective goal programming problems.

Learning Outcomes:
Students completing this course will be able to:
- Identify different types of optimization problems which occur in real life and their characteristics.
- Explain the theoretical concepts related to unconstrained optimization problems and demonstrate optimality conditions and solution approaches for them.
- Develop the concepts of a multi-objective programming problem and demonstrate its solution using goal programming.
- Formulate real-life problems as integer linear programming problems and solve them using Branch and Bound method.

SYLLABUS OF GE 4

Unit I: Unconstrained Optimization **(10 Hours)**

Single and multiple variable problems, Necessary and sufficient conditions for finding extrema, Solution methods: Bisection, Newton, Golden section, Gradient search.

Unit II: **Convex Functions** **(10 Hours)**

Local and global maxima/minima for functions of one and two variables, inflection point, positive/negative definite and semi-definite matrices, convex/concave functions, and their properties, Verifying convexity/concavity through a Hessian matrix.

Unit III: Goal Programming (10 Hours)

Goal Programming: Basics of goal programming, Weighted and pre-emptive goal programming, Formulation of a goal programming problem, Graphical solution method, Modified Simplex method.

Unit IV: Integer Linear Programming (15 Hours)

Introduction to Integer linear programming problem (ILPP), Pure ILPP, Mixed ILPP, and 0-1 ILPP, Applications of ILPP: Capital budgeting, problem Fixed charge problem, Travelling salesman problem, Media allocation, Knapsack problem, Gomory's cutting plane method, Branch and bound method.

Essential/recommended readings :

- Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
- Sinha, S. M. (2006). *Mathematical programming- theory and methods* (1st ed.). New Delhi: Elsevier Science (Indian print).

Practical component (if any) – NIL
Tutorial: [30 Hours]

Essential Readings:

- Bazaraa, M. S., Sherali, H. D., & Shetty, C. M. (2006). *Nonlinear programming-Theory and algorithms (3rd ed.).* New Delhi: John Wiley & Sons (Indian print).
- Chandra, S., Jayadeva, & Mehra, A. (2009). *Numerical optimization with applications*. New Delhi: Narosa Publishing House.

Suggested Readings:

- Antoniou, A., & Lu, Wu-Sheng (2007). *Practical optimization- Algorithms and engineering applications*. New York: Springer.
- Hillier, F. S., & Lieberman, G. J. (2010). *Introduction to operations research- Concepts and cases (9th ed.).* New Delhi: Tata McGraw Hill (Indian print).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

SEMESTER-V

Category I

(B.Sc. Honours in Operational Research)

DISCIPLINE SPECIFIC CORE COURSE – 13: NONLINEAR AND DYNAMIC PROGRAMMING (THEORY AND PRACTICAL)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Nonlinear and Dynamic Programming (DSC-13)	4	3	1	0	Class XII with Maths	Nil

Learning Objectives:

- To impart knowledge about the formulations and solution techniques of nonlinear and dynamic programming.

Learning Outcomes:

Students completing this course will be able to:

- Identify different optimization problems and their characteristics in real-life to be formulated as nonlinear programming problems.
- Explain the theoretical concepts of nonlinear programming problems and demonstrate solution approaches.
- Understand the basics of Quadratic programming problems and describe their various applications. Then, demonstrate solution methods for these problems.
- Formulate and solve nonlinear programming problems in which the objective function and constraints are separable functions using concepts of separable programming.
- Solve different types of real-life problems using Dynamic programming.

SYLLABUS OF DSC-13

Unit I: **Nonlinear Programming (NLP)** **(15 Hours)**

Basics of NLP, Method of Lagrange multiplier, Fritz John optimality conditions, Karush-Kuhn-Tucker (KKT) optimality conditions, Verification of sufficient optimality conditions.

Unit II: Special Nonlinear Programming Problems **(15 Hours)**

Basics of Quadratic programming problem (QPP), Applications of QPP, Wolfe's method, Beale's method, Duality, Separable programming problem and its solution using piece-wise linear approximation.

Unit III: **Dynamic programming** **(15 Hours)**

Multistage decision processes, Recursive nature of computations, Forward and backward recursion, Bellman's principle of optimality, Selective dynamic programming applications and their solutions involving additive and multiplicative separable returns for objective as well as constraint functions, Problem of dimensionality.

Practical component (if any) – NIL
Tutorial: [30 Hours]

Essential/recommended readings

- Chandra, S., Jayadeva, & Mehra, A. (2013). *Numerical optimization with applications.* New Delhi: Narosa Publishing House.
- Ravindran, A., Phillips, D. T., & Solberg, J. J. (2007). *Operations research- principles and practice* (2nd ed.). New Delhi: Wiley India (Indian print).
- Sinha, S. M. (2006). *Mathematical programming- theory and methods* (1st ed.). New Delhi: Elsevier Science (Indian print).
- Wayne, Winston, L. (2003). *Operations research: applications and algorithms,* (4th ed.). Duxbury Press.

Suggestive readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 14: Reliability Theory

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Reliability Theory (DSC-14)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To introduce students about the key concepts and methods in reliability engineering.

- To explain reliability modelling of systems with different configurations
- To explain concept of repair and its impact on the performance of the system along with formulation of maintenance and replacement policies

Learning outcomes

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

- To develop reliability models for non-repairable systems with different configurations
- Develop models for repairable systems using renewal process , Non Homogenous Poisson Process and State- space method
- Formulate system maintenance strategies.

SYLLABUS OF DSC-14

Unit I: Introduction (12 Hours)
Basics of reliability, Classes of life distributions based on notion of aging, concepts of structure function, coherent systems, cut sets, path sets, reliability of series, parallel, k-out-of-n, series-parallel, parallel-series, bridge structure, standby systems

Unit II: Repairable Systems (15 Hours)
Types of Repair, Availability theory, types of Availability measures, Perfect Repair Models: Introduction to Renewal theory, Types of Renewal Processes and their Asymptotic Properties, Reward Renewal Processes, Minimal Repair Models: Introduction to Non Homogenous Poisson Process, Power Law Process

Unit III: State Space Models for System Performance Analysis (10 Hours)
Markovian approach for reliability/ availability analysis of repairable series and parallel systems.

Unit IV: Maintenance Policies (8 Hours)
Types of Maintenance: Corrective Maintenance; Preventive Maintenance, Age Replacement Policy: cost type criterion, Block Replacement Policy: Cost-type criterion

Practical component (if any) [30 Hours]–

- Practicals based on computation of reliability of systems with various configurations
- Practicals based on finding reliability and availability measures of repairable series and parallel systems
- Practicals based on formulation of age and block replacement policies

Essential/recommended readings

- Barlow, R. E., & Proschan, F. (1975). Statistical theory of reliability and life testing. Holt, Rinehert & Winston Inc.
- Gertsbakh, I. (2013). Reliability theory with applications to preventive maintenance. Springer.
- Nakagawa, T. (2005). Maintenance theory on reliability. London: Springer-Verlag.

- Rau, J. G. (1970). Optimization and probability in systems engineering. V.N. Reinhold Co.
- Rausand, M., & Hoyland, A. (2003). System reliability theory: models, statistical methods, and applications. John Wiley & Sons.

Suggestive readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 15: QUANTITATIVE FINANCE

Credit distribution, Eligibility and Pre-requisites of the Course

<table>
<tr><th rowspan="2">Course title & Code</th><th rowspan="2">Credits</th><th colspan="3">Credit distribution of the course</th><th rowspan="2">Eligibility criteria</th><th rowspan="2">Pre-requisite of the course (if any)</th></tr>
<tr><th>Lecture</th><th>Tutorial</th><th>Practical/ Practice</th></tr>
<tr><td>Quantitative Finance (DSC-15)</td><td>4</td><td>3</td><td>1</td><td>0</td><td>Class XII with Maths</td><td>Nil</td></tr>
</table>

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students understand the basics of Quantitative finance.
- To familiarize them with the principles, practices, techniques and applications of quantitative finance, so as to enable them to deal with various business decisions in an efficient manner.

Learning Outcomes

Students completing this course will be able to:

- Relate financial knowledge to varied decisions in a business environment.
- Gain an understanding of financial assets.
- Utilize the concepts, techniques and methods of finance for quantitative analysis.
- Convey financial information and prepare financial management solutions.

SYLLABUS OF DSC-15

Unit I: Introduction to finance functions (6 hours)

Purpose and objectives of Quantitative finance, financial markets, Functions of finance: Investment, Financing and Dividend decisions, roles and responsibilities of a finance manager.

Unit II: Time value of money **(9 hours)**

Time value of money: Present value and Future value; Ordinary Annuity, Annuity Due and Perpetuity, Valuation of securities: Bonds and their valuation, Bond Yields, Common and preferred stock and their valuation.

Unit III: Risk-Return trade-off **(9 hours)**

Introduction to Risk and Return: Concept and significance, application of standard deviation and coefficient of variation, systematic and unsystematic risks, risk and return in a portfolio context, Capital Asset Pricing Model (CAPM), alternatives to CAPM.

Unit IV: Financial statement analysis **(12 hours)**

Financial statements: Balance sheet, Income statement, Cash flows statement. Analysis of financial statements: Ratio analysis, Du Pont equations.

Unit V: Capital Budgeting and Working Capital Management **(9 hours)**

The long term investment decision: Capital budgeting, Estimation of cash flows. Capital budgeting methods: Discounted and non-discounted cash flow based techniques. Interpretation and significance of working capital, permanent and temporary working capital, determinants of working capital, Goal Programming model of working capital management, Cash management: motives and objectives; Baumol's model of cash management.

Practical component (if any) – Nil

Tutorial: [30 Hours]

Essential/recommended readings

- Gitman, L. J., Juchau, R., & Flanagan, J. (2015). *Principles of managerial finance*. Pearson Higher Education AU.
- Koller, T., Dobbs, R., & Huyett, B. (2010). *Value: The four cornerstones of corporate finance*. John Wiley & Sons.
- Levy, H., & Sarnat, M. (1988). *Principles of financial management*. Prentice Hall.
- Ross, S. A., Westerfield, R., & Jaffe, J. F. (1999). *Corporate finance*. Irwin/McGraw-Hill.
- Van Horne, J. C., & Wachowicz, J. M. (2008). *Fundamentals of financial management* (13th ed.). Harlow: Prentice Hall Inc.

Suggestive readings

- Blyth, S. (2013). *An introduction to quantitative finance*. Oxford University Press.
- Wilmott, P. (2013). *Paul Wilmott on quantitative finance*. John Wiley & Sons.

Suggestive readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category II

Operational Research Courses for Undergraduate Programme of study with Operational Research as one of the Core Disciplines

(B.A. Programme with Operational Research as Major discipline)

DISCIPLINE SPECIFIC CORE COURSE – 9: Quantitative Finance and Marketing

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Quantitative Finance and Marketing (DSC-9)	4	3	1	0	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students understand the basics of Financial Management.
- To impart knowledge of central concepts and methods of marketing and related optimization problems.
- To familiarize them with the principles, practices, techniques and applications of financial management, so as to enable them to deal with various business decisions in an efficient manner.

Learning Outcomes

Students completing this course will be able to:

- Relate financial knowledge to varied decisions in a business environment.
- Gain an understanding of financial assets.
- Utilize the concepts, techniques and methods of finance for quantitative analysis.
- Convey financial information and prepare financial and other management solutions.

SYLLABUS OF DSC- 9

Unit I: Introductory concepts in Quantitative finance (9 Hours)

Meaning, significance and scope of finance, profit maximization versus wealth maximization, Interpretation of finance function: Investment, financing and dividend decisions, Time value of money: Present Value and Future Value, Valuation of bonds, Risk and return: Capital Asset Pricing Model, Financial statements: Balance sheet, Income statement and Cash flows statement.

Unit II: Capital Budgeting and Working Capital Management (12 Hours)

The long term investment decision: Capital budgeting, Estimation of cash flows. Capital budgeting methods: Discounted and non-discounted cash flow based techniques. Interpretation and significance of working capital, permanent and temporary working capital, determinants of working capital, Goal Programming model of working capital management, Cash management: motives and objectives; Baumol's model of cash management.

Unit III: Market Analysis (12 Hours)

Concept of Marketing, Marketing Orientation and related concepts, Decision Making: A Quantitative Approach: Business Decisions, Abstraction, Model Building, Solutions, Errors, Model-Building Techniques, Marketing Mix-The Traditional 4 Ps, Marketing Mix- The Modern Concept, Diffusion Modeling, Buyers and Adopters, Mathematical Models for Consumer Buying Behaviour.

Unit IV: New Product Development and Management (12 Hours)

Product Life Cycle (PLC), Product line, Product mix strategies, New product development, , Brand switching analysis, Types of Competition: Perfect and Imperfect., Promotional Efforts and related Models

Practical component (if any) - Nil

Tutorial : [30 Hours]

Essential/recommended readings

- Curtis, A. (2008). Marketing for engineers, scientists and technologists. John Wiley & Sons.
- Gitman, L. J., Juchau, R., & Flanagan, J. (2015). *Principles of managerial finance*. Pearson Higher Education AU.
- Koller, T., Dobbs, R., & Huyett, B. (2010). *Value: The four cornerstones of corporate finance*. John Wiley & Sons.
- Levy, H., & Sarnat, M. (1988). *Principles of financial management*. Prentice Hall.
- Lilien, G. L., Kotler, P., & Moorthy, K. S. (2003). Marketing models. Prentice-Hall of India.
- Ross, S. A., Westerfield, R., & Jaffe, J. F. (1999). *Corporate finance*. Irwin/McGraw-Hill.
- Van Horne, J. C., & Wachowicz, J. M. (2008). *Fundamentals of financial management* (13th ed.). Harlow: Prentice Hall Inc.

Suggestive readings

- Blyth, S. (2013). *An introduction to quantitative finance*. Oxford University Press.
- Kotler, P., & Keller, K. L. (2009). Marketing management. Prentice-Hall.
- Wilmott, P. (2013). *Paul Wilmott on quantitative finance*. John Wiley & Sons.

Suggestive readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 10: Stochastic Modelling and Applications

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Stochastic Modelling and Applications (DSC-10)	**4**	**3**	**0**	**1**	**Class XII with Maths**	**Nil**

Learning Objectives

The Learning Objectives of this course are as follows:

- To make the students familiar with the concept of stochastic modeling and its applications in the field of queueing theory, reliability theory and inventory management.
- To provide students a rigorous mathematical framework to develop mathematical models for different queueing systems.
- To introduce students with the concept of system reliability and make them learn to evaluate reliability of various system configurations.
- To make students learn how to model uncertainties in demand in inventory management problems.
- To provide students hands-on experience of analyzing queueing, reliability and inventory models through practical sessions using certain software.

Learning Outcomes

Students completing this course will be able to:

- Learn the concepts of stochastic processes, Markov processes, Markov chains and apply these mathematical models in real-life problems.
- Understand the concepts and mathematical theory related to queuing systems & system reliability required to understand, analyse and solve any real-world problem.
- Evaluate the performance metrics of any queuing system.
- Compute the system reliability of any type of system-configuration.
- Understand and develop stochastic inventory models.
- Make use of software for problem analysis.

Syllabus of DSC-10

Unit I: Introduction (9 Hours)

Basics of random variables, Probability distributions and their moments, Some standard probability distributions: Binomial, Poisson, Normal, Exponential, Random (stochastic) processes, Lack of memory property of exponential distribution, Markov process, Pure-birth process, Pure-death process.

Unit II: Introduction to Queueing Systems (12 Hours)

Characteristics of a queueing system, Kendall's notation, Performance measures of a queueing system, Markovian queueing models with single & multiple servers, and finite & infinite system capacity – M/M/1, M/M/c.

Unit III: System Reliability (12 Hours)

Introduction to reliability, Reliability function and related concepts like hazard rate, mean time to failure (MTTF), and mean time before failure (MTBF), Classes of lifetime distributions, Hazard rate of exponential and Weibull distributions, Reliability of various system configurations- series, parallel, mixed configuration, k out of n system and stand-by systems.

Unit IV: Stochastic inventory models (12 Hours)

Introduction to stochastic inventory models, Single period probabilistic inventory models with discrete and continuous demand.

Practical component (if any) [30 Hours]:

Practical/Lab to be performed using OR/Statistical packages

- Finding measures of performance for deterministic queuing system.
- Finding measures of performance for M/M/1 queuing system with infinite capacity.
- Finding measures of performance for M/M/1 queuing system with finite capacity.
- Finding measures of performance for M/M/c queuing system with infinite capacity.
- Measuring reliability of different types of system configuration.
- Measuring reliability, hazard rate and MTSF of different types of system configuration.
- Finding optimal inventory policy for probabilistic inventory model with discrete demand.

- Finding optimal inventory policy for probabilistic inventory model with continuous demand.

Essential/recommended readings

- Gross, D., Shortle, J. F, Thompson J. M., & Harris, C. M. (2008), *Fundamentals of Queuing Theory* (4th edition), New Jersey, John Wiley & Sons, inc.
- Rausand, M. & Hoyland, A. (2003), *System Reliability Theory: Models, Statistical Methods & Applications* (2nd edition), New Jersey, John Wiley & Sons, Inc.
- Rau, John G. (1970), *Optimization and Probability in Systems Engineering,* New York, Van Nostrand Reinhold Inc., U.S.
- Ross, S.N. (2008), *Stochastic Processes* (2nd edition), Wiley India Pvt. Ltd.
- Water, D. (2008). *Inventory control and management.* (2nd Edition). John Wiley & Sons.

Suggestive readings

- Hadley, G. and Whitin, T. M. (1979), *Analysis of Inventory Systems*, D. B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category III

Operational Research Courses for Undergraduate Programme of study with Operational Research as one of the Core Disciplines

(B.A Programme with Operational Research as non-Major or Minor discipline)

DISCIPLINE SPECIFIC CORE COURSE – 5: Stochastic Modelling and Applications

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Stochastic Modelling and Applications (DSC-5)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To make the students familiar with the concept of stochastic modeling and its applications in the field of queueing theory, reliability theory and inventory management.
- To provide students a rigorous mathematical framework to develop mathematical models for different queueing systems.
- To introduce students with the concept of system reliability and make them learn to evaluate reliability of various system configurations.
- To make students learn how to model uncertainties in demand in inventory management problems.
- To provide students hands-on experience of analyzing queueing, reliability and inventory models through practical sessions using certain software.

Learning Outcomes

Students completing this course will be able to:

- Learn the concepts of stochastic processes, Markov processes, Markov chains and apply these mathematical models in real-life problems.
- Understand the concepts and mathematical theory related to queuing systems & system reliability required to understand, analyse and solve any real-world problem.
- Evaluate the performance metrics of any queuing system.
- Compute the system reliability of any type of system-configuration.

- Understand and develop stochastic inventory models.
- Make use of software for problem analysis.

Syllabus of DSC-5

Unit I: Introduction (9 Hours)

Basics of random variables, Probability distributions and their moments, Some standard probability distributions: Binomial, Poisson, Normal, Exponential, Random (stochastic) processes, Lack of memory property of exponential distribution, Markov process, Pure-birth process, Pure-death process.

Unit II: Introduction to Queueing Systems (12 Hours)

Characteristics of a queueing system, Kendall's notation, Performance measures of a queueing system, Markovian queueing models with single & multiple servers, and finite & infinite system capacity – M/M/1, M/M/c.

Unit III: System Reliability (12 Hours)

Introduction to reliability, Reliability function and related concepts like hazard rate, mean time to failure (MTTF), and mean time before failure (MTBF), Classes of lifetime distributions, Hazard rate of exponential and Weibull distributions, Reliability of various system configurations- series, parallel, mixed configuration, k out of n system and stand-by systems.

Unit IV: Stochastic inventory models (12 Hours)

Introduction to stochastic inventory models, Single period probabilistic inventory models with discrete and continuous demand.

Practical component (if any) [30 Hours]:

Practical/Lab to be performed using OR/Statistical packages

- Finding measures of performance for deterministic queuing system.
- Finding measures of performance for M/M/1 queuing system with infinite capacity.
- Finding measures of performance for M/M/1 queuing system with finite capacity.
- Finding measures of performance for M/M/c queuing system with infinite capacity.
- Measuring reliability of different types of system configuration.
- Measuring reliability, hazard rate and MTSF of different types of system configuration.
- Finding optimal inventory policy for probabilistic inventory model with discrete demand.
- Finding optimal inventory policy for probabilistic inventory model with continuous demand.

Essential/recommended readings

- Gross, D., Shortle, J. F, Thompson J. M., & Harris, C. M. (2008), *Fundamentals of Queuing Theory* (4th edition), New Jersey, John Wiley & Sons, inc.
- Rausand, M. & Hoyland, A. (2003), *System Reliability Theory: Models, Statistical Methods & Applications* (2nd edition), New Jersey, John Wiley & Sons, Inc.

- Rau, John G. (1970), *Optimization and Probability in Systems Engineering,* New York, Van Nostrand Reinhold Inc., U.S.
- Ross, S.N. (2008), *Stochastic Processes* (2^{nd} edition), Wiley India Pvt. Ltd.
- Water, D. (2008). *Inventory control and management.* (2nd Edition). John Wiley & Sons.

Suggestive readings

- Hadley, G. and Whitin, T. M. (1979), *Analysis of Inventory Systems*, D. B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category IV

BSc. Physical Sciences/ Mathematical Sciences with Operational Research as one of the three Core Disciplines

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

DISCIPLINE SPECIFIC CORE COURSE – 5: STOCHASTIC MODELLING AND APPLICATIONS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Stochastic Modelling and Applications (DSC-5)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To make the students familiar with the concept of stochastic modeling and its applications in the field of queueing theory, reliability theory and inventory management.
- To provide students a rigorous mathematical framework to develop mathematical models for different queueing systems.
- To introduce students with the concept of system reliability and make them learn to evaluate reliability of various system configurations.
- To make students learn how to model uncertainties in demand in inventory management problems.
- To provide students hands-on experience of analyzing queueing, reliability and inventory models through practical sessions using certain software.

Learning Outcomes

Students completing this course will be able to:

- Learn the concepts of stochastic processes, Markov processes, Markov chains and apply these mathematical models in real-life problems.
- Understand the concepts and mathematical theory related to queuing systems & system reliability required to understand, analyse and solve any real-world problem.
- Evaluate the performance metrics of any queuing system.

- Compute the system reliability of any type of system-configuration.
- Understand and develop stochastic inventory models.
- Make use of software for problem analysis.

Syllabus of DSC-5

Unit I: Introduction **(9 Hours)**

Basics of random variables, Probability distributions and their moments, Some standard probability distributions: Binomial, Poisson, Normal, Exponential, Random (stochastic) processes, Lack of memory property of exponential distribution, Markov process, Pure-birth process, Pure-death process.

Unit II: Introduction to Queueing Systems **(12 Hours)**

Characteristics of a queueing system, Kendall's notation, Performance measures of a queueing system, Markovian queueing models with single & multiple servers, and finite & infinite system capacity – M/M/1, M/M/c.

Unit III: System Reliability **(12 Hours)**

Introduction to reliability, Reliability function and related concepts like hazard rate, mean time to failure (MTTF), and mean time before failure (MTBF), Classes of lifetime distributions, Hazard rate of exponential and Weibull distributions, Reliability of various system configurations- series, parallel, mixed configuration, k out of n system and stand-by systems.

Unit IV: Stochastic inventory models **(12 Hours)**

Introduction to stochastic inventory models, Single period probabilistic inventory models with discrete and continuous demand.

Practical component (if any) [30 Hours]:

Practical/Lab to be performed using OR/Statistical packages

- Finding measures of performance for deterministic queuing system.
- Finding measures of performance for M/M/1 queuing system with infinite capacity.
- Finding measures of performance for M/M/1 queuing system with finite capacity.
- Finding measures of performance for M/M/c queuing system with infinite capacity.
- Measuring reliability of different types of system configuration.
- Measuring reliability, hazard rate and MTSF of different types of system configuration.
- Finding optimal inventory policy for probabilistic inventory model with discrete demand.
- Finding optimal inventory policy for probabilistic inventory model with continuous demand.

Essential/recommended readings

- Gross, D., Shortle, J. F, Thompson J. M., & Harris, C. M. (2008), *Fundamentals of Queuing Theory* (4th edition), New Jersey, John Wiley & Sons, inc.
- Rausand, M. & Hoyland, A. (2003), *System Reliability Theory: Models, Statistical Methods & Applications* (2nd edition), New Jersey, John Wiley & Sons, Inc.

- Rau, John G. (1970), *Optimization and Probability in Systems Engineering,* New York, Van Nostrand Reinhold Inc., U.S.
- Ross, S.N. (2008), *Stochastic Processes* (2nd edition), Wiley India Pvt. Ltd.
- Water, D. (2008). *Inventory control and management.* (2nd Edition). John Wiley & Sons.

Suggestive readings

- Hadley, G. and Whitin, T. M. (1979), *Analysis of Inventory Systems*, D. B. Taraporevala and Sons, Published by arrangement with Prentice Hall Inc.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

CATEGORY-V

COMMON POOL OF DISCIPLINE SPECIFIC ELECTIVES (DSE) COURSES OF

(i) B.Sc.(H) OR

(ii) BA(P)with OR Major & Minor

(iii) B.Sc. (Physical Sciences/Mathematical Sciences) with OR as one of

DISCIPLINE SPECIFIC ELECTIVE (DSE-3 (a)): Software Engineering

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Software Engineering (DSE-3(a))	4	3	0	1	Class XII Pass with Mathematics as one of the papers in Class XII	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To introduce the basic concepts of Software Engineering and related terminologies
- The students will be made familiar with the concepts of software development process, various life cycles and reliability assessment.
- To introduce various approaches for software project planning, Risk assessment & mitigation

Learning outcomes

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

- Understand software development life cycle, its various stages, and different approaches for software development projects.
- Know about Software Project management activities including planning, scheduling, risk management, etc.
- Comprehend various software testing approaches.
- Understand about the mathematical models for software reliability assessment and prediction
- Gain knowledge about tools and techniques of large-scale software systems development.

SYLLABUS OF DSE-3(a)

Unit I: Introduction (12 Hours)
Software Scope, Software Development Challenges, Software Engineering Discipline, Software Methodologies and Software development life-cycle Models, Introduction to Agile Software Engineering.

Unit II: Software Requirement Management, System Design and Testing (12 Hours)
Requirement Analysis and Modeling, Techniques, SRS: Needs, Characteristics and its Components, Design Principles, design specification, Cohesiveness and Coupling, Software Testing Fundamentals, , Software testing strategies, Validation Testing, System Testing, Black-Box Testing, White-Box Testing and their types.

Unit III: Software Project Management (9 Hours)
Estimation in Project Planning Process, Project Scheduling, Software Risks, Risk Identification, Risk Projection and Risk Refinement, Risk mitigation, monitoring & management-The RMMM Plan

Unit IV: Understanding Software Reliability (12 Hours)
Introduction to Software Reliability, Difference between Hardware and Software Reliability, Non-homogeneous Poisson Process based modeling, Software Quality Assurance, Quality Standards ISO 9000, Capability Maturity Model (CMM)

Practical component (if any) [30 Hours]:
Practical/Lab to be performed using OR/Statistical packages

- Problems related to Process Model
- Problems related to Requirement Analysis
- Problems related to Design Engineering
- Problems related to Project Management
- Problems related to Project Effort Estimation
- Problems related to Project Risk Management
- Problems related to Software Testing
- Problems related to Software Quality Assurance
- Software Reliability Prediction using mathematical models

Essential/recommended readings

- Aggarwal, K. K., & Singh Y. (2005). Software engineering, New Age International.
- Bell, D. (2005). Software Engineering for students. Pearson Education.
- Jalote, P. (2012). An integrated approach to software engineering. Springer Science & Business Media.
- Pressman, R. S. (2005). Software engineering: a practitioner's approach. Palgrave Macmillan.
- Yamada, S. (2014). Software reliability modeling: fundamentals and applications. Tokyo: Springer.

Suggestive readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-3 (b)): Managerial Economics

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Managerial Economics & DSE 3(b)	4	3	1	0	Class XII with Maths	NIL

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students understand the concepts and techniques used in Micro-economic theory necessary for evaluating business decisions.
- To explain the importance and application of tools of micro economic theory in managerial decision-making.

Learning Outcomes

Students completing this course will be able to:

- Understand the application of economics principles most relevant to managers.
- Develop an understanding of basic concepts and issues in Managerial Economics and their applications in managerial decisions.
- Identify different economic factors and their importance in managerial decision making.
- Understand, evaluate and forecast demand and production functions in economics.
- Design competitive strategies according to the market structure.

SYLLABUS OF DSE-3 (b)

Unit I: Fundamentals of Managerial Economics (6 hours)
Introduction, scope and significance of managerial economics, circular flow in an economy, roles and responsibilities of managerial economist, theory and objectives of the firm, Managerial economics: Microeconomics and Macroeconomics.

Unit II: Demand and Supply analysis (15 hours)
Demand theory and determinants of demand, Law of demand, theory of consumer behavior, Price elasticity of demand, factors affecting price elasticity of demand, Income elasticity of demand, Cross price elasticity of demand, Determinants of Supply, Law of supply, elasticity of supply, Concept, significance and methods of demand forecasting.

Unit III: Cost and Production analysis (15 hours)
Meaning and significance of production, factors of production and production function, Production functions in the short run and long run, Concept and significance of cost, determinants of cost, cost function, types of cost, Economies and diseconomies of scale.

Unit IV: Market structures and pricing (9 hours)
Perfect competition: features and pricing under perfect competition, Monopoly: features and pricing under monopoly, Monopolistic competition: features and pricing under monopolistic competition, Oligopoly: features and pricing under oligopoly.

Practical component (if any) : NIL
Practical/Lab to be performed using OR/Statistical packages
Tutorial : [30 Hours]

Essential/recommended readings

- Mankiw, N. G. (2020). *Principles of economics*. Cengage Learning.
- Peterson, H. C., & Jain, S.K., & Lewis, W.C. (2006). *Managerial Economics* (4/e). Pearson Education.
- Salvator, D., & Rastogi, S.K. (2016). *Managerial Economics: Principles and Worldwide Applications* (8^{th} Ed.). Oxford University Press.
- Samuelson, P., & Nordhaus, W. (2010). *Economics* (19^{th} Ed.). McGraw Hill.
- Thomas, C. R., & Maurice, S. C. (2020). *Managerial economics* (12^{th} Ed.). McGraw-Hill.

Suggestive readings Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-3 (c)): HEALTH SYSTEMS MODELLING

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Health Systems Modelling (DSE-3(c))	4	3	1	0	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- This course aims at providing a useful tool to bridge the ongoing trends of the health care system with the operational research techniques and methods by tackling problems through the integration of quantitative methods and operational research methodology.
- Use of common spreadsheet software, data modelling applications will prove to be the catalysts used for the management of health care system in a more practical environment.

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Learning Outcomes

Students completing this course will be able to:

- Apply their analytical skills and acknowledge the techniques underlining the decisions about delivering the healthcare of supreme quality.
- Review and describe the key roles and responsibilities of health care managers.
- Understand, brainstorm, and implement the scope of health services and follow the footprints of the recent trend in healthcare.
- Create a connection between the people's expectations and what the health care industry has to offer in the clearest way.
- Work on reducing regularity, risks and implementing measures to improve people's health and safety.
- Promote ethics and social responsibility at all levels of health services and management.

SYLLABUS OF DSE-3 (c)

Unit I: Health Care Business Operations & Role of Quantitative Methods (6 Hours)

Health care operations management: role, functions and need, Factors driving increased health care cost, Financial distress in health care, Characteristics of health care services and its management, Implications of operations and logistics management, importance of quantitative methods in health care management.

Unit II: Decision Making in Health Care and Quality Improvement (12 Hours)
Decision making under uncertainty and risk, sensitivity analysis, clinical decision making and its implications for management, Quantitative analysis in strategic planning. Business process map and its improvement methodology, service improvement, six sigma.

Unit III: Facility Location and Layout (6 Hours)
Location methods: Factor rating and center of gravity methods, GIS in health care, product layout.

Unit IV: Process Flow Optimization and Resource Optimization (16 Hours)
Discrete Event Simulation Methodology, Queuing analytics, Capacity problems: outpatient clinic, ICU capacity, operating rooms, daily load levelling of elective procedures, scheduling and staffing problems. Forecasting Time series and Regression analysis: patients' volume forecasting. Resource allocation problems: patients service volume, clinical unit staffing, resident physician restricted work hours, patients discharged from ED.

Unit V: Material Management (5 Hours)
Customer service in material management, Laundry and Linen, Role of Inventory in healthcare, inventory planning and policies.

Practical component (if any): NIL
Tutorial:[30 Hours]
Essential/recommended readings

- Denton, B. T. (2013). Handbook of healthcare operations management. New York: Springer, 10(978-1), 9.
- Kolker, A. (2011). Healthcare management engineering: What does this fancy term really mean?: The use of operations management methodology for quantitative decision-making in healthcare settings. Springer Science & Business Media.
- Langabeer, J. R. (2008). Health care operations management: a quantitative approach to business and logistics. Jones & Bartlett Learning.
- Lewis, J. B., McGrath, R. J., & Seidel, L. F. (2009). Essentials of applied quantitative methods for health services managers. Jones & Bartlett Publishers.
- Ozcan, Y. A. (2017). Analytics and decision support in health care operations management. John Wiley & Sons.
- Ozcan, Y. A. (2009). Quantitative methods in health care management: techniques and applications (2nd ed.). California: John Wiley & Sons.

Suggestive readings Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

CATEGORY-VI

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY THE DEPARTMENT

GENERIC ELECTIVES (GE-5): SCHEDULING TECHNIQUES

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Scheduling Techniques (GE-5)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

- To acquaint students with various scheduling problems and their real-life applications.

Learning outcomes

After completion of the course, students will possess knowledge and skills required to

- Gain an understanding of network analysis and related mathematical models.
- Use standard methodologies for solving network flow problems.
- Manage projects with deterministic and probabilistic activity times.
- Carry out time-cost trade-off analysis in a project.
- Understand the utility of some sequencing problems.

SYLLABUS OF GE-5

Unit I: Introduction to Network Analysis (12 hours)

Meaning and application of a network diagram, Construction of a network diagram, time estimates in network analysis, float and slack analysis, critical path analysis, Critical path method (CPM) for project management.

Unit II: Project Scheduling (12 hours)

Program Evaluation and Review Technique (PERT) for project management, three time estimates in PERT, Expected completion time and standard deviation of completion time in PERT, probability of project completion within scheduled time.

Unit III: Project Crashing (12 hours)

Project time crashing (time-cost trade off analysis): meaning and significance for project management, direct and indirect costs, finding optimal completion time of project by doing time-cost trade off analysis.

Unit IV: Theory of sequencing (9 hours)

Basic concepts: sequencing of jobs through machines; total elapsed time; idle time on a machine; Gantt chart, Flow shop problem, Johnsons' optimality rule, parallel processing.

Practical component (if any) [30 Hours]–

Practical/Lab to be performed on a computer using OR/Statistical packages

- Construct the network of a project with deterministic activity times.
- Finding different types of floats involved in a project network.
- Conduct time-cost trade off analysis in the context of a project network.
- Construct the network of a project with probabilistic activity times.
- Finding expected completion time and variance of completion time in PERT.
- Finding probability of completing the project within scheduled time in PERT.
- Flow shop problem: processing of n Jobs through 2 machines.
- Flow shop problem: processing of n Jobs through 3 machines.
- Flow shop problem: parallel processing.

Essential/recommended readings

- Elmaghraby, S. E. (1977). Activity networks: project planning and control by network models. John Wiley & Sons.
- Ford Jr, L. R., & Fulkerson, D. R. (2015). Flows in networks. Princeton University Press.
- Levy, F. K., & Wiest, J. D. (2016). Management guide to PERT/CPM; with GERT/PDM/DCPM and other networks. Prentice-Hall of India.
- Swarup, K., & Gupta, P. K., & Mohan, M. (2019). Operations Research (Introduction to Management Science). Sultan Chand and Sons.

Suggestive readings: **Nil**

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Semester-VI

Category I

(B.Sc. Honours in Operational Research)

DISCIPLINE SPECIFIC CORE COURSE – 16: QUALITY MANAGEMENT

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Quality Management (DSC-16)	4	3	1	0	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To impart knowledge of concepts related to quality management.
- To impart knowledge of popularly used tools for quality control and management of a plan.
- To develop practical skills for continuous quality improvement.

Learning outcomes

Students completing this course will be able to:

- Demonstrate understanding of total quality management philosophies, concepts, organization, practices, framework, and quality standards.
- Demonstrate understanding of quality management and problem-solving tools and techniques for product and process design.
- Apply statistical analysis tools for measuring and controlling quality.
- Illustrate use of process improvement methods and tools for process analysis and improvement to achieve performance excellence.
- Describe the concept and role of six sigma along with theoretical workings of the implementation of six sigma.

SYLLABUS OF DSC 16

Unit I: Introduction to Quality Management (8 Hours)
Concept of quality management, History, evolution, and importance of quality in organizations, Concepts of product and service quality, Principles, practices and techniques of quality management, Philosophies and frameworks of quality given by various Quality Gurus.

Unit II: Tools and Techniques for Quality Improvement (12 Hours)
Designing quality goods and services, Designing quality processes, Process control and improvement, Cost of quality, Tools: check sheet, flow charts, histograms, pareto analysis, Ishikawa diagram, scatter diagram, PDCA cycle.

Unit III: Statistical Quality Control (15 Hours)
Variation, Causes of variations (natural and assignable), Measurement system analysis, Statistical process control, Process capability measurement, Control charts for variable: mean charts, range charts, Control charts for attributes: p-charts, np-charts, c-charts, u-charts, Product control, Acceptable quality level, Average outgoing quality, Average outgoing quality limit, OC curve, Consumers risk, Producers risk, Acceptable sampling plan: Single sampling plan, Double sampling plan, Sequential sampling plan.

Unit IV: Six Sigma (10 Hours)
Introduction to six-sigma, Evolution of six-sigma, Principles of six-sigma, Statistical basis of 3.4 DPMO, Implementing six-sigma, Application of DMAIC, DMADV, Lean six-sigma and Lean six-sigma in services.

Practical component (if any) – Nil
Tutorial: [30 Hours]

Essential Readings:
- Charantimath, P. M. (2011). *Total Quality Management.* Pearson Education India: India.
- Gupta, S. C., & Kapoor, V. K. (2009). *Fundamentals of applied statistics*. India: Sultan Chand & Sons.
- Besterfield, D. H., Besterfield-Michna, C., Besterfield, G. H., Besterfield-Sacre, M., Urdhwareshe, H., & Urdhwareshe, R. (2014). *Total Quality Management (5th ed.).* Pearson Education India.

Suggested Readings:
- Montgomery, D. C. (2009). *Introduction to statistical quality control.* New York: John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 17: Quantitative Models in Marketing

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Quantitative Models in Marketing (DSC-17)	4	3	1	0	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To impart knowledge of central concepts and methods of marketing and related optimization problems.
- To impart knowledge of mathematical models available in handling real life situations.
- Formulations of various real-world problems arising in science, engineering, and management.

Learning outcomes

Students completing this course will be able to:

- Understand the concepts related to aid management decision making.
- Analyse the difference between different analytical perspectives, management decision tools used in businesses
- Apply their learning by formulating real-world problems under different categories
- Describe the theoretical workings of the producer as well as consumer
- Describe the theoretical workings of the innovation diffusion process and do sales forecasting for new products

SYLLABUS OF DSC-17

Unit I: Scientific Marketing Analysis (8 Hours)
Concept of Marketing, Marketing Orientation and related concepts, Decision Making: A Quantitative Approach: Business Decisions, Abstraction, Model Building, Solutions, Errors, Model-Building Techniques, Marketing Mix-The Traditional 4 Ps, Marketing Mix- The Modern Concept.

Unit II: Models of Consumer Behaviour **(9 Hours)**
Consumer Behaviour, Consumer buying process models, What Influences Consumer Behaviour, Key Psychological Processes, The Buying Decision Process: The Five Stage Model, Other Theories of Consumer Decision Making, External-Internal Influence Diffusion Model, The Howard-Sheth model of Buying Behaviour

Unit III: Theory of Pricing **(9 Hours)**
Product Markets: Perfect competition, Monopoly, Monopolistic competition, Oligopoly; Equilibrium determination and pricing under different market structures.

Unit IV: New Product Development and Management **(9 Hours)**
Product Life Cycle (PLC), Product line, Product mix strategies, New product development, Brand, Brand name selection, Brand equity, Brand switching analysis

Unit V: Promotional Management **(10 Hours)**
Promotion Mix, Push vs. Pull Strategy, Promotional Objectives, Advertising- Meaning and Importance, Types, Media Decisions (Mathematical Model for Media Allocation), Optimal Allocation of Advertising expenditure, Sales Promotion – Purpose and Types, Sales Response to Advertising in Presence of Competition.

Practical component (if any) – Nil
Practical/Lab to be performed on a computer using OR/Statistical packages
Tutorial :[30 Hours]

Essential Readings:

- Hooley G. J., & Hassey, M. K., (1999). Quantitative methods in marketing. International Thomson Business Press.
- Curtis, A. (2008). Marketing for engineers, scientists and technologists. John Wiley & Sons.
- Kotler, P., & Keller, K. L. (2009). Marketing management. Prentice-Hall.
- Lilien, G. L., Kotler, P., & Moorthy, K. S. (2003). Marketing models. Prentice-Hall of India.

Suggested Readings:

- Armstrong, G., Adam, S., Denize, S., & Kotler, P. (2014). Principles of marketing. Australia: Pearson.
- Dowling, G. R., & Dowling, G. R. (2004). The art and science of marketing: marketing for marketing managers. USA: Oxford University Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 18: MACHINE LEARNING

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Machine Learning (DSC-18)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- This course will present foundations of Machine Learning algorithms, as well as their real-world applications.
- The course will cover two major learning approaches: supervised and unsupervised.

Learning outcomes

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

- Differentiate between supervised and unsupervised learning tasks.
- Normalize the data and perform outlier analysis.
- Execute various machine learning algorithms learnt in the course.
- Understand the concepts of regression, clustering and dimensionality reduction.

SYLLABUS OF DSC-18

Unit I: Introduction to Machine Learning (8 Hours)

Definition, History, Future and basic concepts of Machine Learning, Statistical learning vs machine learning, Key elements of Machine Learning, Supervised vs. Unsupervised Learning, Data measurement scales, Feature Engineering: normalizing data, missing value treatment, outliers. Creating graphs (bar/line/pie/boxplot/histogram, etc.), summarizing data, descriptive statistics, univariate analysis (distribution of data), bivariate analysis (cross tabs, distributions and relationships, graphical analysis), Splitting dataset into training and test set.

Unit II: Supervised Learning- I (12 Hours)

Linear Regression: Regression with one variable, multiple variables, over-fitting, regularization. Regression evaluation metrics. Logistic Regression, Discriminant Analysis,

Unit III: Supervised Learning- II (12 Hours)

k-nearest neighbor classifier, Naive Bayes classifier, Neural networks, Boosting, Support vector Machines, Decision trees, Bagging, Ensemble of Trees, Evaluating a Classification Model Performance, K-fold Cross-validation, ROC Curve

Unit IV: Unsupervised Learning (13 Hours)

Clustering: Approaches for clustering, distance metrics, K-means clustering, hierarchical clustering, and feature selection methods. Dimensionality reduction (Principal Component Analysis). Association Rules Analysis.

Practical component (if any) [30 Hours]–

Use Python for practical labs for Machine Learning.

List of Practicals:

- Normalizing Data by Min-Max scaling
- Split datasets into training and test sets and evaluate the decision models.
- Summarizing Data through graphs and descriptive analysis.
- Create Prediction Model for linear regression.
- Make Prediction Model for logistic regression.
- Make prediction models for Naïve Bayes Classifier
- Implement Decision Tree
- Implement SVM classification.
- Perform K-means clustering.
- Perform Principal Component analysis.

Essential Readings

- Alpaydin, E. (2020). Introduction to machine learning. MIT press.
- Brownlee, J. (2018). Statistical methods for machine learning: Discover how to transform data into knowledge with Python. Machine Learning Mastery.
- James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An introduction to statistical learning (Vol. 112, p. 18). New York: springer.
- Raschka, S., & Mirjalili, V. (2019). Python machine learning: Machine learning and deep learning with Python, scikit-learn, and TensorFlow 2. Packt Publishing Ltd.
- Shalev-Shwartz, S., & Ben-David, S. (2014). Understanding machine learning: From theory to algorithms. Cambridge university press.

Suggested Readings: **NIL**

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category II

Operational Research Courses for Undergraduate Programme of study with Operational Research as one of the Core Disciplines

(B.A. Programme with Operational Research as Major discipline)

DISCIPLINE SPECIFIC CORE COURSE – 11: Project Management

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Project Management (DSC-11)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The objective of this course is to acquaint students with the fundamental concepts of project planning and management.

Learning outcomes

After completion of the course, students will possess knowledge and skills required to

- Formulate, evaluate, monitor and control a project.
- Gain an understanding of tools and techniques for project management.
- Use network analysis techniques to solve problems related to project management.
- Manage projects with deterministic and probabilistic activity times.
- Carry out time-cost trade-off analysis in a project.
- Understand the utility of some real-life applications of project management problems.

SYLLABUS OF DSC-11

Unit I: Introduction (6 hours)

Meaning of a project, project classification, Lifecycle and phases of a project, Concept of project management, Objectives and significance of project management, Roles and responsibilities of a project manager, Tools and techniques of project management.

Unit II: Project Appraisal (12 hours)

Market feasibility analysis: Market and demand analysis, collection of primary and secondary information, demand forecasting. Technical feasibility analysis: Material input and manufacturing process, selection of locations, Technology selection. Financial feasibility

analysis: Project cost estimation and working capital requirements, sources of financing, financial risk analysis using payback period and net present value techniques.

Unit III: Project Scheduling and Network analysis (12 hours)

Steps involved in project scheduling, Meaning and application of a network diagram, Construction of a network diagram for a project, time estimates in network analysis, float and slack analysis, critical path analysis, Introduction to Critical path method (CPM) and Program Evaluation and Review Technique (PERT) for project management.

Unit IV: Project Time Crashing (9 hours)

Project time crashing (time-cost trade off analysis): meaning and significance for project management, direct and indirect costs, finding optimal completion time of project by doing time-cost trade off analysis.

Unit V: Project Monitoring, Control and termination: (6 hours)

Data collection and reporting for project evaluation, Social cost-benefit analysis and Abandonment analysis. Project Termination: types of terminations, project termination process.

Practical component (if any) [30 Hours]-

Practical/Lab to be performed on a computer using OR/Statistical packages

- Construction of a network.
- Construct the network of a project with deterministic activity times.
- Finding different types of floats involved in a project network.
- Conduct time-cost trade off analysis in the context of a project network.
- Construct the network of a project with probabilistic activity times.
- Finding expected completion time and variance of completion time in PERT.
- Finding probability of completing the project within scheduled time in PERT.

Essential/recommended readings

- Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. (2011). Linear programming and network flows. John Wiley & Sons.
- Bertsekas, D. (1998). Network optimization: continuous and discrete models (Vol. 8). Athena Scientific.
- Elmaghraby, S. E. (1977). Activity networks: project planning and control by network models. John Wiley & Sons.
- Kerzner, H. (2017). *Project management: a systems approach to planning, scheduling, and controlling*. John Wiley & Sons.
- Larson, E. W., & Gray, C. F. (2021). Project management: The managerial process. 8th edition. McGraw-Hill Education.
- Levy, F. K., & Wiest, J. D. (2016). Management guide to PERT/CPM; with GERT/PDM/DCPM and other networks. Prentice-Hall of India.

Suggestive readings

Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 12: Quality Management

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Quality Management (DSC-12)	4	3	1	0	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To impart knowledge of concepts related to quality management.
- To impart knowledge of popularly used tools for quality control and management of a plan.
- To develop practical skills for continuous quality improvement.

Learning outcomes

Students completing this course will be able to:

- Demonstrate understanding of total quality management philosophies, concepts, organization, practices, framework, and quality standards.
- Demonstrate understanding of quality management and problem-solving tools and techniques for product and process design.
- Apply statistical analysis tools for measuring and controlling quality.
- Illustrate use of process improvement methods and tools for process analysis and improvement to achieve performance excellence.
- Describe the concept and role of six sigma along with theoretical workings of the implementation of six sigma.

SYLLABUS OF DSC 12-

Unit I: Introduction to Quality Management (8 Hours)

Concept of quality management, History, evolution, and importance of quality in organizations, Concepts of product and service quality, Principles, practices and techniques of quality management, Philosophies and frameworks of quality given by various Quality Gurus.

Unit II: Tools and Techniques for Quality Improvement (12 Hours)

Designing quality goods and services, Designing quality processes, Process control and improvement, Cost of quality, Tools: check sheet, flow charts, histograms, pareto analysis, Ishikawa diagram, scatter diagram, PDCA cycle.

Unit III: Statistical Quality Control **(15 Hours)**

Variation, Causes of variations (natural and assignable), Measurement system analysis, Statistical process control, Process capability measurement, Control charts for variable: mean charts, range charts, Control charts for attributes: p-charts, np-charts, c-charts, u-charts, Product control, Acceptable quality level, Average outgoing quality, Average outgoing quality limit, OC curve, Consumers risk, Producers risk, Acceptable sampling plan: Single sampling plan, Double sampling plan, Sequential sampling plan.

Unit IV: Six Sigma **(10 Hours)**

Introduction to six-sigma, Evolution of six-sigma, Principles of six-sigma, Statistical basis of 3.4 DPMO, Implementing six-sigma, Application of DMAIC, DMADV, Lean six-sigma and Lean six-sigma in services.

Practical component (if any) – Nil

Tutorial: [30 Hours]

Essential Readings:

- Charantimath, P. M. (2011). *Total Quality Management.* Pearson Education India: India.
- Gupta, S. C., & Kapoor, V. K. (2009). *Fundamentals of applied statistics*. India: Sultan Chand & Sons.
- Besterfield, D. H., Besterfield-Michna, C., Besterfield, G. H., Besterfield-Sacre, M., Urdhwareshe, H., & Urdhwareshe, R. (2014). *Total Quality Management (5th ed.).* Pearson Education India.

Suggested Readings:

- Montgomery, D. C. (2009). *Introduction to statistical quality control.* New York: John Wiley & Sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category III

Operational Research Courses for Undergraduate Programme of study with Operational Research as one of the Core Disciplines

(B.A Programme with Operational Research as non-Major or Minor discipline)

DISCIPLINE SPECIFIC CORE COURSE – 6: Project Management

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Project Management (DSC-6)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The objective of this course is to acquaint students with the fundamental concepts of project planning and management.

Learning outcomes

After completion of the course, students will possess knowledge and skills required to

- Formulate, evaluate, monitor and control a project.
- Gain an understanding of tools and techniques for project management.
- Use network analysis techniques to solve problems related to project management.
- Manage projects with deterministic and probabilistic activity times.
- Carry out time-cost trade-off analysis in a project.
- Understand the utility of some real-life applications of project management problems.

SYLLABUS OF DSC-6

Unit I: Introduction **(6 hours)**
Meaning of a project, project classification, Lifecycle and phases of a project, Concept of project management, Objectives and significance of project management, Roles and responsibilities of a project manager, Tools and techniques of project management.

Unit II: Project Appraisal **(12 hours)**
Market feasibility analysis: Market and demand analysis, collection of primary and secondary information, demand forecasting. Technical feasibility analysis: Material input and manufacturing process, selection of locations, Technology selection. Financial feasibility

analysis: Project cost estimation and working capital requirements, sources of financing, financial risk analysis using payback period and net present value techniques.

Unit III: Project Scheduling and Network analysis (12 hours)
Steps involved in project scheduling, Meaning and application of a network diagram, Construction of a network diagram for a project, time estimates in network analysis, float and slack analysis, critical path analysis, Introduction to Critical path method (CPM) and Program Evaluation and Review Technique (PERT) for project management.

Unit IV: Project Time Crashing (9 hours)
Project time crashing (time-cost trade off analysis): meaning and significance for project management, direct and indirect costs, finding optimal completion time of project by doing time-cost trade off analysis.

Unit V: Project Monitoring, Control and termination (6 hours)
Data collection and reporting for project evaluation, Social cost-benefit analysis and Abandonment analysis. Project Termination: types of terminations, project termination process.

Practical component (if any) [30 Hours] -
Practical/Lab to be performed on a computer using OR/Statistical packages

- Construction of a network.
- Construct the network of a project with deterministic activity times.
- Finding different types of floats involved in a project network.
- Conduct time-cost trade off analysis in the context of a project network.
- Construct the network of a project with probabilistic activity times.
- Finding expected completion time and variance of completion time in PERT.
- Finding probability of completing the project within scheduled time in PERT.

Essential/recommended readings

- Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. (2011). Linear programming and network flows. John Wiley & Sons.
- Bertsekas, D. (1998). Network optimization: continuous and discrete models (Vol. 8). Athena Scientific.
- Elmaghraby, S. E. (1977). Activity networks: project planning and control by network models. John Wiley & Sons.
- Kerzner, H. (2017). *Project management: a systems approach to planning, scheduling, and controlling*. John Wiley & Sons.
- Larson, E. W., & Gray, C. F. (2021). Project management: The managerial process. 8^{th} edition. McGraw-Hill Education.
- Levy, F. K., & Wiest, J. D. (2016). Management guide to PERT/CPM; with GERT/PDM/DCPM and other networks. Prentice-Hall of India.

Suggestive readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category IV

BSc. Physical Sciences/ Mathematical Sciences with Operational Research as one of the three Core Disciplines

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

DISCIPLINE SPECIFIC CORE COURSE – 6 Project Management

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Project Management (DSC-6)	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The objective of this course is to acquaint students with the fundamental concepts of project planning and management.

Learning outcomes

After completion of the course, students will possess knowledge and skills required to

- Formulate, evaluate, monitor and control a project.
- Gain an understanding of tools and techniques for project management.
- Use network analysis techniques to solve problems related to project management.
- Manage projects with deterministic and probabilistic activity times.
- Carry out time-cost trade-off analysis in a project.
- Understand the utility of some real-life applications of project management problems.

SYLLABUS OF DSC-6

Unit I: Introduction (6 hours)
Meaning of a project, project classification, Lifecycle and phases of a project, Concept of project management, Objectives and significance of project management, Roles and responsibilities of a project manager, Tools and techniques of project management.

Unit II: Project Appraisal (12 hours)
Market feasibility analysis: Market and demand analysis, collection of primary and secondary information, demand forecasting. Technical feasibility analysis: Material input and manufacturing process, selection of locations, Technology selection. Financial feasibility

analysis: Project cost estimation and working capital requirements, sources of financing, financial risk analysis using payback period and net present value techniques.

Unit III: Project Scheduling and Network analysis (12 hours)
Steps involved in project scheduling, Meaning and application of a network diagram, Construction of a network diagram for a project, time estimates in network analysis, float and slack analysis, critical path analysis, Introduction to Critical path method (CPM) and Program Evaluation and Review Technique (PERT) for project management.

Unit IV: Project Time Crashing (9 hours)
Project time crashing (time-cost trade off analysis): meaning and significance for project management, direct and indirect costs, finding optimal completion time of project by doing time-cost trade off analysis.

Unit V: Project Monitoring, Control and termination (6 hours)
Data collection and reporting for project evaluation, Social cost-benefit analysis and Abandonment analysis. Project Termination: types of terminations, project termination process.

Practical component (if any) [30 Hours] -
Practical/Lab to be performed on a computer using OR/Statistical packages

- Construction of a network.
- Construct the network of a project with deterministic activity times.
- Finding different types of floats involved in a project network.
- Conduct time-cost trade off analysis in the context of a project network.
- Construct the network of a project with probabilistic activity times.
- Finding expected completion time and variance of completion time in PERT.
- Finding probability of completing the project within scheduled time in PERT.

Essential/recommended readings

- Bazaraa, M. S., Jarvis, J. J., & Sherali, H. D. (2011). Linear programming and network flows. John Wiley & Sons.
- Bertsekas, D. (1998). Network optimization: continuous and discrete models (Vol. 8). Athena Scientific.
- Elmaghraby, S. E. (1977). Activity networks: project planning and control by network models. John Wiley & Sons.
- Kerzner, H. (2017). *Project management: a systems approach to planning, scheduling, and controlling*. John Wiley & Sons.
- Larson, E. W., & Gray, C. F. (2021). Project management: The managerial process. 8^{th} edition. McGraw-Hill Education.
- Levy, F. K., & Wiest, J. D. (2016). Management guide to PERT/CPM; with GERT/PDM/DCPM and other networks. Prentice-Hall of India.

Suggestive readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

CATEGORY-V

COMMON POOL OF DISCIPLINE SPECIFIC ELECTIVES (DSE) COURSES

(i)B.Sc. (H) OR

(ii)BA(P)with OR AS Major & Minor DISCIPLINE

(iii)B.Sc. (Physical Sciences/Mathematical Sciences) with OR as one of the

DISCIPLINE SPECIFIC ELECTIVE (DSE-4 (a)): Econometric Modelling

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Econometric Modelling (DSE-4(a))	4	3	0	1	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To explain the meaning of econometrics-the social science in which the tools of economic theory, mathematics and statistical inference are applied to study economic phenomena.
- To explain the need and concept behind single equation regression models – Single and Multiple Linear Regression Models and also underlying methodology
- To explain Time Series modelling and forecasting.
- To explain the purpose, concept and methodology behind simultaneous equation models.

Learning Outcomes

Students completing this course will be able to:

- Understand concepts, issues and applications of econometric modelling.
- Analyse Econometric model involving single equation with single response variable.
- Analyse Econometric model involving single equation with multiple response variables.
- Analyse time series and simultaneous equation models.

SYLLABUS OF DSE-4(a)

Unit I: Introduction to Econometrics **(6 hours)**
The nature and scope of Econometrics, The Methodology of Econometrics, Types of data: Time series data, Cross-sectional data, Panel data

Unit II: Regression Analysis **(15 hours)**
Classical Linear Regression Models (CLRMs): Single and Multiple linear regression, Model coefficients, Ordinary least squares estimation, Residuals, fitted values, goodness of fit, Violating the assumptions of CLRMs: Multicollinearity; Hetreoscedasticity; Autocorrelation, Step-wise regression.

Unit III: Time Series Modelling **(12 hours)**
Stationary and non-stationary time series, Consequences and detection of non-stationarity, Introduction to AR, MA and ARMA models, ARIMA model, Box Jenkins approach to forecasting.

Unit IV: Simultaneous Equations Modelling **(12 hours)**
Simultaneous equations models: Basic definitions, Identification problem, Estimation, Forecasting from a simultaneous model

Practical component (if any) [30 Hours]-

Practical/Lab to be performed on a computer using OR/Statistical packages

- Fitting of a single linear regression model using ordinary least squares estimation.
- Fitting of a multiple linear regression model having two explanatory variables using ordinary least squares estimation.
- Fitting of a multiple linear regression model having more than two explanatory variables using ordinary least squares estimation.
- Testing for the presence of Multicollinearity.
- Testing for the presence of Heteroscedasticity.
- Testing for the presence of Autocorrelation.
- Testing for stationary and non-stationary time series.
- Estimating a simultaneous equations model.
- Forecasting from a simultaneous equations model.

Essential/recommended readings

- Dougherty, C. (2011). Introduction to econometrics (4th ed.). New York: Oxford University Press.
- Gujarati , D.N., Porter, D.C., and Pal, M.(2020) Basic Economerics , McGraw Hill Publications.
- Johnston, J. (1984). Econometric methods (3rd ed.). New York: Mc-Graw Hill.
- Koutsoyiannis, A. (2001). Theory of econometrics (2nd ed.). New York: Palgrave Macmillan.

Suggestive readings: Nil

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE (DSE-4 (b)): Research Methodology

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Research Methodology & DSE 4(b)	4	3	0	1	**Class XII with Maths**	**NIL**

Learning Objectives

- To give students an understanding of quantitative and qualitative research's basic techniques and tools.
- To provide exposure to the students about the nature and extent of research orientation, which they are expected to possess for higher studies, research, and the job market.

Learning outcomes

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

- Identity and analyse research problems.
- Understand and apply the types of research designs and research tools.
- Do data collection and formulate research questionnaires and conduct surveys.
- Present research reports.

SYLLABUS OF DSC 4(b)

Unit I : Research : Role and Scope **(6 Hours)**

Nature and scope of Research – Role of Research in decision making. Applications of research in various disciplines. The Research Process – Steps in the research process; the research proposal.

Unit II: Research Design and Documentation **(12 Hours)**
Research Design: Exploratory, Descriptive, Causal. Secondary Data Research: Advantages & Disadvantages of Secondary Data, Criteria for evaluating secondary sources, secondary sources of data in Indian Context, Syndicated Research (in India).

Unit III: Data and Scaling **(14 Hours)**
Primary Data Collection: Survey vs. Observations. Qualitative Research Tools: Depth Interviews focus groups and projective techniques; Measurement & Scaling: Primary scales of Measurement-Nominal, Ordinal, Interval& Ratio. Scaling techniques- paired comparison, rank order scale, constant sum scale, semantic differential scale, itemized ratings, scale, Likert Scale; Questionnaire- form & design**.**

Unit IV: Sampling **(13 Hours)**
Sampling: Sampling techniques, Data Analysis: Chi-square test, non-parametric test: Mann Whitney U test, Wilcoxon Signed-Rank test for paired samples, One-Way ANOVA Analysis, Factor Analysis and Discriminant Analysis. Conjoint Analysis, Report writing.

Practical component (if any) [30 Hours] –
Use Microsoft Excel/SPSS for practical labs for Research Methodology

List of Practicals:
- Chi-square Test
- Mann Whitney U test.
- Wilcoxon Signed-Rank Test.
- One Way ANOVA
- Factor Analysis (PCA)
- Discriminant Analysis (LDA)

Essential/recommended readings

- Cooper, D. R., & Schindler, P. S. (2003). Business research methods, McGraw- Hill Education, India
- Malhotra, N. K. (2019). Marketing Research: An Applied Orientation (7^{th} Ed.). Pearson India.
- Chawla, D., & Sondhi, N. (2016). Research Methodology: Concepts and Cases, Vikas Publishing House, India

Suggestive readings:

- Winston, W. L. (2014). *Marketing analytics: Data-driven techniques with Microsoft Excel*. John Wiley & Sons.

DISCIPLINE SPECIFIC ELECTIVE (DSE-4 (c)): INDUSTRIAL PROJECT

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Industrial Project (DSE-4(c))	4	0	0	4	Class XII with Maths	Nil

A Student will be required to do an industrial project

CATEGORY-VI

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES OFFERED BY THE DEPARTMENT

GENERIC ELECTIVES (GE-6): QUANTITATIVE MODELS IN MARKETING

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Quantitative Models in Marketing (GE-6)	4	3	1	0	Class XII with Maths	Nil

Learning Objectives

The Learning Objectives of this course are as follows:

- To impart knowledge of central concepts and methods of marketing and related optimization problems.
- To impart knowledge of mathematical models available in handling real life situations.
- Formulations of various real-world problems arising in science, engineering, and management.

Learning outcomes

Students completing this course will be able to:

- Understand the concepts related to aid management decision making.
- Analyse the difference between different analytical perspectives, management decision tools used in businesses
- Apply their learning by formulating real-world problems under different categories
- Describe the theoretical workings of the producer as well as consumer
- Describe the theoretical workings of the innovation diffusion process and do sales forecasting for new products

SYLLABUS OF GE-6

Learning Objectives

The Learning Objectives of this course are as follows:

- To impart knowledge of central concepts and methods of marketing and related optimization problems.
- To impart knowledge of mathematical models available in handling real life situations.
- Formulations of various real-world problems arising in science, engineering, and management.

Learning outcomes

Students completing this course will be able to:

- Understand the concepts related to aid management decision making.
- Analyse the difference between different analytical perspectives, management decision tools used in businesses
- Apply their learning by formulating real-world problems under different categories
- Describe the theoretical workings of the producer as well as consumer
- Describe the theoretical workings of the innovation diffusion process and do sales forecasting for new products

SYLLABUS OF GE-6

Unit I: Scientific Marketing Analysis (8 Hours)
Concept of Marketing, Marketing Orientation and related concepts, Decision Making: A Quantitative Approach: Business Decisions, Abstraction, Model Building, Solutions, Errors, Model-Building Techniques, Marketing Mix-The Traditional 4 Ps, Marketing Mix- The Modern Concept.

Unit II: Models of Consumer Behaviour (9 Hours)
Consumer Behaviour, Consumer buying process models, What Influences Consumer Behaviour, Key Psychological Processes, The Buying Decision Process: The Five Stage Model, Other Theories of Consumer Decision Making, External-Internal Influence Diffusion Model, The Howard-Sheth model of Buying Behaviour

Unit III: Theory of Pricing (9 Hours)
Product Markets: Perfect competition, Monopoly, Monopolistic competition, Oligopoly; Equilibrium determination and pricing under different market structures.

Unit IV: New Product Development and Management (9 Hours)
Product Life Cycle (PLC), Product line, Product mix strategies, New product development, Brand, Brand name selection, Brand equity, Brand switching analysis

Unit V: Promotional Management (10 Hours)
Promotion Mix, Push vs. Pull Strategy, Promotional Objectives, Advertising- Meaning and Importance, Types, Media Decisions (Mathematical Model for Media Allocation), Optimal Allocation of Advertising expenditure, Sales Promotion – Purpose and Types, Sales Response to Advertising in Presence of Competition.

Practical component (if any) – NA

Practical/Lab to be performed on a computer using OR/Statistical packages
Tutorial: [30 Hours]
Essential Readings:

- Hooley G. J., & Hassey, M. K., (1999). Quantitative methods in marketing. International Thomson Business Press.
- Curtis, A. (2008). Marketing for engineers, scientists and technologists. John Wiley & Sons.
- Kotler, P., & Keller, K. L. (2009). Marketing management. Prentice-Hall.
- Lilien, G. L., Kotler, P., & Moorthy, K. S. (2003). Marketing models. Prentice-Hall of India.

Suggested Readings:
- Armstrong, G., Adam, S., Denize, S., & Kotler, P. (2014). Principles of marketing. Australia: Pearson.
- Dowling, G. R., & Dowling, G. R. (2004). The art and science of marketing: marketing for marketing managers. USA: Oxford University Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

SEMESTER-4

DEPARTMENT OF COMPUTER SCIENCE
[UG Programme for Bachelor in Computer Science (Honours)]

DISCIPLINE SPECIFIC CORE COURSE - 10 (DSC-10) : Design and Analysis of Algorithms

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC 10 Design and Analysis of Algorithms	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 07 Data Structures with C++

Learning Objectives

The course is designed to develop understanding of different algorithm design techniques and use them for problem solving. The course shall also enable the students to verify correctness of algorithms and analyze their time complexity.

Learning outcomes

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

- Compute and compare the asymptotic time complexity of algorithms.
- Prove correctness of algorithms.
- Use appropriate algorithm design technique(s) for solving a given problem.
- Distinguish between tractable and intractable problems.

Unit 1 (10 hours)

Searching, Sorting, Selection: Linear Search, Binary Search, Insertion Sort, Selection Sort, Bubble Sort, Heapsort, Linear Time Sorting, Selection Problem, running time analysis and correctness.

Unit 2 (5 hours)

Graphs: Review of graph traversals, graph connectivity, testing bipartiteness, Directed Acyclic Graphs and Topological Ordering.

Unit 3 (10 hours)

Divide and Conquer: Introduction to divide and conquer technique, Merge Sort, Quick Sort, Maximum-subarray problem, Strassen's algorithm for matrix multiplication.

Unit 4 (5 hours)

Greedy algorithms: Introduction to the Greedy algorithm design approach, application to minimum spanning trees, fractional knapsack problem, etc. with correctness, and analysis of time complexity.

Unit 5 (5 hours)

Dynamic Programming: Introduction to the Dynamic Programming approach, application to subset sum, integer knapsack problem etc., correctness, and analysis of time complexity.

Unit 6 (5 hours)

Intractability: Concept of polynomial time computation, polynomial time reductions, decision vs optimization problems, Introduction to NP, NP-hard and NP-Complete classes.

Unit 7 (5 hours)

Advanced Analysis of Algorithms: Amortized Analysis.

Essential/recommended readings

1. Cormen, T.H., Leiserson, C.E., Rivest, R. L., Stein C. *Introduction to Algorithms*, 4th edition, Prentice Hall of India, 2022.
2. Kleinberg, J., Tardos, E. *Algorithm Design,* 1st edition, Pearson, 2013.

Additional references

1. Basse, S., Gelder, A. V., *Computer Algorithms: Introduction to Design and Analysis,* 3rd edition, Pearson, 1999.

Practical List (If any): (30 Hours)

1. i. Write a program to sort the elements of an array using Insertion Sort (The program should report the number of comparisons).
   ii. Write a program to sort the elements of an array using Merge Sort (The program should report the number of comparisons).
2. Write a program to sort the elements of an array using Heap Sort (The program should report the number of comparisons).
3. Write a program to multiply two matrices using the Strassen's algorithm for matrix multiplication.

4. Write a program to sort the elements of an array using Radix Sort.
5. Write a program to sort the elements of an array using Bucket Sort.
6. Display the data stored in a given graph using the Breadth-First Search algorithm.
7. Display the data stored in a given graph using the Depth-First Search algorithm.
8. Write a program to determine a minimum spanning tree of a graph using the Prim's algorithm.
9. Write a program to implement Dijkstra's algorithm to find the shortest paths from a given source node to all other nodes in a graph.
10. Write a program to solve the weighted interval scheduling problem.
11. Write a program to solve the 0-1 knapsack problem.

For the algorithms at S.No 1 and 2, test run the algorithm on 100 different input sizes varying from 30 to 1000. For each size find the number of comparisons averaged on 10 different input instances; plot a graph for the average number of comparisons against each input size. Compare it with a graph of nlogn.

DISCIPLINE SPECIFIC CORE COURSE – 11 (DSC11): Database Management Systems

Credit distribution, Eligibility and Prerequisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC 11 Database Management Systems	4	3	0	1	Pass in Class XII	DSC01 Programming using Python / A course in Python at plus 2 level, DSC08

Learning Objectives

The course introduces the students to the fundamentals of database management system and its architecture. Emphasis is given on the popular relational database system including data models and data manipulation. Students will learn about the importance of database structure and its designing using conceptual approach using Entity Relationship Model and formal approach using Normalization. The importance of file indexing and controlled execution of transactions will be taught. The course would give students hands-on practice of structured query language in a relational database management system and glimpse of basic database administration commands.

Learning outcomes

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

- Use database management system software to create and manipulate the database.
- Create conceptual data models using entity relationship diagrams for modeling real-life situations and designing the database schema.
- Use the concept of functional dependencies to remove redundancy and update anomalies.
- Apply normalization theory to get a normalized database scheme.
- Write queries using relational algebra, a procedural language.

SYLLABUS OF DSC11

Unit 1 (5 hours)

Introduction to Database: Purpose of database system, Characteristics of database approach, data models, database management system, database system architecture, three-schema architecture, components of DBMS, data independence, and file system approach vs database system approach.

Unit 2 (7 hours)

Entity Relationship Modeling: Conceptual data modeling - motivation, entities, entity types, attributes, relationships, relationship types, constraints on relationship, Entity Relationship diagram notation.

Unit 3 (7 hours)

Relational Data Model: Update anomalies, Relational Data Model - Concept of relations, schema-instance distinction, keys, relational integrity constraints, referential integrity and foreign keys, relational algebra operators and queries.

Unit 4 (10 hours)

Structured Query Language (SQL): Querying in SQL, DDL to create database and tables, table constraints, update database-update behaviors, DML, aggregation functions group by and having clauses, retrieve data from the database, generate and query views. Access and manipulate databases using ODBC. Basic Database administration SQL commands.

Unit 5 (8 hours)

Database Design: Mapping an Entity Relationship model to relational database, functional dependencies and Normal forms, 1NF, 2NF, 3NF and BCNF decompositions and desirable properties of them.

Unit 6 (8 hours)

File indexing and Transaction Processing: Data Storage and Indexes- Need of file indexes, file organizations, index structures, single- and multi-level indexing, concurrent execution of transactions, ACID properties, need of data recovery and log file.

Essential/recommended readings

1. Elmasri, R., Navathe, B. S. *Fundamentals of Database Systems*, 7th Edition, Pearson Education, 2015.
2. Krogh, J. W. *MySQL Connector/Python Revealed: SQL and NoSQL Data Storage Using MySQL for Python Programmers*, Apress, 2018.
3. Murach J. *Murach's MySQL,* 3rd edition, Pearson, 2019.

Additional References

1. Ramakrishnan, R., Gehrke J. *Database Management Systems*, 3rd Edition, McGraw-Hill, 2014.
2. Silberschatz, A., Korth, H. F., Sudarshan S. *Database System Concepts*, 7th Edition, McGraw Hill, 2019.
3. Connolly, T. M., Begg, C. E. *Database Systems: A Practical Approach to Design, Implementation, and Management*, 6th edition, Pearson, 2019.

Suggested Practical List (If any): (30 Hours)

Practical exercises such as

It has three components.

I. Create and use the following student-society database schema for a college to answer the given (sample) queries using the standalone SQL editor.

STUDENT	Roll No	StudentName	Course	DOB
	Char(6)	Varchar(20)	Varchar(10)	Date

SOCIETY	**SID**	**SocName**	**MentorName**	**TotalSeats**
	Char(6)	Varchar(20)	Varchar(15)	Unsigned int

ENROLLMENT	**Roll No**	**SID**	**DateOfEnrollment**
	Char(6)	Char(6)	**Date**

Here Rollno (ENROLLMENT) and SID (ENROLLMENT) are foreign keys.

1. Retrieve names of students enrolled in any society.
2. Retrieve all society names.
3. Retrieve students' names starting with letter 'A'.
4. Retrieve students' details studying in courses 'computer science' or 'chemistry'.
5. Retrieve students' names whose roll no either starts with 'X' or 'Z' and ends with '9'
6. Find society details with more than N TotalSeats where N is to be input by the user
7. Update society table for mentor name of a specific society
8. Find society names in which more than five students have enrolled
9. Find the name of youngest student enrolled in society 'NSS'
10. Find the name of most popular society (on the basis of enrolled students)
11. Find the name of two least popular societies (on the basis of enrolled students)
12. Find the student names who are not enrolled in any society
13. Find the student names enrolled in at least two societies
14. Find society names in which maximum students are enrolled
15. Find names of all students who have enrolled in any society and society names in which at least one student has enrolled
16. Find names of students who are enrolled in any of the three societies 'Debating', 'Dancing' and 'Sashakt'.
17. Find society names such that its mentor has a name with 'Gupta' in it.
18. Find the society names in which the number of enrolled students is only 10% of its capacity.
19. Display the vacant seats for each society.
20. Increment Total Seats of each society by 10%
21. Add enrollment fees paid ('yes'/'No') field in the enrollment table.
22. Update date of enrollment of society id 's1' to '2018-01-15', 's2' to current date and 's3' to '2018-01-02'.
23. Create a view to keep track of society names with the total number of students enrolled in it.
24. Find student names enrolled in all the societies.
25. Count number of societies with more than 5 student enrolled in it
26. Add column Mobile number in student table with default value '9999999999'
27. Find the total number of students whose age is > 20 years.
28. Find names of students who are born in 2001 and are enrolled in at least one society.
29. Count all societies whose name starts with 'S' and ends with 't' and at least 5 students are enrolled in the society.
30. Display the following information:

Society name Mentor name Total Capacity Total Enrolled Unfilled Seats

II. Do the following database administration commands:
create user, create role, grant privileges to a role, revoke privileges from a role, create index

II. Execute queries given in part I through a high-level language using ODBC connection.

DISCIPLINE SPECIFIC CORE COURSE– 12 (DSC-12): Computer Networks

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits				Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC12 Computer Networks	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b: Java Programming

Learning Objectives
The course objectives of this paper are to:

- Understand the concepts behind computer networks and data communication.
- Learn the different types of networks, network topologies and their characteristics.
- Learn the working of protocols used at various layers.
- Understand the utility of different networking devices.

Learning outcomes

Upon successful completion of the course, students will be able to:
- differentiate between various types of computer networks and their topologies.
- understand the difference between the OSI and TCP/IP protocol suit.

- distinguish between different types of network devices and their functions.
- design/implement data link and network layer protocols in a simulated networking environment.

SYLLABUS OF DSC06

Unit 1 (8 hours)
Introduction: Types of computer networks, Internet, Intranet, network topologies (bus, star, ring, mesh, tree, hybrid topologies), network classifications. layered architecture approach, OSI Reference Model, TCP/IP Reference Model. Transmission Modes: simplex, half duplex and full duplex.

Unit 2 (9 hours)
Physical Layer: Analog signal, digital signal, the maximum data rate of a channel, transmission media (guided transmission media, wireless transmission, satellite communication), multiplexing (frequency division multiplexing, time-division multiplexing, wavelength division multiplexing). Guided Media (Wired) (Twisted pair, Coaxial Cable, Fiber Optics. Unguided Media (Radio Waves, Infrared, Micro-wave, Satellite).

Unit 3 (10 hours)
Data Link and MAC Layer: Data link layer services, error detection and correction techniques, error recovery protocols (stop and wait, go back n, selective repeat), multiple access protocols with collision detection, MAC addressing, Ethernet, data link layer switching, point-to-point protocol.

Unit 4 (8 hours)
Network layer: Networks and Internetworks, virtual circuits and datagrams, addressing, subnetting, Dijkstra Routing algorithm, Distance vector routing, Network Layer protocol- (ARP, IPV4, ICMP).

Unit 5 (10 hours)
Transport and Application Layer: Process to process Delivery- (client-server paradigm, connectionless versus connection-oriented service); User Datagram Protocols, TCP/IP protocol, Flow Control. FTP (File Transfer Protocol), SMTP (Simple Mail Transfer Protocol), Telnet (Remote login protocol), WWW (World Wide Web), HTTP (HyperText Transfer Protocol), URL (Uniform Resource Locator).

Essential/recommended readings

1. Tanenbaum, A.S. & Wethrall, D.J.. *Computer Networks*, 5th edition, Pearson Education, 2012.

2. Forouzan, B. A.. *Data Communication and Networking*, 4th edition, McGraw-Hill Education, 2017.

Additional References

1. Comer, D. E.. *Computer Networks and Internet,* 6th edition*,* Pearson education, 2015.

2. Stallings, W., *Data and Computer Communications,* 10th edition, Pearson education India, 2017.

Suggested Practical List :

Practical exercises such as

Introduce students to any network simulator tool and do the following:

1. To Study basic network command and Network configuration commands.
2. To study and perform PC to PC communication.
3. To create Star topology using Hub and Switch.
4. To create Bus, Ring, Tree, Hybrid, Mesh topologies.
5. Perform an initial Switch configuration.
6. Perform an initial Router configuration.
7. To implement Client Server Network.
8. To implement connection between devices using router.
9. To perform remote desktop sharing within LAN connection.

Computer Science Courses for Undergraduate Programme of study with Computer Science discipline Elective

DISCIPLINE SPECIFIC ELECTIVE COURSE: Data Mining - I

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Data Mining - I	**4**	**3**	**0**	**1**	Pass in Class XII	DSC01 Programming using Python / GE1b Programming with Python

Learning Objectives

This course aims to introduce data mining techniques and their application on real-life datasets. The students will learn to pre-process the dataset and make it ready for application of data mining techniques. The course will focus on three main techniques of data mining i.e. Classification, Clustering and Association Rule Mining. Different algorithms for these techniques will be discussed along with appropriate evaluation metrics to judge the performance of the results delivered.

Learning outcomes

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

1. Pre-process the data for subsequent data mining tasks
2. Apply a suitable classification algorithm to train the classifier and evaluate its performance.
3. Apply appropriate clustering algorithm to cluster the data and evaluate clustering quality
4. Use association rule mining algorithms and generate frequent item-sets and association rules

SYLLABUS OF DSE

Unit 1 (5 hours)

Introduction to Data Mining: Motivation and challenges for data mining, Types of data mining tasks, Applications of data mining, Data measurements, Data quality, Supervised vs. unsupervised techniques

Unit 2 (10 hours)

Data Pre-processing: Data aggregation, sampling, dimensionality reduction, feature subset selection, feature creation, variable transformation.

Unit 3 (10 hours)

Cluster Analysis: Basic concepts of clustering, measure of similarity, types of clusters and clustering methods, K-means algorithm, measures for cluster validation, determine optimal number of clusters

Unit 4 (10 hours)

Association Rule mining: Transaction data-set, frequent itemset, support measure, rule generation, confidence of association rule, Apriori algorithm, Apriori principle

Unit 5 (10 hours)

Classification: Naive Bayes classifier, Nearest Neighbour classifier, decision tree, overfitting, confusion matrix, evaluation metrics and model evaluation.

Essential/recommended readings

1. Tan P.N., Steinbach M, Karpatne A. and Kumar V. *Introduction to Data Mining,* 2nd edition, Pearson, 2021.
2. Han J., Kamber M. and Pei J. *Data Mining: Concepts and Techniques*, 3rd edition, 2011, Morgan Kaufmann Publishers.
3. Zaki M. J. and Meira J. Jr. *Data Mining and Machine Learning: Fundamental Concepts and Algorithms*, 2nd edition, Cambridge University Press, 2020.

Additional References

1. Aggarwal C. C. *Data Mining: The Textbook*, Springer, 2015.
2. Dunham M. *Data Mining: Introductory and Advanced Topics,* 1st edition, Pearson Education India, 2006.

Suggested Practical List (If any): (30 Hours)

Practical exercises such as

All topics covered in theory will be implemented using Python. The operations may be performed on the datasets loaded through scikit, seaborn libraries or can be downloaded from from Open Data Portal (https:// data.gov.in/, UCI repository http://archive.ics.uci.edu/ml/).

Recommended Datasets for :

Classification: Abalone, Artificial Characters, Breast Cancer Wisconsin (Diagnostic)

Clustering: Grammatical Facial Expressions, HTRU2, Perfume data

Association Rule Mining: MovieLens, Titanics

Additional Suggested Practicals List

1. Apply data cleaning techniques on any dataset (e,g, wine dataset). Techniques may include handling missing values, outliers, inconsistent values. A set of validation rules can be prepared based on the dataset and validations can be performed.
2. Apply data pre-processing techniques such as standardization / normalization, transformation, aggregation, discretization/binarization, sampling etc. on any dataset
3. Run Apriori algorithm to find frequent itemsets and association rules on 2 real datasets and use appropriate evaluation measures to compute correctness of obtained patterns
    a) Use minimum support as 50% and minimum confidence as 75%
    b) Use minimum support as 60% and minimum confidence as 60 %

4. Use Naive bayes, K-nearest, and Decision tree classification algorithms and build classifiers on any two datasets. Divide the data set into training and test set. Compare the accuracy of the different classifiers under the following situations:
    I. a) Training set = 75% Test set = 25% b) Training set = 66.6% (2/3rd of total), Test set = 33.3%
    II. Training set is chosen by i) hold out method ii) Random subsampling iii) Cross-Validation. Compare the accuracy of the classifiers obtained.

   Data is scaled to standard format.
5. Use Simple K-means algorithm for clustering on any dataset. Compare the performance of clusters by changing the parameters involved in the algorithm. Plot MSE computed after each iteration using a line plot for any set of parameters.

Project: Students should be promoted to take up one project on any UCI/kaggle/data.gov.in or a dataset verified by the teacher. Preprocessing steps and at least one data mining technique should be shown on the selected dataset. This will allow the students to have a practical knowledge of how to apply the various skills learnt in the subject for a single problem/project.

DISCIPLINE SPECIFIC ELECTIVE COURSE: Combinatorial Optimization

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Combinatorial Optimization	**4**	**3**	**1**	**0**	Pass in Class XII	NIL

Learning Objectives

This course is designed to introduce the fundamentals of combinatorial optimization to the students in terms of both theory and applications, so as to equip them to explore the more advanced areas of convex and non-convex optimizations.

Learning outcomes

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

- Model problems using linear and integer programs
- Apply polyhedral analysis to develop algorithms for optimization problems
- Use the concept of duality for design of algorithms

SYLLABUS OF DSE

Unit 1 (9 hours)

Introduction: Introduction to Combinatorial Optimization Problems, Linear and Integer Programs- LP Formulation, understanding integer programs, computational complexities of IP vs LP, using LP to find optimal or approximate integral solutions, concept of integrality gap.

Unit 2 (14 hours)

Theory of Linear Programming and Algorithmic Perspective to Simplex Method: standard vs. equational form, basic feasible solutions, convexity and convex polyhedra, correspondence between vertices and basic feasible solutions, geometry of Simplex algorithm, exception handling (unboundedness, degeneracy, infeasibility), Simplex algorithm, avoiding cycles.

Unit 3 (12 hours)

Primal-Dual Algorithms: interpretation of dual, optimality conditions for primal and dual, weak and strong duality, complementary slackness, primal-dual algorithm for the shortest path problem.

Unit 4 (10 hours)

Network Flows: linear programming formulations for network flows and bipartite matching, totally unimodular matrices.

Essential/recommended readings

2. Papadimitriou, C.H. & Steiglitz, K. *Combinatorial Optimization: Algorithms and complexity*, New edition, Dover Publications inc., 2000.

Additional References

(i) Bazaraa, M.S., Jarvis, J.J., & and Sherali, H.D. *Linear Programming and Network Flows*, 4th edition, Wiley, 2010.

(ii) Korte, B., & Vygen, J. *Combinatorial Optimization,* 6th edition, Springer, 2018.

Tutorials

Tutorials based on Theory

DISCIPLINE SPECIFIC ELECTIVE COURSE: Network Security

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Network Security		**3**	**1**	**0**	Pass in Class XII	DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b: Java Programming

Learning Objectives

This course will provide students with an understanding of the fundamental concepts, principles, and techniques of network security. Students will learn how to assess, design, and implement secure networks using various tools and technologies.

Learning outcomes

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

- Describe the importance of network security and the principles of the CIA triad (confidentiality, integrity, and availability), types of security threats and attacks
- Describe the basics of cryptography, including symmetric and asymmetric encryption, hash functions, digital signatures, and public key infrastructure (PKI).
- Apply authentication and access control techniques, including password-based, token-based, and biometric authentication, as well as authorization models and single sign-on (SSO).
- Design and implement secure networks using network segmentation, security zones, and VPNs for remote access.

- Implement and manage firewalls, intrusion detection systems (IDS), and intrusion prevention systems (IPS) to protect network resources, secure wireless networks,
- Implement endpoint security and malware protection measures, including antivirus, patch management, and host-based firewalls.

SYLLABUS OF DSE

Unit 1 (10 hours)

Introduction to Network Security and Network Fundamentals: Importance of network security, Confidentiality, integrity, and availability (CIA) triad, Types of security threats and attacks. OSI and TCP/IP models. IP addressing and subnetting. Networking devices (hubs, switches, routers, firewalls). Network protocols and services (HTTP, HTTPS, FTP, SSH, etc.).

Unit 2 (12 hours)

Cryptography Basics, Authentication and Access Control, Secure Network Design: Symmetric and asymmetric encryption, Hash functions and digital signatures, Public key infrastructure (PKI), Common cryptographic algorithms (AES, RSA, SHA, etc.). Authentication techniques (passwords, tokens, biometrics), Authorization and access control models (RBAC, ABAC, MAC, DAC), Single sign-on (SSO) and multi-factor authentication (MFA). Defense-in-depth strategy, Network segmentation and isolation, Security zones and DMZ, VPNs and secure remote access.

Unit 3 (12 hours)

Firewalls and Intrusion Detection/Prevention Systems, Wireless Network Security: Types of firewalls (packet filtering, stateful inspection, application layer), IDS and IPS concepts and deployment, Signature-based and anomaly-based detection, Honeypots and honeynets. Wireless standards and technologies (802.11, Bluetooth, RFID), Wireless security protocols (WEP, WPA, WPA2, WPA3), Rogue access points and wireless attacks, Securing wireless networks.

Unit 4 (8 hours)

Endpoint Security and Malware Protection, Security Monitoring and Incident Response: Antivirus and antimalware solutions, Patch management and software updates, Host-based firewalls and intrusion detection, Mobile device management (MDM). Security Information and Event Management (SIEM) systems, Log management and analysis, Incident response process and procedures, Forensic analysis and evidence handling.

Unit 5 (3 hours)

Network Security Best Practices and Compliance: Security policies and procedures, Risk assessment and management, Security awareness training, Regulatory compliance (HIPAA, GDPR, PCI-DSS, etc.).

Essential/recommended readings

1. Behrouz Forouzan, Cryptography and network security. 3rd edition (2015), McGraw Hill Education.

2. Stallings, W. (2021). Cryptography and Network Security: Principles and Practice (8th Edition). Pearson.
3. Harris, S. (2018). All-in-One CISSP Exam Guide (8th Edition). McGraw-Hill Education.
4. Atul Kahate, Cryptography and Network Security, McGraw-Hill; Fourth edition (8 May 2019); McGraw Hill Education (India).

Additional References

i. Conklin, W. A., White, G., Williams, D., Davis, R., & Cothren, C. (2021). Principles of Computer Security: CompTIA Security+ and Beyond (6th Edition). McGraw-Hill Education.
ii. Chapple, M., & Seidl, D. (2020). Network Security For Dummies. Wiley.
iii. Gibson, D. (2021). CompTIA Security+ Get Certified Get Ahead: SY0-601 Study Guide. YCDA Publishing.

Online Additional Reference Materials:

1. NIST Special Publications: https://csrc.nist.gov/publications/sp
    a. SP 800-53: Security and Privacy Controls for Federal Information Systems and Organizations
    b. SP 800-82: Guide to Industrial Control Systems (ICS) Security
    c. SP 800-115: Technical Guide to Information Security Testing and Assessment
2. ISO/IEC 27000 series: Information Security Management Systems (ISMS)
    a. ISO/IEC 27001: Information Security Management
    b. ISO/IEC 27002: Code of Practice for Information Security Controls
    c. ISO/IEC 27005: Information Security Risk Management
3. Center for Internet Security (CIS) Critical Security Controls: https://www.cisecurity.org/controls/
    a. A prioritized set of actions to improve network security.
4. OWASP Top Ten Project: https://owasp.org/www-project-top-ten/
    a. A list of the most critical web application security risks.
5. SANS Institute Reading Room: https://www.sans.org/reading-room/
    a. A collection of whitepapers and articles on various network security topics.
6. Vendor documentation and best practices guides (Cisco, Juniper, Palo Alto Networks, etc.)

DISCIPLINE SPECIFIC ELECTIVE COURSE: Introduction to Web Programming

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Introduction to web programming	**4**	**3**	**0**	**1**	Pass in Class XII	NIL

Learning Objectives

The course aims at introducing the basic concepts and techniques of client side web programming. The student shall be able to develop simple websites using HTML, CSS and Javascript.

Learning outcomes

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

- Build websites using the elements of HTML.
- Build dynamic websites using the client side programming techniques with CSS, Javascript and jQuery.
- Learn to validate client-side data.

SYLLABUS OF DSE

Unit 1 (5 hours)

Introduction: Introduction to Internet and web design. Basic concepts of web architecture.

Unit 2 (12 hours)

HTML: Introduction to hypertext mark-up language (html), creating web pages, lists, hyperlinks, tables, web forms, inserting images, frames.

Unit 3 (8 hours)

Cascading style sheet (CSS): Concept of CSS, creating style sheet, Importing style sheets, CSS properties, CSS styling (background, text format, controlling fonts), CSS rules, Style Types, CSS Selectors, CSS cascade, working with block elements and objects, working with lists and tables, CSS id and class, box model (introduction, border properties, padding properties, margin properties).

Unit 4 (10 hours)

Javascript: Document object model, data types and variables, functions, methods and events, controlling program flow, JavaScript object model, built-in objects and operators, validations.

Unit 5 (10 hours)

jQuery and JSON: Introduction to jQuery, syntax, selectors, events. JSON file format for storing and transporting data.

Essential/recommended readings

1. Nixon, R. *Learning PHP, MySQL & JavaScript with jQuery, CSS and HTML5*, O'Rielly*,* 2018.
2. Powell, T.A. *HTML & CSS: The Complete Reference, 5th edition*, Tata McGrawHill, 2010.
3. Duckett, J. *JavaScript and JQuery: Interactive Front-End Web Development*, Wiley, 2014.

Additional References

1. Minnick, J. *Web Design with HTML5 and CSS3*, 8th edition, Cengage Learning, 2015.
2. Boehm, A., & Ruvalcaba, Z. *Munarch's HTML5 and CCS,* 4th edition, Mike Murach & Associates, 2018.
3. J. A. Ramalho *Learn Advanced HTML 4.0 with DHTML*, BPB Publications, 2007.
4. Ivan Bayross *Web Enabled Commercial Application Development Using Html, Dhtml, Javascript, Perl CGI*, BPB Publications, 2009.

Suggested Practical List (If any): (30 Hours)

Practical exercises such as

HTML

1. Create an HTML document with following formatting – Bold, Italics, Underline, Colors, Headings, Title, Font and Font Width, Background, Paragraph, Line Brakes, Horizontal Line, Blinking text as well as marquee text.
2. Create an HTML document with Ordered and Unordered lists, Inserting Images, Internal and External linking
3. Create an HTML displaying this semester's time table.
4. Create a website with horizontal and vertical frames. Top horizontal frame showing your college's name and logo. Bottom horizontal frame split into two vertical frames. The left frame with hyperlinks to pages related to faculty, courses, student activities, etc. The right frame showing corresponding pages based on the link clicked on the left frame.
5. Create a student registration form using HTML which has the following controls:

I. Text Box
II. Dropdown box
III. Option/radio buttons
IV. Check boxes
V. Reset and Submit button

CSS

Create a webpage for your department with drop down navigation menu for faculty, courses, activities, etc.. Implement the webpage using styles, rules, selectors, ID, class.

Javascript

1. Create event driven programs for the following:
    a. Enter a number and on click of a button print its multiplication table.
    b. Print the largest of three numbers entered by the user.
    c. Find the factorial of a number entered by the user.
    d. Enter a list of positive numbers using the prompt terminated by a zero. Find the sum and average of these numbers.
2. Create a student registration form using text, radio button, check box, drop down box, text field and all other required HTML elements. Customise the CSS and javascript to input and validate all data. Create functions to perform validation of each element, example:
    a. Roll number is a 7-digit numeric value
    b. Name should be an alphabetical value(String)
    c. Non-empty and valid fields like DOB

jQuery and JSON

1. Change text color and contents using button click events using jQuery
2. Select elements using ID, class, elements name, attribute name
3. Run code on click events in jQuery
4. Handle HTML form, store the data in JSON object, pass them to another page and display it there using jQuery/Javascript

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES

GENERIC ELECTIVES (GE-4a): Data Structures using C++

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE4a Data Structures using C++	**4**	**3**	**0**	**1**	Pass in Class XII	NIL

Learning Objectives

The course aims at developing the ability to use basic data structures like arrays, stacks, queues, lists, trees to solve problems. C++ is chosen as the language to understand implementation of these data structures.

Learning outcomes

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

- Compare two functions for their rates of growth.
- Understand abstract specification of data-structures and their implementation.
- Compute time and space complexity of operations on a data-structure.
- Identify the appropriate data structure(s) for a given application and understand the trade-offs involved in terms of time and space complexity.
- Apply recursive techniques to solve problems.

SYLLABUS OF GE-4a

Unit 1 (7 hours)

Growth of Functions, Recurrence Relations: Functions used in analysis, asymptotic notations, asymptotic analysis, solving recurrences using recursion tree, Master Theorem.

Unit 2 (14 hours)

Arrays, Linked Lists, Stacks, Queues, Deques: Arrays: array operations, applications, sorting, two-dimensional arrays, dynamic allocation of arrays; Linked Lists: singly linked lists, doubly linked lists, circularly linked lists, Stacks: stack as an ADT, implementing stacks using arrays, implementing stacks using linked lists, applications of stacks; Queues: queue as an ADT, implementing queues using arrays, implementing queues using linked lists, double-ended queue as an ADT. Time complexity analysis of operations on all data structures.

Unit 3 (4 hours)

Sorting: Insertion Sort, Count Sort and their complexity analysis.

Unit 4 (4 hours)

Recursion: Recursive functions, linear recursion, binary recursion.

Unit 5 (10 hours)

Trees, Binary Trees: Trees: definition and properties, binary trees: definition and properties, traversal of binary trees and their time complexity analysis. Binary Search Trees: insert, delete (by copying), search operations, time complexity analysis of these operation.

Unit 6 (6 hours)

Binary Heap, Priority Queue: Binary Heaps: motivation and introduction, application of heaps - Priority Queues.

Essential/recommended readings

1. Goodrich, M.T, Tamassia, R., & Mount, D., *Data Structures and Algorithms Analysis in C++,* 2^{nd} edition, Wiley, 2011.
2. Cormen, T.H., Leiserson, C.E., Rivest, R. L., Stein C., Introduction to Algorithms. 4^{th} edition. Prentice Hall of India. 2022.
3. Drozdek, A., *Data Structures and Algorithms in C++*, 4^{th} edition, Cengage Learning, 2012.

Additional References

1. Sahni, S. *Data Structures, Algorithms and applications in C++*, 2^{nd} edition. Universities Press, 2011.
2. Langsam Y., Augenstein, M. J., & Tanenbaum, A. M. *Data Structures Using C and C++*, 2^{nd} edition, Pearson, 2009.

Suggested Practical List (If any): (30 Hours)

Practical exercises such as

1. Perform matrix addition and multiplication.
2. Implement following recursive functions:
    a. Factorialof a number
    b. N^{th} fibonacci number
    c. Power function: x^y
3. Implement singly linked lists.
3. Implement doubly linked lists.

4. Implement circular linked lists.
5. Implement stack data structure and its operations using arrays.
6. Implement stack data structure and its operations using linked lists.
7. Convert Prefix expression to Infix and Postfix expressions, and evaluate.
8. Implement queue data structure and its operations using arrays.
9. Implement queue data structure and its operations using linked lists.
10. Implement Binary Trees and its traversals.

GENERIC ELECTIVES (GE-4b): Introduction to Web Programming

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE4b: Introduction to Programming	**4**	**3**	**0**	**1**	Pass in Class XII	NIL

Learning Objectives

The course aims at introducing the basic concepts and techniques of client side web programming. The student shall be able to develop simple websites using HTML, CSS and Javascript.

Learning outcomes

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

- Build websites using the elements of HTML.
- Build dynamic websites using the client side programming techniques with CSS, Javascript and jQuery.
- Learn to validate client-side data.

SYLLABUS OF GE4b

Unit 1 (5 hours)

Introduction: Introduction to Internet and web design. Basic concepts of web architecture.

Unit 2 (12 hours)

HTML: Introduction to hypertext mark-up language (html), creating web pages, lists, hyperlinks, tables, web forms, inserting images, frames.

Unit 3 (8 hours)

Cascading style sheet (CSS): Concept of CSS, creating style sheet, Importing style sheets, CSS properties, CSS styling (background, text format, controlling fonts), CSS rules, Style Types, CSS Selectors, CSS cascade, working with block elements and objects, working with lists and tables, CSS id and class, box model (introduction, border properties, padding properties, margin properties).

Unit 4 (10 hours)

Javascript: Document object model, data types and variables, functions, methods and events, controlling program flow, JavaScript object model, built-in objects and operators, validations.

Unit 5 (10 hours)

jQuery and JSON: Introduction to jQuery, syntax, selectors, events. JSON file format for storing and transporting data.

Essential/recommended readings

1. Nixon, R. *Learning PHP, MySQL & JavaScript with jQuery, CSS and HTML5*, O'Rielly, 2018.
2. Powell, T.A. *HTML & CSS: The Complete Reference, 5th edition*, Tata McGrawHill, 2010.
3. Duckett, J. *JavaScript and JQuery: Interactive Front-End Web Development*, Wiley, 2014.

Additional References

1. Minnick, J. *Web Design with HTML5 and CSS3*, 8th edition, Cengage Learning, 2015.
2. Boehm, A., & Ruvalcaba, Z. *Munarch's HTML5 and CCS,* 4th edition, Mike Murach & Associates, 2018.
3. J. A. Ramalho *Learn Advanced HTML 4.0 with DHTML*, BPB Publications, 2007.
4. Ivan Bayross *Web Enabled Commercial Application Development Using Html, Dhtml, Javascript, Perl CGI*, BPB Publications, 2009.

Suggested Practical List (If any): (30 Hours)

Practical exercises such as

HTML

1. Create an HTML document with following formatting – Bold, Italics, Underline, Colors, Headings, Title, Font and Font Width, Background, Paragraph, Line Brakes, Horizontal Line, Blinking text as well as marquee text.
2. Create an HTML document with Ordered and Unordered lists, Inserting Images, Internal and External linking
3. Create an HTML displaying this semester's time table.
4. Create a website with horizontal and vertical frames. Top horizontal frame showing

your college's name and logo. Bottom horizontal frame split into two vertical frames. The left frame with hyperlinks to pages related to faculty, courses, student activities, etc. The right frame showing corresponding pages based on the link clicked on the left frame.

5. Create a student registration form using HTML which has the following controls:
   I. Text Box
   II. Dropdown box
   III. Option/radio buttons
   IV. Check boxes
   V. Reset and Submit button

CSS

Create a webpage for your department with drop down navigation menu for faculty, courses, activities, etc.. Implement the webpage using styles, rules, selectors, ID, class.

Javascript

1. Create event driven programs for the following:
   e. Enter a number and on click of a button print its multiplication table.
   f. Print the largest of three numbers entered by the user.
   g. Find the factorial of a number entered by the user.
   h. Enter a list of positive numbers using the prompt terminated by a zero. Find the sum and average of these numbers.
2. Create a student registration form using text, radio button, check box, drop down box, text field and all other required HTML elements. Customise the CSS and javascript to input and validate all data. Create functions to perform validation of each element, example:
   d. Roll number is a 7-digit numeric value
   e. Name should be an alphabetical value(String)
   f. Non-empty and valid fields like DOB

jQuery and JSON

1. Change text color and contents using button click events using jQuery
2. Select elements using ID, class, elements name, attribute name
3. Run code on click events in jQuery

(Computer Science Courses for Undergraduate Programme of study with Computer Science discipline as one of the three Core Disciplines)

DISCIPLINE SPECIFIC CORE COURSE (DSC04): Operating Systems

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC04: Operating Systems	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 01 Programming using Python/ A course in C/C++/Python at plus 2 level.

Learning Objectives

This course introduces the students to Operating Systems and its importance in computer systems. The focus is to explain the common services provided by an operating system like process management, memory (primary, secondary & virtual) management, I/O management, file management. The course talks about the various functional components of the operating and their design.

Learning outcomes

On successful completion of the course, students will be able to

- gain knowledge of different concepts of the operating System and its components.
- learn about shell scripts and would be able to use the system in an efficient manner.

SYLLABUS OF DSC04

Unit 1 (4 hours)

Introduction: Operating Systems (OS) definition and its purpose, Multiprogrammed and Time Sharing Systems, OS Structure, OS Operations: Dual and Multi-mode, OS as resource manager.

Unit 2 (10 hours)

Operating System Structures: OS Services, System Calls: Process Control, File Management, Device Management, and Information Maintenance, Inter-process Communication, and Protection, System programs, OS structure- Simple, Layered, Microkernel, and Modular.

Unit 3 (9 hours)

Process Management: Process Concept, States. Process Control Block, Context Switch, Process scheduling, Schedulers, Overview of threads and Scheduling Algorithms: First Come First Served, Shortest-Job-First, Priority & Round-Robin.

Unit 4 (9 hours)

Memory Management: Physical and Logical address space, Swapping Contiguous memory allocation strategies - fixed and variable partitions, Segmentation, Paging, virtual memory: Demand Paging.

Unit 5 (8 hours)

File and Input / Output Device Management: File Concepts, File Attributes, File Access Methods, Directory Structure: Single-Level, Two-Level, Tree-Structured, and Acyclic-Graph Directories, Magnetic Disks, Solid-State Disks, Magnetic Tapes.

Unit 6 (5 hours)

Shell Scripting: Shell variables, parameter passing conditional statements, iterative statements, writing and executing shell scripts, utility programs (cut, paste, grep, echo, pipe, filter etc.)

Essential/recommended readings

1. Galvin, S. P. B., Gagne, G., *Operating System Concepts*, 9th edition, John Wiley Publications, 2016.
2. G. Nutt, Operating Systems, Pearson, 2009
3. Das, S., *Unix: Concepts and Applications*, 4th edition, TMH, 2009.

Additional References

1. Dhamdhere, D. M., *Operating Systems: A Concept-based Approach,* 2nd edition, Tata McGraw-Hill Education, 2017.
2. Kernighan, B. W., Pike, R., *The Unix Programming Environment*, Englewood Cliffs, NJ: Prentice-Hall, 1984.
3. Stallings, W., *Operating Systems: Internals and Design Principles*, 9th edition, Pearson Education, 2018.
4. Tanenbaum, A. S., *Modern Operating Systems.* 3rd edition, Pearson Education, 2007.

Suggested Practical List (If any): (30 Hours)

Practical exercises such as

1. Execute various LINUX commands for:
   i. Information Maintenance: wc, clear, cal, who, date, pwd
   ii. File Management: cat, cp, rm, mv, cmp, comm, diff, find, grep
   iii. Directory Management : cd, mkdir, rmdir, ls

2. Execute various LINUX commands for:
   i. Process Control: fork, getpid, ps
   ii. Communication: Input-output redirection, Pipe
   iii. Protection Management: chmod, chown, chgrp

3. Write a program(using fork() and/or exec() commands) where parent and child execute:
   i. same program, same code.
   ii. same program, different code.
   iii. before terminating, the parent waits for the child to finish its task.

4. Write a program to calculate sum of n numbers using Pthreads.

5. Write a program to generate a Fibonacci Series of numbers using Pthreads.

6. Write a program to implement best-fit and worst-fit allocation strategies

7. Write a program to copy files using system calls and using pthreads and compare timings.

8. Write a program to implement FCFS scheduling algorithm.

9. Write a program to implement SJF scheduling algorithm.

10. Write a program to implement non-preemptive priority based scheduling algorithm.

Computer Science Courses for Undergraduate Programme of study with Computer Science discipline as one of the two Core Disciplines
(For e.g. courses for B.A. Programmes with Computer Science as Major discipline)

Computer Science Major

DISCIPLINE SPECIFIC CORE COURSE (DSC04): Operating Systems

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC04: Operating Systems	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 01 Programming using Python/ A course in C/C++/Python at plus 2 level

Learning Objectives

This course introduces the students to Operating Systems and its importance in computer systems. The focus is to explain the common services provided by an operating system like process management, memory (primary, secondary & virtual) management, I/O management, file management. The course talks about the various functional components of the operating and their design.

Learning outcomes

On successful completion of the course, students will be able to

- gain knowledge of different concepts of the operating System and its components.
- learn about shell scripts and would be able to use the system in an efficient manner.

SYLLABUS OF DSC04

Unit 1 (4 hours)

Introduction: Operating Systems (OS) definition and its purpose, Multiprogrammed and Time Sharing Systems, OS Structure, OS Operations: Dual and Multi-mode, OS as resource manager.

Unit 2 (10 hours)

Operating System Structures: OS Services, System Calls: Process Control, File Management, Device Management, and Information Maintenance, Inter-process Communication, and Protection, System programs, OS structure- Simple, Layered, Microkernel, and Modular.

Unit 3 (9 hours)

Process Management: Process Concept, States. Process Control Block, Context Switch, Process scheduling, Schedulers, Overview of threads and Scheduling Algorithms: First Come First Served, Shortest-Job-First, Priority & Round-Robin.

Unit 4 (9 hours)

Memory Management: Physical and Logical address space, Swapping Contiguous memory allocation strategies - fixed and variable partitions, Segmentation, Paging, virtual memory: Demand Paging.

Unit 5 (8 hours)

File and Input / Output Device Management: File Concepts, File Attributes, File Access Methods, Directory Structure: Single-Level, Two-Level, Tree-Structured, and Acyclic-Graph Directories, Magnetic Disks, Solid-State Disks, Magnetic Tapes.

Unit 6 (5 hours)

Shell Scripting: Shell variables, parameter passing conditional statements, iterative statements, writing and executing shell scripts, utility programs (cut, paste, grep, echo, pipe, filter etc.)

Essential/recommended readings

1. Galvin, S. P. B., Gagne, G., *Operating System Concepts*, 9th edition, John Wiley Publications, 2016.
2. G. Nutt, Operating Systems, Pearson, 2009
3. Das, S., *Unix: Concepts and Applications*, 4th edition, TMH, 2009.

Additional References

1. Dhamdhere, D. M., *Operating Systems: A Concept-based Approach,* 2nd edition, Tata McGraw-Hill Education, 2017.
2. Kernighan, B. W., Pike, R., *The Unix Programming Environment*, Englewood Cliffs, NJ: Prentice-Hall, 1984.
3. Stallings, W., *Operating Systems: Internals and Design Principles*, 9th edition, Pearson Education, 2018.
4. Tanenbaum, A. S., *Modern Operating Systems.* 3rd edition, Pearson Education, 2007.

Suggested Practical List (If any): (30 Hours)

Practical exercises such as

1. Execute various LINUX commands for:
   i. Information Maintenance: wc, clear, cal, who, date, pwd
   iv. File Management: cat, cp, rm, mv, cmp, comm, diff, find, grep
   v. Directory Management : cd, mkdir, rmdir, ls
2. Execute various LINUX commands for:
   iv. Process Control: fork, getpid, ps
   v. Communication: Input-output redirection, Pipe
   vi. Protection Management: chmod, chown, chgrp
3. Write a program(using fork() and/or exec() commands) where parent and child execute:
   iv. same program, same code.
   v. same program, different code.
   vi. before terminating, the parent waits for the child to finish its task.
4. Write a program to calculate sum of n numbers using Pthreads.
5. Write a program to generate a Fibonacci Series of numbers using Pthreads.
6. Write a program to implement best-fit and worst-fit allocation strategies
7. Write a program to copy files using system calls and using pthreads and compare timings.
8. Write a program to implement FCFS scheduling algorithm.
9. Write a program to implement SJF scheduling algorithm.
10. Write a program to implement non-preemptive priority based scheduling algorithm.

DISCIPLINE SPECIFIC CORE COURSE (A4): Data Mining-II

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
A4: Data Mining - II	**4**	**3**	**0**	**1**	Pass in Class XII	DSC01 Programming using Python, / GE1b

						Programming with Python / A1 Programming Fundamentals using Python ,Data Mining-I

Learning Objectives

The course introduces the students to the supervised and unsupervised learning techniques. Students will learn about the importance of ensemble methods, cluster analysis, anomaly detection and their applicability in mining patterns in real applications. At the end students will be exposed to two advanced topics: text mining and time-series mining. Students will use the learned topics in solving real applications using open-source software.

Learning outcomes

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

- Differentiate between partition-based, density-based and hierarchical clustering
- Build ensemble models to improve predictive performance of the classifier
- Identify anomalies and outliers using supervised and unsupervised techniques
- Analyze time-series data and extract patterns from the stamped data
- Mine textual data and do topic modeling

SYLLABUS OF A4

Unit 1 (9 hours)

Clustering: Partitioning Methods, Hierarchical Methods, Density-Based Methods, Comparison of different methods

Unit 2 (8 hours)

Ensemble Methods: Need of ensemble, Random Forests, Bagging and Boosting

Unit 3 (10 hours)

Anomaly Detection: Outliers and Outlier Analysis, Outlier Detection Methods, Statistical Approaches, Proximity-based and density-based outlier detection, Clustering-based approaches

Unit 4 (8 hours)

Mining Text Data: Document Preparation and Similarity, Clustering Methods for Text, Topic Modeling

Unit 5 (10 hours)

Stream Mining: Time series basics, Date Ranges, Frequencies, and Shifting, Resampling and moving windows functions, Decay function, Clustering stamped data: STREAM and CluStream

Essential/recommended readings

1. Tan P.N., Steinbach M, Karpatne A. and Kumar V. *Introduction to Data Mining,* 2nd edition, Pearson, 2019.
2. Zaki M. J. and Meira J. Jr. *Data Mining and Machine Learning: Fundamental Concepts and Algorithms*, 2nd edition, Cambridge University Press, 2020.
3. Aggarwal C. C. *Data Mining: The Textbook*, Springer, 2015.

Additional References

1. Han J. Kamber M. and Pei J. *Data Mining: Concepts and Techniques*, Morgan Kaufmann Publishers, 2011.
2. Dunham M. *Data Mining: Introductory and Advanced Topics*, Pearson, 2006.

Suggested Practicals List (If any): (30 Hours)

Practical exercise such as

1. Apply Partitioning Methods, Hierarchical Methods, Density-Based Methods for clustering on a data set and compare the performance of the obtained results using different metrics
2. Create an ensemble using Random Forest and show the impact of bagging and boosting on the performance
3. Apply different outlier-detection methods on a noisy dataset and compare their effectiveness in terms of outliers reported
4. Compute similarity between two documents after required document preparation
5. Considering a time-stamped data (sales data/weather data), compare the aggregate values visually using different moving windows function
6. Write a program to find the latent topics in a document using any topic modeling method and display top 5 terms that contribute to each topic along with their strength. Also, visualize the distribution of terms contributing to the topics.

Project: Students should be promoted to take up one project covering at least one unit of the syllabus on any UCI/kaggle/data.gov.in or a dataset verified by the teacher. This will allow the students to have a practical knowledge of how to apply the various skills learnt in the subject for a single problem/project.

Computer Science Courses for Undergraduate Programme of study with Computer Science discipline as one of the two Core Disciplines
(For e.g. courses for B.A. Programmes with Computer Science as Non-major discipline)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
DSC04: Operating Systems	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 01 Programming using Python/ A course in C/C++/Python at plus 2 level

Learning Objectives

This course introduces the students to Operating Systems and its importance in computer systems. The focus is to explain the common services provided by an operating system like process management, memory (primary, secondary & virtual) management, I/O management, file management. The course talks about the various functional components of the operating and their design.

Learning outcomes

On successful completion of the course, students will be able to

- gain knowledge of different concepts of the operating System and its components.
- learn about shell scripts and would be able to use the system in an efficient manner.

SYLLABUS OF DSC04

Unit 1 (4 hours)

Introduction: Operating Systems (OS) definition and its purpose, Multiprogrammed and Time Sharing Systems, OS Structure, OS Operations: Dual and Multi-mode, OS as resource manager.

Unit 2 (10 hours)

Operating System Structures: OS Services, System Calls: Process Control, File Management, Device Management, and Information Maintenance, Inter-process Communication, and Protection, System programs, OS structure- Simple, Layered, Microkernel, and Modular.

Unit 3 (9 hours)

Process Management: Process Concept, States. Process Control Block, Context Switch, Process scheduling, Schedulers, Overview of threads and Scheduling Algorithms: First Come First Served, Shortest-Job-First, Priority & Round-Robin.

Unit 4 (9 hours)

Memory Management: Physical and Logical address space, Swapping Contiguous memory allocation strategies - fixed and variable partitions, Segmentation, Paging, virtual memory: Demand Paging.

Unit 5 (8 hours)

File and Input / Output Device Management: File Concepts, File Attributes, File Access Methods, Directory Structure: Single-Level, Two-Level, Tree-Structured, and Acyclic-Graph Directories, Magnetic Disks, Solid-State Disks, Magnetic Tapes.

Unit 6 (5 hours)

Shell Scripting: Shell variables, parameter passing conditional statements, iterative statements, writing and executing shell scripts, utility programs (cut, paste, grep, echo, pipe, filter etc.)

Essential/recommended readings

1. Galvin, S. P. B., Gagne, G., *Operating System Concepts*, 9th edition, John Wiley Publications, 2016.
2. G. Nutt, Operating Systems, Pearson, 2009
3. Das, S., *Unix: Concepts and Applications*, 4th edition, TMH, 2009.

Additional References

1. Dhamdhere, D. M., *Operating Systems: A Concept-based Approach,* 2nd edition, Tata McGraw-Hill Education, 2017.
2. Kernighan, B. W., Pike, R., *The Unix Programming Environment*, Englewood Cliffs, NJ: Prentice-Hall, 1984.
3. Stallings, W., *Operating Systems: Internals and Design Principles*, 9th edition, Pearson Education, 2018.
4. Tanenbaum, A. S., *Modern Operating Systems.* 3rd edition, Pearson Education, 2007.

Suggested Practical List (If any): (30 Hours)

Practical exercises such as

1. Execute various LINUX commands for:
   - i. Information Maintenance: wc, clear, cal, who, date, pwd
   - vi. File Management: cat, cp, rm, mv, cmp, comm, diff, find, grep
   - vii. Directory Management : cd, mkdir, rmdir, ls

2. Execute various LINUX commands for:
   vii. Process Control: fork, getpid, ps
   viii. Communication: Input-output redirection, Pipe
   ix. Protection Management: chmod, chown, chgrp

3. Write a program(using fork() and/or exec() commands) where parent and child execute:
   vii. same program, same code.
   viii. same program, different code.
   ix. before terminating, the parent waits for the child to finish its task.

4. Write a program to calculate sum of n numbers using Pthreads.

5. Write a program to generate a Fibonacci Series of numbers using Pthreads.

6. Write a program to implement best-fit and worst-fit allocation strategies

7. Write a program to copy files using system calls and using pthreads and compare timings.

8. Write a program to implement FCFS scheduling algorithm.

9. Write a program to implement SJF scheduling algorithm.

10. Write a program to implement non-preemptive priority based scheduling algorithm.

SEMESTER-5

DEPARTMENT OF COMPUTER SCIENCE
[UG Programme for Bachelor in Computer Science (Honours)]

DISCIPLINE SPECIFIC CORE COURSE - 13 (DSC-13) : Algorithms and Advanced Data Structures

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC 13 Algorithms and Advanced Data Structures	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 07 Data Structures with C++, DSC 10 Design and Analysis of Algorithms

Learning Objectives

This course is designed to build upon the fundamentals in data structures and algorithm design and gain exposure to more data structures and algorithms for new problems.

Learning outcomes

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

- Comprehend and use data structures for lists.
- Use hash tables for dictionaries.
- Comprehend and use data structures and algorithms for string matching.
- Apply disk based data structures.
- Implement and analyze advanced data structures and algorithms for graphs.
- Describe the purpose of randomization in data structures and algorithms.

Unit 1 (4 hours)

List and Iterator ADTs: Vectors, Lists, Sequences

Unit 2 (6 hours)

Hash Tables, Dictionaries: Hash Functions, Collision resolution schemes.

Unit 3 (8 hours)

Strings: String Matching: KMP algorithm; Tries: Standard Tries, Compressed Tries, Suffix Tries, Search Engines

Unit 4 (8 hours)

More on Trees: 2-4 Trees, B Trees

Unit 5 (8 hours)

More on Graphs: Bellman Ford Algorithm, Union Find Data Structures - application Kruskal's algorithm

Unit 6 (6 hours)

Randomization: Randomized Quicksort, Randomized Select, Skip lists

Unit 7 (5 hours)

Network Flows: Ford Fulkerson algorithm for max flow problem.

Essential/recommended readings

1. Goodrich, M.T, Tamassia, R., & Mount, D. *Data Structures and Algorithms Analysis in C++*, 2nd edition, Wiley, 2011.
2. Cormen, T.H., Leiserson, C.E., Rivest, R. L., Stein C. *Introduction to Algorithms*, 4th edition, Prentice Hall of India, 2022.
3. Kleinberg, J., Tardos, E. *Algorithm Design*, 1st edition, Pearson, 2013.
4. Drozdek, A. *Data Structures and Algorithms in C++*, 4th edition, Cengage Learning. 2012.

Practical List : (30 Hours)

Practical exercises such as

1. Write a program to sort the elements of an array using Randomized Quick sort (the program should report the number of comparisons).
2. Write a program to find the ith smallest element of an array using Randomized Select.
3. Write a program to determine the minimum spanning tree of a graph using Kruskal's algorithm.
4. Write a program to implement the Bellman Ford algorithm to find the shortest paths from a given source node to all other nodes in a graph.

5. Write a program to implement a B-Tree.
6. Write a program to implement the Tree Data structure, which supports the following operations:
   I. Insert
   II. Search
7. Write a program to search a pattern in a given text using the KMP algorithm.
8. Write a program to implement a Suffix tree.

DISCIPLINE SPECIFIC CORE COURSE – 14 (DSC-14): Theory of Computation

Credit distribution, Eligibility and Prerequisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC 14 Theory of Computation	**4**	**3**	**0**	**1**	Pass in Class XII	DSC04 Object Oriented Programming with C++ / GE1a Programming using C++ /A course in C/C++ at plus 2 level

Learning Objectives

This course introduces formal models of computation, namely, finite automaton, pushdown automaton, and Turing machine; and their relationships with formal languages. make students aware of the notion of computation using abstract computing devices. Students will also learn about the limitations of computing machines as this course addresses the issue of which problems can be solved by computational means (decidability vs undecidability

Learning outcomes

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

- design a finite automaton, pushdown automaton or a Turing machine for a problem at hand.

- apply pumping lemma to prove that a language is non-regular/non-context-free.
- describe limitations of a computing machines and
- recognize what can be solved and what cannot be solved using these machines.

SYLLABUS OF DSC 14

Unit 1 (7 hours)

Introduction: Alphabets, string, language, basic operations on language, concatenation, union, Kleene star.

Unit 2 (15 hours)

Finite Automata and Regular: Regular expressions, Deterministic Finite Automata (DFA), Non-deterministic Finite Automata (NFA), relationship between NFA and DFA, Transition Graphs (TG), properties of regular languages, the relationship between regular languages and finite automata, pumping lemma, Kleene's theorem.

Unit 3 (15 hours)

Context-Free Languages (CFL): Context-Free Grammars (CFG), deterministic and non-deterministic Pushdown Automata (PDA), relationship between CFG and PDA, parse trees, leftmost derivation, Ambiguities in grammars, pumping lemma for CFL, properties of CFL, Chomsky Normal Form.

Unit 4 (8 hours)

Turing Machines and Models of Computations: Turing machine as a model of computation, configuration of Turing machine, Recursive and recursively enumerable languages, Church Turing Thesis, Universal Turing Machine, decidability, Halting problem.

Essential/recommended readings

1. Harry R. Lewis and Christos H. Papadimitriou, *Elements of the Theory of Computation*, 2nd Edition, Prentice Hall of India (PHI), 2002
2. Daniel I.A. Cohen, *Introduction to Computer Theory*, 2nd Edition, Wiley India Pvt. Ltd., 2011.

Additional References

1. J.E. Hopcroft, R. Motwani, and J.D. Ullman, *Introduction to Automata Theory, Languages and Computation*, 3rd edition, Addison Wesley, 2006.
2. Peter Linz, *An Introduction to Formal Languages and Automata*, 6th edition, Jones & Bartlett Learning, 2017.

3. Michael Sipser, *Introduction to the Theory of Computation*, Cengage, 2014

DISCIPLINE SPECIFIC CORE COURSE– 15 (DSC-15): Software Engineering

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC 15 Software Engineering		3	0	1	Pass in Class XII	DSC01 Programming using Python/ DSC04 Object Oriented Programming with C++/A course in C/C++ or Python at plus 2 level

Learning Objectives

This course will acquaint the student with different approaches and techniques used to develop good quality software. The course includes learning of various software development process frameworks, requirement analysis, design modeling, qualitative and quantitative software metrics, risk management, and testing techniques.

Learning outcomes

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

- describe the software development models.
- analyse and model customer requirements and build design models.
- estimate and prepare schedule for software projects.
- analyse the impact of risks involved in software development.
- design and build test cases, and perform software testing.

SYLLABUS OF DSC 15

Unit 1 (9 hours)

Introduction: Software Engineering - A Layered Approach; Software Process – Process Framework, Umbrella Activities; Process Models – Waterfall Model, Incremental Model, and Evolutionary process Model (Prototyping, Spiral Model); Introduction to Agile, Agile Model – Scrum.

Unit 2 (6 hours)

Software Requirements Analysis and Specification: Use Case Approach, Software Requirement Specification Document, Flow-oriented Model, Data Flow Model

Unit 3 (8 hours)

Design Modeling: Translating the Requirements model into the Design Model, The Design Process, Design Concepts - Abstraction, Modularity and Functional Independence; Structure Charts.

Unit 4 (7 hours)

Software Metrics and Project Estimation: Function based Metrics, Software Measurement, Metrics for Software Quality; Software Project Estimation (FP based estimations); Project Scheduling (Timeline charts, tracking the schedule).

Unit 5 (5 hours)

Quality Control and Risk Management: Quality Control and Quality Assurance, Software Process Assessment and Improvement; Software Risks, Risk Identification, Risk Projection, Risk Mitigation, Monitoring and Management.

Unit 6 (10 hours)

Software Testing: Strategic Approach to Software Testing, Unit Testing, Integration Testing, Validation Testing, System Testing; Black-Box and White Box Testing, Basis Path Testing.

Essential/recommended readings

1. Pressman, R.S. *Software Engineering: A Practitioner's Approach*, 9th edition, McGraw-Hill, 2020.
2. Aggarwal, K.K., Singh, Y. *Software Engineering*, 3rd edition, New Age International Publishers, 2007.
3. Jalote, P. An Integrated Approach to Software Engineering, 3rd Edition, Narosa Publishing House, 2005.

Additional References

1. Sommerville, I. *Software Engineering*, 9th edition, Addison Wesley, 2011.
2. *The Definitive Guide to Scrum: The Rules of the Game*, Ken Schwaber, Jeff Sutherland, July 2016.

Suggested Practical List :(30 Hours)

Practical exercises such as

The students document, design and code a module of a Software Project using an appropriate Software Process model. The Software Project should include the use of software engineering tools and include.

1. Problem Statement, Process Model
2. Requirement Analysis: Create Data Flow, Data Dictionary, Use Cases, Sequence Diagram, Software Requirement Specification Document
3. Project Management: Timeline Chart, Compute FP, Effort, Cost, Risk Table.
4. Design Engineering: Architectural Design, Pseudocode of a small module.
5. Coding: Develop at least a single module using any programming Language
6. Testing: Compute Basic path set for at least one module from a project, Generate test cases.

Some of the sample projects are given below:

1. Criminal Record Management: Implement a criminal record management system for jailers, police officers and CBI officers
2. DTC Route Information: Online information about the bus routes and their frequency and fares.
3. Car Pooling: To maintain a web-based intranet application that enables the corporate employees within an organization to avail the facility of carpooling effectively.
4. Patient Appointment and Prescription Management System
5. Organized Retail Shopping Management Software
6. Online Hotel Reservation Service System
7. Examination and Result computation System
8. Automatic Internal Assessment System
9. Parking Allocation System

Computer Science Courses for Undergraduate Programme of study with Computer Science discipline Elective

DISCIPLINE SPECIFIC ELECTIVE COURSE: Data Mining-II

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Data Mining-II	**4**	**3**	**0**	**1**	Pass in Class XII	DSC01 Programming using Python, / GE1b Programming with Python / A1 Programming Fundamentals using Python ,Data Mining-I

Learning Objectives

The course introduces the students to the important supervised and unsupervised learning techniques. Students will learn about the importance of ensemble methods, cluster analysis, anomaly detection and their applicability in mining patterns in real applications. At the end students will be exposed to two advanced topics: text mining and time-series mining. Students will use the learned topics in solving real applications using Open-source software.

Learning outcomes

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

- Differentiate between partition-based, density-based and hierarchical clustering.
- Build ensemble models to improve predictive performance of the classifier.
- Identify anomalies and outliers using supervised and unsupervised techniques.
- Analyze time-series data and extract patterns from the stamped data.
- Mine textual data and do topic modelling.

SYLLABUS OF DSE

Unit 1 (10 hours)

Clustering: Partitioning Methods, Hierarchical Methods, Density-Based Methods, Comparison of different methods

Unit 2 (8 hours)

Ensemble Methods: Need of ensemble, Random Forests, Bagging and Boosting

Unit 3 (10 hours)

Anomaly Detection: Outliers and Outlier Analysis, Outlier Detection Methods, Statistical Approaches, Proximity-based and density-based outlier detection, Clustering-based approaches

Unit 4 (7 hours)

Mining Text Data: Document Preparation and Similarity, Clustering Methods for Text, Topic Modeling

Unit 5 (10 hours)

Stream Mining: Time series basics, Date Ranges, Frequencies, and Shifting, Resampling and moving windows functions, Decay function, Clustering stamped data**:** STREAM and CluStream

Essential/recommended readings

1. Tan P.N., Steinbach M, Karpatne A. and Kumar V. *Introduction to Data Mining,* 2nd edition, Pearson, 2019.
2. Zaki M. J. and Meira J. Jr. *Data Mining and Machine Learning: Fundamental Concepts and Algorithms*, 2nd edition, Cambridge University Press, 2020.
3. Aggarwal C. C. *Data Mining: The Textbook*, Springer, 2015.

Additional References

1. Han J. Kamber M. and Pei J. *Data Mining: Concepts and Techniques*, Morgan Kaufmann Publishers, 2011.
2. Dunham M. *Data Mining: Introductory and Advanced Topics*, Pearson, 2006.

Suggested Practical List : (30 Hours)

Practical exercises such as

Use a dataset of your choice from Open Data Portal (https:// data.gov.in/, UCI repository or a dataset verified by the teacher) or load from scikit, seaborn library for the following exercises to practice the concepts learnt.

1. Apply Partitioning Methods, Hierarchical Methods, Density-Based Methods for clustering on a data set and compare the performance of the obtained results using different metrics.
2. Create an ensemble using Random Forest and show the impact of bagging and boosting on the performance.

3. Apply different outlier-detection methods on a noisy dataset and compare their effectiveness in terms of outliers reported.
4. Compute similarity between two documents after required document preparation.
5. Considering a time-stamped data (sales data/weather data), compare the aggregate values visually using different moving windows function.
6. Write a program to find the latent topics in a document using any topic modeling method and display top 5 terms that contribute to each topic along with their strength. Also, visualize the distribution of terms contributing to the topics.

Project: Students are encouraged to work on a good dataset in consultation with their faculty and apply the concepts learned in the course.

DISCIPLINE SPECIFIC ELECTIVE COURSE: Data Privacy

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Data Privacy	**4**	**3**	**0**	**1**	Pass in Class XII	NIL

Learning Objectives

This course aims to provide students with an ability to identify privacy related aspects of data uses(including attacks on data privacy), evaluate proposed mechanisms for privacy protection and relate to ethical issues related to data privacy.

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

- Understand the basic principles of data privacy and the implications of data breaches.
- Identify and evaluate different methods of protecting sensitive data.
- Explain the role of privacy regulations in safeguarding personal information.
- Implement basic cryptographic techniques to secure data.
- Apply data anonymization techniques to protect personal information.
- Analyze the ethical considerations in data privacy

SYLLABUS OF DSE

Unit 1 (10 hours)

Introduction to Data Privacy and Privacy Regulations: Notion of data privacy, Historical context of data privacy, Types of sensitive data, Privacy laws and regulations.

Unit 2 (15 hours)

Data Privacy Attacks, Cryptography and Data Protection: Type of Attacks/ Data Breaches on Data Privacy, Impact of Data Breaches / Attacks, Introduction to cryptography, Symmetric and asymmetric encryption, Hashing and digital signatures.

Unit 3 (10 hours)

Data Collection, Use and Reuse: Harms Associated with Data collections, use and reuse, Introduction to data anonymization, Data Anonymization Techniques for anonymizing data, Challenges in anonymizing data

Unit 4 (10 hours)

Ethical considerations in Data Privacy: Privacy and Surveillance, Ethics of Data Collection and Use, Bias and discrimination in data analysis

Essential/recommended readings

1. Ronald Leenes, Rosamunde van Brakel, and Serge Gutwirth: *Data Protection and Privacy: The Age of Intelligent Machines*, Hart Publishing, 2017.
2. Naavi: *Personal Data Protection Act of India (PDPA 2020)*: Be Aware, Be Ready and Be Compliant, Notion Press, 2020.
3. Ravinder Kumar Gaurav Goyal, *The Right to Privacy in India: Concept and Evolution*, Publisher: Lightning Source, 2016.

Additional References

1. https://onlinecourses.nptel.ac.in/noc22_cs37/preview
2. https://www.coursera.org/learn/northeastern-data-privacy/home/info

Suggested Practical List : (30 Hours)

Practical exercises such as

1. Data Privacy Audit: Students can conduct a data privacy audit of a company or organization to identify potential vulnerabilities and risks in their data privacy practices.

2. Privacy Impact Assessment: Students can conduct a privacy impact assessment (PIA) of a new technology or system to identify potential privacy risks and develop strategies to mitigate them.
3. Regulation Compliance: Students can explore the requirements of the Data Protection Regulations and develop a plan for ensuring compliance with the regulation.
4. Cryptography: Students can learn about different cryptographic techniques and tools, such as encryption, hashing, and digital signatures, and implement them in practice.
5. Anonymization Techniques: Students can learn about data anonymization techniques, such as k-anonymity, differential privacy, and data masking, and apply them to a real-world dataset.
6. Privacy Policy Analysis: Students can analyze the privacy policies of different companies and identify gaps or areas for improvement.
7. Privacy-Enhancing Technologies: Students can explore privacy-enhancing technologies (PETs), such as virtual private networks (VPNs), Tor, and secure messaging apps, and evaluate their effectiveness in protecting privacy.
8. Privacy Breach Response Plan: Students can develop a privacy breach response plan for a company or organization, including steps to take in the event of a data breach and strategies for communicating with affected parties.
9. Ethical Considerations: Students can explore ethical considerations in data privacy, such as the balance between privacy and security, the impact of data collection and analysis on marginalized communities, and the role of data ethics in technology development.
10. Case Studies: Students can analyze case studies of privacy breaches or successful privacy protection strategies, and identify key lessons and takeaways.

DISCIPLINE SPECIFIC ELECTIVE COURSE: Unix Network Programming

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	
		Lecture	Tutorial	Practical/ Practice		
Unix Network Programming	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b: Java Programming

Learning Objectives

This course introduces the concepts of Internet protocols, ports used during communication, Client/Server concepts and various transport protocols used in computer network applications and services. The objective is to equip the students with technical knowledge of it comprises of the study of the sockets used with TCP and UDP.

Learning outcomes

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

- Describe and analyze the various Internet Transport layer protocols used in TCP AND UDP.
- Comprehend the concepts and structures of both TCP based connection-oriented and UDP based connectionless client server applications.
- Write various real-life client-server applications using socket programming.
- Modify, maintain and extend the present internet client-server applications and write any new type of internet applications to suit the current needs of Internet users.

SYLLABUS OF DSE

Unit 1 (6 hours)

Introduction Basics of Client Server applications, Example of day time client server, concurrent servers, protocols, sockets, port numbers.

Unit 2 (17 hours)

Connection-oriented Socket Applications: Elementary TCP sockets – Socket, connect, bind, listen, accept, fork and exec function, close function, Socket Address Structures, Byte Ordering and Manipulation Functions, TCP Client and Server for Echo, Signal Handling in case of crashing and rebooting of server, Shutdown process function. Socket Options: Getsockopt and stockpot functions, Socket states, Generic socket option.

Unit 3 (15 hours)

Connectionless Socket Applications: TCP-oriented basic concurrent client server applications, UDP oriented Echo client and server application, Handling of errors like lost datagram, Lack of flow control with UDP, determining outgoing interface with UDP.

Unit 4 (7 hours)

Elementary name and Address conversions: Domain Name System, socket functions like gethostbyname, gethostbyname2, gethostbyaddr function, uname function, gethostname function, getservbyname and getservbyport functions.

Essential/recommended readings

1. W. Richard Stevens, Bill Fenner, Andrew M. Rudoff, *Unix Network Programming*, The sockets Networking API, Vol. 1, 3rd Edition, PHI.
2. B. A. Forouzan: *Data Communications and Networking*, THM Publishing Company Ltd
3. R. Stevens, *Unix Network Programming*, PHI 2nd Edition

Suggested Practical List : (30 Hours)

Practical exercises such as

1. Implement TCP Echo client and TCP Echo server (Iterative).
2. Implement TCP Echo client and TCP Echo server (Concurrent).
3. Implement TCP daytime client and TCP daytime server (Iterative).
4. Implement TCP daytime client and TCP daytime server (concurrent).
5. Implement UDP Echo Client and UDP Echo Server.
6. Implement UDP daytime Client and UDP daytime server.
7. Implement TCP client and server (concurrent) where client gets input from the user and sends it to server. Server displays it on the screen. Server then gets another input from the user and sends it to client. Client displays it on the screen. The process continues till server or client sends “bye” to the other party.
8. Implement TCP client and server (concurrent) where client requests server to transfer a file. Assume file is smaller than 1K size. If the file is present on the server, it is sent to the client otherwise an error message is sent to client. Client copies the file on the hard disk and disconnects.
9. Implement UDP client and UDP server where server displays the IP address and port number of the client sending the datagram. Client sends a datagram (size 64 bytes) three times to the same server. Server sends the message back to client. Client reports the time elapsed in sending and receiving of the message. Use connected UDP sockets.
10. Write a program to
    a) display name of the host
    b) all IP addresses of the host.
    c) Check whether FTP and HTTP services are running on the system.
    d) Display the name of the service running on port number specified by user.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES

(For all the Generic Elective courses offered by your department, please put it in the format provided below)

GENERIC ELECTIVES (GE-5a): Operating Systems

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE-5a Operating Systems	**4**	**3**	**0**	**1**	Pass in Class XII	Knowledge of Programming in C/C++/Java/Python at class XII level or above

Learning Objectives

The course introduces Operating System and its importance in computer systems. The focus is to explain the common services provided by an operating system like process management, memory (primary, secondary & virtual) management, I/O management, file management. The course talks about the various functional components of the operating and their design.

Learning outcomes

On successful completion of the course, students will be able to gain knowledge of different concepts of the operating System and its components. They would learn about shell scripts and would be able to use the system in an efficient manner.

SYLLABUS OF GE-5a

Unit 1 (5 hours)

Introduction: Operating Systems (OS) definition and its purpose, Multiprogrammed and Time-Sharing Systems, OS Structure, OS Operations: Dual and Multi-mode, OS as resource manager.

Unit 2 (6 hours)

Operating System Structures: OS Services, System Calls: Process Control, File Management, Device Management, and Information Maintenance, Inter-process Communication, and Protection, System programs, OS structure- Simple, Layered, Microkernel, and Modular.

Unit 3 (10 hours)

Process Management: Process Concept, States. Process Control Block, Context Switch, Process scheduling, Schedulers, Overview of threads and Scheduling Algorithms: First Come First Served, Shortest-Job-First, Priority & Round-Robin.

Unit 4 (10 hours)

Memory Management: Physical and Logical address space, Swapping Contiguous memory allocation strategies - fixed and variable partitions, Segmentation, Paging, virtual memory: Demand Paging.

Unit 5 (8 hours)

File and Input / Output Device Management: File Concepts, File Attributes, File Access Methods, Directory Structure: Single-Level, Two-Level, Tree-Structured, and Acyclic-Graph Directories, Magnetic Disks, Solid-State Disks, Magnetic Tapes.

Unit 6 (6 hours)

Shell Scripting: Shell variables, parameter passing conditional statements, iterative statements, writing and executing shell scripts, utility programs (cut, paste, grep, echo, pipe, filter etc.)

Essential/recommended readings

1. Galvin, S. P. B., Gagne, G., *Operating System Concepts*, 9th edition, John Wiley Publications, 2016.
2. G. Nutt, Operating Systems, Pearson, 2009

Additional References

1. Dhamdhere, D. M., *Operating Systems: A Concept-based Approach,* 2nd edition, Tata McGraw-Hill Education, 2017.
2. Kernighan, B. W., Pike, R., *The Unix Programming Environment*, Englewood Cliffs, NJ: Prentice-Hall, 1984.
3. Stallings, W., *Operating Systems: Internals and Design Principles*, 9th edition, Pearson Education, 2018.
4. Tanenbaum, A. S., *Modern Operating Systems.* 3rd edition. Pearson Education, 2007.

Suggested Practical List : (30 Hours)

Practical exercises such as

1. Usage of following commands: ls, pwd, cat, who, rm, mkdir, rmdir,cd.

2. Usage of following commands: cal, cat(append), cat(concatenate), mv, cp, man, date.
3. Usage of following commands: chmod, grep, bc.
4. Write a shell script to display date in the mm/dd/yy format.
5. Write a shell script to display the multiplication table any number.
6. Write a shell script to find the factorial of a given number.
7. Program to show the pyramid of special character "*".
8. Write a shell script to find the sum of digits of a given number.
9. Write a shell script to perform the tasks of basic calculator.
10. Write a shell script to find the power of a given number.
11. Write a shell script to check whether the number is Armstrong or not.
12. Write a shell script to find the GCD (greatest common divisor) of two numbers.
13. Write a shell script to check if the number entered at the command line is prime or not.
14. Write a shell script to display on the screen sorted output of "who" command along with the total number of users.
15. Write a shell script to accept a login name. If not a valid login name display message – "Entered login name is invalid".
16. Write a shell script to compare two files and if found equal asks the user to delete the duplicate file.
17. Write a shell script to merge the contents of three files, sort the contents and then display them page by page.
18. Write a shell script to check whether the file have all the permissions or not.
19. Write a shell script to modify "cal" command to display calendars of the specified months.
20. Write a shell script to modify "cal" command to display calendars of the specified range of months.

GENERIC ELECTIVES (GE-5b): Advanced Web Programming

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE5b: Advanced Web Programming	**4**	**3**	**0**	**1**	Pass in Class XII	Knowledge of HTML, CSS

Learning Objectives

The course aims to familiarize the students with the concepts and techniques of server side web programming. This will enable the students to create dynamically generated web pages using HTML, PHP, MySql and JQuery.

Learning outcomes

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

- develop interactive and dynamic websites.
- write programs to communicate with the server using GET and POST methods
- learn to connect and manipulate databases using MySql
- validate server-side/backend data

SYLLABUS OF GE-5b

Unit 1 (7 hours)

Introduction to PHP: Basic syntax, defining variables and constants, data types including arrays, operators and expressions, decision making statements, constructs for iterations.

Unit 2 (5 hours)

String Handling: Creating a string and accessing its content, searching and replacing content of a string, and other built-in functions.

Unit 3 (12 hours)

Handling HTML Form with PHP: Creating a form, submitting data to the server at the backend using GET and POST methods, GET vs POST methods, PHP global functions.

Unit 4 (15 hours)

Database: Connectivity with MySQL: Connectivity with database, database creation, creating tables, create, retrieve, update, and delete (CRUD) operations

Unit 5 (6 hours)

jQuery and JSON: Introduction to jQuery syntax (selectors, events, AJAX, JSON).

Essential/recommended readings

1. Nixon, R. Learning PHP, MySQL & JavaScript with jQuery, CSS and HTML5, O'Reilly, 2018.
2. Holzner S. PHP: The Complete Reference, McGraw Hill, 2017
3. Murach J, Murach's PHP and MySQL, 2nd edition, Mike Murach & Associates, 2014.
4. Duckett, J. JavaScript and JQuery: Interactive Front-End Web Development, Wiley, 2014.

Additional References

1. https://www.w3schools.com/php/default.asp

2. https://www.tutorialspoint.com/php/index.htm

Suggested Practical List : (30 Hours)

Practical exercises such as

1. Write a PHP script to reverse the digits of a number.
2. Create a web page containing two text boxes and a button named “Evaluate”. When the user enters numbers in the text boxes and clicks on the “Evaluate” button, a function should evaluate the sum of the numbers and display the result.
3. Write a PHP script to perform following string operations using in-built functions and built an interactive web page having buttons for each of the following operation:
    a. Find the length of a string
    b. Find a substring from a string
    c. Replace text within a string
    d. Remove whitespace and other predefined characters from both sides of a string.
    e. Check if a value is a string
    f. Convert the first character of each word in a string into uppercase.
4. Design a Login form and validate that form using PHP code. Display error message box when data is not valid otherwise redirect to the next page and display “Welcome username!”.
5. Design a student registration form, using appropriate input fields consisting of following:
    a. First Name
    b. Last Name
    c. Gender
    d. Roll Number
    e. Phone Number
    f. Course

Submit and retrieve the form data using $_POST, $_GET variable.

6. Write PHP Code to make connection to MySql database, create database and tables and perform insertion, deletion, and retrieval of the data (Using SQL operations like .JOIN, ORDER BY, GROUP BY) Display the messages such as “The record is added in the database!” when data is inserted into the database, “A record is deleted from the database” when data is deleted from the database. Use appropriate button names such as Add Data, Delete Data, and Display Data.

jQuery and JSON

1. Change text color and contents using button click events using jQuery
2. Select elements using ID, class, elements name, attribute name
3. Run code on click events in jQuery

4. Handle HTML form, store the data in JSON object, pass them to another page and display it there using jQuery/Javascript

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE5c: Java Based Web App Development	4	3	0	1	Pass in Class XII	DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b: Java Programming / A programming course at class XII level

Learning Objectives

The course aims to familiarize the students with the concepts and techniques of web app development based on Java. The students will learn about database connectivity, use of HTTP protocol, client side programming, and use of servlets and JSP for server side programming.

Learning outcomes

On successful completion of this course, students will be able to:

- develop an understand of client-server architecture, HTTP protocol, and web application components.
- connect an application to database and perform basic database operations.
- create servlets and JSP for web applications
- deploy web applications

SYLLABUS OF GE-5c

Unit 1 (8 hours)

Review of Programming Language: Programming Constructs, Data types, Operators, Concepts of Class, Interface, Inheritance, Exception Handling, Util package, Multithreading, event handling.

Unit 2 (10 hours)

Java Database Connections: Database connectivity, Connection, statement, result set object, Metadata, Connection pooling, CRUD operations, Prepared and callable statements

Unit 3 (15 hours)

Introduction to servlets: Concepts of Streams, events and listener, recap of HTML, CSS, XML, Servlet package and interface, life cycle of servlet, deployment descriptor, Filters, HHTP and Generic servlet, request dispatcher, Request Response classes, Dynamic page designing using servlet.

Unit 4 (12 hours)

Introduction to JSP: JSP Life cycle, tags in JSP, custom tags, Expression Language, Introduction to Struts Framework, Implicit objects, database access using JSP

Essential/recommended readings

1. Herbert Schildt, *Java : The Complete Reference*, 12th edition, McGraw-Hill Education, 2021.
2. Hans Bergsten, *Java Server Pages*, 3rd edition, O′Reilly, 2003.
3. Jim Keogh, *The Complete Reference J2EE*, 1st edition, McGraw-Hill Education, 2017.

Suggested Practical List : (30 Hours)

Practical exercises such as

1. Setting up the development environment: Install Java Development Kit (JDK), Eclipse IDE, and Apache Tomcat web server. Create a new web project in Eclipse.
2. Writing and deploying a "Hello World" servlet: Create a simple servlet that prints "Hello World" on the web page. Deploy the servlet on Tomcat and test it in a web browser.
3. Handling HTTP requests and responses: Write a servlet that reads input from HTTP requests and sends output as HTTP responses.
4. Creating a JSP page: Create a JSP page that displays dynamic.
5. Write a servlet that handles form submissions and saves the data to a database using JDBC.
6. Write a servlet that implements user authentication and authorization using a database.
7. Creating a web application using MVC architecture: Create a web application using Model-View-Controller (MVC) architecture. Use servlets as controllers, JSP pages as views.
8. Deploying a web application to a server: Configure and deploy a web application to a server using Apache Tomcat Manager or other deployment tools.

(Computer Science Courses for Undergraduate Programme of study with Computer Science discipline as one of the three Core Disciplines)

DISCIPLINE SPECIFIC CORE COURSE (DSC-5): Database Management Systems

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC 5: Database Management Systems	**4**	**3**	**0**	**1**	Pass in Class XII	NIL

Learning Objectives

The course introduces the students to the fundamentals of database management system and its applications. Emphasis is given on the popular relational database system. Students will learn about the importance of database structure and its designing using Entity Relationship diagram and formal approach using normalization. Basic concepts of file indexing and transaction processing will be taught. The course would give students hands-on practice of structured query language to create, manipulate and implement a relational database.

Learning outcomes

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

- Use relational database management software to create and manipulate the database.
- Create conceptual data models using entity relationship diagrams for modeling real-life situations and map it to corresponding relational database schema.
- Use the concept of functional dependencies to remove redundancy and update anomalies.
- Apply normalization theory to get a normalized database scheme to get anomalies free database.
- Write queries in relational algebra.
- Implement relational databases and formulate queries for data retrieval and data update problems using SQL.
- Learn the importance of index structures and concurrent execution of transactions in database systems.

SYLLABUS OF DSC-5

Unit 1 (5 hours)

Introduction to Database: Database, characteristics of database approach, data models, database management system, three-schema architecture, components of DBMS, data independence, and file system approach vs database system approach.

Unit 2 (6 hours)

Entity Relationship Modeling: Conceptual data modeling - motivation, entities, entity types, attributes, relationships, relationship types, constraints on relationship, Entity Relationship diagram as conceptual data model.

Unit 3 (6 hours)

Relational Data Model: Data anomalies, Relational Data Model - Characteristics of a relation, schema-instance distinction, types of keys, relational integrity constraints. Relational algebra operators like selection, projection, cartesian product, join and write queries using them.

Unit 4 (8 hours)

Structured Query Language (SQL): DDL to create database and tables, table constraints, DML, Querying in SQL to retrieve data from the database, aggregation functions group by and having clauses, generate and query views.

Unit 5 (10 hours)

Database Design: Mapping an Entity Relationship diagram to corresponding relational database scheme, functional dependencies and Normal forms, 1NF, 2NF, and 3NF decompositions and desirable properties of them.

Unit 6 (10 hours)

File indexing and Transaction Processing: Need of file indexes, types of indexes, file organizations, single- and multi-level indexing, concurrent execution of transactions, ACID properties, need of data recovery.

Essential/recommended readings

1. Elmasri, R., Navathe, B. S., *Fundamentals of Database Systems*, 7th edition, Pearson Education, 2016.
2. Murach, J., *Murach's MySQL,* 3th edition, Pearson, 2019.

Additional References

1. Connolly, T. M., Begg, C. E., *Database Systems: A Practical Approach to Design, Implementation, and Management*, 6th edition, Pearson, 2019.
2. Ramakrishnan, R., Gehrke, J., *Database Management Systems*, 3rd edition, McGraw-Hill, 2014.
3. Silberschatz, A., Korth, H.F., Sudarshan S., *Database System Concepts*, 7th edition, McGraw Hill, 2019.

Suggested Practical List : (30 Hours)

Practical exercises such as

Create and use the following student-course database schema for a college to answer the given queries using the standalone SQL editor.

STUDENT	<u>**Roll No**</u>	**StudentName**	**CourseID**	**DOB**
	Char(6)	Varchar(20)	Varchar(10)	Date

COURSE	<u>**CID**</u>	**CourseName**	**Course Type**	**Teacher-in-charge**	**TotalSeats**	**Duration**
	Char(6)	Varchar (20)	Char (8)	Varchar (15)	Unsigned int	Unsigned int

ADMISSION	<u>**Roll No**</u>	<u>**CID**</u>	**DateOfAdmission**
	Char(6)	Char(6)	Date

Here Rollno (ADMISSION) and SID (ADMISSION) are foreign keys. Note that course type may have two values viz. Fulltime and Parttime and a student may enroll in any number of courses

1. Retrieve names of students enrolled in any course.

3. Retrieve students' names starting with letter ‘A’.
4. Retrieve students' details studying in courses ‘computer science’ or ‘chemistry’.
5. Retrieve students’ names whose roll no either starts with ‘X’ or ‘Z’ and ends with ‘9’
6. Find course details with more than N students enrolled where N is to be input by the user
7. Update student table for modifying a student name.
8. Find course names in which more than five students have enrolled
9. Find the name of youngest student enrolled in course ‘BSc(P)CS’
10. Find the name of most popular society (on the basis of enrolled students)
11. Find the name of two popular part time courses (on the basis of enrolled students)
12. Find the student names who are admitted to full time courses only.
13. Find course names in which more than 30 students took admission

14. Find names of all students who took admission to any course and course names in which at least one student has enrolled
15. Find course names such that its teacher-in-charge has a name with ‘Gupta’ in it and the course is full time.
16. Find the course names in which the number of enrolled students is only 10% of its total seats.
17. Display the vacant seats for each course
18. Increment Total Seats of each course by 10%
19. Add enrollment fees paid (‘yes’/’No’) field in the enrollment table.
20. Update date of admission of all the courses by 1 year.
21. Create a view to keep track of course names with the total number of students enrolled in it.
22. Count the number of courses with more than 5 students enrolled for each type of course.
23. Add column Mobile number in student table with default value ‘9999999999’
24. Find the total number of students whose age is > 18 years.
25. Find names of students who are born in 2001 and are admitted to at least one part time course.
26. Count all courses having ‘science’ in the name and starting with the word ‘BSc’.

Students are also encouraged to implement the database given in the textbook and do the related queries.

Computer Science Courses for Undergraduate Programme of study with Computer Science discipline as one of the two Core Disciplines
(For e.g. courses for B.A. Programmes with Computer Science as Major discipline)

Computer Science Major

DISCIPLINE SPECIFIC CORE COURSE (DSC-5): Database Management System

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC05: Database Management System	**4**	**3**	**0**	**1**	Class XII Passed	NIL

Learning Objectives

The course will give an overview of categories of data models used by database management systems and writing queries in relational algebra. The importance of file indexing and controlled execution of transactions will be taught. The course would give students hands-on practice to write complex queries, nested queries using aggregate functions in SQL and to use basic database administration commands.

Learning outcomes

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

- Write queries using relational algebra, a procedural language.
- Use the concept of functional dependencies to remove data anomalies and arrive at normalized database design.
- Understand the data storage system, file organization and need of file indexing.
- Learn the importance of transaction processing and concurrency control.
- Write complex and nested SQL queries, and learn basic database administration commands.
- Acquire information about emerging technologies.

SYLLABUS OF DSC 05

Unit 1 (6 hours)

Data models and Relational Algebra: Categories of data models, types of database users, Relational Algebra Operations from SET Theory, SELECT, PROJECT, JOIN, DIVISION Operations.

Unit 2 (8 hours)

Normalization: Functional dependencies, minimal cover, normalizing database with multiple keys till 3NF, Boyce-Codd Normal Form

Unit 3 (8 hours)

Database Storage and index Structures: Storage of data, file structure, file organization and its types: Sequential, Heap and Indexed, Hash file, need for file Indexing, single- and multi-level indexing.

Unit 4 (8 hours)

Transaction Processing: Concurrent execution of transactions and their handling, ACID properties, need of data recovery and log files.

Unit 5 (8 hours)

Advanced SQL: Nested and complex queries using Inner JOIN, Left JOIN, Right JOIN, Full JOIN, views, Database Administration Commands: COMMIT, ROLLBACK, drop database, control permissions etc.

Unit 6 (7 hours)

Emerging Technology: Distributed Database Concepts, Introduction to emerging technologies like Data Warehousing and OLAP, Data Mining.

Essential/recommended readings

1. Elmasri R. and Navathe B. S. *Fundamentals of Database Systems*, 7th Edition, Pearson Education, 2016.
2. Murach J. *Murach's MySQL,* 3th Edition, Pearson, 2019.

Additional References

1. Silberschatz, A., Korth, H.F., & Sudarshan, S. Database System Concepts, 8th Edition, McGraw Hill, 2019.

2. Ramakrishnan, R. & Gehrke, J. Database Management Systems, 3rd Edition, Tata McGraw Hill Education, 2014.

Suggested Practical List : (30 Hours)

MySQL might be used for practical purposes.

The following concepts must be introduced to the students:

1. Multiple table queries (join on different and same tables)
2. Nested select statements
3. Set manipulation using (any, in, contains, all, not in, not contains, exists, not exists union, intersect, minus, etc.)
4. Categorization using group by... having
5. Arranging using order by

List of sample queries to be done using the above schema.

Create tables with relevant column and integrity constraints and populate the tables with data.

Perform the following queries on the database:

1. Display all the details of all employees working in the company.
2. Display ssn, lname, fname, address of employees who work in department no 7.
3. Retrieve the birthdate and address of the employee whose name is 'Franklin T. Wong' and who is a manager
4. Retrieve the name and salary of every employee working in department ‘Production’
5. Display maximum and minimum salaries of each department
6. Retrieve all employee names whose address is in ‘Bellaire’ and working on at least one project
7. Modify the datatype of hours column to float in works_on table.
8. Retrieve all employees who age is more than 35 years
9. Retrieve all employees in department 5 whose salary is between 50,000 and 60,000(inclusive)
10. Add another column named “Join_Date” in the employee table and “Address” in the department table
11. Retrieve the names of all employees who do not have supervisors
12. Retrieve SSN and department name for all employees
13. Retrieve the name and address of all employees who work for the 'Research' department
14. For every project located in 'Stafford', list the project number, the controlling department number, and the department manager's last name, address, and birthdate

15. For each employee, retrieve the employee's name, and the name of his or her immediate supervisor
16. Retrieve all combinations of Employee Name and Department Name
17. Make a list of all project numbers for projects that involve an employee whose last name is 'Narayan' either as a worker or as a manager of the department that controls the project
18. Increase the salary of all employees working on the 'ProductX' project by 15%. Retrieve employee name and increased salary of these employees
19. Retrieve a list of employees and the project name each works in, ordered by the employee's department, and within each department ordered alphabetically by employee first name
20. Select the names of employees whose salary does not match with salary of any employee in department 10
21. Drop the column "Join_Date" from the employee table
22. Retrieve the name of each employee who has a dependent with the same first name and same sex as the employee
23. Retrieve the employee numbers of all employees who work on project located in Bellaire, Houston, or Stafford.
24. Change the name of existing table DEPT_LOCATIONS to DLOCATIONS
25. Find the sum of the salaries of all employees, the maximum salary, the minimum salary and the average salary for each department. Display with proper headings
26. Find the sum of the salaries and number of employees of the 'Marketing' department, as well as the maximum salary, the minimum salary, and the average salary in this department
27. Select the names of employees whose salary is greater than the average salary of all employees in department 10
28. For each department, retrieve the department number, the number of employees in the department and their average salary
29. For each project, retrieve the project number, the project name, and the number of employees who work on that project for more than 10 hours
30. Change the location and controlling department number for all projects having more than 5 employees to 'Bellaire' and 6 respectively
31. For each department having more than 10 employees, retrieve the department name, number of employees drawing more than 40,000 as salary
32. Display employee names having no dependent in descending order along with their age
33. For each department, find the number of female and number of male employees along with name of manager of that department
34. Find the name and age of youngest employee in each department
35. Change the name of MINIT attribute of an employee table to MNAME using alter command
36. Create a view to keep names of employees and their department names if they are not working on any project
37. Create a view to keep track of all employee names who are working on same projects as that of employee 'Franklin T. Wong'
38. Execute system administrative commands like commit, rollback, granting control permissions, etc.

DISCIPLINE SPECIFIC CORE COURSE (A5): Machine Learning

0CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
A5: Machine Learning	**4**	**3**	**0**	**1**	Pass in Class XII	A1 Programming Fundamentals using Python, A2 Data Visualization using Python

Learning Objectives

The course aims at introducing the basic concepts and techniques of machine learning so that a student can apply machine learning techniques to a problem at hand.

Learning outcomes

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

- Differentiate between supervised and unsupervised learning tasks.
- Appreciate the need of preprocessing, feature scaling and feature selection.
- Understand the fundamentals of classification, regression and clustering
- Implement various machine learning algorithms learnt in the course.

SYLLABUS OF A5

Unit 1 (8 hours)

Introduction: Basic definitions and concepts, key elements, supervised and unsupervised learning, introduction to reinforcement learning, applications of ML.

Unit 2 (10 hours)

Preprocessing: Feature scaling, feature selection methods. dimensionality reduction (Principal Component Analysis).

Unit 3 (12 hours)

Regression: Linear regression with one variable, linear regression with multiple variables, gradient descent, over-fitting, regularization. Regression evaluation metrics.

Unit 4 (15 hours)

Classification: Decision trees, Naive Bayes classifier, logistic regression, k-nearest neighbor classifier, perceptron, multilayer perceptron, neural networks, Support Vector Machine (SVM). Classification evaluation metrics.

Essential/recommended readings

1. Mitchell, T.M. *Machine Learning*, McGraw Hill Education, 2017.
2. James, G., Witten. D., Hastie. T., Tibshirani., R. *An Introduction to Statistical Learning with Applications in R*, Springer, 2014.
3. Alpaydin, E. *Introduction to Machine Learning*, MIT press, 2009.

Additional References

1. Flach, P., *Machine Learning: The Art and Science of Algorithms that Make Sense of Data*, Cambridge University Press, 2015.
2. Christopher & Bishop, M., *Pattern Recognition and Machine Learning*, New York: Springer-Verlag, 2016.
3. Sebastian Raschka, *Python Machine Learning,* Packt Publishing Ltd, 2019.

Suggested Practicals List : (30 Hours)

Practical exercise such as

Use Python for practical labs for Machine Learning. Utilize publically available datasets from online repositories like https://data.gov.in/ and https://archive.ics.uci.edu/ml/datasets.php

For evaluation of the regression/classification models, perform experiments as follows:

i. Scale/Normalize the data
ii. Reduce dimension of the data with different feature selection techniques

iv. Perform k-cross-validation on datasets for evaluation

Report the efficacy of the machine learning models as follows:

i. MSE and R^2 score for regression models
ii. Accuracy, TP, TN, FP, TN, error, Recall, Specificity, F1-score, AUC for classification models

For relevant datasets make prediction models for the following

1. Naïve Bayes Classifier
2. Simple Linear Regression multiple linear regression
3. Polynomial Regression
4. Lasso and Ridge Regression
5. Logistic regression
6. Artificial Neural Network
7. *k*-NN classifier
8. Decision tree classification
9. SVM classification
10. K-Means Clustering
11. Hierarchical Clustering

Computer Science Courses for Undergraduate Programme of study with Computer Science discipline as one of the two Core Disciplines
(For e.g. courses for B.A. Programmes with Computer Science as Non-major discipline)

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC05: Database Management System	**4**	**3**	**0**	**1**	Pass in Class XII	NIL

Learning Objectives

The course will give an overview of categories of data models used by database management systems and writing queries in relational algebra. The importance of file indexing and controlled execution of transactions will be taught. The course would give students hands-on practice to write complex queries, nested queries using aggregate functions in SQL and to use basic database administration commands.

Learning outcomes

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

- Write queries using relational algebra, a procedural language.
- Use the concept of functional dependencies to remove data anomalies and arrive at normalized database design.
- Understand the data storage system, file organization and need of file indexing.
- Learn the importance of transaction processing and concurrency control.
- Write complex and nested SQL queries, and learn basic database administration commands.
- Acquire information about emerging technologies.

SYLLABUS OF DSC 05

Unit 1 (6 hours)

Data models and Relational Algebra: Categories of data models, types of database users, Relational Algebra Operations from SET Theory, SELECT, PROJECT, JOIN, DIVISION Operations.

Unit 2 (8 hours)

Normalization: Functional dependencies, minimal cover, normalizing database with multiple keys till 3NF, Boyce-Codd Normal Form

Unit 3 (8 hours)

Database Storage and index Structures: Storage of data, file structure, file organization and its types: Sequential, Heap and Indexed, Hash file, need for file Indexing, single- and multi-level indexing.

Unit 4 (8 hours)

Transaction Processing: Concurrent execution of transactions and their handling, ACID properties, need of data recovery and log files.

Unit 5 (8 hours)

Advanced SQL: Nested and complex queries using Inner JOIN, Left JOIN, Right JOIN, Full JOIN, views, Database Administration Commands: COMMIT, ROLLBACK, drop database, control permissions etc.

Unit 6 (7 hours)

Emerging Technology: Distributed Database Concepts, Introduction to emerging technologies like Data Warehousing and OLAP, Data Mining.

Essential/recommended readings

1. Elmasri R. and Navathe B. S. *Fundamentals of Database Systems*, 7th Edition, Pearson Education, 2016.
2. Murach J. *Murach's MySQL,* 3th Edition, Pearson, 2019.

Additional References

1. Silberschatz, A., Korth, H.F., & Sudarshan, S. Database System Concepts, 8th Edition, McGraw Hill, 2019.

Suggested Practical List : (30 Hours)

MySQL might be used for practical purposes.

The following concepts must be introduced to the students:

1. Multiple table queries (join on different and same tables)
2. Nested select statements
3. Set manipulation using (any, in, contains, all, not in, not contains, exists, not exists union, intersect, minus, etc.)
4. Categorization using group by........having
5. Arranging using order by

List of sample queries to be done using the above schema.

Create tables with relevant column and integrity constraints and populate the tables with data.

Perform the following queries on the database:

1. Display all the details of all employees working in the company.
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5. Display maximum and minimum salaries of each department
6. Retrieve all employee names whose address is in ‘Bellaire’ and working on at least one project
7. Modify the datatype of hours column to float in works_on table.
8. Retrieve all employees who age is more than 35 years
9. Retrieve all employees in department 5 whose salary is between 50,000 and 60,000(inclusive)
10. Add another column named “Join_Date” in the employee table and “Address” in the department table
11. Retrieve the names of all employees who do not have supervisors
12. Retrieve SSN and department name for all employees
13. Retrieve the name and address of all employees who work for the 'Research' department
14. For every project located in 'Stafford', list the project number, the controlling department number, and the department manager's last name, address, and birthdate
15. For each employee, retrieve the employee's name, and the name of his or her immediate supervisor
16. Retrieve all combinations of Employee Name and Department Name
17. Make a list of all project numbers for projects that involve an employee whose last name is 'Narayan’ either as a worker or as a manager of the department that controls the project
18. Increase the salary of all employees working on the 'ProductX' project by 15%. Retrieve employee name and increased salary of these employees
19. Retrieve a list of employees and the project name each works in, ordered by the employee's department, and within each department ordered alphabetically by employee first name

20. Select the names of employees whose salary does not match with salary of any employee in department 10
21. Drop the column "Join_Date" from the employee table
22. Retrieve the name of each employee who has a dependent with the same first name and same sex as the employee
23. Retrieve the employee numbers of all employees who work on project located in Bellaire, Houston, or Stafford.
24. Change the name of existing table DEPT_LOCATIONS to DLOCATIONS
25. Find the sum of the salaries of all employees, the maximum salary, the minimum salary and the average salary for each department. Display with proper headings
26. Find the sum of the salaries and number of employees of the 'Marketing' department, as well as the maximum salary, the minimum salary, and the average salary in this department
27. Select the names of employees whose salary is greater than the average salary of all employees in department 10
28. For each department, retrieve the department number, the number of employees in the department and their average salary
29. For each project, retrieve the project number, the project name, and the number of employees who work on that project for more than 10 hours
30. Change the location and controlling department number for all projects having more than 5 employees to 'Bellaire' and 6 respectively
31. For each department having more than 10 employees, retrieve the department name, number of employees drawing more than 40,000 as salary
32. Display employee names having no dependent in descending order along with their age
33. For each department, find the number of female and number of male employees along with name of manager of that department
34. Find the name and age of youngest employee in each department
35. Change the name of MINIT attribute of an employee table to MNAME using alter command
36. Create a view to keep names of employees and their department names if they are not working on any project
37. Create a view to keep track of all employee names who are working on same projects as that of employee 'Franklin T. Wong'
38. Execute system administrative commands like commit, rollback, granting control permissions, etc.

Semester-VI

DEPARTMENT OF COMPUTER SCIENCE

[UG Programme for Bachelor in Computer Science (Honours)]

DISCIPLINE SPECIFIC CORE COURSE – 16 (DSC-16) : Artificial Intelligence

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC-16 Artificial Intelligence	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b: Java Programming

Learning Objectives

The course objectives of this course are to:

- To introduce basic concepts and techniques of Artificial Intelligence (AI).
- To apply informed search techniques for different applications.
- To learn various knowledge representation techniques and writing Prolog programs.
- To learn about the latest techniques for developing AI systems.

Learning outcomes

On successful completion of this course, students will be able to:

- identify problems that are amenable to solutions by specific AI methods.
- state the utility of different types of AI agents.
- apply different informed search techniques for solving real world problems.
- use knowledge representation techniques for AI systems.

SYLLABUS OF DSC-16

Unit 1 6 Hours

Introduction: Introduction to artificial intelligence, background and applications, Turing test, Weak AI, Strong AI, Narrow AI, Artificial General Intelligence, Super AI, rational agent approaches to AI, introduction to intelligent agents, their structure, behavior and task environment.

Unit 2 12 Hours

Problem Solving and Searching Techniques: Problem characteristics, production systems, control strategies, breadth-first search, depth-first search, hill climbing and its variations, heuristics search techniques: best-first search, A* algorithm, constraint satisfaction problem, means-end analysis, introduction to game playing, min-max and alpha-beta pruning algorithms.

Unit 3 16 Hours

Knowledge Representation: Propositional logic, First-Order Predicate logic, resolution principle, unification, semantic nets, conceptual dependencies, frames, and scripts, production rules, Introduction to Programming in Logic (PROLOG).

Unit 4 8 Hours

Understanding Natural Languages: Components and steps of communication, the contrast between formal and natural languages in the context of grammar, Chomsky hierarchy of grammars, parsing, and semantics, Parsing Techniques, Context-Free and Transformational Grammars, Recursive and Augmented transition nets.

Unit 5 3 Hours

AI The Present and the Future: Symbolic AI, Data-driven AI and Machine Learning, Introduction to Machine Learning and Deep Learning based AI, some applications of symbolic and data driven AI, Interpretable and Explainable AI, Ethics of AI: benefits and risks of AI.

Essential/recommended readings

1. Russell, Stuart, J. and Norvig, Peter, *Artificial Intelligence - A Modern Approach*, Pearson, 4th edition, 2020..
2. Bratko, Ivan, *Prolog Programming for Artificial Intelligence*, Addison-Wesley, Pearson Education, 4th edition, 2012.
3. Patterson, DAN,W, *Introduction to A.I. and Expert Systems* – PHI, 2007.
4. Clocksin, W., F. and Mellish, *Programming in PROLOG*, 5th edition, Springer, 2003.

Additional references

1. Kaushik, Saroj, *Artificial Intelligence*, Cengage Learning India, 2011.
2. Rich, Elaine and Knight, Kelvin, *Artificial Intelligence*, 3rd edition, Tata McGraw Hill, 2010

Practical List :

Practical exercises such as

1. Write a program in Prolog to implement TowerOfHanoi(N) where N represents the number of disks.
2. Write a program to implement the Hill climbing search algorithm in Prolog.
3. Write a program to implement the Best first search algorithm in Prolog.
4. Write a program to implement A* search algorithm in Prolog.
5. Write a program to implement the min-max search algorithm in Prolog.

6. Write a program to solve the Water-Jug Problem in Prolog.
7. Implement sudoku problem (minimum 9×9 size) using constraint satisfaction in Prolog.
8. Write a Prolog program to implement the family tree and demonstrate the family relationship.
9. Write a Prolog program to implement knowledge representation using frames with appropriate examples.
10. Write a Prolog program to implement conc(L1, L2, L3) where L2 is the list to be appended with L1 to get the resulted list L3.
11. Write a Prolog program to implement reverse(L, R) where List L is original and List R is reversed list.
12. Write a Prolog program to generate a parse tree of a given sentence in English language assuming the grammar required for parsing.
13. Write a Prolog program to recognize context free grammar a^nb^n.

DISCIPLINE SPECIFIC CORE COURSE – 17 (DSC-17): Machine Learning

Credit distribution, Eligibility and Prerequisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC-17 Machine Learning	4	3	0	1	Pass in Class XII	DSC01 Programming using Python_/ A course in Python at plus 2 level

Learning Objectives

The course aims at introducing the basic concepts and techniques of machine learning so that a student can apply machine learning techniques to a problem at hand.

Learning outcomes

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

- Differentiate between supervised and unsupervised learning tasks.
- State the need of preprocessing, feature scaling and feature selection.
- Formulate classification, regression and clustering problems as optimization problems
- Implement various machine learning algorithms learnt in the course.

SYLLABUS OF DSC-17

Unit 1 (5 Hours)

Introduction: Basic definitions and concepts, key elements, supervised and unsupervised learning, introduction to reinforcement learning, applications of ML.

Unit 2 (8 Hours)

Preprocessing: Feature scaling, feature selection methods. dimensionality reduction (Principal Component Analysis).

Unit 3 (12 Hours)

Regression: Linear regression with one variable, linear regression with multiple variables, gradient descent, over-fitting, regularization. Regression evaluation metrics.

Unit 4 (12 Hours)

Classification: Decision trees, Naive Bayes classifier, logistic regression, k-nearest neighbor classifier, perceptron, multilayer perceptron, neural networks, back-propagation algorithm, Support Vector Machine (SVM). Classification evaluation metrics.

Unit 5 (8 Hours)

Clustering: Approaches for clustering, distance metrics, K-means clustering, hierarchical clustering.

Essential/recommended readings

1. Mitchell, T.M. *Machine Learning*, McGraw Hill Education, 2017.
2. James, G., Witten. D., Hastie. T., Tibshirani., R. *An Introduction to Statistical Learning with Applications in R*, Springer, 2014.
3. Alpaydin, E. *Introduction to Machine Learning*, MIT press, 2009.

Additional References

1. Flach, P., *Machine Learning: The Art and Science of Algorithms that Make Sense of Data*, Cambridge University Press, 2015.
2. Christopher & Bishop, M., *Pattern Recognition and Machine Learning*, New York: Springer-Verlag, 2016.
3. Sebastian Raschka, *Python Machine Learning,* Packt Publishing Ltd, 2019

Suggested Practical List:

Practical exercises such as

Use Python for practical labs for Machine Learning. Utilize publicly available datasets from online repositories like https://data.gov.in/ and https://archive.ics.uci.edu/ml/datasets.php

For evaluation of the regression/classification models, perform experiments as follows:

- Scale/Normalize the data
- Reduce dimension of the data with different feature selection techniques
- Split datasets into training and test sets and evaluate the decision models
- Perform k-cross-validation on datasets for evaluation

Report the efficacy of the machine learning models as follows:

- MSE and R^2 score for regression models
- Accuracy, TP, TN, FP, TN, error, Recall, Specificity, F1-score, AUC for classification models

For relevant datasets make prediction models for the following

1. Naïve Bayes Classifier
2. Simple Linear Regression multiple linear regression
3. Polynomial Regression
4. Lasso and Ridge Regression
5. Logistic regression
6. Artificial Neural Network
7. *k*-NN classifier
8. Decision tree classification
9. SVM classification
10. K-Means Clustering
11. Hierarchical Clustering

DISCIPLINE SPECIFIC CORE COURSE– 18 (DSC-18): Introduction to Parallel Programming

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC-18 Introduction to Parallel Programming	**4**	**3**	**0**	**1**	Pass in Class XII	DSC-02 Computer Systems Architecture DSC04 /A course in C/C++ at plus 2 level, DSC-07 Data Structures with C++, DSC-08 Operating Systems

Learning Objectives

The course introduces the students to the basic concepts and techniques of parallel programming. It enables them to design and implement parallel algorithms. The course would give the students hands-on practice to write parallel programs using shared and distributed memory models using OpenMP and Message Passing Interface (MPI).

Learning outcomes

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

- State the need of Parallel algorithms
- Describe architectures for parallel and distributed systems.
- Develop elementary parallel algorithms for shared memory models.
- Develop elementary parallel algorithms for distributed memory models.

SYLLABUS OF DSC-18

Unit 1 (6 Hours)

Introduction to Parallel Computing: Trends in microprocessor architectures, memory system performance, dichotomy of parallel computing platforms, physical organization of parallel platforms, communication costs in parallel machines, SIMD versus MIMD architectures, shared versus distributed memory, PRAM shared-memory model, distributed-memory model.

Unit 2 (15 Hours)

OpenMP programming for shared memory systems: Thread Basics, Controlling Thread and Synchronization Attributes, Multi-thread and multi-tasking, Context Switching, Basic OpenMP thread functions, Shared Memory Consistency Models and the Sequential Consistency Model, Race Conditions, Scoping variables, work-sharing constructs, critical sections, atomic operations, locks, OpenMP tasks, Introduction to tasks, Task queues and task execution, Accessing variables in tasks, Completion of tasks and scoping variables in tasks, Recursive task spawning and pitfalls

Unit 3 (15 Hours)
MPI programming for distributed memory systems: MPI basic communication routines (Introduction to MPI and basic calls, MPI calls to send and receive data, MPI call for broadcasting data, MPI Non-blocking calls, MPI Collectives (MPI Collectives and MPI broadcast, MPI Gathering and scattering collectives, MPI reduction and Alltoall collectives, MPI collectives design), Types of interconnects (Characterization of interconnects, Linear arrays, 2D mesh and torus, cliques)

Unit 4 (9 Hours)
Applications: Matrix-matrix multiply, Odd-Even sorting, distributed histogram, Breadth First search, Dijkstra's algorithm

Essential/recommended readings

1. Grama, A., Gupta, A., Karypis, G., Kumar, V., *Introduction to Parallel Computing*, 2nd edition, Addison-Wesley, 2003.
2. Quinn, M. *Parallel Programming in C with MPI and OpenMP*, 1st Edition, McGraw-Hill, 2017.
3. Revdikar, L., Mittal, A., Sharma, A., Gupta, S., *A Naïve Breadth First Search Approach Incorporating Parallel Processing Technique For Optimal Network Traversal*, International Journal of Advanced Research in Computer and Communication Engineering Vol. 5, Issue 5, May 2016.

Additional References

No additional references mentioned

Suggested Practical List :

Practical exercises such as

1. Implement Matrix-Matrix Multiplication in parallel using OpenMP
2. Implement distributed histogram Sorting in parallel using OpenMP
3. Implement Breadth First Search in parallel using OpenMP
4. Implement Dijkstra's Algorithm in parallel using OpenMP

DISCIPLINE SPECIFIC ELECTIVE COURSES

DISCIPLINE SPECIFIC ELECTIVE COURSE: Social Network Analytics

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Social Network Analytics	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 01 Programming using Python, DSC03 Mathematics for Computing

Learning Objectives

The course introduces basic graph theory and draws distinction between graph as an abstract structure and real-life situation modelled as network. This course aims to expose the students to the strengths and capabilities of network analysis and their applications through the use of open source software.

Learning outcomes

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

- Model real life situation as networks
- Identify and apply quantitative network measures to characterize social networks at the local and global level
- Generate synthetic networks that satisfy properties of real world networks
- Discover, analyse and evaluate the intrinsic community structure of networks
- Model an information diffusion process for predictive analysis of networks

SYLLABUS OF DSE

Unit 1 (7 Hours)

Introduction to Social Network Analysis: Graph theory, random walk, degree distribution, mapping of real world situation into networks and applications of social network analysis, types of networks

Unit 2 (10 Hours)

Network Measures: Centrality measures, Page Rank, Hubs and Authority, Assortativity, Transitivity and Reciprocity, Similarity and Structural Equivalence

Unit 3 (10 Hours)

Network Models: Properties of Real-World Networks, Random Network Model, Small World Network Model, Preferential Attachment Model

Unit 4 (10 Hours)

Community Structure in Networks: Types of Communities, Community Detection algorithms and evaluation of communities obtained

Unit 5 (8 Hours)

Information Diffusion in Social Media: Information Cascades, Diffusion of Innovations, Basic Epidemic Models

Essential/recommended readings

1. Chakraborty T. *Social Network Analysis*, 1st edition, Wiley India Pvt. Ltd., 2021.
2. Zafarani R., Abbasi M. A., Liu H. *Social Media Mining: An Introduction*, 1st edition, Cambridge University Press, 2014.
3. Barabási A. L. , Pósfai M. *Network Science*, 1st edition, Cambridge University Press, 2016.

Additional References

1. Easley, Kleinberg J. *Networks, Crowds, and Markets: Reasoning About a Highly Connected World*, 1st edition, Cambridge University Press, 2012.

Suggested Practical List :

Practical exercises such as

Python Packages like igraph, NetworkX, NDlib etc. may be used for programming

1. Plot a weighted directed network such that node size and edge width is proportional to their degree and edge weight respectively
2. Compute and plot degree distribution of a real-world network. Also compute its local and global properties.
3. Generate three networks of 1000 nodes each using Random Network Model, Small World Network Model, Preferential Attachment Model and compare their characteristics.
4. Compute different centrality measures to identify top-N nodes and compare their ranks with those obtained by PageRank method.
5. Apply community detection algorithms on a small real-world network (e.g. Karate club) and compare modularity using bar plot. Also plot the communities revealed with different colors.
6. Simulate diffusion trends for different epidemic models and present results using appropriate visuals.

DISCIPLINE SPECIFIC ELECTIVE COURSE: Computer Graphics

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Computer Graphics	**4**	**3**	**1**	**0**	Pass in Class XII	DSC 03 (Mathematics for Computing - I), DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b Java Programming

Learning Objectives

This course introduces fundamental concepts of Computer Graphics with focus on modeling, rendering and interaction aspects of computer graphics. The course emphasizes the basic principles needed to design, use and understand computer graphics system.

Learning outcomes

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

- Describe Standard raster and vector scan devices as well as Graphical Input and output devices
- Implement algorithms for drawing basic primitives such as line, circle and ellipse.
- Implement algorithms for line clipping, polygon clipping and polygon filling.
- Implement a 3D object representation scheme, carryout 2D and 3D transformation, 3D projections
- Implement visible surface determination algorithms, Illumination models and surface rendering methods
- Implement a simple computer animation algorithm

SYLLABUS OF DSE

Unit 1 (8 Hours)

Introduction: Introduction to Graphics systems, Basic elements of Computer graphics, Applications of computer graphics. Architecture of Raster and Random scan display devices, input/output devices.

Unit 2 (8 Hours)
Drawing and clipping primitives: Raster scan line, circle and ellipse drawing algorithms, Polygon filling, line clipping and polygon clipping algorithms

Unit 3 (12 Hours)
Transformation and Viewing: 2D and 3D Geometric Transformations, 2D and 3D Viewing transformations (Projections- Parallel and Perspective), Vanishing points.

Unit 4 (9 Hours)
Geometric Modeling: Polygon Mesh Representation, Cubic Polynomial curves (Hermite and Bezier).

Unit 5 (8 Hours)
Visible Surface determination and Surface Rendering: Z-buffer algorithm, List-priority algorithm and area subdivision algorithm for visible surface determination. Illumination and shading models, RGB Color model and Basics of Computer Animation.

Essential/recommended readings

1. Hearn, D & Baker, M.P. *Computer Graphics*, 2nd edition, Prentice Hall of India, 2009.
2. Foley, J. D., Dam, A.V, Feiner, S. K., & Hughes, J. F. *Computer Graphics: Principles and Practice in C*, 2nd edition, Pearson education, 2002.
3. Rogers, D. F. *Mathematical Elements for Computer Graphics*, 2nd edition, McGraw Hill Education, 2017.

Additional References

1. Bhattacharya, S. *Computer Graphics*, Oxford University Press, 2018.
2. Marschner, S., & Shirley, P. *Fundamentals of Computer Graphics,* 4th edition CRC Press, 2017.

Suggested Practical List :

Practical exercises such as

1. Write a program to implement Bresenham's line drawing algorithm.
2. Write a program to implement a midpoint circle drawing algorithm.
3. Write a program to clip a line using Cohen and Sutherland line clipping algorithm.
4. Write a program to clip a polygon using Sutherland Hodgeman algorithm.
5. Write a program to fill a polygon using the Scan line fill algorithm.
6. Write a program to apply various 2D transformations on a 2D object (use homogeneous Coordinates).
7. Write a program to apply various 3D transformations on a 3D object and then apply parallel and perspective projection on it.
8. Write a program to draw Hermite /Bezier curve.

DISCIPLINE SPECIFIC ELECTIVE COURSE: Deep Learning

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Deep Learning	**4**	**3**	**0**	**1**	Pass in Class XII	DSC03 Mathematics for Computing - I, DSC17 Machine Learning

Learning Objectives

The objective of this course is to introduce students to deep learning algorithms and their applications in order to solve real problems.

Learning outcomes

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

- Describe the feed-forward and deep networks.
- Design single and multi-layer feed-forward deep networks and tune various hyper-parameters.
- Implement deep neural networks to solve a problem
- Analyze performance of deep networks.
- Use pre-trained models to solve a problem.

SYLLABUS OF DSE

Unit 1 (8 Hours)
Introduction to neural networks: Artificial neurons, perceptron, computational models of neurons, Structure of neural networks, Multilayer feedforward neural networks (MLFFNN), Backpropagation learning, Empirical risk minimization, bias-variance tradeoff, Regularization, output units: linear, softmax , hidden units:tanh, RELU

Unit 2 (8 Hours)
Deep neural networks: Difficulty of training DNNs, Greedy layerwise training, Optimization for training DNN's, Newer optimization methods for neural networks(AdaGrad, RMSProp, Adam), Regularization methods(dropout, drop connect, batch normalization).

Unit 3 (8 Hours)
Convolution neural networks(CNNs): Introduction to CNN - convolution, pooling, Deep CNNs - LeNet, AlexNet. Training CNNs, weights initialization, batch normalization, hyperparameter optimization, Understanding and visualizing CNNs, Using a pre trained convnet

Unit 4 (8 Hours)
Recurrent neural networks (RNNs): Sequence modeling using RNNs, Backpropagation through time, LongShort Term Memory (LSTM), Bidirectional RNN, Bidirectional LSTM
Unit 5 (8 Hours)
Unsupervised deep learning: Autoencoders, Generative Adversarial Networks.

Unit 6 (5 Hours)
Applications: Computer vision, Speech recognition and NLP.

Essential/recommended readings

1. Ian Goodfellow, Yodhua Bengio and Aaron Courville, *Deep Learning,* MIT Press Book**,** 2016.
2. Francois Chollet, *Deep Learning with python***,** *2nd edition*, Meaning Publications Co, 2021.

Additional References

1. Bunduma, N., *Fundamentals of Deep Learning*, 1st edition, O'reilly Books, 2017.
2. Heaton, J., *Deep Learning and Neural Networks*, 1st edition, Heaton Research Inc., 2015.

Suggested Practical List :

Practical exercises such as

The following practicals are to be conducted using Python.

1. Implement a feed-forward neural networks for classifying movie reviews as positive or negative(using IMDB dataset)
2. Implement a deep-neural feed-forward network for estimating the price of house, given real-estate data(Boston Housing Price)
3. Implement a deep-neural network for classifying news wires by topic (Reuters dataset).
4. Implement CNN for classifying MNIST dataset
5. Create a model for time-series forecasting using RNN/LSTM
6. Implement an auto-encoder

DISCIPLINE SPECIFIC ELECTIVE COURSE: Ethical Hacking

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Ethical Hacking	**4**	**3**	**0**	**1**	Pass in Class XII	Any Programming Language at plus 2 level or above

Learning Objectives

The objective of this course is to enable students to be part of such a team that can conduct the security assessment of an organization through the process of ethical hacking. This course will introduce the students, the idea of security assessment of systems and networks under investigation and how to perform them under the legal and ethical framework. Further, this course will outline the importance of various stages of ethical hacking, including but not limited to tasks such as penetration testing, and usage of various tools at each stage.

Learning outcomes

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

- Understand and acknowledge the relevance of legal, ethical, and professional challenges faced by an ethical hacker.
- Apply fundamental principles of system, application, and network security to ethically attack / penetrate the system to uncover the security flaws.
- Perform evaluation of security systems through a systematic ethical hacking process and recommend countermeasures to improve security.
- Understand and use various tools and techniques used in various stages of the ethical hacking process.

SYLLABUS OF DSE

Unit 1 (4 Hours)

Introduction: Overview of information security threats and attack vectors, vulnerability assessment and penetration testing concepts, information security controls, security laws and standards. OWASP.

Unit 2 (6 hours)

Footprinting and Reconnaissance: Introduction to network reconnaissance tools such ipconfig, ifconfig, domain tools, nmap, Wireshark, etc.

Unit 3 (6 hours)

Scanning and Enumeration: Network penetration testing, Password cracking techniques and countermeasures, NetBIOS tools

Unit 4 (6 hours)

Gaining and Maintaining Access: Network level attacks and countermeasures, Metasploit framework, Burp Suite

Unit 5 (6 hours)

Exploitation and Covering Tracks: Privilege escalation, social Engineering**,** identity theft, countermeasures, Covering tracks using attrib command and creating Alternate Data Stream (ADS) in Windows, Erasing evidence from Windows logs, Strategies for maintaining access.

Unit 6 (6 hours)

Advanced stages: Denial of service, Session hijacking, hacking web servers, hacking web applications, sql injection etc.

Unit 7 (6 hours)

NIST Cybersecurity framework and ISO standards: NIST cybersecurity framework, Cyber Kill chain, ISO/IEC 27001 and related standards.

Unit 8 (5 Hours)

Cyber Defense and Reporting: Preparing vulnerability assessment reports, presenting post testing findings, preparing recommendations

Essential/recommended readings

1. Patrick Engbretson, The Basics of Hacking and Penetration Testing, 2nd Edition, Syngress, 2013.
2. Georgia Weidman, Penetration TEsting: A Hands-On Introduction to Hacking, 1st Edition, No Starch Press, 2014.

Additional References

1. Peter Kim, The Hacker Playbook 3: Practical Guide to Penetration Testing, Zaccheus Entertainment, 2018.
2. Jon Erickson, Hacking: The Art of Exploitation, No Starch Press, 2008.
3. Online Resources:
    a. https://www.sans.org/cyberaces/
    b. https://skillsforall.com/
    c. https://www.hackingloops.com/ethical-hacking/

Suggested Practical List

Practical exercises such as

Perform the following activities.

(NOTE: Exercise extra caution while performing these exercises and codes)

1. Perform various Virtual Machine based exercises on https://vulnhub.com/
2. Perform exercises from https://www.hacker101.com/
3. Follow the lessons and activities from https://www.hackingloops.com/ethical-hacking/
4. Activities on Google site for hacking https://google-gruyere.appspot.com/
5. ACtivities on OWASP WebGoat https://github.com/WebGoat/WebGoat

DISCIPLINE SPECIFIC ELECTIVE COURSE: Cloud Computing

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
Cloud Computing	**4**	**3**	**0**	**1**	Pass in Class XII	NIL

Learning Objectives

The objective of an undergraduate cloud computing course is to provide students with a comprehensive understanding of cloud computing technologies, services, and applications.

Learning outcomes

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

- Knowledge of the fundamental concepts and principles of cloud computing, including virtualization, scalability, reliability, and security.
- Ability to design, develop, and deploy cloud-based applications using popular cloud platforms and services.
- Familiarity with cloud computing architectures, including Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).
- Understanding of the economic, legal, and ethical implications of cloud computing, including issues related to data privacy, ownership, and security.
- Ability to evaluate and select cloud-based solutions based on their technical, economic, and business requirements.
- Understanding of the broader societal and environmental impacts of cloud-based services and applications.

SYLLABUS OF DSE

Unit 1
Overview of Computing Paradigm: Recent trends in Computing : Grid Computing, Cluster Computing, Distributed Computing, Utility Computing, Cloud Computing,

Unit 2

Introduction to Cloud Computing: Introduction to Cloud Computing, History of Cloud Computing, Cloud service providers, Benefits and limitations of Cloud Computing,

Unit 3

Cloud Computing Architecture: Comparison with traditional computing architecture (client/server), Services provided at various levels, Service Models- Infrastructure as a Service(IaaS), Platform as a Service(PaaS), Software as a Service(SaaS), How Cloud Computing Works, Deployment Models- Public cloud, Private cloud, Hybrid cloud, Community cloud, Case study of NIST architecture.

Unit 4

Case Studies: Case study of Service model using Google Cloud Platform (GCP), Amazon Web Services (AWS), Microsoft Azure, Eucalyptus.

Unit 5

Cloud Computing Management: Service Level Agreements(SLAs), Billing & Accounting, Comparing Scaling Hardware: Traditional vs. Cloud, Economics of scaling.

Unit 6

Cloud Computing Security: Infrastructure Security- Network level security, Host level security, Application level security, Data security and Storage- Data privacy and security Issues, Jurisdictional issues raised by Data location, Authentication in cloud computing.

Essential/recommended readings

1. Thomas Erl, Ricardo Puttini and Zaigham Mahmood, Cloud Computing: Concepts, Technology and Architecture, Publisher: PHI, 2013.
2. Rajkumar Buyya, James Broberg, and Andrzej Goscinski, Cloud Computing: Principles and Paradigms, Wiley, 2013.
3. Boris Scholl, Trent Swanson, and Peter Jausovec, Cloud Native: Using Containers, Functions, and Data to Build Next-Generation Applications, Publisher : Shroff/O'Reilly, 2019.

Additional References

1. *Cloud Computing Bible,* Barrie Sosinsky*, Wiley-India,* 2010
2. *Cloud Computing: Principles and Paradigms,* Editors: Rajkumar Buyya, James Broberg, Andrzej M. Goscinski*, Wile,* 2011
3. *Cloud Computing: Principles, Systems and Applications, Editors:* Nikos Antonopoulos, Lee Gillam*, Springer,* 2012
4. *Cloud Security: A Comprehensive Guide to Secure Cloud Computing,* Ronald L. Krutz, Russell Dean Vines*, Wiley-India,* 2010

Suggested Practical List:

Practical exercises such as

1. Create virtual machines that access different programs on same platform.
2. Create virtual machines that access different programs on different platforms

3. Working on tools used in cloud computing online:
    a. Storage
    b. Sharing of data
    c. manage your calendar, to-do lists,
    d. a document editing tool
4. Exploring Google cloud
5. Exploring Microsoft cloud
6. Exploring Amazon cloud

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES

GENERIC ELECTIVES (GE-6a): Computer Networks

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE6a Computer Networks	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b Java Programming

Learning Objectives
The course objectives of this paper are to understand the concepts behind computer networks and data communication. learn the different types of networks, network topologies and their characteristics. learn the working of protocols used at various layers. understand the utility of different networking devices.

Learning outcomes

On successful completion of the course, students will be able to:
- differentiate between various types of computer networks and their topologies.
- understand the difference between the OSI and TCP/IP protocol suit.
- distinguish between different types of network devices and their functions.
- design/implement data link and network layer protocols in a simulated networking environment.

SYLLABUS OF GE-6a

Unit 1
Introduction: Types of computer networks, Internet, Intranet, network topologies (bus, star, ring, mesh, tree, hybrid topologies), network classifications. layered architecture approach, OSI Reference Model, TCP/IP Reference Model. Transmission Modes: simplex, half duplex and full duplex.

Unit 2
Physical Layer: Analog signal, digital signal, the maximum data rate of a channel, transmission media (guided transmission media, wireless transmission, satellite

communication), multiplexing (frequency division multiplexing, time-division multiplexing, wavelength division multiplexing). Guided Media (Wired) (Twisted pair, Coaxial Cable, Fiber Optics. Unguided Media (Radio Waves, Infrared, Micro-wave, Satellite).

Unit 3

Data Link and MAC Layer: Data link layer services, error detection and correction techniques, error recovery protocols (stop and wait, go back n, selective repeat), multiple access protocols with collision detection, MAC addressing, Ethernet, data link layer switching, point-to-point protocol.

Unit 4

Network layer: Networks and Internetworks, virtual circuits and datagrams, addressing, subnetting, Dijkstra Routing algorithm, Distance vector routing, Introduction to Network Layer protocol- (ARP, IPV4, ICMP).

Unit 5

Introduction to Transport and Application Layer: Introduction to Process to process Delivery- (client-server paradigm, connectionless versus connection-oriented service); User Datagram Protocols, TCP/IP protocol, Flow Control. FTP (File Transfer Protocol), SMTP (Simple Mail Transfer Protocol), Telnet (Remote login protocol), WWW (World Wide Web), HTTP (HyperText Transfer Protocol), URL (Uniform Resource Locator).

Essential/recommended readings

1. Tanenbaum, A.S. & Wetherall, D.J., *Computer Networks*, *5th edition*, Pearson Education, 2012.

2. Forouzan, B. A., *Data Communication and Networking*, *4th edition*, McGraw-Hill Education, , 2017.

Additional References

1. Comer, D. E., *Computer Networks and Internet,* 6th edition*,* Pearson Publication, 2015.

2. (ii) Stallings, W., *Data and Computer Communications*, 10th edition, Pearson education India, 2017.

Suggested Practical List :

Practical exercises such as

Introduce students to CISCO Packet Tracer and do the following:

1. To Study basic network command and Network configuration commands.
2. To study and perform PC to PC communication.
3. To create Star topology using Hub and Switch.
4. To create Bus, Ring, Tree, Hybrid, Mesh topologies.
5. Perform an initial Switch configuration.
6. Perform an initial Router configuration.
7. To implement Client Server Network.
8. To implement connection between devices using router.
9. To perform remote desktop sharing within LAN connection.

GENERIC ELECTIVES (GE-6b): Internet Technologies: Web App Design and Development

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE6b: Internet Technologies: Web App Design and Development	**4**	**3**	**0**	**1**	Pass in Class XII	NIL

Learning Objectives

The course aims at:
- Develop understanding of Web Development Architecture.
- Using React components in Web applications
- Introduce REST APIs Design
- Understanding of Angular Architecture, data-binding and dependency injection
- Understand form validations and application of templates

Learning outcomes

On successful completion of the course students will be able to

- Develop interfaces for single page applications
- Develop a complete client side solutions using angular js
- Develop a RESTful web services.
- Apply form validations

SYLLABUS OF GE-6b

Unit 1

Introduction to React: Definition of React, React library, React Developer tools, Introduction to ES6, Declaring variables, Arrow Functions, Objects and Arrays, modules, Introduction to AJAX, Functions in AJAX Pure React: Page setup, virtual DOM, React Element, React DOM, Constructing Elements with Data, React Components, DOM Rendering, First React Application using Create React App, React with JSX, React Element as JSX Props, State and Component Tree: Property Validation, Validating Props with createClass, Default Props, ES6 Classes and stateless functional components, React state management, State within the component tree, state vs props, Forms in React

Unit 2

Rest APIs: JSON: Introduction, Syntax, Data Types, Objects, Schema. REST API:

Introduction, WRML, REST API Design, Identifier Design with URIs, Interaction Design with HTTP, Representation Design, Caching, Security.

Unit 3

Angular.js.: Introduction to Angular: Angular architecture; introduction to components, component interaction and styles; templates, interpolation and directives; forms, user input, form validations; data binding and pipes; retrieving data using HTTP; Angular modules

Essential/recommended readings

1. D. Brad, B. Dayley and C. Dayley, *Node. js, MongoDB and Angularjs Web Development: The definitive guide to using the MEAN stack to build web applications*, 2nd edition, Addison-Wesley, 2018.
2. D. Herron, *Node.js Web Development*, 5th edition, Packt Publishing, 2020.
3. A. Banks and E. Porcello, *Learning React: Functional Web Development with React and Redux*, 1st edition, O'Reilly, 2017.
4. M. Masse, *REST API – Design Rulebook*, 1st edition, O'Reilly, 2011.

Additional References

No additional references mentioned.

Suggested Practical List :

Practical exercises such as

1. Angular.js:
a. Build a simple Angular.js application that displays a list of items.
b. Create a form in Angular.js to add new items to the list.
c. Implement filtering and sorting functionality in Angular.js to manipulate the displayed list.
d. Integrate Angular.js with a RESTful API to fetch data and display it in the application.
e. Implement authentication and authorization using Angular.js routing and services.

2. React:
a. Create a basic React component that displays "Hello, World!" on the screen.
b. Build a React application that fetches data from a REST API and renders it in a list.
c. Implement form handling in React to create, update, and delete items from the list.
d. Create a search functionality using React to filter the displayed list based on user input.
e. Implement routing in React to navigate between different pages within the application.

3. REST API:
a. Build a simple REST API using a framework like Node.js and Express.
b. Create endpoints to perform CRUD operations (Create, Read, Update, Delete) on a specific resource (e.g., users, products).
c. Implement authentication and authorization mechanisms using JSON Web Tokens (JWT) to secure the API.
d. Develop endpoints that handle file uploads and downloads.

GENERIC ELECTIVES (GE-6c): Artificial Intelligence

Credit distribution, Eligibility and Pre-requisites of the Course

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
GE6c: Artificial Intelligence	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b: Java Programming

Learning Objectives

The course objectives of this course are to:

- To introduce basic concepts and techniques of Artificial Intelligence (AI).
- To apply informed search techniques for different applications.
- To learn various knowledge representation techniques and writing Prolog programs.
- To learn about the latest techniques for developing AI systems.

Learning outcomes

On successful completion of this course, students will be able to:

- identify problems that are amenable to solutions by specific AI methods.
- state the utility of different types of AI agents.
- apply different informed search techniques for solving real world problems.
- use knowledge representation techniques for AI systems.

SYLLABUS OF GE-6c

Unit 1 6 Hours

Introduction: Introduction to artificial intelligence, background and applications, Turing test, Weak AI, Strong AI, Narrow AI, Artificial General Intelligence, Super AI, rational agent approaches to AI, introduction to intelligent agents, their structure, behavior and task environment.

Unit 2 12 Hours

Problem Solving and Searching Techniques: Problem characteristics, production systems, control strategies, breadth-first search, depth-first search, hill climbing and its variations, heuristics search techniques: best-first search, A* algorithm, constraint satisfaction problem, means-end analysis, introduction to game playing, min-max and alpha-beta pruning algorithms.

Unit 3 16 Hours

Knowledge Representation: Propositional logic, First-Order Predicate logic, resolution principle, unification, semantic nets, conceptual dependencies, frames, and scripts, production rules, Introduction to Programming in Logic (PROLOG).

Unit 4 8 Hours

Understanding Natural Languages: Components and steps of communication, the contrast between formal and natural languages in the context of grammar, Chomsky hierarchy of grammars, parsing, and semantics, Parsing Techniques, Context-Free and Transformational Grammars, Recursive and Augmented transition nets.

Unit 5 3 Hours

AI The Present and the Future: Symbolic AI, Data-driven AI and Machine Learning, Introduction to Machine Learning and Deep Learning based AI, some applications of symbolic and data driven AI, Interpretable and Explainable AI, Ethics of AI: benefits and risks of AI.

Essential/recommended readings

1. Russell, Stuart, J. and Norvig, Peter, *Artificial Intelligence - A Modern Approach*, Pearson, 4th edition, 2020..
2. Bratko, Ivan, *Prolog Programming for Artificial Intelligence*, Addison-Wesley, Pearson Education, 4th edition, 2012.
3. Patterson, DAN,W, *Introduction to A.I. and Expert Systems* – PHI, 2007.
4. Clocksin, W., F. and Mellish, *Programming in PROLOG*, 5th edition, Springer, 2003.

Additional references

1. Kaushik, Saroj, *Artificial Intelligence*, Cengage Learning India, 2011.
2. Rich, Elaine and Knight, Kelvin, *Artificial Intelligence*, 3rd edition, Tata McGraw Hill, 2010

Practical List :

Practical exercises such as

14. Write a program in Prolog to implement TowerOfHanoi(N) where N represents the number of disks.
15. Write a program to implement the Hill climbing search algorithm in Prolog.
16. Write a program to implement the Best first search algorithm in Prolog.
17. Write a program to implement A* search algorithm in Prolog.
18. Write a program to implement the min-max search algorithm in Prolog.
19. Write a program to solve the Water-Jug Problem in Prolog.
20. Implement sudoku problem (minimum 9×9 size) using constraint satisfaction in Prolog.
21. Write a Prolog program to implement the family tree and demonstrate the family relationship.
22. Write a Prolog program to implement knowledge representation using frames with appropriate examples.
23. Write a Prolog program to implement conc(L1, L2, L3) where L2 is the list to be appended with L1 to get the resulted list L3.
24. Write a Prolog program to implement reverse(L, R) where List L is original and List R is reversed list.
25. Write a Prolog program to generate a parse tree of a given sentence in English language assuming the grammar required for parsing.
26. Write a Prolog program to recognize context free grammar $a^n b^n$.

(Computer Science Courses for Undergraduate Programme of study with Computer Science discipline as one of the three Core Disciplines)

DISCIPLINE SPECIFIC CORE COURSE (DSC06): Computer Networks

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC06: Computer Networks	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b: Java Programming

Learning Objectives
The course objectives of this paper are to:

- Understand the concepts behind computer networks and data communication.
- Learn the different types of networks, network topologies and their characteristics.
- Learn the working of protocols used at various layers.
- Understand the utility of different networking devices.

Learning outcomes

Upon successful completion of the course, students will be able to:
- differentiate between various types of computer networks and their topologies.
- understand the difference between the OSI and TCP/IP protocol suit.
- distinguish between different types of network devices and their functions.
- design/implement data link and network layer protocols in a simulated networking environment.

SYLLABUS OF DSC06

Unit 1 (8 hours)
Introduction: Types of computer networks, Internet, Intranet, network topologies (bus, star, ring, mesh, tree, hybrid topologies), network classifications. layered architecture approach,

OSI Reference Model, TCP/IP Reference Model. Transmission Modes: simplex, half duplex and full duplex.

Unit 2 (9 hours)
Physical Layer: Analog signal, digital signal, the maximum data rate of a channel, transmission media (guided transmission media, wireless transmission, satellite communication), multiplexing (frequency division multiplexing, time-division multiplexing, wavelength division multiplexing). Guided Media (Wired) (Twisted pair, Coaxial Cable, Fiber Optics. Unguided Media (Radio Waves, Infrared, Micro-wave, Satellite).

Unit 3 (10 hours)
Data Link and MAC Layer: Data link layer services, error detection and correction techniques, error recovery protocols (stop and wait, go back n, selective repeat), multiple access protocols with collision detection, MAC addressing, Ethernet, data link layer switching, point-to-point protocol.

Unit 4 (8 hours)
Network layer: Networks and Internetworks, virtual circuits and datagrams, addressing, subnetting, Dijkstra Routing algorithm, Distance vector routing, Network Layer protocol-(ARP, IPV4, ICMP).

Unit 5 (10 hours)
Transport and Application Layer: Process to process Delivery- (client-server paradigm, connectionless versus connection-oriented service); User Datagram Protocols, TCP/IP protocol, Flow Control. FTP (File Transfer Protocol), SMTP (Simple Mail Transfer Protocol), Telnet (Remote login protocol), WWW (World Wide Web), HTTP (HyperText Transfer Protocol), URL (Uniform Resource Locator).

Essential/recommended readings

1. Tanenbaum, A.S. & Wethrall, D.J.. *Computer Networks*, 5th edition, Pearson Education, 2012.

2. Forouzan, B. A.. *Data Communication and Networking*, 4th edition, McGraw-Hill Education, 2017.

Additional References

1. Comer, D. E.. *Computer Networks and Internet,* 6th edition*,* Pearson education, 2015.

2. Stallings, W., *Data and Computer Communications,* 10th edition, Pearson education India, 2017.

Suggested Practical List :

Practical exercises such as

Introduce students to any network simulator tool and do the following:

1. To Study basic network command and Network configuration commands.
2. To study and perform PC to PC communication.

3. To create Star topology using Hub and Switch.
4. To create Bus, Ring, Tree, Hybrid, Mesh topologies.
5. Perform an initial Switch configuration.
6. Perform an initial Router configuration.
7. To implement Client Server Network.
8. To implement connection between devices using router.
9. To perform remote desktop sharing within LAN connection.

(B.A. Programmes with Computer Science as Major discipline)

Computer Science Major

DISCIPLINE SPECIFIC CORE COURSE (DSC06): Computer Networks

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC06 Computer Networks	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b: Java Programming

Learning Objectives

The course objectives of this paper are to:

- Understand the concepts behind computer networks and data communication.
- Learn the different types of networks, network topologies and their characteristics.
- Learn the working of protocols used at various layers.
- Understand the utility of different networking devices.

Learning outcomes

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

- differentiate between various types of computer networks and their topologies.
- understand the difference between the OSI and TCP/IP protocol suit.
- distinguish between different types of network devices and their functions.
- design/implement data link and network layer protocols in a simulated networking environment.

SYLLABUS OF DSC06

Unit 1 (8 hours)

Introduction: Types of computer networks, Internet, Intranet, network topologies (bus, star, ring, mesh, tree, hybrid topologies), network classifications. layered architecture approach,

OSI Reference Model, TCP/IP Reference Model. Transmission Modes: simplex, half duplex and full duplex.

Unit 2 (9 hours)
Physical Layer: Analog signal, digital signal, the maximum data rate of a channel, transmission media (guided transmission media, wireless transmission, satellite communication), multiplexing (frequency division multiplexing, time-division multiplexing, wavelength division multiplexing). Guided Media (Wired) (Twisted pair, Coaxial Cable, Fiber Optics. Unguided Media (Radio Waves, Infrared, Micro-wave, Satellite).

Unit 3 (10 hours)
Data Link and MAC Layer: Data link layer services, error detection and correction techniques, error recovery protocols (stop and wait, go back n, selective repeat), multiple access protocols with collision detection, MAC addressing, Ethernet, data link layer switching, point-to-point protocol.

Unit 4 (8 hours)
Network layer: Networks and Internetworks, virtual circuits and datagrams, addressing, subnetting, Dijkstra Routing algorithm, Distance vector routing, Network Layer protocol- (ARP, IPV4, ICMP).

Unit 5 (10 hours)
Transport and Application Layer: Process to process Delivery- (client-server paradigm, connectionless versus connection-oriented service); User Datagram Protocols, TCP/IP protocol, Flow Control. FTP (File Transfer Protocol), SMTP (Simple Mail Transfer Protocol), Telnet (Remote login protocol), WWW (World Wide Web), HTTP (HyperText Transfer Protocol), URL (Uniform Resource Locator).

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Suggested Practical List :

Practical exercises such as

Introduce students to any network simulator tool and do the following:

1. To Study basic network command and Network configuration commands.
2. To study and perform PC to PC communication.

3. To create Star topology using Hub and Switch.
4. To create Bus, Ring, Tree, Hybrid, Mesh topologies.
5. Perform an initial Switch configuration.
6. Perform an initial Router configuration.
7. To implement Client Server Network.
8. To implement connection between devices using router.
9. To perform remote desktop sharing within LAN connection.

DISCIPLINE COURSE (A6): Deep Learning

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
A6: Deep Learning	**4**	**3**	**0**	**1**	Pass in Class XII	A5 Machine Learning

Learning Objectives

The objective of this course is to introduce students to deep learning algorithms and their applications in order to solve real problems.

Learning outcomes

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

- Describe the feed-forward and deep networks.
- Design single and multi-layer feed-forward deep networks and tune various hyper-parameters.
- Implement deep neural networks to solve a problem
- Analyze performance of deep networks.
- Use pre-trained models to solve a problem.

SYLLABUS OF A6

Unit 1 (15 hours)
Introduction to neural networks: Artificial neurons, perceptron, computational models of neurons, Structure of neural networks, Multilayer feedforward neural networks (MLFFNN), Backpropagation learning, Empirical risk minimization, bias-variance trade-off, Regularization, output units: linear, softmax, hidden units:tanh, RELU

Unit 2 (15 hours)
Deep neural networks: Difficulty of training DNNs, Greedy layerwise training, Optimization for training DNN's, Newer optimization methods for neural networks (AdaGrad, RMSProp, Adam), Regularization methods (dropout, drop connect, batch normalization).

Unit 3 (15 hours)
Convolution neural networks (CNNs): Introduction to CNN - convolution, pooling, Deep CNNs - LeNet, AlexNet. Training CNNs, weights initialization, batch normalization, hyperparameter optimization, Understanding and visualizing CNNs, Using a pre-trained convnet

References

1. Heaton, J., Deep Learning and Neural Networks, 1st edition, Heaton Research Inc., 2015.
2. Francois Chollet, *Deep Learning with python*, *2nd edition*, Meaning Publications Co, 2021.

Additional References

(i) Ian Goodfellow, Yodhua Bengio and Aaron Courville, *Deep Learning,* MIT Press Book, 2016.
(ii) Bunduma, N., *Fundamentals of Deep Learning*, 1st edition, O'reilly Books, 2017.

Suggested Practical List

The following practicals are to be conducted using Python.

1. Implement a feed-forward neural networks for classifying movie reviews as positive or negative (using IMDB dataset)
2. Implement a deep-neural feed-forward network for estimating the price of house, given real-estate data (Boston Housing Price)
3. Implement a deep-neural network for classifying news wires by topic (Reuters dataset).
4. Implement CNN for classifying MNIST dataset.

Computer Science Courses for Undergraduate Programme of study with Computer Science discipline as one of the two Core Disciplines: non-Major
(For e.g. courses for B.A. Programmes with Computer Science as Non-major discipline)

DISCIPLINE SPECIFIC CORE COURSE (DSC06): Computer Networks

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical/ Practice		
DSC06 Computer Networks	**4**	**3**	**0**	**1**	Pass in Class XII	DSC 04 Object Oriented Programming with C++/ GE 1a Programming using C++ / GE1b Programming with Python/ DSC 01 Programming using Python/ GE 3b: Java Programming

Learning Objectives

The course objectives of this paper are to:

- Understand the concepts behind computer networks and data communication.
- Learn the different types of networks, network topologies and their characteristics.
- Learn the working of protocols used at various layers.
- Understand the utility of different networking devices.

Learning outcomes

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

- differentiate between various types of computer networks and their topologies.
- understand the difference between the OSI and TCP/IP protocol suit.
- distinguish between different types of network devices and their functions.
- design/implement data link and network layer protocols in a simulated networking environment.

SYLLABUS OF DSC06

Unit 1
Review of: Types of computer networks, Internet, Intranet, network topologies (bus, star, ring, mesh, tree, hybrid topologies), network classifications. layered architecture approach,

OSI Reference Model, TCP/IP Reference Model. Transmission Modes: simplex, half duplex and full duplex.

Unit 2
Physical Layer: Analog signal, digital signal, the maximum data rate of a channel, transmission media (guided transmission media, wireless transmission, satellite communication), multiplexing (frequency division multiplexing, time-division multiplexing, wavelength division multiplexing). Guided Media (Wired) (Twisted pair, Coaxial Cable, Fiber Optics. Unguided Media (Radio Waves, Infrared, Micro-wave, Satellite).

Unit 3
Data Link and MAC Layer: Data link layer services, error detection and correction techniques, error recovery protocols (stop and wait, go back n, selective repeat), multiple access protocols with collision detection, MAC addressing, Ethernet, data link layer switching, point-to-point protocol.

Unit 4
Network layer: Networks and Internetworks, virtual circuits and datagrams, addressing, subnetting, Dijkstra Routing algorithm, Distance vector routing, Network Layer protocol- (ARP, IPV4, ICMP).

Unit 5
Transport and Application Layer: Process to process Delivery- (client-server paradigm, connectionless versus connection-oriented service); User Datagram Protocols, TCP/IP protocol, Flow Control. FTP (File Transfer Protocol), SMTP (Simple Mail Transfer Protocol), Telnet (Remote login protocol), WWW (World Wide Web), HTTP (HyperText Transfer Protocol), URL (Uniform Resource Locator).

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Additional References

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2. Stallings, W. *Data and Computer Communications,* 10th edition. Pearson education India, 2017.

Suggested Practical List :

1. Simulate Cyclic Redundancy Check (CRC) error detection algorithm for noisy channel.
2. Simulate and implement stop and wait protocol for noisy channel.
3. Simulate and implement go back n sliding window protocol.
4. Simulate and implement selective repeat sliding window protocol.
5. Simulate and implement distance vector routing algorithm.
6. Simulate and implement the Dijkstra algorithm for shortest-path routing.

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